Twentieth Century Locomotives

TREATING ON THE

DESIGNING, CONSTRUCTION, REPAIRING AND OPERATING OF RAILWAY MACHINERY

FOR THE USE OF

ALL RAILWAY MEN EAGER TO LEARN THINGS ABOUT RAILWAY MACHINERY, BUT MORE PARTICULARLY FOR SUPERINTENDENTS OF MOTIVE POWER, MASTER MECHANICS, MASTER CAR BUILDERS, MECHANICAL ENGINEERS, SHOP FOREMEN, ENGINEERS, FIREMEN AND TRAINMEN

BY

ANGUS SINCLAIR COMPANY

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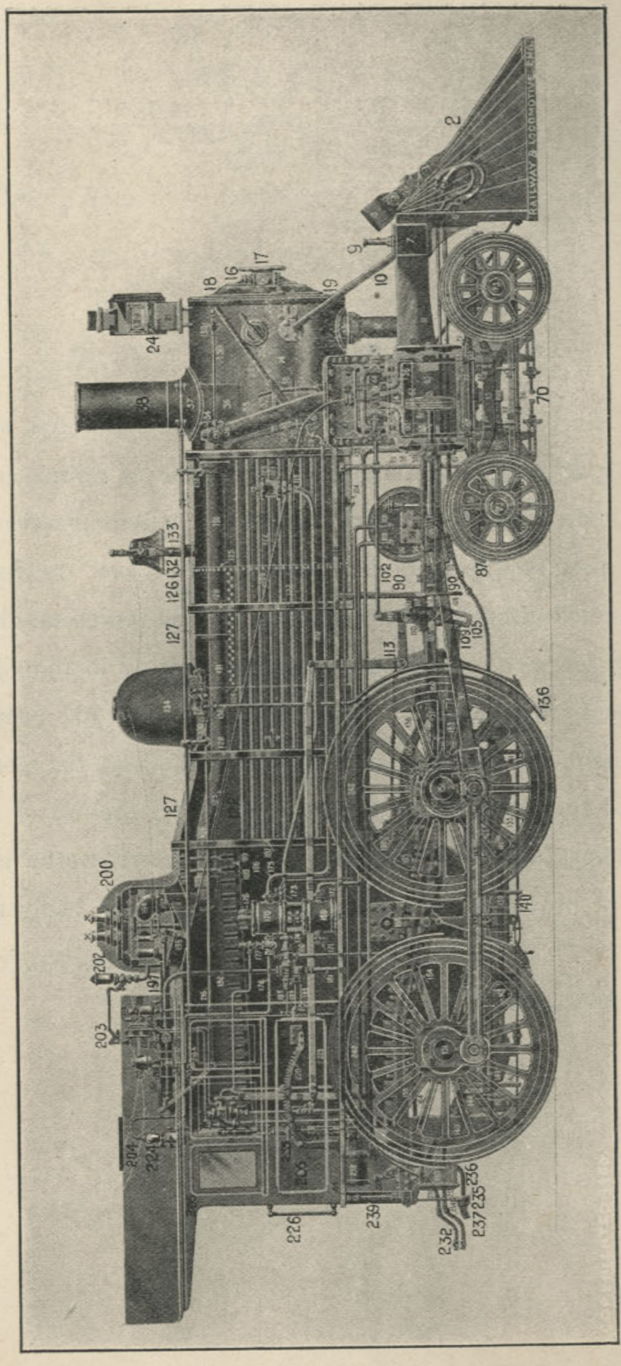
PREFACE

THE aim of this book is to supply people connected with the designing, building, maintaining and repairing of railroad machinery, with descriptions and illustrations of modern practice. The greater part of the work has been drawn from the pages of RAILWAY AND LOCOMOTIVE ENGINEERING and represents the most recent practice as described by men working in the different departments represented. The articles on shop work, comprising the repairs of locomotives and boilers, are the best, the most complete, and the most practical ever presented for the use of railway men. They form the winnowed grain of a fertile crop and are capable of providing knowledge that has long been badly needed.

ANGUS SINCLAIR.

New York, May, 1904.



THE AMERICAN LOCOMOTIVE.

Names of parts on pages v and vi

NAMES OF PARTS OF LOCOMOTIVE ON PRECEDING PAGE.

1 Pilot.
2 Draw Head Attachment.
3 Folding Draw Head.
4 Air Signal Hose.
5 Air Brake Hose.
6 Hose Hangers.
7 Buffer Beam.
8 Pilot Bracket.
9 Flagstaff.
10 Arch Brace.
11 Front Frame.
12 Cinder Chute.
13 Cinder Chute Slide.
14 Extension Front.
15 Headlight Step.
16 Signal Lamp.
17 Number Plate.
18 Smoke Arch Door.
19 Smoke Arch Front.
20 Smoke Arch Ring.
21 Headlight Bracket.
22 Headlight Case.
23 Headlight Reflector.
24 Headlight Burner.
25 Cleaning Door.
26 Netting.
27 Deflector Plate.
28 Deflector Plate Adjuster.
29 Air Pump Exhaust Pipe.
30 Blower.
31 Nozzle Stand.
32 Nozzle Tip.
33 Steam Pipe (2).
34 T-Pipe.
35 Dry Pipe Joint.
36 Petticoat or Draft Pipe.
37 Stack Base.
38 Smoke Stack.
39 Arch Hand Rail.
40 Oil Pipe Plug.
41 Cylinder Saddle.
42 Steam Chest Casing Cover.
43 Steam Chest Cover.
44 Steam Chest.
45 Relief Valve.
46 Balance Plate.
47 Balanced Valve.
48 Valve Yoke.
49 Valve Stem.
50 Valve Stem Packing.
51 Steam Passages to Chest.
52 Valve Seat.
53 Bridges.
54 Exhaust Port.
56 Steam Ports.
57 Cylinder.
58 Back Cylinder Head.
59 Piston Packing.
60 Piston Rod.
61 Piston Head.
62 Piston Packing Rings.
63 Truck Center Castings.
64 Front Cylinder Head.
65 Cylinder Head Casing.
66 Cylinder Lagging.
67 Cylinder Casing.
68 Cylinder Cocks.
69 Cylinder Cock Rigging.
70 Engine Truck.
71 Engine Truck Wheel.
72 Engine Truck Tire.
73 Engine Truck Axle.
74 Engine Truck Brass.
75 Engine Truck Box.
76 Engine Truck Pedestal.
77 Engine Truck Frame.
78 Engine Truck Pedestal Brace.
79 Engine Truck Frame Brace.
80 Engine Truck Equalizer.
81 Engine Truck Spring Hanger.
82 Engine Truck Spring.
83 Engine Truck Spring Band.
84 Engine Truck Spring Pocket.
85 Safety Hanger.
86 Truck Brake.
87 Wheel Guard.
88 Signal Pipe.
89 Guides.
90 Guide Yoke.
91 Guide Block.
92 Main Rod.
93 Main Rod Front Strap.
94 Key.
95 Cross Head Pin.
96 Cross Head.
97 Main Frame.
98 Air Drum Bracket.
99 Air Drum.
100 Pump Connection.
101 Train Pipe Connection.
102 Valve Stem Rod.
103 Train Pipe.
104 Wash Out Plugs.
105 Link.
106 Suspension Stud.
107 Link Block Pin.
108 Link Block.
109 Eccentric Connection, Back Up.
110 Eccentric Connection, Go Ahead.
111 Link Hanger.
112 Tumbling Shaft Arm.
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207 Air Gauge.
208 Steam Gauge.
209 Steam Turret.
210 Injector Throttle.
211 Blower Cock.
212 Gauge Lamp.
213 Signal Whistle.
214 Air Pump Throttle.
215 Throttle Lever.
216 Pneumatic Sander.
216a Sand Lever.
217 Reverse Lever.
218 Engineer's Brake Valve.
219 Gauge Cocks.
220 Quadrant.
221 Cut Out Valve.
222 Fire Door.
223 Cylinder Cock Lever.
224 Cylinder Lubricator.
225 Oil Can Shelf.
226 Hand Hold.
227 Shake Lever Stub.
228 Ash Pan Damper Handle.
229 Whistle Signal Valve.
230 Brake Valve Reservoir.
231 Train Pipe.
232 Train Pipe Hose.
233 Signal Pipe.
234 Signal Pipe Hose.
235 Feed Pipe Hanger.
236 Feed Pipe.
237 Feed Pipe Hose.
238 Tail Piece of Frame.
239 Cab Bracket.
240 Counter Balance Weight.

CLASSIFICATION OF LOCOMOTIVES

TYPE	WHEEL ARRANGEMENT	NAME	TOTAL WHEELS
0-4-0		4 WHEEL SWITCHER	4 WHEELS
0-6-0		6 " "	6 "
0-8-0		8 " "	8 "
0-4-2		4 COUPLED WITH TRAILING TRUCK	6 "
0-6-2		6 " " " "	8 "
0-8-2		8 " " " "	10 "
0-4-4		FORNEY 4 COUPLED	8 "
0-6-4		" 6 "	10 "
0-4-6		" 4 "	10 "
0-6-6		" 6 "	12 "
2-4-0		4 COUPLED	6 WHEELS
2-6-0		MOGUL	8 "
2-8-0		CONSOLIDATION	10 "
2-10-0		DECAPOD	12 "
2-4-2		COLUMBIA	8 WHEELS
2-6-2		PRAIRIE	10 "
2-8-2		MIKADO	12 "
2-4-4		4 COUPLED DOUBLE ENDER	10 "
2-6-4		6 " " "	12 "
2-8-4		8 " " "	14 "
2-4-6		4 " " "	12 "
2-6-6		6 " " "	14 "
4-4-0		8 WHEEL	8 WHEELS
4-6-0		10 WHEEL	10 "
4-8-0		12 WHEEL	12 "
4-4-2		ATLANTIC	10 WHEELS
4-6-2		PACIFIC	12 "
4-4-4		4 COUPLED DOUBLE ENDER	12 "
4-6-4		6 " " "	14 "
4-4-6		4 " " "	14 "
4-6-6		6 " " "	16 "

Railway & Locomotive Engineering

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EDUCATIONAL

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RADIAL SPRING BUFFER

VALVE SETTING MODEL

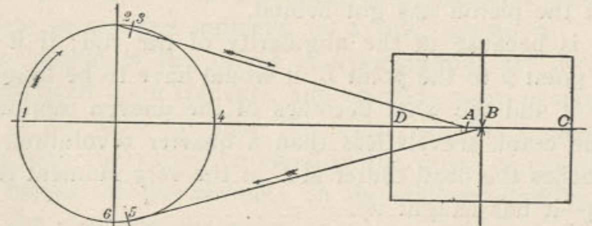
Twentieth Century Locomotives.

ELEMENTARY LESSONS ON FIRST PRINCIPLES.

First Lesson.

It is not the purpose of these articles to instruct old students of steam engineering, but to present in the plainest possible language clear explanations of some of the first principles that are not understood by the average of young men in our shops or upon our locomotives.

Most of the books upon these subjects are too deep for men not well up in the higher mathematics, or the subjects are



Elementary Lessons on First Principles.

PLATE I.

enveloped in a shroud of mysterious motion curves that frighten off our too timid students.

Engineers and firemen, as well as the average railroad mechanic, are familiar with many features of the locomotive as a whole or in detail, know that they must be so and so, but, asked to give the reason—the why and the what—and they are lost;

they are like the savage who knows that for a time the sun has hid her face, but what caused the eclipse is, to him, a mystery.

Suppose we commence lesson number one with the

ANGULARITY OF THE CONNECTING ROD.

What is known as the angularity of the rod affects the motion of the piston, and makes it necessary to change the motion of the valve to correspond to the irregular motion of the piston.

Let us look up the why. On page 1 is an outline sketch of the crank pin path, main rod and piston. Now it is perfectly plain that when the crank pin is at 1 or at 4 the piston will be at *D* or *C*, the extreme end of the cylinder. As the piston and cross-head are keyed solidly together, we will consider only the motion of one, as in this case their motions are exactly the same. The angularity of the rod always decreases by increasing the length of rod; so in this case we show the rod but half the usual length, as compared to the proportions of other parts; this will serve to show the effect of angularity more plainly. Now, suppose we start the pin from 1 in the direction of the arrow; at 2 the crank has traveled over one-quarter of its path, or 90° of the circle, but the piston has failed to get to the center of the cylinder, and is at the point marked *A*, and not until the pin reaches point 3 does the piston complete half its stroke, and arrive at *B*—the pin has made more than half its extreme travel back and forth, but the piston has got behind.

This is because of the angularity of the rod; if it reached from the point 2 to the point *B*, it would have to be longer. Let us follow it and see what becomes of the uneven motions; from 3 to 4 the crank travels less than a quarter revolution, but the piston reaches the dead center at *C* at the very moment the crank gets to 4—it has caught up.

Let us see why. Remember that when the pin is at 1 and 4, the rod is in line with the center line of the cylinders, and not at an angle to them, and that its angularity is constantly changing in degree, becoming more as it goes away from the dead points at 1 and 4, and less as it approaches them.

Let us follow the piston back from *C* to the center of the cylinder at *B*. You will see that the pin has only got to 5; the constantly increasing angularity has made the piston travel a full half stroke before the pin has got to the quarter; the piston reaches *A* again when the pin gets to 6, the quarter, but the

moment the pin gets past 6 the angularity of the rod commences to decrease till it reaches 1 again, which it does by the time the piston is at the end of the cylinder at *D*.

Now, you see, the pin has to travel from 5 clear around to 3, in order to make the piston go from the center of the cylinder to the back head and to the center again, while it only has to go from 3 to 5—a considerably shorter distance—to make the piston go from the center of the cylinder to the front at *C*, and back to the center. Something is working unevenly. What is it?

The fly-wheel, in a stationary, and the moving weight of engine and train in a locomotive, act as governors that prevent uneven impulses given to the pistons from affecting the regular rotary motion of the crank pin, and, as that is coupled to the piston by the main rod, the result is that the pistons travel unevenly; not only do they stop and start at each end of the stroke, but they make one-half their journey quicker than they do the other half. In a full revolution of the crank the piston will always travel the least while the crank is making the half revolution farthest from the piston, and travel the most while making the half revolution nearest the piston.

In locomotive practice it is customary to place the center line of cylinders slightly above the center line of the wheels, and this increases the angularity on the lower half of the crank pin's path, and decreases it in the upper half; but this change is so slight that locomotive builders, as a rule, ignore it.

The motion of the valves of a locomotive are derived from eccentrics fixed upon the axle, and coincide more nearly with the motion of the main pin than the piston, so that something must be done with the valves to equalize the point of cut off for the uneven motion of the pistons. In the ordinary link motion this is done by changing the point of suspension, or saddle pin, of the links, upon which we will now treat.

Let us just go a little out of our way to say that where the link motion is used on a locomotive without a rocker it is called a

DIRECT-MOTION ENGINE,

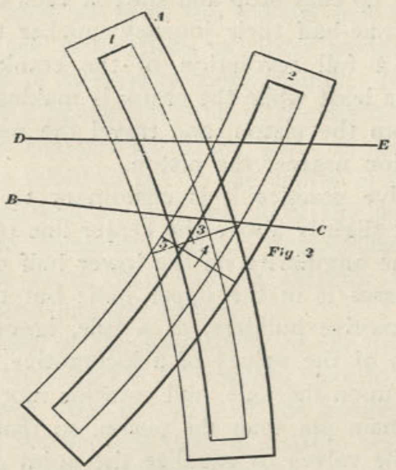
and the eccentric that is in gear, for instance the forward eccentric, when engine is running ahead, leads, or is ahead of the crank pin, while the forward motion eccentric on an indirect engine, or one employing a rocker, follows the crank pin, or is behind it, when engine is running ahead. Most locomotives running in America have rockers, and are therefore indirect motion engines.

Returning to the subject of the

SUSPENSION OF THE LINK,

you must remember that the angularity of the rod makes the piston travel unevenly, and that the angularity of the eccentric rods makes them move their ends of the link unevenly, and that these motions are tied together by the link, and the combined motion between the two points used to move the valves.

There are a great many other things to take into consideration in designing a link motion, any of which would distort the motion; but we will not go into these now, as the object is to explain why the link hanger stud is located behind the center of link, not to teach you how to lay it out.



LESSONS ON FIRST PRINCIPLES.
PLATE 2.

The ordinary link motion is not the best expansion gear, but it is the simplest and cheapest reversing gear known, and has almost superseded all other forms of motion for locomotive work.

It is impractical to set the link motion to cut off exactly square for all points of cut off in both backward and forward gear, but it can be set to cut off pretty nearly square where it is liable to be used the most; and, to enable it to do this, other points of cut off are often left a little out.

We have seen that in practice the wheel moved in a steady and uniform motion, but that the piston moved further during

one-half the stroke than during the other half, and consequently must move faster during one-half the revolution of the wheel than during the other half.

The eccentrics are set nearly quartering to the pin, so that when the pistons are moving the fastest, when sweeping through the center of the cylinders, the valves are moving the slowest; while, on the other hand, when the pistons are at the ends of their travel, and are therefore moving slowest, the eccentrics are at or near the quarters, and are moving the valves the fastest and the most, thus giving a quick opening at the beginning of the stroke. Now we have seen that the piston moves faster when on the forward half of the stroke, when the pin is nearest the cylinder, than on the back half, when the pin is away from the cylinder, and this difference in piston movement is made while the valve is doing the most work.

In designing valve motion, the position of the link is laid out as it would stand when cutting steam off at half stroke of the pistons, regardless of the position of the pins, as in Fig. 2, Plate 2, where the link numbered 1 shows the position when cutting off at half stroke for one end, and the link numbered 2, the position of same link when cutting off at half stroke for the return stroke of piston. The line *D E* is the center line of the engine, and the line *B C* the center line of the link motion.

If the link hanger was fixed at *A*, and reached to the center of the link in either position, as at the points 3 or 4, the cut-off could not be even, as the hanger would not allow the link to move from 3 to 4.

By selecting a mean point at 5, found at the intersection of the lines drawn across the center of the link, the motion is so modified in each case as to cut off steam at exactly half stroke, regardless of the angularity of the rod. If steam is cut off evenly at half stroke, it will be cut off very nearly even for other points. Links are sometimes suspended out of the center, for other reasons, which will be explained.

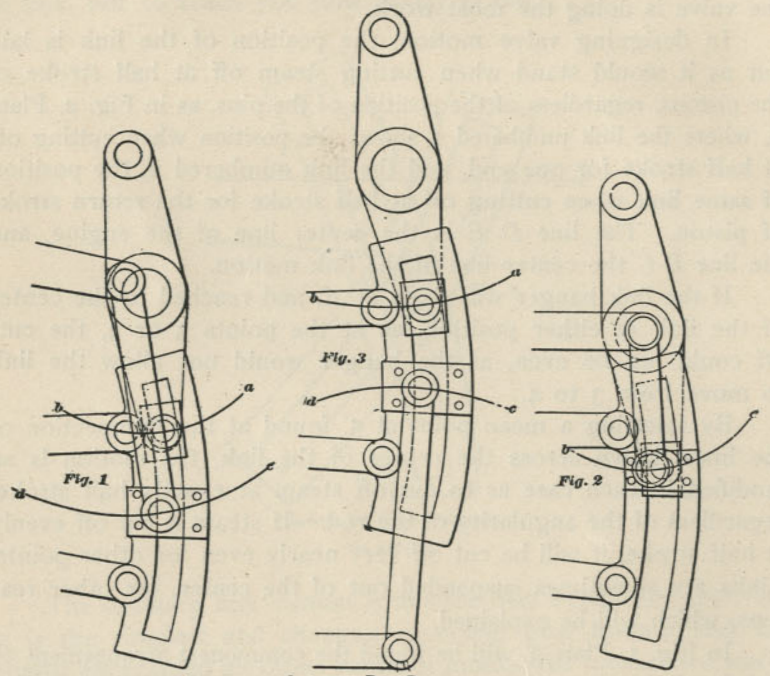
In Fig. 1, Plate 3, will be found the commonest arrangement of hanging links on our locomotives. As the raising of the link slightly affects the position of the pin at top of hanger, forward and back, the best results would be obtained by making the tumbling shaft arm as long, at least, as the eccentric blade, but this is impractical. To prevent the raising and lowering of the link at each end of its stroke, the hanger should be long. In this form the arc *a b*, through which the lower end of the rocker arm and the link block travels, coincides considerably with the arc *c d*, through which the hanger carries the link; the difference between these two arcs is provided for by the link sliding up and down on the block, familiarly known as the

SLIP OF THE BLOCK.

This was a great bugbear to early builders, and many devices were gotten up to avoid it, the best known device of this kind being the one used by Wm. Mason and other builders of his time. This is shown in Fig. 2. He suspended the link from

ABOVE THE CENTER,

and fixed the length of the hanger so that, when the engine was working in eight or ten inches the upper end of the hanger would stand on a line with the center of the rocker, and the



LESSONS ON FIRST PRINCIPLES
PLATE 3.

suspension stud on the link would stand on a line with the link block, then the link and the lower end of rocker swing through the same arc, and the slip of the block was reduced to a minimum.

Of course, when the link is in full gear, or in backing, there is a difference in the slip, but it was reduced the most in the

position most used. The object in reducing the slip was to prevent wear of the parts, but it was impossible to entirely prevent slip, as the angle of the link would cause some movement, and the consequence was that the links were worn more, all load coming upon a part of the link little larger than the die block, and a shoulder was soon worn.

Again it was found that locomotives with links hung in this manner were not so smart as those of the same style, but having the then common

UNDERHUNG LINK,

as in Fig. 3, and its value used to be a matter of considerable speculation and dispute among engineers and designers. Old runners will, we believe, bear us out in the assertion that these engines with underhung links were really smarter than those with overhung links.

The cause is plain when we examine the arcs *a b* and *c d*, in Fig. 3. It will be seen that, when the link swings away from the center, carrying the block with it, that the two arcs leave one another, causing excessive slip. This was greater in full throw than when hooked up, as the center of the link travels a shorter distance back and forth than the ends do. With this motion the valve was delayed at the ends, which kept the exhaust port full open longer, as well as the steam port on the other end. When the link approached its central position it was hurried in the same proportion that it had been delayed in its outward trip, thus giving a quick opening of the valve and closure of the exhaust.

STEAM AND MOTIVE POWER

By Angus Sinclair.*

MECHANICAL EQUIVALENT OF HEAT.

Steam, the vapor of water, is the most convenient medium known for transforming heat, the kinetic energy of fuel, into mechanical work. The operation is usually carried on by means of the steam engine. According to the laws of thermodynamics, which are accepted as the gospel of steam engineering, heat and mechanical energy are mutually convertible; and heat requires for its production and produces by its disappearance mechanical energy in the proportion of 778.3 foot pounds for each unit of heat, known also as the thermal unit. The thermal or heat unit is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at a temperature slightly above the freezing point. As water increases in temperature, a slightly larger quantity of heat is required to raise the temperature one degree, owing to the expansion of the water and consequent disappearance of heat in doing internal and external work. At 400° Fahr. the dynamical or work value of one degree is about 800 foot pounds. This fact should be borne in mind by engineers experimenting with high pressures of steam.

In most calculations relating to heat, engineers and scientists employ the heat unit as a basis of measurement. In ordinary engineering operations, the heat required to raise the temperature of one pound of water one degree at any temperature is calculated as a heat unit.

WORK OF CONVERTING WATER INTO STEAM.

As a convenient means of noting the phenomena connected with the mechanical power developed by the conversion of water into steam, suppose we place one pound of water at the freezing point in a vessel convenient for measurement, and, applying heat,

*These articles were written in 1886, and the railway practice described has become antiquated; but the principles discussed are everlasting.

follow, observe, and record the events of a cycle similar to that which steam makes in passing through the boiler and cylinders of a steam engine. Let us place the water at a temperature of 32° Fahr. at the bottom of a glass tube of indefinite length, open at the top, and having a cross sectional area of one square foot —144 square inches. At the freezing point, one pound of water measures 27.7 cubic inches, therefore the volume we are going to experiment with will cover the level bottom of the tube to a depth of .1923 inch. If we now apply the flame of a spirit lamp or other source of regular heat to the tube beneath the water, the temperature will begin steadily to rise until 212° Fahr., the boiling point at atmospheric pressure, is reached. The water will then be gradually evaporated into steam, but the temperature will remain the same until vaporization is completed. If it took ten minutes for the heat of the lamp flame to raise the temperature of the water from 32° Fahr., the freezing point, to 212° Fahr., the boiling point, it would take nearly fifty-five minutes longer before the whole of the water would be converted into steam, and the thermometer would indicate no elevation of temperature for the great additional amount of heat expended. It takes nearly 5½ times the quantity of heat to evaporate one pound of water—or any other weight, for that matter—that it takes to raise the same quantity from the freezing to the boiling point, and the great expenditure of heat is not sensible to the thermometer.

LATENT HEAT.

Philosophers have been accustomed to explain the disappearance of heat by saying that it became "latent" in the steam. The expression is ambiguous, and has led to much misapprehension of what really becomes of the heat when water is converted into steam. Physicists now give a more detailed explanation of this phenomenon.

There are certain exceedingly powerful molecular forces called chemical affinity and cohesion exerted by nature upon water tending to condensation, attracting the atoms into a close tenacious embrace. The application of sufficient heat will have the effect of performing the internal work necessary to overcome the attraction of the atoms, a change of condition will be accomplished, and the water will be expanded into steam. The heat applied will do the work of tearing the atoms apart and in keeping them for a time in that condition. Still further application of heat under proper conditions would have the effect of separating the constituent gases of water. The process of expansion into steam is obstructed by outside resistance, principally by that presented by the pressure of the atmosphere. The work performed against the latter influences is called external work.

HEAT OF VAPORIZATION.

When the heat was applied beneath our tube the power of the flame was first devoted to raising the temperature of the water, and 180 heat units were expended in this manner augmenting the temperature from 32° to 212° Fahr. The heat continues to pass into the water and steam is gradually formed, boiling goes on, and when the last drop of the water has been evaporated, 966 heat units, besides that used to heat the water, have been expended, making a total of 1,146 heat units which is known as the total heat of vaporization. The degree of heat that has been insensible to the thermometer, viz., 966 heat units, is often spoken of as the latent heat of steam at atmospheric pressure.

SATURATED STEAM.

The steam formed in the way described, where only sufficient heat is applied to evaporate the water, has a certain density and pressure corresponding to the temperature. In such condition the steam is said to be saturated, being incapable of vaporizing more water into the same space without increase of temperature. Saturated steam contains just sufficient heat to maintain the vaporous condition, and the smallest abstraction of heat results in a portion of the steam returning into the condition of water, when it loses its capacity for doing work. In all good boilers where the steam is held in contact with water, it is used in the saturated condition. When boilers are of defective design, or where rapid forcing is resorted to in generating steam, water in the form of spray passes off along with the steam and causes great loss of heat, besides endangering the machinery from the pressure of the inelastic water in the cylinders. But when water is passed out of the boiler in this way, without receiving the heat required for evaporization, it is sometimes made to show that the boiler evaporates a large quantity of water to the pound of coal burned. Of course it will be perceived that only the heat sensible to the thermometer has been put into the water that passes over in the form of spray, the minute particles of the water being carried by the lighter steam. Saturated steam is also known as dry and anhydrous steam.

SUPERHEATED STEAM.

If we had continued the heat under our tube after all the water was evaporated, the steam would have received more heat than what was necessary to evaporate it from water, and it would become superheated. Superheated steam is valuable when it can be obtained conveniently, because it contains heat that can be parted with before condensation ensues. When saturated steam is expanded without meeting resistance, as in throttling, it is slightly superheated. That is, the heat due to a high pressure remains in the steam at a lower pressure. The first effect of imparting additional heat to saturated steam is analagous to the effect of applying heat to water, but the work is done to convert the vapor of steam into a perfect gas. When this is completed the heat goes to increase the temperature and to perform internal work. If the application of heat is continued to the required rise of temperature, the gas of water will be dissociated into the original elements of oxygen and hydrogen.

RELATIVE VOLUMES OF WATER AND STEAM.

The steam formed by our process of evaporation occupies 1,644 times the space which held the water, that being the relative volumes of water and steam at atmospheric pressure. According to what is known as Boyle's law, a perfect gas, that is a fluid, in which all internal forces have been overcome, expands so that the volume varies inversely with the pressure. Steam is not a perfect gas, but it follows the law referred to close enough for practical purposes. A pressure of two atmospheres would therefore reduce the volume of our steam one-half, and maintain it at double the pressure. But we will return to the experiment of steam being formed under one atmosphere.

Our tube being one foot square in area, 144 square inches, the steam forms a column 26.36 feet high. In taking possession of this length of tube the steam had to work up against the atmospheric pressure of 14.7* pounds to the square inch. The weight of the atmosphere presses upon the surface of the boiling water like an invisible piston, and the weight had to be lifted before the steam could rise. So in rising, the steam raises a weight equivalent to $14.7 \times 144 = 2{,}116.8$ pounds. Raising this through 26.36 feet amounts to 55,798 foot pounds of external

*Our calculations are based on the atmospheric pressure at sea level—14.7 lbs. As this pressure varies according to altitude, accurately obtained by barometric measurements, existing local conditions must govern in all cases.

work done during the evaporation of one pound of water at atmospheric pressure.

WORK REPRESENTED BY THE HEAT EXPENDED.

We are now in a position to account for all the heat expended and show its equivalent in work or stored energy. In the first place, 180 heat units were employed in raising the temperature of the water to the boiling point, which amounts to $180 \times 778.3 = 140{,}094$ foot pounds. The 966 heat units, the so-called latent heat of steam, were expended before evaporation was completed, making 751,837.8 foot pounds put into the steam and insensible to the thermometer. We have seen that 55,798 foot pounds of this aggregation were expended overcoming atmospheric resistance—doing external work—leaving 696,139.8 foot pounds as the mechanical equivalent of the heat used in forcing the water apart, overcoming the internal forces of attraction, and holding the atoms of the steam apart. The work done is analagous to the operation of raising the weight of a great hammer or pile driver, and holding it in position ready for a blow. The whole of the heat energy put into the water, except what is expended in overcoming external resistance, viz., 891,931.8 foot pounds represented by the latent heat in the steam, and the 140,094 foot pounds represented by the heat expended in raising the temperature of the water are available for passing into a condenser or to perform mechanical work.

Or, if the pound of steam were returned into water at a temperature of 32°, it would be capable of raising to the boiling point nearly $5\frac{1}{2}$ pounds of water, the only loss of heat being the quantity used in overcoming the pressure of the atmosphere.

A striking feature perceived in the operation of turning the steam back into water, is the small loss of heat that occurs. Of the 1,146 total heat units expended, 1,074 units are available for returning into the water and heating it—an efficiency of 94 per cent. It may be interesting to ascertain why the column of steam falls so far short in efficiency for doing work when applied to the steam engine.

STEAM UNDER HEAVY PRESSURE.

As the low tension of steam employed in our example would be useless for any purpose connected with railroad motive power, we will take up a case of generating steam at a pressure familiar to those engaged in railroad engineering. Suppose we again put in our tube a pound of water at a temperature of 32° Fahr. and apply heat. Instead of leaving the tube open to the atmosphere, we will put a piston weighing 130.3 pounds to the square inch on the surface of the water, and we will further suppose that the piston will be perfectly steam tight and capable of moving upward with no friction. As the atmospheric pressure will rest upon the upper side of the piston, steam cannot be formed without raising an absolute load of 145 pounds to the square inch.

BOILING POINT RISES WITH INCREASE OF PRESSURE.

On heat being now applied, the temperature of the water will keep rising until the thermometer registers 355.6° Fahr., at which point boiling will begin. This fact we may be assured of, although no thermometer is used, if the pressure be maintained. For the knowledge of this and a great many other interesting and important particulars about heat and steam, the engineering world is indebted to Regnault, a distinguished French physicist. Heat continuing to pass into the water, boiling will go on, steam will be formed and the piston raised till the last drop of water is evaporated. When this operation is completed, it will be found that 866.8 heat units beyond that used to raise the temperature of the water to the boiling point have been expended in turning the water into steam. Reckoned from the freezing point, the total heat of vaporization would in this case be 1,190.4 heat units, as compared with 1,146 heat units when evaporation was performed at atmospheric pressure. The volume now occupied by the steam is 192 times greater than the space which held the pound of water, and the piston with its total load, 145 pounds $\times$ 144 square inches $=$ 20,880 pounds, has been raised 3.0777 feet, during external work equal to 64,686 foot pounds, representing 83.24 heat units.

When the quantity of heat expended in overcoming external resistance is deducted from the total heat of evaporization, it will be found that 1,106.16 heat units, or 860,924 foot pounds, have been elevated to an altitude convenient for doing work.

The calculations made in connection with evaporating one pound of water in a tube, apply to the ordinary process followed of evaporating water in steam boilers.

We have taken no account of the loss of heat that occurs in the furnace.

DOING WORK BY EXPANSION OF STEAM.

In ordinary railroad practice the steam would be raised from water at about 50° Fahr. temperature, so that only about 1.172

heat units would be put into the work of raising steam to 145 pounds absolute pressure. Of this quantity 83.23 heat units are lost, so far as being returned into work is concerned, since the heat energy has been used up already in doing the work of overcoming external resistance. The economy of the engine that is going to use the pound of steam depends upon its capability to lower the temperature by expansion while doing work against resistance behind a piston.

In ordinary circumstances, the higher the temperature of steam admitted to the cylinder of a steam engine, and the lower the point at which it arrives when the exhaust occurs, the greater will be the amount of steam converted into work, and consequently the greater will be the economy of the steam engine. This law is modified by various circumstances which will be dwelt upon further on.

USING STEAM WITHOUT EXPANSION.

Suppose that by the aid of other steam in the boiler pushing it through the intervening pipes and passages, our pound of steam

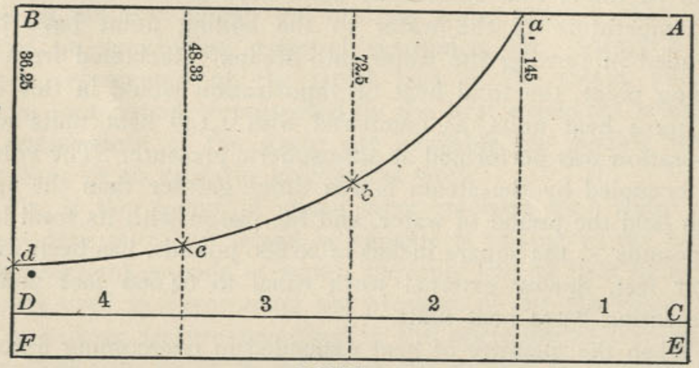


PLATE 4.

of 145 pounds absolute pressure enters a cylinder 16.8 $\times$ 24 inches, and, without loss of heat or pressure, pushes the piston to the end of the stroke. The whole volume of steam generated from one pound of water would just be sufficient to completely fill the cylinder at the pressure named. If our pound of steam were admitted to the cylinder under the conditions, without clearance or back pressure, and at the completion of the stroke exhausted into a perfect vacuum, a diagram of the action of the steam would be a complete rectangle as *A B E F*, Fig. 1, Plate 4. The height *A* would represent the pressure at the point of admission, which

would be maintained until the point *B*, at the end of the stroke was reached, when the steam would instantaneously fall to the lowest point *F*, and follow that level during the return stroke to *E*. In this case all the heat employed in raising the temperature of our pound of water and evaporating it into steam would pass out through the exhaust, except the small portion of heat energy converted into the work of overcoming internal resistance in the steam generator.

Although it is impracticable to make a cylinder receive and exhaust steam in the way described, there are many cases where steam engines are worked in a manner that approximates the case given so far as waste of steam is concerned. All engines working the steam full stroke, and consequently performing no work by the expansive power of the steam that passes through the cylinders, do their work at the expense of enormous waste of heat, and practically pass all the heat transferred from the fuel to the water out through the exhaust. The economical thermal efficiency of an engine worked in this way is about as low as it can be. The steam does its work in the cylinder by sheer pressure of the densely compressed volume crowding out of the boiler. Worked in this way, the action of steam on a piston resembles the action of water on a hydraulic ram where the water is forced against the ram by the action of the pump behind it. Or steam passing from without expansion and passing to the exhaust by the way of a cylinder, resembles a stream of water passing through a turbine, with the exception that in the latter case work is taken out of the water by reduction of its velocity, while in the case of the stream its full potentiality for work is present at the moment of its release.

HELP THAT SCIENCE HAS GIVEN THE STEAM ENGINEER.

Numerous insuperable obstacles stand in the way of admitting steam without loss or diminution of pressure into a cylinder made of conductive materials, or to exhaust it without back pressure; but to render clear certain calculations respecting the manipulation of steam, it is convenient to assume that other impracticable operations are possible. Many valuable and interesting laws, facts and figures relating to the behavior and action of steam, which the engineering world accepts as being absolutely correct, could not be demonstrated with any degree of accuracy in the ordinary practical working of the steam engine. They are the discoveries and calculations of accomplished physicists and mathematicians, who have devoted laborious and skilful special investigation to the subject aided by ingeniously designed apparatus. In studying out questions relating to heat and steam, the engineer often has to accept as implicitly as he believes the multiplication table, formulas and tables of data given in handbooks which he has no means of verifying. Facts, figures and tables about heat and steam that excite but little attention from the men daily using them, are in themselves monuments of assiduous and accurate scientific labor, built up by eminent men who have devoted life-long efforts to the investigating of nature's laws. Among the physicists and mathematicians whose names are identified with the investigations bearing directly in steam engineering, are many whose existence is merely an abstraction to the ordinary engineer, yet their labors have materially lightened his work, and supplied him with data for calculations that enable him to measure heat as accurately as the farmer measures his corn.

APOSTLES OF ENGINEERING SCIENCE.

More than two centuries ago, Boyle, an Irish nobleman and chemist, discovered the law that the pressure of a gas varies inversely as its volume, and directly as its intensity, and which is yet often spoken of as Boyle's law. About the same time Mariotte, a French physicist, was investigating the same subject, and his discoveries were similar to those of Boyle, but somewhat fuller, so that the law referred to relating to gases is often called the Mariotte law. About a century ago Benjamin Thompson, Count Rumford, an American engineer, discovered and proved the immateriality of heat, and showed that heat and mechanical work are mutually convertible. Rumford's work prepared the way for the labors of Joule, an English scientist, whose ingenious experiments and investigations resulted in the determining of the mechanical equivalent of heat.

His experiments made out 772 foot pounds as being the mechanical equivalent of raising the temperature of one pound of water one degree at its greatest density, but later investigations have proved the correct equivalent to be 778.3 foot pounds.

Early in this century, Dalton, the famous English chemist, and Gay-Lussac, a noted French chemist, made some very important discoveries as regards the effects of temperature on steam. A few years later Messrs. Fairbairn and Tate, celebrated British engineers and physicists, by calculation and experiment established the relative volumes and pressures of steam through a range of temperature suitable for the steam engineering practice of that time. The same department of research was afterwards taken up by Regnault, the famous French scientist, already referred to, and he conducted at the expense of the French government and under the auspices of the French Academy of Sciences a most exhaustive series of experiments with heat, water and steam. They were wonderfully accurate, and extended through a wide range of temperatures and pressures. That was fifty years ago, and the results they ascertained still remain standard, and are regarded as models of precise physical work. The experimental inductions of Regnault relating to the densities of, or volumes occupied by, steam under different pressures, were to a great extent demonstrated mathematically to be correct by Professor Rankine, the celebrated Scotch mathematician and engineer, who also formulated numerous equations of thermodynamics. Of late years Daniel Kinnear Clark, the celebrated investigator of locomotive problems, and Chief Engineer Isherwood, of the American Navy, have made many valuable discoveries respecting the action of steam in the practical operations of the steam engine, and their demonstrations of the cause and extent of cylinder condensation entitle them to eminent positions as physicists.

CUTTING OFF AT QUARTER STROKE.

The cylinders of a locomotive do not provide the facilities for working steam expansively that the cylinders of some engines give, but a material saving of heat and fuel can be effected if the limited possibilities are properly utilized. We may take a cylinder of the same dimensions as those given in the previous example, and work the steam expansively. Suppose we admit steam for 25 per cent. of the stroke, or 6 ins., an operation very common with locomotive work. To make the conditions of this experiment agree with those of the last one, we must ignore the effects of clearance and other disturbing elements, and assume that the steam enters the cylinder at boiler pressure, or 145 lbs. absolute, during 6 ins. of the stroke, and that after being cut off by the closure of the valve it expands according to the Mariotte law. The ratio of expansion in this case will be 4. That is, the steam will be expanded until at the finish of the stroke it will occupy four times the space it did when admission ended. The ratio of expansion is found by dividing the whole stroke in inches by the distance in which steam was admitted, thus $24 \div 6 = 4$.

THE CURVE OF EXPANDING STEAM.

As the piston is pushed onward past the point of cut off, the steam passing into the increased volume will expand according to the ordinates of a hyperbolic curve *a b c d*, Fig. 1, Plate 4. When the piston reaches the point *b*, the steam occupies twice its original volume, and the pressure has fallen to 72.5 lbs. When *c* is reached, the steam occupies three times its original volume and the pressure is 48.33 lbs.; and when the end of the stroke *d* and point of release is reached, the steam occupies four times its original volume, and the pressure is 36.25 lbs. The actual performance would be a little different from this because there would be a fall of pressure due to the steam performing the work of pushing the piston along and from other causes, but this calculation is near enough to show the performance of a good locomotive doing actual service, and to form the basis for estimating the work an engine can do, using steam at certain pressures and ratios of expansion.

PROPORTION OF HEAT CONVERTED INTO WORK.

In our example of an engine working with steam full stroke, the steam escaped through the exhaust practically at boiler pressure, and carried away with it nearly all the heat used by the fire in raising one pound of water to steam at 145 lbs. pressure. When the steam is worked expansively, as in the last example, a portion of the heat is converted into work, and the quantity thus utilized represents the measure of economy in a steam engine. In the engine working with four volumes of expansion, the steam while doing work falls from 145 lbs. to 36.25 lbs. absolute pressure, and as a consequence the temperature of the steam falls from 355.6° to 260.7° Fahr. According to Regnault's tables, one pound of steam of 145 lbs. pressure absolute, expanded against resistance down to 32° Fahr, without cylinder condensation, converts 498 heat units into work. In the case under consideration, the steam is exhausted at 36.25 lbs., and according to the same authority still contains 387 heat units that would be converted into work by expansion to 32° Fahr. This indicated that $498 - 387 = 111$ heat units of the steam have been converted into work by the act of expansion, and therefore that that quantity is utilized out of the total measure of heat expended.

There were 1,172 heat units expended in converting the pound of water into steam, so the economical efficiency of the work done is $111 / 1172 = .093$, or a little under 10 per cent. From these figures it will be perceived that with an engine working under exceptionally favorable conditions, an enormous quantity of heat is necessarily lost by passing out through the exhaust. Increasing the ratio of expansion increases the direct gain of heat, but it generally introduces indirect sources of loss that neutralize the gain, or in many instances involve loss instead of preservation of heat energy.

The steam engine cylinder, especially that of the ordinary locomotive, will not produce a diagram of pressure equal in area to that employed in the illustration with similar boiler pressure, but a good steam-jacketed condensing engine working with steam of like pressure in cylinders of the same size will do its work with nearly an equal amount of economy. In the illustration given only one-quarter of a pound of steam is supposed to have been used, but the proportion of economy would be nearly the same as if a whole pound of steam had been used under enlarged conditions.

TO ESTIMATE THE MEAN PRESSURE OF EXPANDING STEAM.

The mean pressure of the steam used throughout the stroke, in the foregoing example, may be found by dividing the diagram into a number of equal ordinates, one line of which passes through the point of cut off, and another borders the end of expansion, and taking the sum of the average pressure. The more common way is to make the calculation by the aid of hyperbolic logarithms. Find 4, the ratio of expansion on the number line in a table of hyperbolic logarithms, and take the number opposite to it, which will be 1.386. Add 1 to this number and multiply the same by the absolute steam pressure thus, $2.386 \times 145 = 346$. Divide this by 4, the ratio of expansion, and the product will be 86.5, the mean pressure in pounds per square inch of steam of 145 lbs. absolute pressure cut off at 25 per cent. of the stroke.

To obtain a fairly accurate average pressure the proper allowance must be made for clearance.

To make this calculation apply to a locomotive, 18 lbs. at least must be deducted for back pressure. This would reduce the mean effective pressure to 68.5 pounds.

ECONOMY OF USING STEAM EXPANSIVELY.

The economy of heat resulting from using steam expansively has already been noticed. Another advantage in using steam expansively is that a greater proportion of work can be obtained from a given weight of steam. The cylinder of the engine, we have been using as an illustration, takes one pound of steam at each stroke, and produces an average piston pressure of 145 lbs. to the square inch. To ascertain the mean effective pressure throughout the stroke, 18 lbs. must be deducted for back pressure, leaving the calculation 145 — 18 = 127 lbs. With the steam cut-off at 6 ins., and therefore only using one-quarter of the weight of steam employed in the full stroke example, we obtain an average mean effective pressure for four fillings of the cylinder or strokes, and the total work obtained therefrom is $68.5 \times 4 = 274$ lbs. average, more than double the work obtained from one pound of steam without expansion.

The case would not come out just this way in practice, for there would be considerable cylinder condensation when the steam was used expansively, but the example will indicate approximately the result of working steam expansively in a locomotive.

As all engineers who wish to estimate the quantity of steam used in their cylinders under different conditions have not charge of cylinders that are self-measuring, as in the example given, it may be well to state a general rule for finding the weight of steam used in any cylinder.

Let us take a cylinder 18 ins. in diameter. The area of the piston is 254.47 sq. ins. Each inch in the stroke represented that number of cubic inches. Suppose steam is cut off at 6 ins., the quantity admitted will be $254.47 \times 6 = 1{,}526.82$, or .8835 of a cubic foot. One cubic foot of steam at 145 lbs. absolute pressure weighs .3294 of a pound, so $.3294 \times .8835 = .29$ lb. the quantity of steam used in such a cylinder while cutting off at 6 ins.

This is merely an approximation, for there are several circumstances which interfere with the volume and pressure of steam admitted into a cylinder, but it is near enough the truth to find out the power likely to be developed in a cylinder of certain proportions while cutting off at a given point.

MEASURING THE STEAM THAT PASSES THROUGH THE EXHAUST.

Reckoning the quantity of steam that should be used in a cylinder by calculating its cubic content, the point of cut off, and the pressure of steam does fairly well as a means of finding out the amount of power likely to be developed with a certain cylinder capacity; but when the question arises of how much steam a cylinder is actually using to do the work required of an

engine, a more accurate method must be adopted. No engine takes steam into the cylinder at boiler pressure, very few cylinders hold the steam to an even pressure up to the point of cut off, and no engine is worked without more or less back pressure. The amount of these disturbing elements cannot be estimated near enough for practical purposes, and the indicator diagram is universally used as a medium of calculation by those who wish to find out with any degree of accuracy how much steam an engine is using.

The indicator diagram does not account for all the steam that passes into a cylinder, but its record is the best that science and mechanical ingenuity have yet produced. When steam flows from a boiler into a cylinder it goes into a comparatively cold vessel, with the result that part of the heat contained in the steam is used to raise the temperature of the metal of the cylinder. As saturated steam is always at the dew point, or ready to fall back into water on the abstraction of any heat, the steam which gives up its heat to the cylinder becomes water, or, in other words, is condensed. The steam condensed in this way loses its work-performing energy, it applies no propelling force to the engine piston, and therefore does not act upon the piston of an indicator, so it exerts no direct influence on the diagram.

Engineers have found that the most accurate way of estimating the steam accounted for by the indicator diagram, is to calculate the volume of steam that passes out through the exhaust. This is done in several ways. A common way is the selecting of a point on the diagram just previous to the opening of the exhaust, and there measuring the pressure of steam above vacuum. The displacement of the piston in cubic feet up to that point, plus the clearance space multiplied by the weight of a cubic foot of steam pressure selected, will give the weight of steam present.

THOMPSON'S METHOD OF FINDING THE QUANTITY OF STEAM USED.

A method of estimating the steam indicated by the diagram, which is very convenient and easy of application to locomotive work, is that prepared by Mr. E. W. Thompson. To apply the plan a knowledge of the mean effective steam pressure of the diagram is alone essential. Let us calculate the steam consumption represented by the diagram, shown in Fig. 2, Plate 5, by Mr. Thompson's method. The diagram was taken from an engine belonging to the Chicago & Northwestern Railway. The cylinders are 16×24 ins., drivers 5 ft. 3 ins. diameter, boiler pressure was 135 lbs. by gauge,

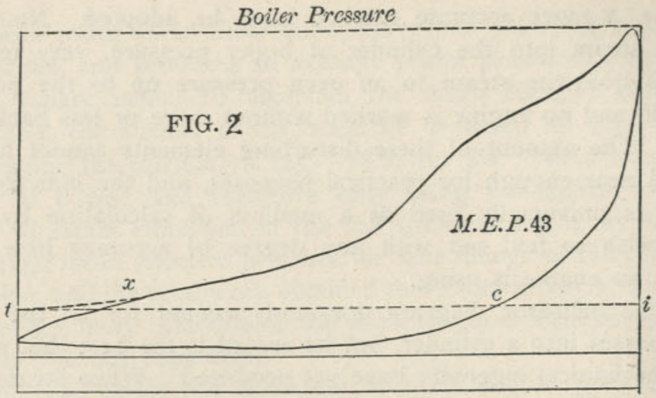


FIG. 2

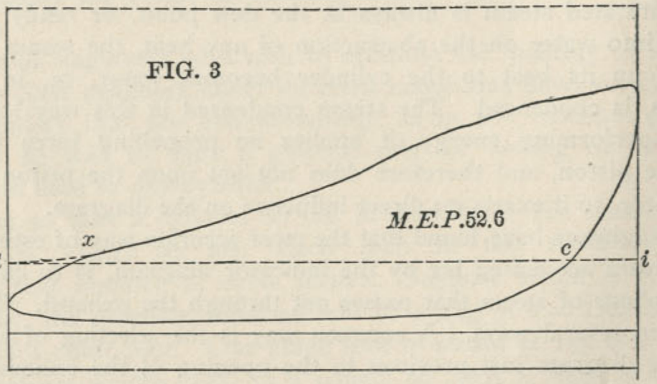


FIG. 3

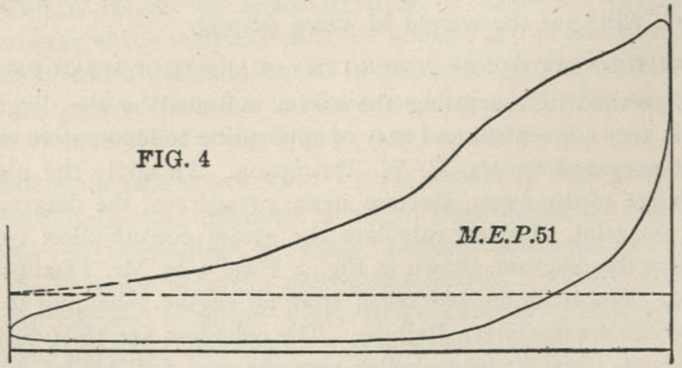


FIG. 4

PLATE 5

and the engine was making 228 revolutions per minute when the card was taken. The indicator spring was 80 lbs. to the inch. All these particulars are not necessary for calculating by the Thompson process the steam used, but they may be interesting for other purposes.

We draw a vertical line at each end of the diagram defining its exact length. The expansion line is continued by a dotted line from the point of release *x* to the end of the diagram *t*, making the expansion curve what it would have been had the valve not opened till the end of the stroke. From the point *t*, or height of unreleased terminal pressure, we draw the line *t c i* parallel with the atmospheric line. At *t* the terminal pressure above the vacuum line is measured, and found to be 34 lbs. In the annexed table, which is condensed from one used in Hemenway's Indicator Practice, we look for the number opposite T P 34, and find it to be 1,152.26. The columns in the table give the steam represented by pounds and half-pounds, that being as near as can be measured correctly with the strong springs used for locomotive indicator work.

THOMPSON'S COMPUTATION TABLE.

TP	TP	TP	TP	TP	TP
....	11.0.....398.640	21.0..... 732.690	31.0....1 056.480	41.0....1,374.320	51.0....1,688.100
....	11.5.....415.725	21.5..... 749.060	31 5....1,072.418	41 5 . . 1,390.043	51.5....1,703.620
....	12 0.....432.720	22.0. ... 765.380	32.0....1,088.320	42.0....1,405.740	52 0....1,719.120
....	12.5 ....449.688	22 5 .... 781.763	32.5....1,104.350	42.5 ....1.421.413	52.5... 1,734.600
3.0......117.300	13.0 ....466.570	23.0 .... 798.100	33.0 ...1,120.350	43.0....1,437.060	53.0....1,750.060
3.5......135.748	13.5.....483.435	23 5..... 814.393	33.5 ...1,136.420	43.5....1,452.900	53.5....1,765.500
4.0......153.880	14.0.....500.220	24.0..... 830.640	34 0....1,152.260	44 0....1,468.720	54.0....1,780.920
4.5......171.945	14.5.....517.070	24 5..... 846.965	34.5....1,168.170	44.5....1,484.520	54.5....1,796 320
5.0......189.750	15.0.....533.850	25.0..... 863.250	35.0....1,184.050	45.0... 1,500.300	55.0....1,811.700
5.5......207.598	15.5.....550.638	25.5..... 879.495	35.5....1,199.900	45.5....1,516.060	55.5....1,827.338
6.0......225 240	16.0.....567.360	26.0..... 895.700	36.0....1,215 720	46.0....1,531.800	56.0....1,842.960
6.5......242.970	16.5.....584.100	26.5..... 911.865	36.5 .. 1,231.693	46.5....1,547.520	56.5....1,858.568
7.0......260.540	17.0.....600.780	27.0..... 927.990	37.0 ...1,247.640	47.0....1.563.220	57.0....1,874.160
7.5......278.063	17.5 ....617.400	27.5..... 944.075	37.5....1,263.563	47.5....1,578.900	57.5....1,889.738
8.0......295 440	18.0.....633.960	28.0..... 960.120	38.0....1,279.460	48.0....1,594.560	58.0....1,905.300
8.5......312.800	18.5 ....650.460	28.5..... 676.268	38.5....1,295.333	48.5....1,610.200	58.5....1,920.848
9.0......330.030	19.0 ....666.900	29.0..... 992.380	39 0....1,311.180	49.0....1,625.820	59.0....1,936.380
9.5 .....347.273	19.5.....683.378	29.5.....1,008.458	39.5....1,327.003	49.5....1,641.420	59.5....1,951.898
10.0.....364.400	20.0.....699.800	30.0.....1,024.500	40.0....1,342.800	50.0....1,657.000	60.0.., 1,967 400
10 5....,381.570	20.5.....716.270	30.5.....1,040.508	40.5....1,358.573	50.5....1,672.560	60.5....1,982.888

The number found has to be divided by the mean effective steam pressure of the diagram, and the quotient will be the amount of steam used per horse power per hour, without taking into account the discrepancies due to clearance and compression. Allowance is made for these by multiplying the amount of steam by 2.5, the length in inches of the line *t c*, and dividing the product by 3.219, the length in inches of the line *t i* or total length of the diagram. The complete problem is $1{,}152.26 \div 43 = 26.8 \times 2.5 = 67 \div 3.219 = 20.8$ pounds of steam exhausted per horse power per hour, as shown by the indicator. This does not give any account of the loss of steam due to cylinder condensation.

WORK OF A COMMON LINK MOTION LOCOMOTIVE.

That steam distribution shows the work done by a common link motion engine cutting off at about 7½ ins. and running at a fairly high speed, the piston speed having been 912 ft. per minute. With a moderate quantity of coal the engine would appear to do the work with little more than three pounds of coal per horse power per hour. The diagram looks inferior compared to those ordinarily taken from automatic engines, and it is small compared to the theoretical diagram, but the absence of a horizontal steam line, or the want of distinctly defined points of cut off, release and the beginning of compression do not always render it certain that the engine is making inferior use of the steam passed through the cylinders.

This is a fairly representative diagram for an American locomotive working with the throttle full open, the reverse lever well hooked up; and something exceedingly close to its outlines would be got from the majority of our passenger engines that can do their work in the first notch ahead of the center. This engine has a high exhaust pipe of ample proportions, and a single nozzle which gave free afflux of steam and kept the counter pressure very low.

Through the action of somewhat high compression, the steam inside the cylinder is almost equal to boiler pressure when the piston begins its stroke, but as the piston moves away from the cylinder head, the flow of steam is not sufficient to keep the increasing volume of cylinder full, and what Hemenway calls initial expansion is present from the beginning of the stroke. That is, the passages and valve opening not being large enough to admit sufficient steam to maintain the initial pressure, the steam expands and the pressure falls before cut off takes place. This reduces the power of an engine, but it is doubtful if it detracts much from the economical use of steam. The link motion closely hooked up, leaves such a limited valve travel that the events of the stroke are not sharply defined on the lines of the diagram, the exact points of cut off, release and beginning of compression being hard to identify. A fault that many engineers would find in the diagram is the great amount of compression, but those who have investigated the subject of cylinder condensation most thoroughly are disposed to hold that compression, while kept within fair limits, is no source of heat waste. While compression is merely sufficient to raise the steam in the cylinder at the beginning of the stroke to steam-chest pressure it cannot be called excessive.

EFFECT OF THROTTLING.

The diagram shown in Fig. 3, Plate 5, was taken from the same locomotive under what would be regarded among railroad men as merely slightly different conditions from the other one, yet the slight change in conditions materially affects the economical operation of the engine. The boiler pressure was 135 lbs., the speed was 132 revolutions per minute or 528 ft. per minute of piston speed, and the reverse lever was in the 9-in. notch, which in reality permitted the steam to follow the piston 10¼ ins. of the stroke. The boiler pressure was the same as when diagram No. 2 was taken, but the initial cylinder pressure in this instance was only 100 lbs., as compared with 135 in the other case. There was less compression in the diagram No. 3, but the principal cause of the reduced cylinder pressure was that the engine was worked with the throttle partly closed. At the comparatively slow speed of the piston there was no reason why the cylinder pressure during admission should not have been within 8 per cent. of boiler pressure, but in reality it was 26 per cent. below boiler pressure. The man who handled the throttle was alone to blame for this. It results from engineers not being properly impressed with the importance of working their engines so that the full ratio of expansion shall be obtained. The engine is allowed to drag along with a light throttle and the lever in the 9-in. notch, when it ought to be hooked up to 6 ins. and the throttle opened wide. With a full throttle, in the 6-in. notch, at the speed reported, this engine would have developed as much power as she did in the 9-in. notch with the throttle partly closed, and the steam would have been used to greater advantage. The practice of marking the quadrants different from what the real points of cut off are, is responsible for much waste of steam, and was so in this instance. The first two notches were marked 6 and 9 respectively, and the real points of valve closure were 7½ and 10¼. An engineer gets to think he is working his engine to good advantage at 6 ins., and 9 ins. does not appear to be letting the steam follow too far. If the man at the throttle understood that, instead of being cut off at 9 ins., the steam was following the piston nearly half stroke when the lever was in the second notch, he would, in nearly every instance, link up more promptly.

It has always been admitted by those best able to judge, that the safe and economical operation of American railroads has depended greatly upon the intelligence and care of trainmen. The engineer is one of the most important factors in this element, and it is right that his natural care and intelligence should be developed. This cannot be done by ignoring his needs. The road that permits the locomotives to run with the quadrant notches wrongly marked is deceiving the engineer, and the mechanical management is to blame for waste of coal that results.

Let us examine the testimony of diagram No. 3 and compare its record with the previous example. The mean effective pressure is 52.6 lbs. The terminal steam pressure is 45 lbs. above the vacuum line. In the Thompson table, 45 gives 1500.3. The total length of the diagram is 3.25 ins.; the distance from *t* to *c* is 2.9375. The computation of the steam used is then $1500.3 \div 52.6 = 28.52 \times 2.9375 = 83.777 \div 3.25 = 25.8$ pounds of steam exhausted per horse power per hour. That is using close to one-fifth more steam to do the work, which could be saved by merely pulling up the reverse lever one notch. A locomotive doing the kind of work this one was employed upon, uses about 50 lbs. of coal per train mile. A change which is calculated to reduce this coal consumption to 40 lbs. per mile would effect material reduction in the operating expenses and is worth looking into.

EFFECT OF KEEPING THE THROTTLE WIDE OPEN.

That a fairly high mean effective pressure can be maintained in the cylinders of a good link motion cutting off short is proven by Fig. 4, which was taken from another engine while running at 192 revolutions per minute, and a piston speed of 768 ft. The boiler pressure was 140 lbs., and the initial cylinder pressure is 135 lbs. Working with an average cylinder pressure almost as high as that maintained by the illustration given in Fig. 3, this engine had a terminal pressure of 39 lbs., yet the work was done with an expenditure of 21.3 lbs. of steam per horse power per hour. The axiom of steam engineering, "Get the steam into the cylinder at high pressure and exhaust it at low pressure," was followed as closely as possible with the engine.

While the practice of running with the throttle wide open may be considered good engineering, there are circumstances where steam is saved by running with the throttle partly closed. It is unnecessary to discuss the causes that produce this condition, for

all intelligent engineers may be depended upon to run the engine in the way that observation has indicated would give the best results.

VELOCITY OF STEAM.

The utility of high-pressure steam as a means of transforming heat into mechanical work results in a great measure from its expansive force, and the velocity and freedom with which steam passes from one vessel to another or out into the atmosphere. The velocity of the flow of steam depends directly upon its pressure, and is as the velocity of a body falling freely by gravity from a height equal to a column of steam represented by the steam pressure, or to the difference of level between the height of the column of steam and the height represented by the pressure of air or other vapor into which the steam is passing. One exception to this is that the velocity of steam flowing into a vacuum is constant at all pressures.

To calculate the velocity with which steam of any given pressure passes into a medium having a pressure equal to the atmosphere, the following process may be followed: The required height of the column of steam is estimated by its proportion to a column of water due to a certain pressure. The square root of the height multiplied by 8, that well known rule regarding falling bodies, gives the velocity of steam due to the pressure. Suppose we wish to find out the velocity of steam of 10 lbs. pressure above the atmosphere. It is well known that 1 lb. of pressure represents a column of water 2.3 ft. high, and 10 lbs. pressure will represent a column of water 23 ft. high. At that pressure above the atmosphere, 1 lb. of steam occupies 1,008 times the volume of a pound of water. So $23 \times 1{,}008 = 23{,}184$ the height of the column of steam. Then $\sqrt{23{,}184} \times 8 = 1{,}218$, the velocity in feet per second of steam of the pressure given. A small fraction is omitted, but the result is nearly correct enough for practical purposes.

The quantity of steam of any pressure that will pass out of a safety valve, a whistle slot or other opening can be calculated by this rule; but it is found that when the opening is made in a thin slot the escaping jet of steam suffers a contraction, so that its area is reduced from 30 to 50 per cent.

To calculate the velocity with which steam will pass into a cylinder or other vessel that is already filled with vapor above atmospheric pressure, the difference between the two pressures has to be taken. Suppose we have a steam chest pressure of

100 lbs. above the atmosphere, and at the beginning of the stroke the cylinder has a pressure of 35 lbs. due to back pressure and compression. The question is, at what velocity will the steam begin to pass from the steam chest into the cylinder? Deducting the lower pressure from the higher one will give a basis for a column to generate the velocity. The velocity of steam passing from any higher to a lower level may be found at any point by this process.

ADVANTAGES OF USING HIGH-PRESSURE STEAM.

The degree of pressure at which steam is admitted into the cylinder of a steam engine exercises a direct and important bearing upon the economical working of the engine. American engineers have always been noted for employing high tension steam, and this feature of our engineering practice has done much to develop the peculiarities of the American type of steam engine. When Watt and his contemporaries in Britain were operating their ponderous engines with pressures seldom more than 10 lbs. above the atmosphere, Oliver Evans and other early American engineers were using steam of 100 lbs. pressure and upwards to the square inch. As a result the small non-condensing engines developed certain powers with one-tenth of the weight of machinery used abroad, and compared favorably in point of economy with the elaborate and expensive engines that found favor and patronage in other countries. The force of numbers in following a bad example led many of our engineers to adopt the European practice of low steam pressure, but it was a move in the wrong direction which all those concerned had to pay for.

Those who have been able to note the rise in steam pressures from about two atmospheres or under to twelve or fifteen atmospheres as common working pressures, are well aware that the change has effected enormous saving in fuel. When 10 lbs. above the atmosphere was the steam pressure ordinarily employed, each horse power developed by the engine would require the consumption of 15 lbs. or more of good coal per hour. Work was done so expensively under these conditions that the use of steam in transportation was seriously curtailed. Had no material change taken place, millions of acres of land in the states remote from the seaboard, that are now producing wheat and corn, and give comfortable homes to prosperous settlers, must have remained a wilderness, for the cost of transportation would have rendered the produce of no value to the producer. Increase

of steam pressure, combined with other mechanical improvements, has changed all this. The plain slide-valve engines employing steam of 100 lbs. pressure now used in many factories, do their work with a coal consumption of about 5 lbs. per horse power per hour. Superior types of engines produce much better results, and high-class engines now produce a horse power on about $1\frac{1}{2}$ lbs. of fuel. A considerable share of this saving is due to improvement in mechanism, but the greater proportion results from the use of high pressure steam.

Using steam of high pressure is economical for several reasons; in the first place, steam of high pressure admits of a wide range of expansion. Examples have already been given of the increase of work that may be obtained from a given volume of steam by using it expansively. Every pound of increased tension augments the value of the steam as a medium of doing work, and one of the most urgent themes among officers responsible for the economical operation of railroads is that of having the potential power of the high-pressure steam confined by the strong boilers converted into the work of turning a locomotive's driving wheels, instead of being reduced and its forces wasted by passing through a restricted throttle opening. The quantity of heat expended in raising steam to a tension of 150 pounds is very little more than that required to evaporate the water at atmospheric pressure, yet the high tension makes a wonderful addition to the capacity of steam for doing work in an ordinary cylinder. As has already been explained, it takes 1,146 heat units to convert one pound of water into steam at atmospheric pressure. The expenditure of 47 more heat units raises the steam to a pressure of 150 pounds. Heat is the source from which all the power of steam is derived—and if the steam engine was a perfect means of converting heat into work, the small quantity of heat employed to raise the tension of steam from gauge zero to 150 lbs. would be proportionally of the same value as the heat first applied to the water. But with the imperfect steam engine at the service of the industrial world, the first 1,146 heat units would practically be worthless for motive power purposes, at least with non-condensing engines. The heat units added to make up a good working pressure of steam constitute the active element in the boiler, and provide the means of converting heat into work.

A second advantage gained by using steam of high pressure is, that the proportion of the heat expended in overcoming external resistance, is small compared to the total heat expended.

A third advantage is that the proportion of back pressure in the cylinder that uses high-pressure steam is smaller than is practicable with a cylinder using low-pressure steam. There is always more or less steam in the cylinder that fails to escape when the exhaust port is opened and it obstructs the piston during the return stroke. The amount of back pressure is not materially affected by the initial pressure of steam. With high initial pressure the obstruction of back pressure is not likely to seriously affect the efficiency of an ordinary engine, but with low initial pressure the case is different, and a large proportion of work done by the steam on one side of the piston may be expended in expelling the steam on the exhaust side.

DISADVANTAGES OF USING HIGH-PRESSURE STEAM.

Although the advantages of using high-pressure steam are manifold, the practice entails a few drawbacks. The temperature of the boiler being high corresponding to the steam tension, the gases of combustion must pass out at a relatively high temperature, carrying away heat that might be retained in a boiler furnishing low-pressure steam. The boiler that furnishes steam of high pressure must be stronger and better made than one that is intended for carrying light pressure. There is considerably more friction to the rubbing surfaces of an engine operated with high-pressure steam than that with low pressure. When the steam pressure carried on British locomotives was under 100 lbs., they were run without any cylinder lubrication, and there was very little cutting of rubbing surfaces; but steam of 140 lbs. cannot be used without the means of oiling valves and pistons. Even with a good means of supplying lubricants, there appears to be a high percentage of the power of engines using high-pressure steam absorbed in overcoming internal resistances.

LIMITS TO THE ADVANTAGES OF HIGH-PRESSURE STEAM.

There is probably a limit not beyond the prevailing range of high boiler pressures, where increase of tension will cease to be economical. A superficial knowledge of the laws relating to steam has led some engineers into error respecting the economy that may be obtained by continuing to increase boiler pressures. They reason that increase of steam pressure from 10 to 100 lbs. having been productive of the most gratifying results, to raise the working pressures 100 or 200 lbs. more must lead to a proportionate saving of coal, the only added outlay being for stronger boilers. Like many other problems in steam engineering, this one would

not work out in the way popularly expected. As the tension of steam increased the proportion of saving obtained by higher pressures increases slowly. A perfect steam engine is not found at work any more than the cylinder we figured on that produced no condensation or reduction of pressure, but calculations based on the theoretical performance of a perfect steam engine may put the case clearly to our readers, and show why the economical limit of steam pressure may be nearly reached when boilers carry 150 lbs. of pressure per square inch. The following table shows the steam per horse power per hour required in a perfect non-condensing engine at certain gauge pressures:

Gauge pressure.	Pounds steam per I. H. P. per hour.	Gauge pressure.	Pounds steam per I. H. P. per hour.
10	69	90	17
20	41	100	16.25
30	32	125	14.70
40	26	150	13.60
50	23	175	12.80
60	21	200	12.16
70	19	250	11.20
80	18	300	10.48

A critical examination of the figures given will show that increasing the pressure from 10 to 30 lbs. reduced the steam consumption more than one-half, and increasing the pressure from 50 to 100 lbs. reduced the consumption of steam 6.75 lbs. per horse power per hour. Increasing the pressure from 100 to 150 lbs. did not bring forth such a gratifying result in the way of saving as the others, still the horse power per hour was obtained with a reduction of 2.65 lbs. of steam per horse power per hour. The next increase of 50 lbs. pressure brings only a steam reduction of 1.44 lb., and every succeeding increase of pressure is followed by items of steam saving that grow beautifully less.

No high-pressure steam engine obtains the work named out of the quantities of steam mentioned, for no account is there allowed for losses due to condensation, back pressure and other causes, but well-designed steam engines properly managed do their work with a saving that closely corresponds to the figures given when increase of initial pressure is introduced.

ECONOMICAL LIMIT OF WORKING STEAM EXPANSIVELY.

The table given of steam used per horse power per hour for various pressures is worked out on the supposition that the steam is expanded down to atmospheric pressure without loss of energy from liquefaction or other causes. Expansion to this extent and under such conditions is impracticable, and the calculations made on such a basis are useful only as an intelligible means of comparative measurement. But although expansion of steam to the extent given in the table is out of the question, expansion within possible limits is the correct line of economical working. We hear a good deal said occasionally about the most economical point of cut off and the economical limit of working steam expansively, but the objections urged against wide ratios of expansion do not apply to locomotive practice. Steam is very rarely expanded too far with locomotives having the link motion and fairly well protected cylinders; and the advice will generally be accepted as sound to make the ratio of expansion as great as possible. There is undoubtedly a limit where expansive steam makes expensive operating, but it is seldom reached in locomotive practice. Taking the ordinary locomotive as having a stroke of 24 ins., the shortest point of cut off possible with the link motion, to give an opening that will admit steam enough for ordinary work, is 6 ins., or 25 per cent. of the stroke, a proportion that holds good with engines having a shorter or longer stroke. When the cut off takes place at 6 ins., release will happen at 16 ins., or less, so that the steam is not expanded three times before the valve opens. The expansion will not be more than four to one, reckoned to the end of the stroke when the steam is passing out during part of the time.

This is far short of the economical limit of expansion. The trans-Atlantic steamers that have been operated most economically use from 7 to 8 expansions with compound engines and steam-jacketed cylinders, but many engineers believe that the expansion is far too limited.

HIGH PRESSURE AND SMALL CYLINDERS.

There is another cause not yet adverted to for high-pressure steam being more economical than steam of low tension. High-pressure steam performs a given measure of work with much less cylinder capacity than what is practicable with steam of low pressure. Increasing the diameter of the cylinder adds rapidly to the extent of rubbing surface which causes loss of useful effect by frictional resistance, and also increases the area that produces condensation of steam. An ordinary locomotive carrying 100 lbs. gauge pressure and cutting off at 9 ins., will have an average cylinder pressure of 40 lbs. while making 150 revolutions per minute. If the driving wheels are 5 feet diameter, this piston speed will

keep the train going about 26 miles per hour. The same locomotive carrying 145 lbs. boiler pressure, will average 60 lbs. cylinder pressure. An engine with cylinders 16 in. diameter will do as much work with 145 lbs. boiler pressure as an engine with cylinders 20 ins. diameter can develop while using steam of 100 lbs. pressure.

The constant increase of weight of trains and acceleration of speed makes a demand for more powerful locomotives, and the present tendency is toward heavier engines and larger cylinders. The cylinders have been increased in rapid succession from 17 to 18, 19, 20 and 22 ins., with stroke ranging from 24 to 32 ins., the same proportion of power being maintained with compound locomotives. It has been demonstrated repeatedly that increase of cylinder, when the higher sizes are reached, has not been attended with a corresponding increase of power. Few master mechanics are satisfied with the performance of large cylinder locomotives, the complaint being heard on all sides that they are not nearly so good for their inches as smaller engines. The cause of this is not far to seek. In the first place, the steam ports of large cylindered engines are seldom proportionally as large as the ports of smaller engines. Then a serious proportion of the added power is lost by friction, and a great portion of the steam is condensed by the increase of cylinder area. An engine with cylinders 19 × 24 ins. has over 300 sq. ins., equal to 19 per cent. more rubbing surface in the cylinders than an engine with cylinders 17 × 24 ins. The increase of area that acts the part of a condenser to the steam is considerably greater for the larger cylinders. Rubbing surface in a cylinder induces greater friction and causes much greater internal resistance than any other part of the engine except the slide valve, consequently every effort should be made to reduce this surface to its smallest possible limit.

Material increase of boiler pressure should be resorted to as a means of obtaining increase of power without making the cylinders larger. This convenient means of increasing power is seldom resorted to, and in most instances where pressures have been raised above the common practice it has not been done with a view of keeping down the cylinder area. A master mechanic has a type of engine with cylinders 17 × 24 ins. and wheels 60. ins. diameter, the boiler carrying steam of 130 lbs. pressure. This engine in starting in full gear develops 13,500 lbs. traction, and in running at 26 miles an hour, cutting off at 9 ins., the tractive force is 6,358 lbs. The engines are not handling the trains satisfactorily, and new ones are ordered with cylinders 18 ins. diameter, the other dimensions being the same except that the boiler is larger. When these engines go into service they are reputed to be little or no better than the old ones, and everybody is surprised. Now, if the boiler pressure had been increased 15 lbs. and the old size of cylinders retained, the engines would have developed as much power, at the same time having 152 sq. ins. less cylinder area. By increasing the boiler tension to 160 lbs., the old size of cylinders would have developed power equal to that of a pair of cylinders 19 × 24 using the lower working pressure. The engine with the small cylinders and high boiler pressure would not indicate so much power when linked close up, but the internal frictional resistances would be so much less and other sources of waste would be so much reduced that the engine could be depended upon to do much more work with less expenditure of steam.

LARGE CYLINDERS.

Too much cylinder capacity for the boiler and for the weight on drivers has been the weak feature of American locomotive design, and the master mechanics now realize the increased expense of operating that arises from this cause. With stationary engine and marine engine work, the practice has been very successfully followed by using large cylinders that would admit of early cut off and large ratio of expansion while performing the necessary work, the tendency to loss from condensation being restrained by steam jacketing and superheating.

Many engineers and inventors have insisted that a practice which results in valuable saving of fuel in the case of stationary and marine engines ought to be applicable to locomotives, hence the many efforts to provide valve motion that would give a prompt opening and closure of steam ports, and permit steam to be put into the cylinders of locomotives more quickly than is possible with the slow valve movement given by the link. These men reason that, if the valve movement could be sufficiently accelerated for short points of cut off, steam would be admitted at much higher average pressure, and that four or five expansions could be obtained before the steam was released. Some good, practicable valve motions have been produced embodying this idea, but there is no evidence that they effected any economy in the use of steam.

Another practice has been to provide a large cylinder in the expectation that the engine would be worked habitually with the shortest possible cut-off and steam saved thereby. A case in point

was a group of passenger engines with cylinders 18 × 24 inches, which were working a certain run of trains with moderate success. It was found that when the trains were heavy or the weather unfavorable, the engines had to be worked a great part of the time in the 9-in. notch, and it was all the boilers could do to provide steam. The master mechanic thought that if the cylinders were made one inch larger the engineer would seldom need to drop the reverse lever lower than the 6-in. notch, and that, consequently, the engines would do the work with greater ease and with a smaller comsumption of fuel. So he had some engines built with the increased size of cylinders, but they never gave satisfaction. The best engineers on the road fail to make time with them when the nozzles were the same size as those of the other engines. When the nozzles were made smaller the engines burned more coal to do the same work as that performed by the engines with the smaller cylinders. The large cylinders had eventually to be bushed. This was a representative case, for many master mechanics have had experience of a similar kind, although they may not have bushed the cylinders.

A trouble, too, with large cylinders is that the engine needs more attention, and what might be called humoring, than the ordinary engineer is liable to bestow. In starting from a station the lever must be pulled back to the short cut off as quickly as possible, or the steam pressure will begin dropping down. When a hard part of the road is encountered, there is a great temptation to drop the links a notch, but with an over-cylindered engine this will lead to loss of boiler pressure which will not be regained till the steam is shut off. A man who properly understands the peculiarities of this kind of engine, and works her accordingly, will get the best possible work out of the machine, and in his hands she may prove economical, but an engine that cannot be successfully operated by ordinary engineers is not adapted for common train service.

DIFFICULTY OF IMPROVING STEAM DISTRIBUTION IN LOCOMOTIVE CYLINDERS.

When the locomotives are designed with a valve motion specially adapted for cutting off steam earlier than 25 per cent. of the stroke, the leading obstacle to their success economically appears to be excessive cylinder condensation. This subject has received surprisingly small attention from railroad mechanical men, and its importance is rarely realized, or there would be more work done to keep the cylinders protected from cooling influences.

The economy of cutting off steam very early in the stroke is, to a great extent, dependent upon the pressure carried. With very high initial pressure it may be possible to cut off earlier than 25 per cent. of the stroke and obtain good results without the use of steam jacketed cylinders, but under ordinary pressure a cut-off much short of 25 per cent. of the stroke produces the condition that moved W. K. Clark to his famous saying: "Expansive working that is expensive working."

CYLINDER CONDENSATION.

Saturated steam is constantly on the dew point and on the least portion of the heat of vaporization being taken away, a corresponding portion of the steam falls into water just as it acts on a large scale in a condenser. In fact, all cylinders act as condensers to a greater or less extent, and some of them appear to be more efficient as a means of converting steam into water than as a means of converting the heat of steam into mechanical energy. When the steam becomes water it loses its power to perform mechanical work in the cylinder, therefore, the percentage of steam that condenses in the cylinder represents so much loss of power.

In the Newcomen engines, the earliest form of steam engines used for industrial purposes, the steam was condensed in the cylinder to create a vacuum, the cooling being done by injection of cold water. With an engine worked on this system, there were enormous losses of heat through the cylinder having to be reheated to the temperature of the steam each stroke. When James Watt first began experimenting with an engine of this type, he found that it took about four times the quantity of steam for each stroke that was necessary to fill the cylinder, three volumes having been wasted in heating up the metal of the cylinders. This led to his invention of the separate condenser, which avoided the necessity for cooling the cylinder to the temperature of the condensing water.

The Newcomen engine presented an example of extreme waste from cylinder condensation. The heat losses occurring in cylinders not cooled down intentionally are much smaller than the waste inseparable from the earliest style of condensing engine, but they are, nevertheless, still very serious in many modern steam engines. The leading physicists and engineers who have devoted much attention to investigating the extent of cylinder condensation have shown that in engines without steam jacketed cylinders, cutting off steam earlier than half stroke, the loss from cylinder condensation is seldom less than 20 per cent. of the whole steam that enters the cylinders and that it often rises to 50 per cent. and upward.

In the ordinary working of the steam engine, cutting off at 25 per cent. of the stroke, the steam from the boiler at say 145 lbs. absolute pressure, having therefore a temperature of 356° Fahr., passes into a comparatively cool cylinder and the iron of the cylinder absorbs heat till its temperature is equal to that of the steam. The portion of the steam robbed of its heat becomes spray, and helps to dampen the steam filling the cylinder. When the steam is cut off and expansion goes on, a portion of the heat of the steam is transformed into mechanical energy, and a proportional amount of condensation takes place. By the time release is reached the pressure of steam has fallen to about 40 lbs. absolute, and the temperature to 267° Fahr. The steam which became water under the heavy pressure at the beginning of the stroke is now ready, owing to release of pressure, to flash back into steam, and it re-evaporates at the moment it is passing out of the cylinder, carrying away with it a great deal of heat extracted from the walls of the cylinder. According to Tyndall, the aqueous vapor of the atmosphere has seventy times the absorptive power of dry air. This same attribute extends evidently in a like proportion to wet steam, which draws heat from the metal of the cylinder very freely, and carries it away to the atmosphere, leaving the metal to be reheated by the next induction of steam. During the return stroke a portion of the steam left in the cylinder is compressed after the valve closes, and the mechanical work done by the piston in squeezing the steam into contracted space is converted into heat and helps to raise the temperature of the cylinder to approach that of the incoming steam. Nearly all the experiments carried out to ascertain the extent of cylinder condensation have shown that compression is not only a convenient means of cushioning the reciprocating parts, but it contributes a very important element to economy of steam by filling the clearance spaces and helping to reheat the cylinder. There is good reason for believing that the men who have labored to increase the capacity of the cylinder by producing an improved valve motion that would materially reduce compression, have lost more in steam than they gained in power by the change.

The serious losses that occur in the steam engine cylinder through condensation have been well known to scientific men for years, yet the men who are responsible for leaving the locomotive cylinders badly exposed to refrigerating influences are very slow to realize the extent of waste caused thereby. Steam jacketing is impracticable for the locomotive, but good lagging is not, and there are few locomotives that have their cylinders so well protected by this means as they might be.

ISHERWOOD ON CYLINDER CONDENSATION.

Chief Engineer Isherwood is one of the best authorities on the effect cylinder condensation exerts upon the economical operation of the steam engine, and he writes upon the subject as follows:

"The discovery that the cylinder of a steam engine acted alternately as a condenser and as a boiler condensing a portion of the entering steam during its admission and revaporizing the resulting water of condensation during the period of expansion and during the exhaust stroke, which phenomena were caused wholly by the interaction of the metal of the cylinder, and would not have happened had the cylinder been constructed of a material which neither received nor imparted heat, was made a great many years ago by the writer. The discovery was made and proven in the only way possible, namely, by weighing the water fed into the boiler, and ascertaining by means of the indicator, the weight of steam present as such in the cylinder at the point of cutting off and at the end of the stroke of the piston, adding to the last quantity the weight of steam condensed in the cylinder to furnish the heat transmitted into the power developed by the expanding steam, the latter obtained also by means of the indicator. The difference between the weight of water fed into the boiler and the weight of steam accounted for by the indicator at the above two points of the stroke of the piston is the weight of steam condensed in the cylinder at those points by the interaction of the metal of which it is made.

* * * * * * * * * * *

"No theory of the steam engine can have any value which is not based on the great fact of cylinder condensation by the interaction of the metal, and on the variations in the quantity of that condensation due to different conditions. Nothing else will explain the results of steam engineering, and here, as everywhere in industrial art, the properties of matter must be considered in connection with abstract laws if practical results are to be correctly predicted, or even understood."

TABLE I.

AREAS OF CIRCLES IN SQUARE INCHES.

Diameter in inches.	Area in square inches.	Diameter in inches.	Area in square inches.	Diameter in inches.	Area in square inches.
$\frac{1}{64}$	.000192	$1\frac{11}{16}$	2.2365	$4\frac{7}{8}$	18.666
$\frac{1}{32}$	.000767	$1\frac{3}{4}$	2.4053	5	19.635
$\frac{1}{16}$	.003068	$1\frac{13}{16}$	2.5801	$5\frac{1}{8}$	20.629
$\frac{1}{8}$	.012272	$1\frac{7}{8}$	2.7612	$5\frac{1}{4}$	21.648
$\frac{3}{16}$	.02761	$1\frac{15}{16}$	2.9483	$5\frac{3}{8}$	22.691
$\frac{1}{4}$	.04908	2	3.1416	$5\frac{1}{2}$	23.758
$\frac{5}{16}$	.07670	$2\frac{1}{8}$	3.5466	$5\frac{5}{8}$	24.851
$\frac{3}{8}$	.11045	$2\frac{1}{4}$	3.9761	$5\frac{3}{4}$	25.967
$\frac{7}{16}$	.15033	$2\frac{3}{8}$	4.4301	$5\frac{7}{8}$	27.109
$\frac{1}{2}$	.19635	$2\frac{1}{2}$	4.9087	6	28.274
$\frac{9}{16}$	.24851	$2\frac{5}{8}$	5.4119	$6\frac{1}{8}$	29.465
$\frac{5}{8}$	.30680	$2\frac{3}{4}$	5.9396	$6\frac{1}{4}$	30.679
$\frac{11}{16}$	.37122	$2\frac{7}{8}$	6.4918	$6\frac{3}{8}$	31.919
$\frac{3}{4}$	.44179	3	7.0686	$6\frac{1}{2}$	33.183
$\frac{13}{16}$	.51849	$3\frac{1}{8}$	7.6699	$6\frac{5}{8}$	34.472
$\frac{7}{8}$	.60132	$3\frac{1}{4}$	8.2958	$6\frac{3}{4}$	35.785
$\frac{15}{16}$	.69029	$3\frac{3}{8}$	8.9462	$6\frac{7}{8}$	37.122
1	.7854	$3\frac{1}{2}$	9.6211	7	38.485
$1\frac{1}{16}$	.88664	$3\frac{5}{8}$	10.3210	$7\frac{1}{8}$	39.871
$1\frac{1}{8}$	.99402	$3\frac{3}{4}$	11.0447	$7\frac{1}{4}$	41.283
$1\frac{3}{16}$	1.1075	$3\frac{7}{8}$	11.7933	$7\frac{3}{8}$	42.718
$1\frac{1}{4}$	1.2272	4	12.566	$7\frac{1}{2}$	44.179
$1\frac{5}{16}$	1.3530	$4\frac{1}{8}$	13.364	$7\frac{5}{8}$	45.664
$1\frac{3}{8}$	1.4849	$4\frac{1}{4}$	14.186	$7\frac{3}{4}$	47.173
$1\frac{7}{16}$	1.6229	$4\frac{3}{8}$	15.033	$7\frac{7}{8}$	48.707
$1\frac{1}{2}$	1.7671	$4\frac{1}{2}$	15.904	8	50.266
$1\frac{9}{16}$	1.9175	$4\frac{5}{8}$	16.800	$8\frac{1}{8}$	51.849
$1\frac{5}{8}$	2.0739	$4\frac{3}{4}$	17.721	$8\frac{1}{4}$	53.456

TABLE I.—*Continued.*

Diameter in inches.	Area in square inches.	Diameter in inches.	Area in square inches.	Diameter in inches.	Area in square inches.
8⅜	55.088	13¾	148.490	19⅛	287.272
8½	56.745	13⅞	151.201	19¼	291.040
8⅝	58.426	14	153.938	19⅜	294.832
8¾	60.132	14⅛	156.700	19½	298.648
8⅞	61.862	14¼	159.485	19⅝	302.489
9	63.617	14⅜	162.296	19¾	306.355
9⅛	65.397	14½	165.130	19⅞	310.245
9¼	67.201	14⅝	167.990	20	314.16
9⅜	69.029	14¾	170.874	20⅛	318.10
9½	70.882	14⅞	173.782	20¼	322.06
9⅝	72.760	15	176.715	20⅜	326.05
9¾	74.662	15⅛	179.673	20½	330.06
9⅞	76.589	15¼	182.655	20⅝	334.10
10	78.540	15⅜	185.660	20¾	338.16
10⅛	80.516	15½	188.692	20⅞	342.25
10¼	82.516	15⅝	191.748	21	346.36
10⅜	84.541	15¾	194.828	21⅛	350.50
10½	86.590	15⅞	197.933	21¼	354.66
10⅝	88.664	16	201.062	21⅜	358.84
10¾	90.763	16⅛	204.216	21½	363.05
10⅞	92.886	16¼	207.395	21⅝	367.28
11	95.033	16⅜	210.598	21¾	371 54
11⅛	97.205	16½	213.825	21⅞	375 83
11¼	99.402	16⅝	217.077	22	380.13
11⅜	101.623	16¾	220.354	22⅛	384.47
11½	103.869	16⅞	223.655	22¼	388.82
11⅝	106.139	17	226.981	22⅜	393.20
11¾	108.434	17⅛	230.331	22½	397.61
11⅞	110.754	17¼	233.706	22⅝	402.04
12	113.098	17⅜	237.105	22¾	406.49
12⅛	115.467	17½	240.529	22⅞	410.97
12¼	117.859	17⅝	243.977	23	415.48
12⅜	120.277	17¾	247.450	23⅛	420.00
12½	122.719	17⅞	250.948	23¼	424.56
12⅝	125.185	18	254.470	23⅜	429.13
12¾	127.677	18⅛	258.016	23½	433.74
12⅞	130.192	18¼	261.587	23⅝	438.36
13	132.733	18⅜	265.183	23¾	443.01
13⅛	135.297	18½	268.803	23⅞	447.69
13¼	137.887	18⅝	272.448	24	452.39
13⅜	140.501	18¾	276.117	24⅛	457.11
13½	143.139	18⅞	279.811	24¼	461.86
13⅝	145 802	19	283.529	24⅜	466.64

TABLE I.—*Continued.*

Diameter in inches.	Area in square inches.	Diameter in inches.	Area in square inches.	Diameter in inches.	Area in square inches.
24½	471.44	29⅞	700.98	35¼	975.91
24⅝	476.26	30	706.86	35⅜	982.84
24¾	481.11	30⅛	712.76	35½	989.80
24⅞	485.98	30¼	718.69	35⅝	996.78
25	490.87	30⅜	724.64	35¾	1003.79
25⅛	495.80	30½	730.62	35⅞	1010.82
25¼	500.74	30⅝	736.62	36	1017.88
25⅜	505.71	30¾	742.64	36⅛	1024.96
25½	510.71	30⅞	748.69	36¼	1032.06
25⅝	515.73	31	754.77	36⅜	1039.19
25¾	520.78	31⅛	760.87	36½	1046.35
25⅞	525.84	31¼	766.99	36⅝	1053.53
26	530.93	31⅜	773.14	36¾	1060.73
26⅛	536.05	31½	779.31	36⅞	1067.96
26¼	541.19	31⅝	785.51	37	1075.21
26⅜	546.36	31¾	791.73	37⅛	1082.50
26½	551.55	31⅞	797.98	37¼	1089.79
26⅝	556.76	32	804.25	37⅜	1097.11
26¾	562.00	32⅛	810.54	37½	1104.47
26⅞	567.27	32¼	816.86	37⅝	1111.84
27	572.56	32⅜	823.21	37¾	1119.24
27⅛	577.87	32½	829.58	37⅞	1126.67
27¼	583.21	32⅝	835.97	38	1134.12
27⅜	588.57	32¾	842.39	38⅛	1141.59
27½	593.96	32⅞	848.83	38¼	1149.09
27⅝	599.37	33	855.30	38⅜	1156.61
27¾	604.81	33⅛	861.79	38½	1164.16
27⅞	610.27	33¼	868.31	38⅝	1171.73
28	615.75	33⅜	874.85	38¾	1179.33
28⅛	621.26	33½	881.41	38⅞	1186.95
28¼	626.80	33⅝	888.00	39	1194.59
28⅜	632.36	33¾	894.62	39⅛	1202.26
28½	637.94	33⅞	901.26	39¼	1209.96
28⅝	643.55	34	907.92	39⅜	1217.68
28¾	649.18	34⅛	914.61	39½	1225.42
28⅞	654.84	34¼	921.32	39⅝	1233 19
29	660.52	34⅜	928.06	39¾	1240.98
29⅛	666.23	34½	934.82	39⅞	1248.80
29¼	671.96	34⅝	941.61	40	1256.64
29⅜	677.71	34¾	948.42	40⅛	1264.51
29½	683.49	34⅞	955.25	40¼	1272.40
29⅝	689.30	35	962.11	40⅜	1280.31
29¾	695.13	35⅛	969.00	40½	1288.25

TABLE I—*Continued.*

Diameter in inches.	Area in square inches.	Diameter in inches.	Area in square inches.	Diameter in inches.	Area in square inches.
40⅝	1296.22	46	1661.91	52¾	2185.42
40¾	1304.21	46⅛	1670.95	53	2206.18
40⅞	1312.22	46¼	1680.02	53¼	2227.05
41	1320.26	46⅜	1689.11	53½	2248.01
41⅛	1328.32	46½	1698.23	53¾	2269.07
41¼	1336.41	46⅝	1707.37	54	2290.22
41⅜	1344.52	46¾	1716.54	54¼	2311.48
41½	1352.66	46⅞	1725.73	54½	2332.84
41⅝	1360.82	47	1734.95	54¾	2354.29
41¾	1369.00	47⅛	1744.19	55	2375.83
41⅞	1377.21	47¼	1753.45	55¼	2397.48
42	1385.45	47⅜	1762.74	55½	2419.23
42⅛	1393.70	47½	1772.06	55¾	2441 07
42¼	1401.99	47⅝	1781.40	56	2463.01
42⅜	1410.30	47¾	1790.76	56¼	2485.05
42½	1418.63	47⅞	1800.15	56½	2507.19
42⅝	1426.99	48	1809.56	56¾	2529.43
42¾	1435.37	48⅛	1819.00	57	2551.76
42⅞	1443.77	48¼	1828.46	57¼	2574.20
43	1452.20	48⅜	1837.95	57½	2596.73
43⅛	1460.66	48½	1847.46	57¾	2619.36
43¼	1469.14	48⅝	1856.99	58	2642.08
43⅜	1477.64	48¾	1866.55	58¼	2664.91
43½	1486.17	48⅞	1876.14	58½	2687.84
43⅝	1494.73	49	1885.75	58¾	2710.86
43¾	1503.30	49⅛	1895.38	59	2733.97
43⅞	1511.91	49¼	1905.04	59¼	2757.20
44	1520.53	49⅜	1914.72	59½	2780.51
44⅛	1529.19	49½	1924.43	59¾	2803.93
44¼	1537.86	49⅝	1934.16	60	2827.44
44⅜	1546.56	49¾	1943.91	60¼	2851.05
44½	1555.29	49⅞	1953.69	60½	2874 76
44⅝	1564.04	50	1963.50	60¾	2898.57
44¾	1572.81	50¼	1983.18	61	2922.47
44⅞	1581.61	50½	2002.96	61¼	2946.48
45	1590.43	50¾	2022.86	61½	2970.58
45⅛	1599.28	51	2042.82	61¾	2994 78
45¼	1608.16	51¼	2062.90	62	3019.08
45⅜	1617.05	51½	2083.08	62¼	3043.47
45½	1625.97	51¾	2103.35	62½	3067.97
45⅝	1634.92	52	2123.72	62¾	3092 56
45¾	1643.89	52¼	2144.18	63	3117.25
45⅞	1652.89	52½	2164.76	63¼	3142.04

TABLE I.—*Continued.*

Diameter in inches.	Area in square inches.	Diameter in inches.	Area in square inches.	Diameter in inches.	Area in square inches.
63½	3166.93	75¾	4506.67	88	6082.14
63¾	3191.91	76	4536.47	88¼	6116.74
64	3217.00	76¼	4566.36	88½	6151.45
64¼	3242.18	76½	4596.36	88¾	6186.25
64½	3267.46	76¾	4626.45	89	6221.15
64¾	3292.84	77	4656.64	89¼	6256.15
65	3318.31	77¼	4686.92	89½	6291 25
65¼	3343.86	77½	4717.31	89¾	6326.45
65½	3369.56	77¾	4747.79	90	6361.74
65¾	3395.33	78	4778.37	90¼	6397.13
66	3421.20	78¼	4809.05	90½	6432.62
66¼	3447.17	78½	4839.83	90¾	6468.21
66½	3473.24	78¾	4870.71	91	6503.90
66¾	3499.40	79	4901.68	91¼	6539.68
67	3525.66	79¼	4932.75	91½	6575.56
67¼	3552.02	79½	4963.92	91¾	6611.55
67½	3578.48	79¾	4995.19	92	6647.63
67¾	3605.04	80	5026.56	92¼	6683.80
68	3631.69	80¼	5058.03	92½	6720.08
68¼	3658.44	80½	5089.59	92¾	6756.45
68½	3685.29	80¾	5121.25	93	6792.92
68¾	3712.24	81	5153.01	93¼	6829.49
69	3739.29	81¼	5184.87	93½	6866.16
69¼	3766.43	81½	5216.82	93¾	6902.93
69½	3793.68	81¾	5248.88	94	6939.79
69¾	3821.02	82	5281.03	94¼	6976.76
70	3848.46	82¼	5313.28	94½	7013.82
70¼	3876.00	82½	5345.63	94¾	7050.98
70½	3903.63	82¾	5378.08	95	7088.24
70¾	3931.37	83	5410.62	95¼	7125.59
71	3959.20	83¼	5443.26	95½	7163.04
71¼	3987.13	83½	5476.01	95¾	7200.60
71½	4015.16	83¾	5508.84	96	7238.25
71¾	4043.29	84	5541.78	96¼	7275.99
72	4071.51	84¼	5574.82	96½	7313.84
72¼	4099.84	84½	5607.95	96¾	7351.79
72½	4128.26	84¾	5641.18	97	7389.83
72¾	4156.78	85	5674.51	97¼	7427.97
73	4185.40	85¼	5707.94	97½	7466.21
73¼	4214.11	85½	5741.47	97¾	7504.55
73½	4242 93	85¾	5775.10	98	7542.98
73¾	4271.84	86	5808.82	98¼	7581.52
74	4300.85	86¼	5842.64	98½	7620.15
74¼	4329.96	86½	5876.56	98¾	7658.88
74½	4359 17	86¾	5910.58	99	7697.71
74¾	4388.47	87	5944.69	99¼	7736.63
75	4417.87	87¼	5978.91	99½	7775 66
75¼	4447.38	87½	6013.22	99¾	7814.78
75½	4476.98	87¾	6047.63	100	7854.00

TABLE II.

Properties of Saturated Steam.

(Abridged from Tables calculated by Charles T. Porter.)

Absolute pressure in pounds per square inch.	Temperature in degrees, Fahrenheit.	Heat-units per pound reckoning from zero.	Heat-units per pound contained in the water.	Weight in decimals of a pound per cubic foot.	Specific volume.
1	102	1145	102.1	.0030	20620
2	126.3	1152.5	126.4	.0058	10720
3	141.6	1157.1	141.9	.0085	7326
4	153.1	1160.6	153.4	.0112	5600
5	162.3	1163.4	162.7	.0137	4535
6	170.1	1165.8	170.6	.0163	3814
7	176.9	1167.9	177.4	.0189	3300
8	182.9	1169.7	183.5	.0214	2910
9	188.3	1171.4	188.9	.0239	2607
10	193.2	1172.9	193.9	.0264	2360
11	197.8	1174.2	198.5	.0289	2157
12	202	1175.5	202.7	.0313	1988
13	205.9	1176.7	206.7	.0337	1846
14	209.6	1177.9	210.4	.0362	1722
14.7	212	1178.6	212.9	.0380	1644
15	213.1	1178.9	213.9	.0387	1612
16	216.3	1179.9	217.2	.0413	1514
17	219.4	1180.9	220.4	.0437	1427
18	222.4	1181.8	223.4	.0462	1351
19	225.2	1182.6	226.3	.0487	1282.1
20	227.9	1183.5	229	.0511	1220.3
21	230.5	1184.2	231.7	.0536	1164.4
22	233	1185	234.2	.0561	1113.5
23	235.4	1185.7	236.7	.0585	1066.9
24	237.7	1186.5	239	.0610	1024.1
25	240	1187.1	241.3	.0634	984.8
26	242.2	1187.8	243.5	.0658	948.4
27	244.3	1188.5	245.7	.0683	914.6
28	246.3	1189	247.7	.0707	883.2
29	248.3	1189.7	249.8	.0731	854
30	250.2	1190.3	251.7	.0755	826.8
31	252.1	1190.8	253.6	.0779	801.2
32	254	1191.4	255.5	.0803	777.2
33	255.7	1191.9	257.3	.0827	754.7

TABLE II.—*Continued.*

Absolute pressure in pounds per square inch.	Temperature in degrees Fahrenheit.	Heat-units per pound, reckoning from zero.	Heat-units per pound contained in the water.	Weight in decimals of a pound per cubic foot.	Specific volume.
34	257.5	1192.5	259.1	.0851	733.5
35	259.2	1193	260.8	.0875	713.4
36	260.9	1193.5	262.5	.0899	694.5
37	262.5	1194	264.2	.0922	676.6
38	264	1194.5	265.8	.0946	659.7
39	265.6	1195	267.4	.0970	643.6
40	267.1	1195.4	268.9	.0994	628.2
41	268.6	1195.9	270.5	.1017	613.4
42	270.1	1196.3	272	.1041	599.3
43	271.5	1196.7	273.4	.1064	586.1
44	272.9	1197.2	274.9	.1088	573.7
45	274.3	1197.6	276.3	.1111	561.8
46	275.7	1198	277.7	.1134	550.4
47	277	1198.4	279	.1158	539.5
48	278.3	1198.8	280.4	.1181	529
49	279.6	1199.2	281.7	.1204	518.6
50	280.9	1199.6	283	.1227	508.5
51	282.1	1200	284.2	.1251	499.1
52	283.3	1200.4	285.5	.1274	490.1
53	284.5	1200.7	286.7	.1297	481.4
54	285.7	1201.1	288	.1320	472.9
55	286.9	1201.4	289.2	.1343	464.7
56	288.1	1201.8	290.3	.1366	457
57	289.1	1202.1	291.5	.1388	449.6
58	290.3	1202.5	292.7	.1411	442.4
59	291.4	1202.8	293.8	.1434	435.3
60	292.5	1203.2	294.9	.1457	428.5
61	293.6	1203.5	296	.1479	422
62	294.7	1203.8	297.1	.1502	415.6
63	295.7	1204.1	298.2	.1525	409.4
64	296.8	1204.5	299.2	.1547	403.5
65	297.8	1204.8	300.3	.1570	397.7
66	298.8	1205.1	301.3	.1592	392.1
67	299.8	1205.4	302.4	.1615	386.6
68	300.8	1205.7	303.4	.1637	381.3
69	301.8	1206	304.4	.1660	376.1
70	302.7	1206.3	305.4	.1682	371.2
71	303.7	1206.6	306.4	.1704	366.4
72	304.6	1206.9	307.3	.1726	361.7
73	305.6	1207.1	308.3	.1748	357.1
74	306.5	1207.4	309.3	.1770	352.6

TABLE II.—*Continued.*

Absolute pressure in pounds per square inch.	Temperature in degrees, Fahrenheit.	Heat-units per pound, reckoning from zero.	Heat-units per pound contained in the water.	Weight in decimals of a pound per cubic foot.	Specific volume.
75	307.4	1207.7	310.2	.1792	348.3
76	308.3	1208	311.1	.1814	344.1
77	309.2	1208.2	312	.1836	340
78	310.1	1208.5	313	.1858	336
79	310 9	1208.8	313.8	.1880	332.1
80	311.8	1209	314.7	.1901	328.3
81	312.7	1209 3	315 6	.1923	324.6
82	313.5	1209.6	316.5	.1945	320.9
83	314.4	1209 8	317.3	.1967	317 3
84	315 2	1210	318.2	.1989	313.9
85	316	1210.3	319	.2010	310.5
86	316.8	1210.6	319.9	.2032	307.2
87	317.6	1120.8	320.7	.2053	304
88	318.5	1211	321.5	.2075	300.8
89	319 3	1211.3	322.4	.2097	297.7
90	320	1211.6	323.2	.2118	294.7
91	320.8	1211.8	324	.2139	291.8
92	321.6	1212	324.8	.2161	288.9
93	322.4	1212.3	325.6	.2183	286.1
94	323.1	1212.5	326.4	.2204	283.3
95	323.9	1212.7	327.1	.2225	280.6
96	324.6	1213	327.9	.2245	278
97	325.4	1213.2	328.7	.2267	275.4
98	326.1	1213.4	329 4	.2288	272.8
99	326.8	1213.6	330.2	.2309	270.3
100	327.6	1213.8	331	.2330	267.9
101	328.3	1214	331.7	.2351	265.5
102	329	1214.3	332.4	.2372	263.2
103	329.7	1214.5	333.1	.2392	260.9
104	330 4	1214.7	333.9	.2413	258.7
105	331.1	1214.9	334.6	.2434	256.5
106	331.8	1215.1	335.3	.2455	254.3
107	332.5	1215.3	336	.2475	252.2
108	333.2	1215 6	336.7	.2496	250.1
109	333.9	1215.8	337.4	.2517	248
110	334.5	1216	338.1	.2538	246
111	335 2	1216.2	338.8	.2558	244
112	335 9	1216.4	339 5	.2579	242
113	336.5	1216.6	340.2	.2599	240.1
114	337.2	1216.8	340.8	.2620	238.2
115	337.8	1217	341.5	.2640	236.3
116	338.5	1217.2	342.2	.2661	234.5

TABLE II.—*Continued.*

Absolute pressure in pounds per square inch.	Temperature in degrees, Fahrenheit.	Heat-units per pound, reckoning from zero.	Heat-units per pound contained in the water.	Weight in decimals of a pound per cubic foot.	Specific volume.
117	339.1	1217.4	342.8	.2682	232.7
118	339.7	1217.6	343.5	.2702	231
119	340.4	1217.8	344.2	.2722	229.3
120	341	1217.9	344.8	.2743	227.6
121	341.6	1218.1	345.4	.2763	226
122	342.2	1218.3	346.1	.2783	224.4
123	342.9	1218.5	346.7	.2803	222.8
124	343.5	1218.7	347.3	.2823	221.2
125	344.1	1218.9	348	.2843	219.7
126	344.7	1219.1	348.6	.2862	218.2
127	345.3	1219.3	349.2	.2882	216.7
128	345.9	1219.4	349.8	.2902	215.2
129	346.5	1219.6	350.4	.2922	213.7
130	347.1	1219.8	351.1	.2942	212.3
131	347.6	1220	351.7	.2962	210.9
132	348.2	1220.2	352.3	.2982	209.5
133	348.8	1220.4	352.9	.3001	208.1
134	349.4	1220.5	353.5	.3021	206.7
135	350	1220.7	354.1	.3040	205.4
136	350.5	1220.9	354.6	.3060	204.1
137	351.1	1221	355.2	.3080	202.8
138	351.7	1221.2	355.8	.3099	201.5
139	352.2	1221.4	356.4	.3119	200.2
140	352.8	1221.5	357	.3139	199
141	353.3	1221.7	357.5	.3159	197.8
142	353.9	1221.9	358.1	.3179	196.6
143	354.4	1222	358.7	.3199	195.4
144	355	1222.2	359.2	.3219	194.2
145	355.5	1222.4	359.8	.3239	193
146	356	1222.5	360.4	.3259	191.9
147	356.6	1222.7	360.9	.3279	190.8
148	357.1	1222.9	361.5	.3299	189.7
149	357.6	1223	362	.3320	188.6
150	358.1	1223.2	362.6	.3340	187 5
151	358.7	1223.3	363.1	.3358	186.4
152	359.2	1223.5	363.6	.3376	185.3
153	359.7	1223.7	364.2	.3394	184.3
154	360.2	1223.9	364.7	.3412	183.3
155	360.7	1224	365.2	.3430	182.3
156	361.2	1224.1	365.8	.3448	181.3
157	361.8	1224.3	366.3	.3467	180.3
158	362.3	1224.4	366.8	.3485	179.3

TABLE II.—*Continued.*

Absolute pressure in pounds per square inch.	Temperature in degrees, Fahrenheit.	Heat-units per pound, reckoning from zero.	Heat-units per pound contained in the water.	Weight in decimals of a pound per cubic foot.	Specific volume.
159	362.8	1224.6	367.3	.3503	178.3
160	363.3	1224.8	367.9	.3521	177.3
161	363.8	1224.9	368.4	.3540	176.4
162	364.3	1225	368.9	.3558	175.5
163	364.8	1225.2	369.4	.3577	174.6
164	365.2	1225.3	369.9	.3596	173.7
165	365.7	1225.5	370.4	.3615	172.8
166	366.2	1225.6	370.9	.3634	171.9
167	366.7	1225.8	371.4	.3652	171
168	367.2	1225.9	371.9	.3671	170.1
169	367.7	1226.1	372.4	.3690	169.2
170	368.2	1226.2	372.9	.3709	168.4
171	368.6	1226.4	373.4	.3727	167.6
172	369.1	1226.5	373.9	.3745	166.8
173	369.6	1226.7	374.4	.3763	166
174	370	1226.8	374.9	.3781	165.2
175	370.5	1226.9	375.4	.3799	164.4
176	371	1227.1	375.9	.3817	163.6
177	371.4	1227.2	376.3	.3835	162.8
178	371.9	1227.4	376.8	.3853	162
179	372.4	1227.5	377.3	.3871	161.2
180	372.8	1227.7	377.8	.3889	160.4
181	373.3	1227.8	378.3	.3908	159.7
182	373.7	1227.9	378.7	.3926	159
183	374.2	1228.1	379.2	.3944	158.3
184	374.6	1228.2	379.7	.3962	157.6
185	375.1	1228.3	380.1	.3981	156.9
186	375.5	1228.5	380.6	.3999	156.2
187	376	1228.6	381.1	.4017	155.5
188	376.4	1228.7	381.5	.4036	154.8
189	376.9	1228.9	382	.4054	154.1
190	377.3	1229	382.4	.4072	153.4
191	377.7	1229.1	382.9	.4090	152.7
192	378.2	1229.3	383.3	.4108	152
193	378.6	1229.4	383.8	.4125	151.3
194	379	1229.5	384.2	.4143	150.7
195	379.5	1229.7	384.7	.4160	150.1
196	380	1229.8	385.1	.4178	149.5
197	380.3	1229.9	385.6	.4196	148.9
198	380.7	1230.1	386	.4214	148.3
199	381.1	1230.2	386.5	.4232	147.7
200	381.6	1230.3	386.9	.4250	147.1

WORKSHOP OPERATIONS.

LOCOMOTIVE RUNNING REPAIRS.

By L. C. Hitchcock.

DRIVING BOXES.

When an engine is undergoing general repairs, special attention should be given to the driving boxes and driving-box brasses, to see that they are fitted up in first-class order. If any part of the work is slighted do not let these parts come in for their share, for nothing is more discouraging to a good engineer than to have his engine pound in the driving boxes and brasses, and a renewal is the only remedy where the brass is too large for the journal, and if the box closes, or the wedge is not the proper taper, the play of the box between the shoe and wedge cannot be taken up by setting up the wedge. These evils can be overcome only by removing the box, which necessitates trouble and expense.

Some engineers, and foremen too, for that matter, in cases of this kind advocate planing the wedge until it has the proper taper to overcome the play of the box between the shoe and wedge. This I consider poor policy, for reasons which I will hereafter give. When an engine comes into the machine shop for general repairs, after having been in service for two or three years, the driving boxes, shoes and wedges are in a majority of cases very much in need of repairs; the shoes and wedges need lining and facing, the boxes will need planing, and the brasses will generally require renewing, or in case they are heavy enough they will be too large for the journals, or be loose in the box. When there is plenty of material in the brasses, and they are too large for the journals and loose in the boxes, it sometimes pays (when everything else is equal) to shim the brasses tight in the boxes, this will also close them to the journals, but in most cases this shimming does not pay. I think that the better plan is to put in new brasses while the opportunity is offered. Where the brasses to be renewed are of the solid pattern, in the form of a half circle, the box should first be planed out to a true circle, leaving the distances from the crown to the points *A A*, Fig. 1, Plate 6, about $\frac{1}{16}$ in. greater on the side which is to go next to the hub of the driver; this will prevent the brass from working out of the box, should it become slightly loose, and this distance should be great enough to allow that part of the brass which rests in the points *AA* to be from $\frac{3}{4}$ in. to 1 in. below the center after the brass is bored to the required size. The outside of the brass should now be either planed in the slotter, or turned to the size that the box was finished, then the brass may be fitted to the box by planing from the edges which are to bear in the points *AA* a sufficient amount to allow the brass to go into the box the last inch at about twenty tons pressure; this will generally spread the bottom part of the box about

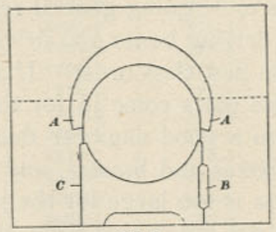


Fig. 1.

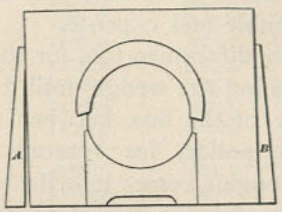


Fig. 2.

PLATE 6.

$\frac{1}{16}$ in. Now, at about the point represented by the dotted lines, and centrally between the flanges, bore a one-inch hole through box and brass on each side, and into these holes put brass plugs, making a good driving fit. The brasses should now be bored out to fit the journals before the cellars are fitted into the boxes. Boring the brasses generally allows the bottom of the boxes to close about $\frac{1}{32}$ in., if the brass is put in under the pressure mentioned, and this leaves the top of box $\frac{1}{32}$ in. narrower than the bottom part; this causes the part which contains the cellar to be a trifle wider at the bottom than

at the top, provided that the sides of this opening were originally planed parallel; this makes the removal of the cellar easy after it is started, even if it is very tight when up to place.

Some builders cast the boxes with a slot across the sides of the openings which contain the cellars, and in some cases these slots are also cast in the cellars. When the cellars are in place this leaves openings from side to side of the boxes, as shown at *B*, Fig. 1, and a rib at top and bottom of both box and cellars. I do not like this plan, for in replacing a cellar the top will strike against the bottom of the top rib on the box, if the cellar tips in the least. A good way to overcome this evil is to plane out about $1\frac{1}{2}$ in. wide from each end of each rib on cellars and boxes, liners can then be riveted on, of the required thickness to make the cellars tight in the boxes, and both sides of the cellars and boxes will appear as shown at *C*, and the cellars will be sure to go straight to their places, if entered properly. Now, fit the brasses to the journals, being careful to make that part which comes below the center of the journal, when the box is in place, exactly the size that the journal is in diameter.

After the brass has been brought to a general bearing on the journal, I think it a good practice to file from the crown a place about $1\frac{1}{2}$ in. wide and $\frac{1}{32}$ in. deep; this insures a good bearing on the sides to start with; after the brasses fit the cellars, and they being $\frac{1}{32}$ in. taper will go nearly up to their places before becoming tight, they should be fitted tight enough so that when they are up to their places the box cannot close a particle, and still not be tight enough to spread the box. Now, with the cellars in place, plane the shoe, and wedge bearing faces of the boxes, leaving each side an equal distance from the center of the brass, and perfectly parallel with each other.

Now, a word in regard to not being able to take up the lost motion of boxes between the shoes and wedges by setting the wedges up. As previously mentioned, the cause of this trouble is that either the shoes and wedges have not been planed parallel, or that the shoe and wedge bearing faces of the box are not parallel; the latter is generally the case. Now, if a brass is pressed into a box at twenty tons pressure, and the shoe and wedge bearing faces are planed before the brass is bored out, or the cellars fitted, when the brass is bored out the bottom of the box will close; this throws the planed faces out of parallel, and the box is in the condition represented in an exaggerated manner by Fig. 2, and, if the wedge has been planed square with the top of frame it will stand in the position shown at *A*, and any attempt to set it up will cause it to strike between the box and frame at the top, leaving the bottom loose, and, if the top is planed off to fit the box, it will be as shown at *B*, and the box cannot work freely between the shoe and wedge. Should a driving spring become weak, and let the frame down a little, the box will pound between the shoe and wedge, and should any unevenness in the track cause the box to lower, it will stick. But boxes sometimes get into the condition just described when the shoe and wedge bearing faces were parallel when the engine was first turned out of the shop, and this is owing to the cellar not having been fitted in the proper manner at the start, or having been filed smaller by some roundhouse man the first time the box was packed after going into service. I have heard of men reducing the cellars after the engine came out of the machine shop, so that they would not have so much trouble while packing them. This I consider very poor policy, for this reason: As the brass wears, the tendency of the box is to close in at the bottom, if it has been put in under sufficient pressure to hold it tight in the box, and when the cellar is loose the box closes to it, and the evils described are produced.

Allowing a driving brass to run hot is a more serious thing than some engineers appear to realize, for it is sometimes, and where it becomes very hot it is in a majority of cases, followed by evils which can only be remedied by the removal of the box. The trouble referred to is the journal boring out of the brass, and is produced as follows: The first things to become heated are the journal and brass. When heated, they expand; the box, being cold, does not expand, and is held tightly between the shoe and wedge, if properly fitted up, and does not give as the journal expands; the consequence is that the journal cuts its way in the brass until it has become free. Most engineers will remember that in most instances of hot driving boxes small particles of brass will be seen which have worked out from between the box and wheel hub. When the journal cools off it will resume its original size; the brass is then too large, and the journal will pound from side to side when the engine is working hard; but some one may say, "When a driving brass heats and expands, the box will stick between the shoe and wedge, and a good engineer will at once pull the wedge down a little, to allow the box to work freely." True, he may do this, but this does not prevent the journal and brass expanding faster than the box, in which case the journal is sure to cut its way in the brass.

In some shops they take up the lateral motion caused by the

faces of the boxes against the wheel hubs by planing from the inside flange of each shoe and wedge where it bears on the jaw, and putting a liner on the outside flange; this crowds the box towards the hub face, and takes up the lateral motion, but at the same time the size of the shoe and wedge has been thrown out of standard, and the spring saddle will not stand an equal distance from the inside and outside of the frame. I think that care should at all times be taken to keep all parts to a standard size, for where this is not done it causes much trouble where many engines are to be kept in repair. A better way to do in the case cited would be to measure the distance between the driver hubs, and from outside to outside of engine frames, and find whether the wear was from the face of the box or from the driver hubs. The liner should then be put where needed to keep all parts to standard dimensions. This is best, I think, even if the face of the box has to be planed off, or that of the wheel hub turned to allow for a liner of sufficient thickness to warrant it remaining in place.

While speaking of liners for this purpose, I will say that I have seen very good results follow facing the hubs of engine truck and driving wheels, and also the faces of the driving boxes with babbitt metal, and the difference in labor would make the use of this metal cheaper than turning and riveting on brass plates.

LAYING OUT BACK CYLINDER HEAD.

By Ira A. Moore.

How many of the younger machinists and machinists' apprentices have, I wonder, thought how they would proceed, if given a task of laying out, drilling and putting in place a back cylinder head? Of course, this would not be so difficult a job to do if jigs were available, to which the head could be drilled. But all shops do not have jigs, and a machinist may often be called upon to do work of this kind when very few tools are provided.

We will assume that we are working in the roundhouse at some division terminal, where the only machine tools provided are a drill press, a small lathe and planer, and that an engine comes in with the right back cylinder head badly broken. One is sent to us from the main shops, but it is only finished in the lathe and is not drilled for the studs or guide blocks. How shall we lay it out properly?

Some one may say, "lay it out from the old head," but this is not possible to do in all cases. The old head may have been broken too badly; then, too, the old head may not have been properly put up in the first place. The best way, I think, is to have ideas of our own relative to these matters; then we are independent.

Now we know that the joints will have to be ground, so we will first remove all of the studs which fastened the head to the cylinder, then with two pieces of wood and two bolts make a clamp, like Fig. 1, Plate 7, and fasten it around the neck of the cylinder head. Then thread each end of a rod or use a bolt long enough to pass through the cylinder and head, when the head is in place. After applying oil and emery to the joints, fasten the head to place by passing the rod or bolt through a plate of iron long enough to span the front end of

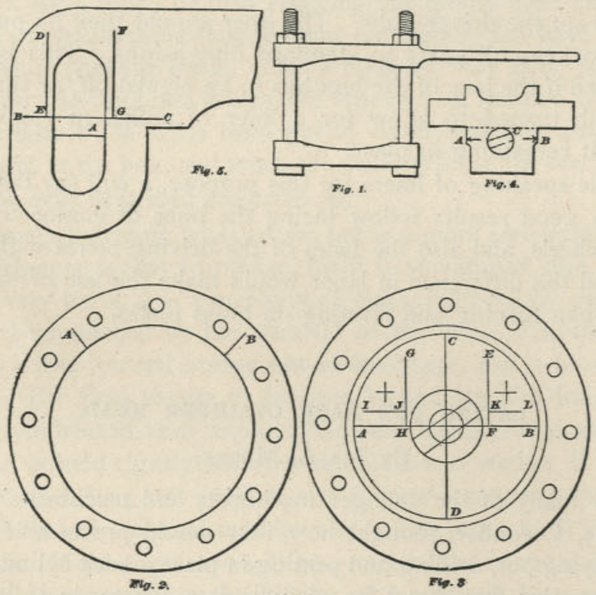


PLATE 7.

the cylinder, then pass the rod through the cylinder and head, fasten it at the back end by passing it through a plate of iron, of sufficient length to span the stuffing box in the head. The head can then be turned and ground by the use of the wooden clamp, previously adjusted. The necessary pressure can be given by tightening the nut on back end of rod.

After the joint is perfect we can easily determine which part of the head should go to the top of the cylinder by the position of the clearance space cast in it, for, with the head in place, this space should conform with the steam port in the cylinder.

Now, dampen some lamp black with oil (do not have it too thin) and apply a very light coat of the mixture all around the inner edge of the joint on the cylinder, also around each stud hole and outer edge of the flange, and with the lamp black also make two fine lines, A B, Fig. 2, across the face of the flange, one at each end of the steam port. Now, take a piece of stiff wrapping paper large enough to cover the end of the cylinder, and having the helper hold it firmly to place, rub the surface of the paper with your hand over all points where it touches the flange; this will give you on the paper a clear impression of all stud holes, marks A B, etc.

Remove the paper now and cut out the center and outer circumference, being careful to cut close to the lines, then with a lead pencil make a dot in the center of each stud hole impression. Now lay the template on the head, being careful to lay the side with marks on toward you, and having the lines A B, one at each end of clearance space; then have the template held firmly to place while you with a fine center punch, mark over each pencil dot a punch mark through the template into the head; remove the template and from the punch marks lay out the stud hole .02 in. larger than the studs. Now drill them to the marks, replace the studs and you will find on trial that the head will slip to place nicely.

Fasten it to place with a nut at the top, bottom and each side, then on a stick or piece of flattened copper wire, driven firmly into the stuffing box, get the center of same. Now place a straight edge on top of the frames just back of the cylinder, of sufficient length to reach from frame to frame, and to this adjust a level; it does not matter if the engine is not exactly level, if care is taken to adjust the level to the straight edge.

Fasten the level now on the top of a shorter straight edge (being very careful not to reverse the level from its former position when adjusted to the long straight edge), and place the short straight edge with the level on it against the face of cylinder head flange to which the guides are attached; adjust the straight edge until the level is correct, and along its top edge, through the center of the stuffing box, scribe line A B, Fig. 3, and also through the center scribe line, C D, at right angles to line A B. Those lines now form the foundation from which we will work, for we know that line A B is level with the engine and that line C D is plumb with it.

Now, the distance that the guide blocks should be apart on the head might be determined from the position of those in the guide yoke, but the yoke might also be broken, and we will consider such to be the case in the present instance, and that the entire head has been renewed, planed up and sent to us without having the holes drilled for the blocks.

We will now turn our attention to the cross head and must bear in mind that when all parts are in place the center of the hole into which the piston rod fits in the cross head must be exactly in line with the center of the stuffing box in cylinder head. So after centering the hole in cross head we will span with our dividers from this center point to point *A*, Fig. 4, and from center of stuffing box, Fig. 3, mark this distance to the *right* of center on line A B; then from this mark scribe line E F, parallel with line C D; now do likewise with distance from center point in cross head to point B, Fig. 4, and scribe line G H, Fig. 3, parallel with line C D; then across the end of the cross head and just flush with the lower bearing surfaces of each lug scribe dotted line C, Fig. 4, and from the center of hole set the dividers $\frac{1}{32}$ in. *above* line C. This is to allow for a $\frac{1}{32}$ in. liner between each bottom guide and block.

Now from points F and H, on line A B, Fig. 3, mark this distance on lines E F, and G H, and from the marks thus made, scribe lines I J and K L parallel with line A B.

When the blocks are in place their inner edges should be flush with lines E F and G H, and their lower faces flush with lines I J and K L. All of the lines should be scribed lightly so they can be filed out after the holes are drilled.

Now mark the top of the outer block, No. 1, and the top of the inner block, No. 2, and from the inner edge of block, No. 1, space the distance to the center of the lug by which it was secured to the head and to the right of line E F, and parallel with it, mark this distance. Now get the distance from the bottom surface of the block to center of lug and above and parallel with line K L, mark the latter distance on the head. Proceed in like manner with block No. 2, only scribe to the left of line G H and above line I J. The points of intersection of the four lines last made are the points for the center of the holes for the block lugs, and the holes should be drilled and reamed to warrant a snug driving fit of the block lugs.

The holes over the piston-gland studs can now be located on line A B or CD, as the case may require, the head will then be ready to drill; but before removing it we will remove the center stick of the stuffing box, bolt the yoke to place and run a fine line or wire through the cylinder and secure it to the yoke by hanging a weight to it after passing it over the stick A, Fig. 5, driven firmly into the slot through which the main rod plays; now center the line from the counter bore in front end of cylinder and stuffing box in back head; then with the short straight edge, with level on it, we will scribe on the forward side of the yoke, line B C, just flush with the line through the cylinder; then mark on stick A a point at which the line through cylinder rests on it; remove the line or wire and proceed to lay out the holes for the back blocks, in exactly the same manner as we did those for the forward blocks on the head, after which both yoke and head can be removed and drilled, and before replacing them, after the drilling is done, each block should be fitted to place, for when again put up they should remain in place. When both are finished and bolted to place we are ready to line up the guides.

STANDARD SIZES FOR LOCOMOTIVE REPAIRS.

The modern plan of building locomotives and other machinery on the interchangable system renders it a comparatively easy matter to maintain standard lengths and sizes in making repairs in the roundhouse and machine shop.

In the olden time, when no two engines were alike, even from the same builder, and when contracts were given to several different firms for locomotives, there was some excuse for an irregular system, or no system, in making repairs, but those days are gone, and roads now, or at least, new roads, are equipped with engines from one builder.

It is a bad practice to alter the length of a spring hanger in order to equalize an engine. The spring is at fault, and not the hanger. The spring is changeable, its "set" is sometimes more, sometimes less. The hanger is rigid, and does not change. Make up for the weakness of the spring by putting liners, or "Dutchmen," under the gib in hanger, and when you get a spring that has full set, take liners out. When hangers are repaired, bring them back to the original length. Find out from a new engine what that length should be, and make a drawing or templet of the same, and keep it as a standard for the men to work by. If this plan were adopted it would save a vast amount of "cutting and trying." As an example, suppose that an engine has one weak spring. The foreman or machinist gives it a squint, and reasons, very properly, that if those two hangers were shortened just a little, or that spring saddle lengthened a trifle, she would sit all right; suiting the action to the word, the work is done. After a few trips that particular spring breaks, and a new one must take its place. What is the result? Another man puts it in, he sees that something is wrong; just what, he does not know; but one thing is quite evident, that spring gear is all out of whack, and so he tinkers at this or that hanger, puts a different shape to equalizer, saddle or something, he don't care much what —anything, so as to make her set level.

The standard set of each spring should be known, and the spring compared with that standard before being put in, and, if weak, pick out the liners to make it up to "correct pitch" before you put it in. It will save lots of jacking and sweat this hot weather.

After a few years, if a haphazard style of repairing is carried on, there will be no standards, and it will be impossible, without a great amount of study, to tell what the original size was.

The same may be said of the other parts of a locomotive, set screws, nuts, keys, etc. Keep them to standard. By so doing, a supply can be kept on hand, and not a great variety, either, always ready for an emergency, and sure to fit. 'Twill save many extra jobs at night and on Sunday. The expense of keeping up engines will be greatly reduced and their life prolonged.

It will save much wear and tear on the foreman. Every repair shop on the road should be furnished from the general shop with a complete set of blue prints of all parts of the engines, or at least of those pieces that will have to be repaired. From these prints patterns or templets can be made for the use of blacksmith or machinist. Jigs can be made for drilling holes, so that the labor of laying out can in a large measure be done away with.

See that the men are thoroughly informed on these points. The foreman's labor should be to think them out, and instruct the men in their use, and see that they are taken care of, and kept to standard.

LINING GUIDES.

By Ira A. Moore.

Every apprentice who is learning his trade in a locomotive repair shop, and who is as anxious to advance as he should be, will embrace the first opportunity to line a set of guides. There are some things connected with this part of the work that can be learned only by practice, but we will endeavor to show as plainly as possible how the work should be done.

The purpose of the guides is to keep the piston in line with the center of cylinder. Hence to have them fulfil their purpose, they must be lined parallel with center of cylinder and with each other, and the right height to bring center of hole in cross head same height as center of cylinder.

Suppose it is desired to line a set of four-bar guides, that a new back cylinder head has been put on, also a new guide yoke, and new guide blocks are necessary. Before putting the guides up they should be faced to a face-plate and at right angles to the edge. The ends should be planed slightly below the wearing surface. Steel guides can usually be made nearly straight by springing them under a press, after which they can be finished by filing, using a coarse file first, then finishing by draw-filing with a fine file. It is not necessary to use a scraper.

The guides are now ready to be put up, but as we are to have a new back cylinder head and new guide yoke, the holes for the guide-blocks must first be laid out and drilled. To lay out the holes in head, fasten it in place, then by means of a straight edge across the frames scribe the line *a b*, Fig. 15, Plate 8, then draw *cd* at right angles to *a b*, and through the center *o* of stuffing box.

It is sometimes inconvenient to use a square for drawing line *c d;* hence we will use dividers and small straight edge. Put a center in stuffing box, being careful to have it just flush with the head. Then, with the dividers set to any convenient radius, scribe the arcs 1 and 2 across the line *a b*. Make a small center punch mark at the intersections of the line and arcs; then with these intersections as centers, and a little longer radius than arcs 1 and 2 were drawn with, draw arcs 3 and 4. Call their intersection point *g*. With a straight edge draw the line *c d* through *g* and the center of stuffing box, when it will be at right angles to *a b*. Now draw *e f* through the center of stuffing box and parallel with *a b*. The width of the guides is 3 ins., and the distance between them $5\frac{1}{2}$ ins. Hence the distance from *o* to *h* and *i*, Fig. 15, is $4\frac{1}{4}$ ins., which is equal to half the distance between the guides plus half the width of guide. Draw *h l* and *i m* parallel with *c d* and $4\frac{1}{4}$ ins. on each side of it. The centers of the guide-block holes will lie in these lines, and a certain distance above the line *e f*, which distance we will now find. Referring to Fig. 16, which is an end view of the cross head, it will be seen that the line *a b*, which passes through the centers of the wings, is above the center of the piston hole *c*. It is desired to have the center of the guide-block holes and the line *a b*, Fig.

16, lie in the same level; and since *o*, Fig. 15, and *c*, Fig. 16, must lie in the same straight line, if *h r* and *i s*, Fig. 15, be made equal to the distance between *c* and the line *a b*, Fig. 16, then *r* and *s*, Fig. 15, are the centers of guide-block holes, which should be drilled not less than 1 5-32 ins.

To lay out the block holes in guide yoke, put it in place on engine, then scribe the line *a b*, Fig. 17, parallel with top of frames. Run a line *l*, Fig. 17, through the center of cylinder, letting it extend a short distance back of guide yoke, then scribe *i j*, Fig. 17, at right angles to *a b*. To draw *i j* without using a square, make a small center-punch mark at *r* on the line *a b*, Fig. 17, directly over the inside of the vertical part of the yoke. Then with any convenient radius scribe the arcs *s* and *t*, using *r* as center. With the

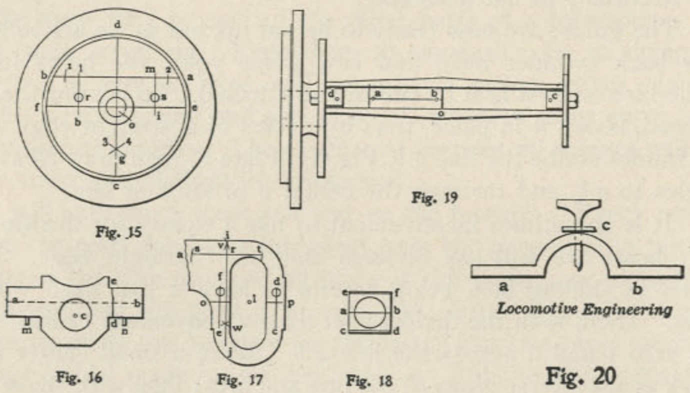


PLATE 8.

intersections of the arcs and line as centers, and any radius, scribe the arcs *v* and *w*.

The line *i j* through the intersections of these arcs is at right angles to *a b*. Now draw the line *o p* parallel with *a b* and the same height as center of cylinder. Draw *c d* and *e f* parallel with *i j* and $4\frac{1}{4}$ ins. on each side of the line through the center of cylinder; the $4\frac{1}{4}$ ins. being equal to half the width of cross head plus half the width of the guide. The centers of the guide-block holes will be on these lines, and a distance above *o p* equal to the shortest distance between the line *a b* and center of piston-rod hole *c*, Fig. 16.

Drill these holes same size as those in cylinder head. The guides should be far enough apart to allow the cross head $\frac{1}{32}$ in. lateral motion.

After the holes are drilled in heads and yoke, put them in

place again and fasten them permanently. The guide blocks can now be turned up. They should be a tight fit in the holes. Put washers between the nuts on the back ones and the yoke. This will allow the length of the body of the shank to equal the thickness of guide yoke.

While the blocks are in the lathe a circle should be made on their outer ends, as shown in Fig. 18. This circle will be made use of in laying out the blocks for planing, which we will now proceed to do.

Plug the center up with lead, then get the center of circle on the end of block. Scribe the line *a b*, Fig. 18, through this center and at right angles to the sides of the block. The thickness of the wings of the cross head, or the distance *d e*, Fig. 16, is 3 inches, and it is desired to have $\frac{1}{4}$-inch liner between blocks and guides. Hence the thickness of blocks will be $\frac{1}{2}$ inch less than that of the wings of cross head, or $2\frac{1}{2}$ ins.; or, in other words, the top of the block, after it is planed, will be at the line *e f*, Fig. 18, and the bottom at *c d*, which lines are parallel with *a b* and $\frac{2\frac{1}{2}}{2} = 1\frac{1}{4}$ ins. above and below it. Lay out all the blocks in this way, then after having them planed to these lines, and also parallel with the center of the block, put them in the holes and lay out the bolt holes, which can be done in the following manner:

Put the guides in place as shown in Fig. 19, using common C-clamps to hold them against the blocks, being careful to place them where they will not interfere with getting a scratch awl into the bolt holes in guides. Now run a line through center of cylinder as for laying out guide-block holes, then set the edges of bottom guides parallel with this line, making the distance between the line and guides equal to half the distance between the side gibs on cross head. Then the distance between the guides will be the diameter of the line more than the width of cross head, or about $\frac{1}{32}$ in., which is the amount of side motion the cross head should have. After getting the bottom guides in the proper position, take a scratch awl and scribe lines on cylinder head and on guide yoke, along outside edge of outside guide and inside edge of inside guide. Then should they move, they can be easily put in place again by bringing them back to these lines. The top guides must be exactly above them, and since they are too far above the line through cylinder to use calipers in setting them, we will have to use some other plan. Get two parallel pieces of iron of the same dimensions and place one on engine frame, just back of cylinder head on each side of engine. They should be thick enough to hold a straight edge above the top guides. Put a straight edge on these parallels, and let one end extend out over the guides. Now put a square on the straight edge, and let the blade touch the inside edge of the outer bottom guide. When the square is in this position, the inside edge of outside top guide should also touch the blade of the square. If it does not do so it must be moved out or in until it is in the proper place. Now move the parallels and straight edge to the back end of guides and set back end of outside top guide in the same way. If it is necessary to move it very much, it will throw the front end slightly out of line; hence it is well to try each end at least twice.

To set the inner top guide set calipers to the distance between the bottom guides, then set the top inside guide parallel with outside guide and same distance apart as bottom guides using the calipers to determine when they are this distance apart.

The guides now have the proper position, which should be marked on cylinder head and yoke same as bottom guides. Now the bolt holes in the blocks can be laid out with a scratch awl through the holes in guides. Before moving the guides, make a line on both top and bottom of blocks along the edges of guides. These lines will show how much to plane off the edges of blocks to have them flush with the guides when the job is finished. Now take the guides down; take the blocks out and have them planed to these lines, also the holes drilled. They should be drilled about half way through the block from each side.

Put the blocks in place again and set their tops parallel with a straight edge placed across the frames and over the blocks. If the frame is lower than the blocks, put a parallel piece under the straight edge on each side to raise it up; then caliper between block and straight edge to determine when block is in the right position, or if a straight edge cannot be used, a level may be substituted; but it should be of the kind commonly known as an adjustable level. Then should the engine not be setting exactly level, the level can be adjusted to the incline by putting it on top of the straight edge across the frames and adjusting it to the incline of the straight edge. Now put the level on top of one of the blocks, being careful not to turn it end for end, and it will show which way to turn the block to give it the right position. Don't forget to put the back cylinder head casing on (provided it is solid or not in two pieces) before going any further, otherwise it will be impossible to get it on without either cutting it in two or taking the guides down.

Loose bolts should be used for lining the guides, but should nearly fill the holes. Put pieces of pipe as long as the guides are thick between the heads of bolts and top of blocks. Now put up the bottom guides and put nuts on the bolts to hold them up to within $\frac{1}{4}$ in. of blocks (thickness of liners in this case), and stretch a line through center of cylinder.

We must have some way to know when the guides are the right height. Fig. 20 is a tool generally known as a guide liner or guide gauge, used for finding height of guides. It is made of $\frac{5}{8}$-in. square steel, with a $\frac{1}{4}$-in. screw through its center, as shown. To set the gauge, set the cross head on its back end and clamp a straight edge on the bottom of each wing *m* and *n*, Fig. 16; then lay the gauge on the cross head with the faces *a* and *b*, Fig. 20, against the straight edges as shown in cut. Now run the screw up or down until the point is the same height as center of piston-rod hole in cross head, then fasten it with the lock-nut, *c*, Fig. 20. Put the gauge across the bottom guides, when the point of screw should be same height as center of line through cylinder to have guides right height. But it is possible to have the line and point of screw same height, and yet not have the guides right. Suppose we find on trial that, according to the gauge, the guides are the right height at the front end. Now, put a straight edge across the frames just back of front blocks, then set calipers to the distance between the straight edge and one of the guides, say, the inside one. Try the calipers between the straight edge and the outside guide. Suppose it is found to be $\frac{1}{8}$ in. lower than the other. Since according to the gauge the guides were the right height, we must make the distance between each of them and the straight-edge equal, without changing their average height. This can be done by raising the low guide half the difference of their distances below the straight edge, or, in the present case, by raising the outside guide 1-16 in. and letting the other down the same amount. Now put the straight edge across the frames opposite the back end of guides and set them the right height in the same way. The front ends should be gone over again, since adjusting the back ends will affect the other end. Now put liners enough between blocks and guides to hold them in this position when the nuts are screwed up tight.

It is best to use one liner thick enough to fill space between block and guide, except about 1-16 in., which can be filled with liners such as tins and Russia iron. Screwing up the nuts will be liable to spring the guides up or down in the center of their length. A straight edge placed on their face will show how much and which way they are sprung. Suppose it is found that the outside one is to be sprung up in the center, or at *o*, Fig. 19. To straighten it, unscrew the nut on front bolt and put a strip of tin between guide and block at back end of block. When the nut is screwed up, this strip will strike the block first, and as the nut is tightened it will spring the guide down at *o*. Now try the straight edge again. Possibly the guide is now low at *o*; if so, the strip is too thick and must be taken out and replaced with a thinner one, say, two thicknesses of thick paper. Tighten the nut and try the straight edge again. Experience will teach the workman more about the use of these strips for straightening the guides than anything that can be written.

When a strip is placed between the bolt and the center of the guide's length, a liner of the same thickness should be taken out, otherwise the guide will be the thickness of the strip too low, supposing it to be a lower guide. But if the strip is on the other side of the bolt, it will not affect the height of the guide at the end.

Now put the cross head in place and slide it to one end of guides, when very likely it will be found to have a "rock" in it; that is, it will not set perfectly solid on both guides. Suppose it to be at back end of guides, and when it is down on inside guide it is away from outside guide at back end of cross head. This indicates either that outside guide is too low, or other one is too high at that end. Hence, enough liner will have to be put under inside block, or taken from under outside, to remedy that defect. This will throw the guides slightly out of line, but not enough to have any harmful effect. Slide the cross head to the other end, and if a "rock" is found there, remedy it in the same way. Care should be taken to have the guides perfectly parallel with the cross head crosswise, or the bearing will all be on one side of face of guide, thus increasing its liability to heat.

Sliding the cross head from end to end a few times after putting a little oil on guides, will show where the bearing is. If it is found to be on one edge of face of guide, it can be remedied either by letting the high side down by putting strips of the proper thickness between blocks and guides on the high side, or removing them from the low side. Before commencing to put on the top guides, it is better to trim the bottom liners, especially at the ends of blocks, because after the top guide is in place they are difficult to get at.

Now put a support under the inside bottom guide and take out the bolts, when the top inside guide can be laid in place and enough liners put between it and blocks to hold it about 1-64 in. away from cross head. It can be sprung up or down at the center if necessary,

in the same way as the bottom ones were. Proceed in the same way with the outside guide, when we will be ready to ream the bolt holes. Having used loose bolts in lining the guides, no doubt they are now slightly out of line sidewise; but lines have been made on cylinder head and guide yoke to indicate their proper position, hence all that is necessary now is to set them to these lines, clamp them in that position, ream the bolt holes and put in the bolts.

To enable the roundhouse machinist to keep the guides in line when closing them, we will give him some points for his guidance. Scribe the line *a b*, Fig. 19, on outside and inside of cross head, and parallel with faces of guides. Make a center-punch mark *a* and *b* on this line near each end of cross head, and on the guide blocks the same distance above faces of guides as *a* and *b* are, make the center punch marks *c* and *d*. Then, when closing the guides, all that is necessary to bring the cross head back to the proper height is to bring these four points into a straight line on both inside and outside of cross head.

FITTING PEDESTAL BINDERS AND SETTING FRAMES.

When the back frames have been taken down to allow extensive boiler repairs, or for other reasons, it is important that when they are put in place again, that they be properly lined and squared up. In what follows we will show how this can be accomplished.

The last operation, when taking the frames down, should be to put them bottom side up on blocks at least a foot high. This will leave them in a convenient position for fitting the pedestal binders.

We will suppose that new pedestal binders are necessary, and the first thing to be done in fitting them is to prepare the frame, or bottom ends of pedestal jaws, for receiving them.

The fit *a a'*, *b b'*, Fig. 1, Plate 9, should be filed at right angles to the frame's length and all to the same bevel, which should be about 7 degrees from a right angle to the top of frame. *b'* and *a* should be $\frac{1}{8}$ in. below the face of pedestal jaw, as shown in Fig. 1, to allow the jaws to be refaced without destroying the fit. Before the pedestal binder is laid out it should be planed on one side.

Now bolt two straps of iron, about $8 \times 1\frac{1}{2} \times \frac{1}{8}$ in. (*c c'*, Fig. 1), to the frame as shown, and let them extend a tright angles to the frame. Lay the binder on these strips, planed side down, and against the side of the pedestal jaw, being careful to have the ends extend the same distance back and front of the fit. After setting the planed side of the pedestals at right angles to the side of the pedestal jaw, by bending the straps *c c′* up or down, clamp it in that position. Now with a small straight-edge, held against the fit and against the bottom of the binder, scribe a line on binder. Do the same at the four places. Scribe lines on the edge of binder next to frame to show the right bevel to plane to.

Make the depth of recess $\frac{1}{16}$ in. more than the distance *d e*, Fig. 1. After planing off the recess to these lines, if the work has been accurately done, the binder will drop to within $\frac{1}{8}$ in. of the bottom of frame. It should now be fitted down $\frac{1}{16}$ in. farther by filing when the holes may be laid out. If possible the bolt holes should be laid out and drilled, so that no reaming will be necessary, since reaming the holes weakens the frame. It is important that the hole for the wedge-adjusting bolt be in the proper position. If it is too far from the face of pedestal jaw, it will interfere with

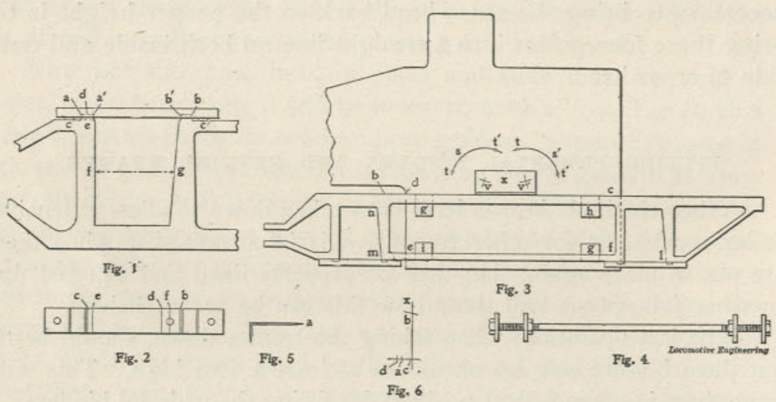


PLATE 9.

the driving box. If the hole is too far the other way, it will come in contact with the face of pedestal jaw.

To find its proper position, proceed as follows: Fig. 2 is the pedestal binder. The line *b* represents the face of back pedestal jaw, and *c* the face of front of jaw. The line *f g*, Fig. 1, is parallel with top of frame and passes through the center of pedestal. If the distance between *d* and *e*, Fig. 2, is $12\frac{3}{4}$ ins., and the driving box is $11\frac{1}{4}$ ins., it is evident that the thickness of driving shoe will be $\frac{12\frac{3}{4} - 11\frac{1}{4}}{2} = \frac{3}{4}$ ins. Hence scribe the line *e*, Fig. 2, $\frac{3}{4}$ in. from *c*. The distance between *e* and *d* equals the size of driving box $= 11\frac{1}{4}$ ins. It is now plain that the space *d b* represents the thickness of the bottom of wedge. Suppose the diameter of that part of the bolt that enters

the wedge to be $1\frac{1}{4}$ ins., then the center of bolt hole in binder should be $\frac{11}{16}$ in. back of line *d*, or on the line *f*. This will allow $\frac{1}{16}$ in. clearance between the bolt and driving box.

Having finished this part of the work, we will proceed to put frames in place. But before putting them up, the expansion plate studs should be examined carefully, and if any of them show signs of leaking, they should be replaced with new ones.

Any studs that prevent the frame liners from sliding out and in when the frame is in place should be taken out, and the new ones not put in until after liners are fitted.. A die nut should be run over the old studs that are good to straighten up the thread.

Now place some blocks across the pit directly under where the pedestals will come when frames are in place, to support them while fitting the liners and buckles. Set the frame on the blocks, and then raise or lower it to the proper height, which may be determined by using the buckles as a gauge. When the frame is the right height the buckle will slide on the studs.

Now put in the splice bolts, then fasten the deck in place. Set inside calipers to the distance between the frames at the deck. Then by means of rods and plates of iron like Fig. 4, which should be made of at least $\frac{3}{4}$-in. iron, placed one at *l*, one at *m*, and one at *n*, Fig. 3, set the frames the same distance apart at these points that it is at the deck, using the calipers as a gauge.

Now run lines through the center of cylinders, letting them extend to the back end of frames. Then measure the distance from the outside of pedestal jaws to the lines. This distance should be the same at all the pedestals, but very likely will not be.

Suppose the distance from the left front pedestal to the line to be $11\frac{1}{2}$ ins., and right front 12 ins. This indicates that the frames are $\frac{1}{4}$ in. too far to the left in front. To draw them over insert an iron wedge between the boiler and frame at *d* and at *e*, Fig. 3, on right side and drive them down until the frame has been drawn over the required distance, which in the present case is $\frac{1}{4}$ in. As the right frame is drawn out, the left will be drawn in by the rods, previously mentioned, which bind the frames together.

Now insert iron wedges between frame and boiler at *d* and *e* on left side of engine, but do not drive them down any, as these are merely to fill up space between frame and boiler to hold the frames in place after they have been drawn over.

We will now go to the back pedestals. Suppose the distance from the left pedestal to the line through cylinders to be $11\frac{5}{8}$ ins., and from right pedestal to line to be $11\frac{7}{8}$ ins.; then the proper distance from pedestal to line on both sides is $\frac{11\frac{5}{8}+11\frac{7}{8}}{2}=11\frac{3}{4}$ ins. Hence, the frames are $\frac{1}{8}$ in. too far to the right. Draw them to the left by means of wedges at *c* and *f* on left side, then insert wedges on right side to hold them firmly in place. Now try the front pedestals again, as setting the back ones will be liable to throw them slightly out of line. If such is the case they can be put in line again by driving the wedges farther down on the side that is farthest from the line, being careful to first raise the wedges on opposite side.

We now have the frames the same distance from the lines at all four pedestals, but something more is necessary. They must be at right angles to a line drawn across their tops. We will try them at the front pedestals first.

Put a straight edge across the frames at *b*, Fig. 3, and then place the short side of a 2-ft. square against the straight edge, when the side of pedestal should be parallel with long side of square. Suppose it is found to be $\frac{1}{8}$ in. away from the square at bottom end on left side, then the right pedestal will be that distance from square at top end, since the frames are held parallel by the rods. They could be squared up by raising the bottom wedge (in front) on right side and driving the one on left side down, but that would throw both frames about $\frac{1}{16}$ in. too far to the left. To square them up, and at the same time keep them in line, proceed as follows:

Raise the bottom wedge on right side enough to allow the bottom of pedestal to go toward the boiler $\frac{1}{64}$ in., and drive bottom wedge on left side down enough to draw bottom of pedestal out $\frac{1}{16}$ in. This will leave them out of square the same as they were, but only half as much, and they have been drawn $\frac{1}{32}$ in. too far to the left. Now raise the top wedge on left side enough to allow top of pedestal to go toward boiler $\frac{1}{16}$ in., and drive top wedge on right side the same amount.

We now have the frames square and have drawn them back into line. Proceed in the same manner with the back pedestals. The frames now have the proper position, and in order to determine whether they move or not, and to know when the liners are the right thickness, the position of the frames should be marked in some way, and a very good one is to use a tram similar to the one shown in Fig. 5. Make a center punch mark on the side of boiler, near *c*, *d*, *e* and *f*, Fig. 3; then, with the point *a*, Fig. 5, in these marks, scribe arcs on the frames at the four places.

Do the same on other side of engine. It is plain that these arcs must come to the same position when the liners are fitted and the buckles on. We are now ready to fit the liners, *g*, *h*, *i*, *j*, Fig. 3. Generally the old liners can be used again. If they are too thin to fill space between boiler and frame, a piece of boiler plate can be riveted onto the side next the frame. If a piece of the exact thickness cannot be had, rivet one on slightly thicker than is required, then plane it down to the exact thickness.

After the liners are in place, the studs can be screwed in through the holes in them by using a stud nut.

The buckles should be loose enough on frame to allow them to slide on it without binding when the boiler is expanding or contracting.

The lateral, or cross, braces can now be put on. If they are not the right length, have the blacksmith lengthen or shorten them to suit.

To lay out the holes in a new expansion plate when the studs are in the boiler, with any degree of accuracy, is generally not very easily done. The following method has been found to give satisfaction: Make a small center punch mark in the center of each stud that is to pass through the plate. Then set dividers to any convenient radius—say, 10 ins.—and with centers of studs as centers scribe the arcs *s s′*, Fig. 3, on the side of boiler, and make two center punch marks *t t′* on each arc, about 90 degrees apart if possible; more or less will answer the purpose, but 90 degrees will give the best results. Now, lay the expansion plate *x*, Fig. 3, on top of frame, as shown (this is not the position usually occupied by an expansion plate, but will serve our purpose), with the part that goes next to boiler against the ends of studs. If we now use the points *t t′* as centers, and with the same radius used to scribe *s s′*, scribe arcs *v v′* on expansion plate, their point of intersection will not lie in a line with the center of stud, but will be to the side of this line nearest the arc *s or s′*; or, in other words, the radius used was too short. The correct radius with which to draw the arcs *v v′* can be found thus:

On a board or other plain surface, draw two indefinite lines at right angles to each other, Fig. 6; then lay off the distance *a c* equal to the length of the studs, and *a d* equal to the thickness of the expansion plate. With *a* as a center and the same radius that the arcs *s s′*, Fig. 3, were drawn with, scribe the arc *b*, Fig. 6, across the line *x y*. Now set the dividers to the distance *b d*, which is the correct radius with which to scribe the arcs *v v′* Fig. 3, on expansion plate, using *t t′* as centers, to have their point of intersection in line with center of stud. Hence this point will be center of hole in expansion plate.

It is hardly necessary to say that an arc must be scribed on side of boiler from center of each stud that passes through the plate.

FITTING UP DRIVING SHOES AND WEDGES.

BY IRA A. MOORE.

The driving shoes and wedges are a very important part of the locomotive's mechanism, and it is important that they be properly fitted up. If they are not as they should be, trouble will be very apt to follow. The faces of the shoe should be exactly parallel with the axle and at right angles to the top of frame. If the faces are not parallel with the axle, the journal will be liable to heat, since the pressure upon it due to the traction of the engine will not be equally distributed. The main shoes should be of the proper thickness to bring the center of axle in the center of the pedestal, or at least in the center of pedestal on one side of the engine, and on the other side the right thickness to hold the axle at right angles to the center of cylinders.

The other shoes should be the proper thickness to give the right distance between the centers of the driving axles. The wedges should be parallel with the shoes.

How to bring these results about will be made as plain as possible in what follows. We will assume that we are working on a four-wheel connected engine, and that the frames are in line and ready otherwise for laying out, which must be done before the shoes and wedges can be fitted up. Therefore we will proceed to get some points on the frames from which to work in fitting up the shoes and wedges.

It has been said that the driving axles must be at right angles to the center of the cylinders. Hence a point must be obtained on each of the back frames and as near the center of the main pedestal as possible, through which if a line be drawn, it will be at right angles to the center of cylinders. To get these points, proceed in the following manner:

First, stretch lines through the center of cylinders and extend them to 3 ft. back of the back cylinder heads. Put a double square, similar to the one shown, Fig. 1, Plate 10, across the frames about 6 ins. back of cylinder heads, and clamp it there. The distance is immaterial, but must be the same on both sides of

the engine. The main part of this square is made of steel. The squares *d d* slide in the slots *a a*, and are held in the desired position by thumb nuts at *b b*. When the square has been secured in place, slide the squares *d d* out until they just touch the lines through the cylinders, as shown at *c*, Fig. 1. Make a mark on the edge of the squares, as shown at *e*, the same distance above the line on each side of engine. With a tram like the one shown in Fig. 2 get a point on the cylinder saddle casting midway between the centers of cylinders, and as low as possible. The main part *d* of this tram is made of $\frac{1}{4}$-in. pipe (except the point *a*, which is of steel), into which a piece of round steel with a point bent at right angles to its length is made to slide, and is held in any desired place by the thumbscrew *c*.

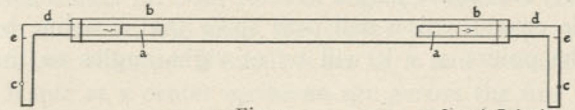


Fig. 1.

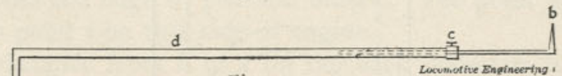


Fig. 2.

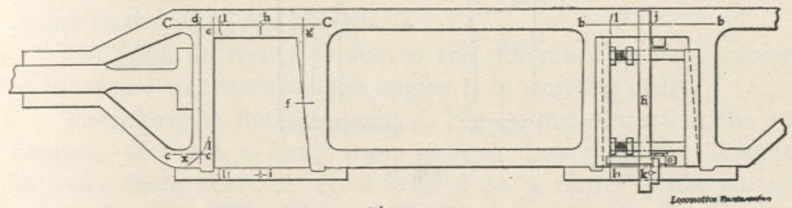


Fig. 3.

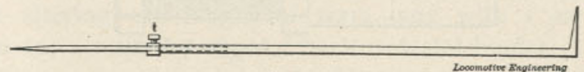


Fig. 4.

PLATE 10.

To use this tram, place the point *a* against the vertical part of the double square, keeping the body of tram in front of the square, and the point *a* on the mark *e*, Fig. 1, mentioned above. Then with point *b*, Fig. 2, scribe an arc on the saddle casting as near as possible to the center. Do the same on the other side of engine, and if the tram is the right length, the arcs will intersect near the bottom of saddle casting. Mark the center with a center-punch, as we will have occasion to use this point later on. Call this point *a*. On the outside, and parallel with the top of the frame, draw the lines *b b*, *C C*, Fig. 3, directly above and extending a short distance back and front of pedestals, making them all the same distance below the top of frame.

Now on the front jaw of each of the front pedestals draw the line *c c* parallel with the line *b b* and the same distance below it on each frame. The body of the tram, shown in Fig. 4, is made of $\frac{1}{2}$-in. pipe, with the points of steel, one end being made to slide into the pipe in order to admit of adjustment, and is held in place by the set-screw *t*.

With the straight point of this tram in the point *a* on cylinder saddle casting, scribe the arc *l*, Fig. 3, on the front pedestal jaw and across the line *c c*. Mark the point of intersection of line and arc with a small center punch, then try the tram in it to prove its correctness. Repeat the operation on opposite side of the engine. Call these points *x*.

A little consideration will now show that if a line be drawn through the points *x x* it will be at right angles to the center

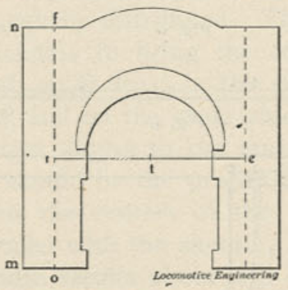


Fig. 5.

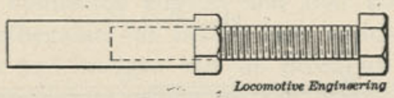


Fig. 6.

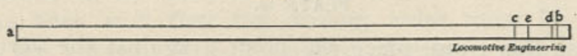


Fig. 7.

PLATE 11.

of cylinders. Now take a T square and draw a line through *x* and at right angles to the top of frame. Make a center punch mark where this line crosses the line *C C* and call this point *d*. Do the same on the other frame. A line drawn through *d d* will be parallel to the line through *x x*, hence will be at right angles to center of cylinders.

Now we must find the point *h*, through which, if a line be drawn at right angles to the top of frame, it will pass through the center of pedestal. A very good way to find this point is to draw a line from the upper end of the face of front pedestal jaw across and at right angles to *b b*. Make a center punch mark where the lines cross and call this point *e*. Draw a similar line from *f*, which is midway between the top and bottom ends of the back pedestal jaw. Call its point of intersection with *C C* point *g*. The point *h* is midway between *e* and *g*. Set a pair of large dividers to the points *d* and *h*. Then with *d* on opposite frame, as a center, scribe an arc across the line *C C*, and the point of intersection is the point *h* on that frame.

Now take the T square and draw a line through *h* and across the pedestal binder on both sides of engine. Make a center punch mark *i* on this line and near the center of the edge of pedestal binder on one side, set a small tram to *h* and *i*, then with *h* on opposite frame as a center scribe an arc across the line previously drawn across the edge of pedestal binder. The point of intersection is the point *i* on that side of engine.

The distance from *h* to *j* on the back pedestals is $\frac{1}{32}$ in. less than the length of the side rod, which length is the distance from center to center of rod brasses.

The $\frac{1}{32}$ in. difference is due to the difference in temperatures of the frame and rod when the engine is in working order.

Therefore, to find the point *j*, Fig. 3, put centers in the rod brasses, then set a long tram to $\frac{1}{32}$ in. less than the distance between these centers. Now with *h* as a center scribe an arc across the line *b b*. The point of intersection is the point *j*. Without altering the length of tram, and with *i* as a center, scribe an arc across the edge of back pedestal binder. Now take the small tram, set it to *h i* and with *j* as a center scribe an arc on the back pedestal binder and across the one drawn with the long tram. The point of intersection is the point *k*. Get the corresponding points on the other side in the same manner.

Now get the size of the driving box with calipers and scale, set a pair of dividers to half the size, and with *j* and *k* as centers scribe the arc *l* on frame and l_1 on pedestal binder. It is easy to see that the face of the shoe when it is finished must be in a straight line between these arcs in order to have the center of axle *t* (Fig. 5), Plate 11, in a line between *j* and *k*. If the boxes are not all the same size, the same operation must be gone through for all boxes of a different size. If, as is sometimes the case, the brass is bored out of center, or, in other words, the distance $r\ t$ is not the same as $e\ t$, Fig. 5, a different course must be pursued.

Put a center in the brass, being careful to have it flush with the side of the box, and with a pair of hermaphrodite calipers find the center t. Scribe a line on the box at right angles to $m\ n$ and through t, also a line at r at right angles to the line through the center and exactly opposite the face, or part of the box that comes in contact with the shoe. Now, if r is the front of the box set the dividers to $r\ l$ and scribes the arcs $l\ l_1$ as described above.

We are now ready for the shoes and wedges. The length of the shoes should be $\frac{1}{32}$ in less than the distance from the top of pedestal to the pedestal binder, and they should be faced to the pedestal jaw. The wedges should be 2 ins. shorter than the shoes, and faced to pedestal jaw same as shoes.

Assuming that they have all been treated in the manner described, we will proceed to lay them out for planing. Put each one in its proper place, and put about $\frac{5}{16}$ in. under each wedge, then they will be that distance away from the pedestal binder when they are adjusted to the size of the box. This is to allow them to be pulled down to give the box room to expand if it should heat. Some plan must be used to hold them firmly against the pedestal jaws while being laid out, and a very good one is to use what is termed spreaders, one of which is shown in Fig. 6. It is made of a short piece of 1-in. pipe, which is slipped over the end of a $\frac{7}{8}$-in. hexagon headed bolt onto which a nut has been screwed.

Use two of these in each pedestal, as shown in Fig. 3. Put one about 2 ins. from the top of pedestal and the other the same distance from the bottom. Now, secure a straight-edge about 5 ft. long between the pedestal binders and the bottom spreader, by means of block of wood and a small wooden wedge, as shown at o, Fig. 3.

In the same way secure another straight-edge between the top spreader and top of pedestal also shown in Fig. 3. Now, with a small straight-edge h, Fig. 3, adjust the others so that their front edges will lie in a line between j and k, or h and i, as the case may be.. Of course, this must be done at each end of the long straight edges in order to have them parallel with the center of axle.

It is plain that the straight-edges now occupy the same horizontal position that we desire the center of axle to occupy when

we have finished. Now, set an adjustable square to half the size of the driving-box $+ \frac{1}{2}$ in., or, if the brass is not bored out central, set the square to the distance $r\ t$ (Fig. 5) $+ \frac{1}{2}$ in. Put the square against the back edge of the short straight-edge, letting the blade extend forward along the side of the flange of the shoe, being careful to keep the blade parallel with the frame, as shown in Fig. 3. Then with a scratch-awl against the end of the blade of the square, scribe a line on the side or flange of the shoe. Make two lines on the outside flange and as near the end of shoe as possible, and one on the inside about midway of the shoe's length. Do the same to the shoe on the other side, then change the straight-edges to the front pedestal and repeat the operation, when the shoes will be ready for the planer.

After being planed the face should be exactly $\frac{1}{2}$ in. from the lines on the flanges. The reason $\frac{1}{2}$ in. is added to half the size of the box when laying the shoes out is that there may be some way to prove that they have been planed as laid out, then it is easier to plane to a certain distance of a line than exactly to it.

When the shoes have been planed, put them in place again and put in the spreaders. Now lay out the wedges from the shoes in the following manner: Set the adjustable square to the size of the box $+ \frac{1}{2}$ in., then with the head of the square against the face of the shoe scribe lines on the flanges of wedges similar to those on the shoes and in the same relative position. Set them upon the planer bed by these lines and plane in the same manner as the shoes.

Since it is with the flanges of the shoes and wedges that the lateral motion of the engine is regulated, the outside flanges must have a certain thickness which may be found as follows:

On a smooth strip of wood mark off the distance $a\ b$, Fig. 7, which is the distance between the wheel hubs, also the distance $a\ c$, from outside to outside of frames. Draw the line d across the stick, making the distance between it and b equal to the lateral motion desired, which should be $\frac{3}{32}$ in. for the front and $\frac{1}{8}$ in. for the back wheels. Now, make the distance from d to e equal to twice the thickness of the outside flange of the driving box. Then half the distance $e\ c$ will be the thickness of the outside flanges of the shoes and wedges.

Enough should be planed off the inside flanges to make the width of the shoes and wedges $\frac{3}{32}$ in. less than distance between the flanges of the driving boxes and the corners should be rounded enough to clear the fillets in the boxes and no more, since that would weaken the flanges and increase their inability to crack.

HOW TO PUT ON A NEW BOILER, FIT UP SPRING HANGERS, DRIVING SADDLES, ETC.

BY IRA A. MOORE.

When the necessity arises for changing the boiler on a locomotive, the engine will have to be completely stripped, the wheels and truck taken out and the back frames taken down. If the shop is not provided with a crane sufficiently strong to lift the boiler, temporary trucks will have to be put under it, so that it can be run out of the way.

A truck should be put under the mud ring and another just back of cylinder saddle.

Before loosening the boiler from cylinder saddle, the distance between front of water leg and back of cylinder saddle should be taken on a strip of wood, then by using the strip it is easy to get the proper distance between these two points when the new boiler is being put in place.

Possibly the new boiler is not at hand, and in the meantime let us turn our attention to some other parts of the work. The work on the driving shoes and wedges can also be done while the frames are down, if a starting point is obtained before loosening them from the discarded boiler. Before loosening the frames from boiler the distance from outside to outside of frames at pedestal jaws should also be taken on a stick.

After fitting the pedestal binders set the frames on blocks on the floor in the same position that they occupy when on the engine, except the distance between them need not be the same, they may be any convenient distance apart—say, 2 or 2½ ft.

If a line had been drawn through the points *x*, Fig. 3, Plate 10, before frames were taken down, it would have been at right angles to the center of cylinders, and also at right angles to the frames. Therefore the frames must be set on the blocks so that a line through these points will be at right angles to the frames. To determine when they are in this position, put a straight-edge across the top of frames and set it so that it will coincide with a line drawn through *x* and at right angles to top of frame.

Now, by using a large square, determine whether or not the straight-edge is at right angles to the frame. If not, one of the frames can be moved back or forward, as the case may be, being careful to keep the frames parallel with each other. After they once have the right position they can be kept from moving by binding them together with strips of wood.

Now is a convenient time to "square up" the driving saddles. The first step is to ascertain whether they are worn enough to make them too short. The legs of the saddles should be long enough to reach from top of frame to bottom of pockets in the top of driving boxes, when the boxes are down on pedestal binders, as shown in Fig. 1, Plate 12. Suppose the distance between the frame *x* and pedestal binder *y* to be 17 ins. and distance through frame 4 ins., making 21 ins.; hence the distance between the dotted line *b* and top of pedestal binder is 21 inches. Now, if the length of the box minus the depth of the pockets *d d'* is 13½ ins., then the length of the legs of saddle should be 21 — 13½ = 7½ ins.

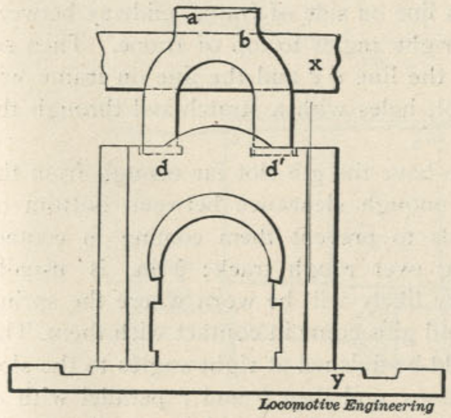


Fig. 1.

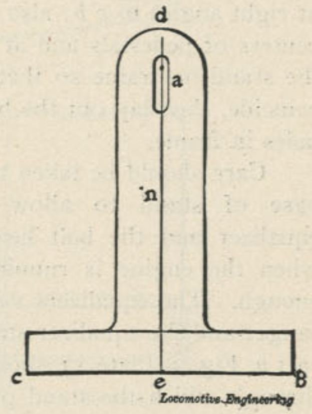


Fig. 2.

PLATE 12.

While this is the proper length of the saddle legs, yet should they be found to be not more than ½ in. shorter than this, they may be used again. The bottom of the pocket in the saddle will generally be worn more on one side than the other, as shown by the dotted line *a*, Fig 1. When the bottom of pocket is squared up at right angles to the side of saddle, if it is deeper than the thickness of band on the spring minus ⅛ in., a plate of iron thick enough to bring it back to its original depth should be fitted into it. Now put a parallel piece of iron whose thickness is slightly more than the depth of pocket, and whose other dimensions are nearly equal to those of the pocket, into it, then turn the saddle upside down on a face plate. With a surface gauge scribe lines across the legs, making the distance between them and the line *b*, Fig. 1, equal to the length of the shortest leg in the set of saddles.

Proceed in the same manner with the other saddles, then when the legs are chipped and filed to these lines, they will all be the same length, and their ends will lie in a plane at right angles to the saddle and to the bottom of pocket.

The equalizer stands will also need some attention. If the slot for the gib is not too much worn, the blacksmith can bring it back to the original size. Sometimes a new top welded on will make them all right.

Perhaps a new stand is necessary. If so, before laying out the bolt holes, the face *c b* should be planed at right angles to the top of stand, Fig. 2.

Scribe the line *d e*, Fig. 2, through the center of the slot *a* and at right angles to *c b*; also a line on side of frame, midway between centers of pedestals and at right angles to top of frame. Then set the stand on frame so that the line *d e* and the line on frame will coincide, then lay out the bolt holes with a stratch-awl through the holes in frame.

Care should be taken to have the gib slot far enough from the base of stand to allow enough clearance between bottom of equalizer and the bolt heads to prevent them coming in contact when the engine is running over rough track; $\frac{5}{8}$ in. is usually enough. The equalizers very likely will be worn where the spring hanger and the equalizer stand gibs come in contact with them. The part *a*, Fig. 3, Plate 13, should be finished at right angles to the slot through which the stand passes, and then *b* and *c* parallel with *a*. A plate of steel about $\frac{3}{8}$ in. thick should be put between the equalizer and the stand gib to prevent the gib cutting into the equalizer. When the plate wears, it is very easy to replace it with a new one. These plates can be made from broken leaves of driving springs. To determine when *b* and *c*, Fig. 3, are parallel with *a*, put the equalizer up side down in a vise, then put a straight-edge across it at *a* and another at *b* or *c*. Then by looking across them they will show which side of *b* or *c* must be filed to make it parallel with *a*. If it is *b* that is finished first, then put a straight-edge across at *b* and make *c* parallel with it, as described above.

The spring gear is now all fitted up, except the hangers. They should be the right length to hold the springs and also the equalizers parallel with top of frame when the driving saddles are resting on frame. Hence before they can be fitted up their proper length must be found, which can be done in the following manner:

Put the driving saddles and springs on the frame in their proper positions, also the equalizers and stands. Put the stand

gibs in place. Set the equalizers so that a line through *b* and *c*, Fig. 3, will be parallel with top of frame and as high as the gibs will allow them to go. Set the springs with the gib bearings on each one will be the same distance from top of frame. Now the distance between the gib bearing on equalizer and on the spring, minus the draw, is the proper length of hanger, which length is the distance between the gibs. The draw should be from $\frac{7}{8}$ to $1\frac{1}{4}$ ins., depending on the weight to be carried by, and the strength of the spring. The heavier the spring the less the draw required, and the heavier the engine the more draw necessary.

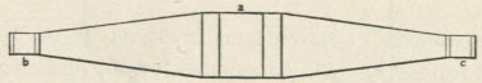


Fig. 3.

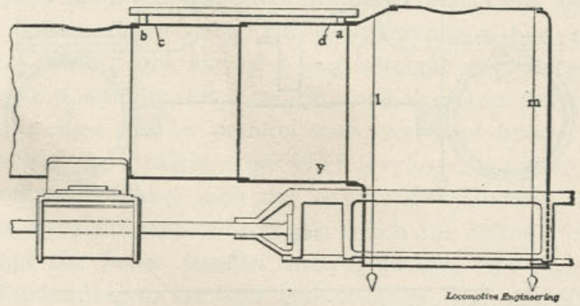


Fig. 4.

PLATE 13.

If the hangers as they were taken off the engine are not the right length, the blacksmith can change them to suit, and also close the slots if that is necessary.

The front frame fastenings should be carefully examined. We will now get the cylinder saddle ready for the boiler.

The cylinders should be blocked up perfectly level both ways.

The blocks can be put between the cylinders, letting the bottom of saddle rest on them. It will be necessary to have some thin strips of wood at hand to put under wherever required to level them.

Since the front frames have not been taken down, it is well to support their back ends in some way, preferably with screw jacks. Remove all scale and dirt from top of saddle.. Now run the new boiler ahead until the distance between the back of saddle and front of water leg is the same as with the old boiler, as determined by the strip of wood mentioned above. The boiler should be blocked on trucks the same as the old one was for running out of the way. Now let front end of boiler down nearly to saddle. This can be done by means of a jack under the front end. Then set front end central between cylinders in the following manner:

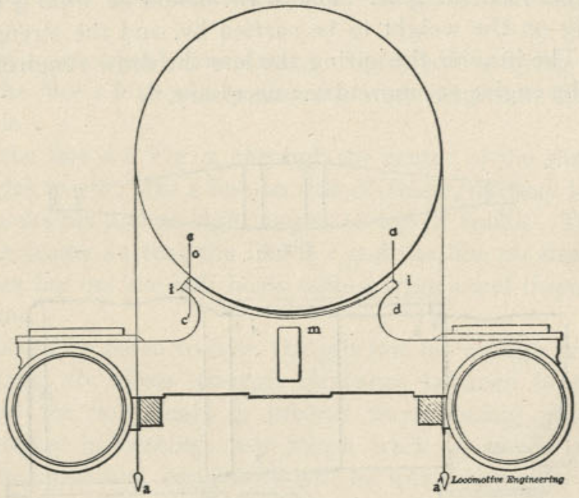


Fig. 5.

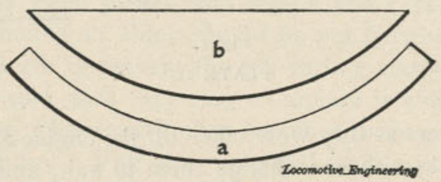


Fig. 6.

PLATE 14.

Put a line over boiler just back of cylinders, letting the ends to which small weights have been attached, come below the frames, as shown at *a a'*, in Fig. 5, Plate 14.

If the boiler is central the distance between line and frame will be the same on each side. If the boiler needs throwing to one side, it can be done by setting the jack at a slight angle, letting the top stand away from the side to which it is desired to throw the boiler; then when the weight is put on the jack, it will right itself and throw the boiler over.

We will next plumb the back end. Put lines over the wagon top at *l* and *m*, Fig. 4, Plate 13, letting them extend below the mud ring. When the boiler is vertical the distance from the lines to the boiler will be the same at all four corners. If the boiler is not plumb, the distance between lines and boiler will be greatest on the low side.

On account of the sides of water leg not being parallel with each other, or with the center line of boiler, it sometimes happens that the distance from the lines to boiler cannot be made the same at the four corners. In such cases the distances should be averaged up.

The boiler must be level lengthwise. This is sometimes determined by putting a level on top of the dome, but this is not reliable. A better way is to caliper the boiler at *a* and *b*, Fig. 4, Plate 13. Suppose the boiler is 50 ins. in diameter at *a* and 49 ins. at *b*, then the distance from center to circumference is $\frac{1}{2}$ in. more at *a* than at *b*. Now, if one end of a long straight-edge be put on the parallel piece *d*, and the other end on *c*, which is $\frac{1}{2}$ in. thicker than *d*, the straight-edge will be parallel with center of boiler. Put the level on top of the straight-edge when leveling the boiler. Set the boiler level and parallel with the centers of cylinders, and at the same time have the smoke arch just touch the cylinder saddle.

To get the boiler parallel with cylinders, run lines through them and extending to the back end of boiler, and set boiler central between them by measuring from lines to water leg at the four corners.

If, on account of water leg not being parallel with center line of boiler, the distance cannot be made the same at the four places, it should be averaged up.

Since adjusting one end of boiler will throw the other slightly out of place, each end should be tried two or three times. We now have the boiler parallel with the cylinders and the smoke arch touching the cylinder saddle at, it may be, only one corner, as shown at *o*, Fig. 5, Plate 14.

Now the arch must be fitted into the saddle, and it is necessary to have a line on the back and one on the front of saddle to work to. We will now proceed to get these lines.

First, measure the vertical distance between smoke-arch and saddle at the place where they are farthest apart, either back or front; then on the vertical lines *c c'* and *d d'*, Fig. 5, lay off this distance $i\ i'$ at the four corners of the saddle. Raise the front end of boiler enough to clear the saddle, and run it back out of the way, being careful to first mark it, so that it can be run ahead to the same place again.

Make a wooden template, *a*, Fig. 19, to fit the curve of the smoke-arch at the front, and one at the back of saddle, and have them a little longer than the width of saddle. Now, by means of the templates draw the curved lines *m* through the points $i\ i'$ on both front and back of saddle. Chip the saddle to these lines and make it straight lengthwise by using a straight-edge. A better fit will be obtained if another pair of templates like *b*, Fig. 6, Plate 14, is made to fit the ones used to lay out the saddle; the convex edge being fitted to the concave edge of *a*. Then by using red lead on the edge of template the high places on saddle can be at once detected. On account of any irregularity that may be in the curve of the bottom of smoke arch, it is well to have the templates, Fig. 6, marked in some way; then, when using them, be careful not to turn them end for end. Now run the boiler ahead again, and let the front end down on the saddle, when it will be as much lower than the back end as was taken out of the saddle. Hence the back end will have to be let down enough to level the boiler again.

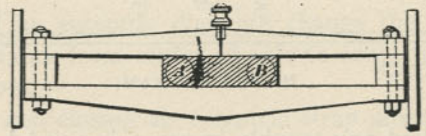
Lines should again be run through the cylinders, and measurements taken from them to the boiler, as described above, to ascertain whether the work on saddle has been correctly done.

Suppose it is found that the line on left side is $\frac{1}{8}$ in. farther from the boiler than the other one; then to bring the cylinders in line with the boiler about $\frac{1}{32}$ in. would have to be taken off the left back and the right front corners of cylinder saddle. The bolt holes can now be drilled in smoke arch, preferably by using a twist drill through the holes in saddle, the drill to be same size as holes. If the holes cannot be drilled in this way, they will have to be laid out and the boiler run back in order to get at them. After drilling run the boiler ahead again, ream the holes and put in bolts.

We are now ready to put up and line the frames. Except the manner of finding the height of frames, this can be done as described on page 1. Since the frames are parallel with the cylinders and the cylinders have been set level, the frames must also be level. A very good way to level them is to level one of them lengthwise first —say, the left one—then put straight edges across them at *x* and *y*, Fig. 4, Plate 13, and raise or lower the right one enough to bring the straight edges level, which will give the frames the same height.

WEAR OF CROSS HEAD.

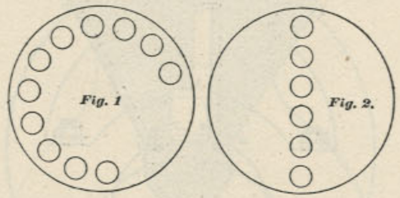
An easy method of finding the wear on cross head can be seen by consulting the annexed cut. As there is constantly a doubt in the minds of many regarding the wear of gibes and cross head, this method should make it clear to them which guides should be closed, the top or the bottom guide. In suburban service where engines are running forward and backward, the heaviest wear comes on the bottom guides.



When engine is in shop, overhauled and cross head planed, a circle should be described on cross head at both ends, as shown in sketch at *A B*. When guides need reducing a compass should be used in center *A B* which will indicate which way guides need lining, up or down.

HOW TO REMOVE A REFRACTORY AXLE.

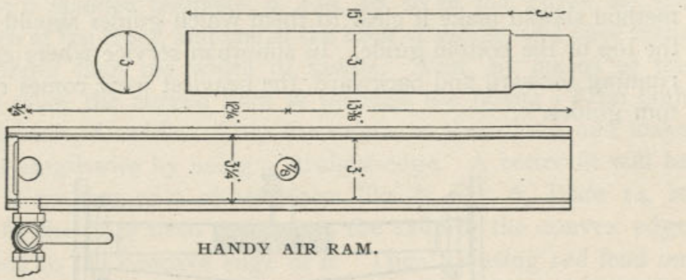
Occasionally one finds a refractory axle when the ordinary methods prove inadequate. Fig. 1 shows the wrong way to accomplish any results. When drilling must be resorted to, the proper



way to drill is as shown in Fig. 2, and no further trouble will be experienced when the pressure is applied.

HANDY AIR RAM.

A very handy tool is shown here. It is made out of a piece of gas pipe, and the size must be determined according to the kind of work to be done. The bottom end is capped, and acts as a pedestal, and the plunger is made three-fourths the length of the pipe. At an equal distance from the end a $\frac{1}{4}$-in hole is drilled as a vent, and at the bottom a suitable hose connection is made. An angle cock to this connection completes the outfit. Anyone



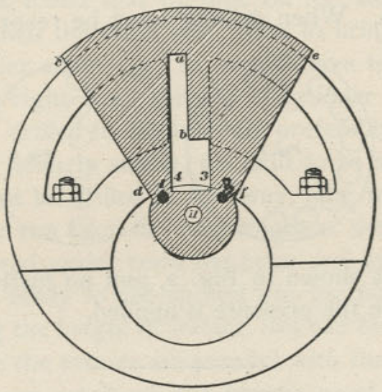
HANDY AIR RAM.

who has ever had any trouble in removing rod bolts can see the value of it. It is less dangerous than the powder gun, and just as effective.

A HANDY TEMPLATE.

FOR LAYING OUT ECCENTRICS.

In making new eccentrics the template shown in the engraving is used to insure uniform work, the pieces are planed at the joint and bolted together, and the center line laid out at right angles to the joint, and the hole bored; this template is then laid on, as shown in



ECCENTRIC TEMPLATE.

the shaded lines of the cut, the two pins, shown at 1 and 2, project through the lower side of the template, and, being at equal distances from the center line, from a center square, the line from *b* to *a* being the center of the eccentric, or on a line drawn through the center of

the shaft and the center of the eccentric, then the lower opening at 3 and 4 are guides to scribe the key way by, and the outside of the template at *e f* and *c d* becomes guides to scribe the lines to drill the set-screw holes by. This plan secures uniformity of the work and precludes the possibility of mistakes in laying it out. Eccentrics are kept in stock, and it is a great convenience to be able to put on a new one without the usual delays in cutting the key way by hand after finding out where you want it by the cut-and-try plan.

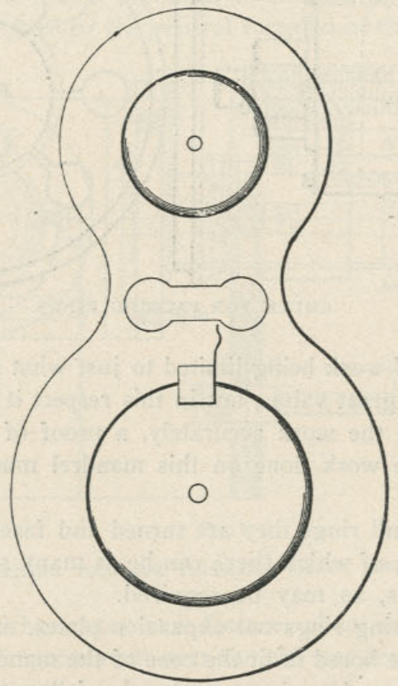
TURNING OFF ECCENTRICS.

Turning off an eccentric does not change the throw as some imagine, the distance from center of axle to center of eccentric determines the throw.

Boring out and closing an eccentric strap affects the travel of the valve and requires lengthening of the eccentric rod.

DOCTORING A CRACKED HUB.

The accompanying cut shows the method adopted by the Erie people, at Jersey City, in taking care of a driv-



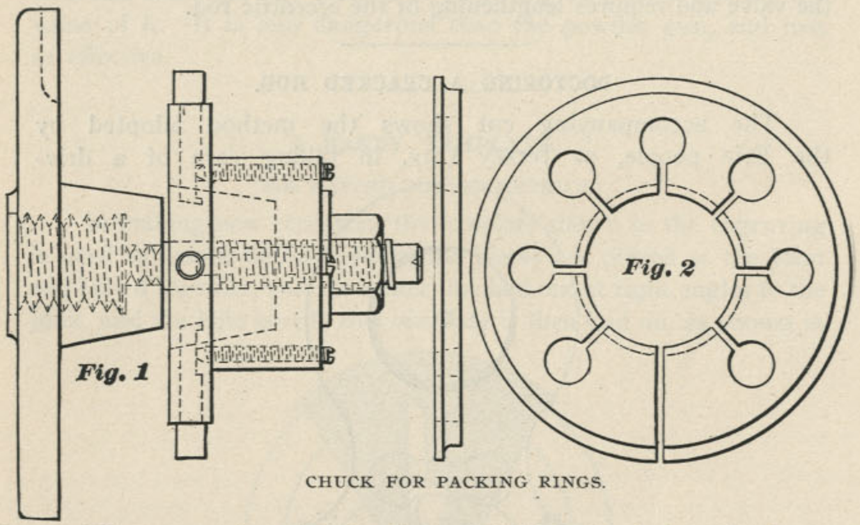
Locomotive Engineering

REPAIRING A CRACKED HUB.

ing-wheel hub that was cracked on the outside at the key way; it represents the job as we saw and sketched it from an engine just in off the road. The outline immediately above the crack is that of an opening cut in the hub face about 1¼ ins. deep, the ends 1¾ ins. diameter and the center 1¼ ins. wide, into which was fitted a piece of steel which was driven in hot, and thus made to draw while cooling. The recess was slightly undercut, so as to retain the binder after being upset in place.

SPECIAL CHUCK FOR TURNING LOCOMOTIVE PACKING RINGS.

The accompanying cut shows a handy mandrel for facing parallel the "bull" rings and spring rings of locomotive pistons and is made of old piston spider heads and follower plates.



CHUCK FOR PACKING RINGS.

The range of work being limited to just what it is made for, it may not seem of great value; but in this respect it is like the pistol in Texas, it does the work accurately, a proof of the value in all shop kinks. The work done on this mandrel must be bored in a common chuck.

In making bull rings they are turned and faced, resting on the steel pins, Fig. 1, of which there can be as many sets, for different sizes of cylinders, as may be required.

In facing spring rings use expansion plates, made as shown in Fig. 2. These are bored to fit the cone of the mandrel near the face plate, and are brought up square by the follower and nut. The amount of expansion we find to be not over ⅛ in., and if we

make our rings standard sizes, we do not need a large number of plates.

While a common chuck is theoretically true, a machinist who has run a "packing lathe" knows it is impossible to chuck such work true, as the tendency is to spring the work out and away at the jaws. On this mandrel the strain in tightening is towards the plate in all cases.

The thread on the stud is ½ V, leaving the top flat, so as not to wear loose in the follower, which should fit well to hold everything central.

Make a slot in the face plate to admit of a caliper or template for gauging the spring rings.

As the expansion plates are made of old follower plates, any shop can afford one for each sized cylinder in service.

SOME HANDY TOOLS FOR RAILROAD SHOPS.

The tool shown in Fig. 1 is for turning lifting shaft bearings in the ordinary lathe that is too small to allow it to swing on the centers. It was designed by the general foreman of the Grand Crossing,

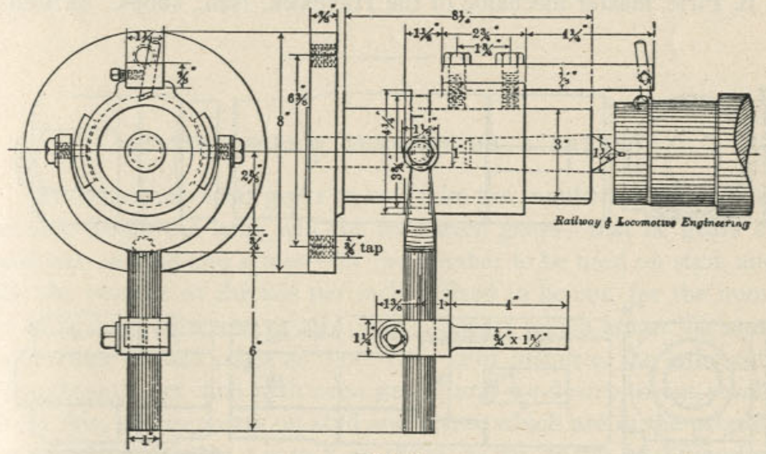


Fig. 1

TURNING TOOL FOR TUMBLING SHAFT BEARING.

Wis., shops, and has many new features about it that seems to the writer to be an improvement over the old star feed which is usually used for this purpose.

The main features of this are, as shown, a sliding sleeve on a fixed mandrel, bolted to the face plate, whose center is inserted in the center of the lifting shaft, and the sleeve is fed by a positive feed secured in the tool post of the lathe.

Cut No. 2 shows a very handy tool for using on a turret lathe when cutting the thread on taper rod keys. The key is held in the chuck without difficulty and saves centering and turning in a lathe.

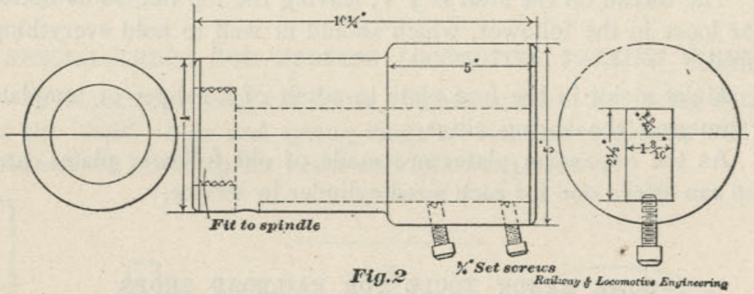


Fig.2

TURRET CHUCK FOR HOLDING ROD KEYS.

Fig. 3 is a sketch of a handy tool for a slotter, designed by Mr. A. B. Pirie, master mechanic of the Havelock, Neb., shops. It needs

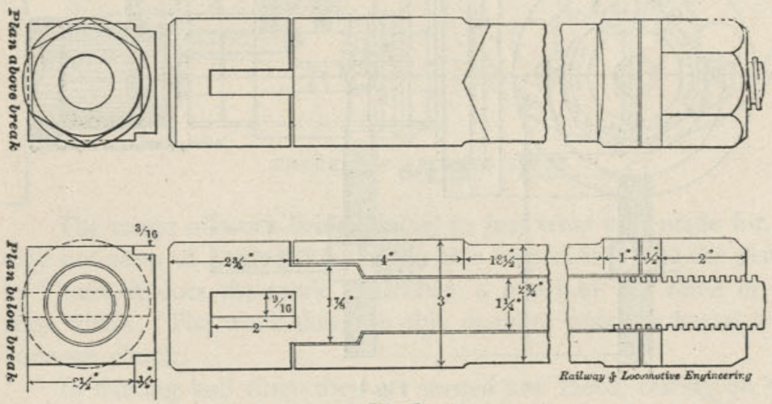


Fig.3

TOOL HOLDER FOR SLOTTING MACHINE.

no explanation, as the different views make the construction perfectly clear.

Fig. 4 shows a tool designed by Mr. J. D. Young, at the Havelock, Neb., shops, and is found to be very handy for thread cutting. It is fastened in the tool post and in case the thread-cutting part of

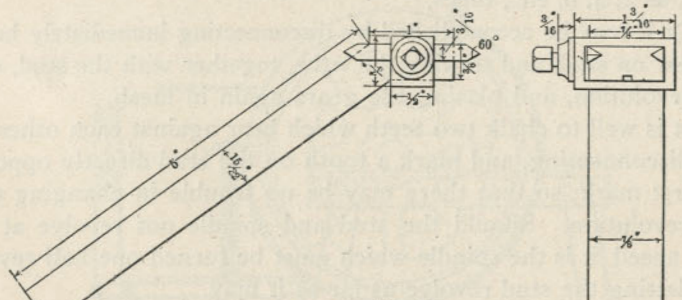


Fig.4

A HANDY THREADING TOOL.

the tool becomes dull it can be replaced very quickly and will catch the thread in the same place without any resetting of the tool, thereby saving much time where much of this work is done.

CUTTING SCREW THREADS ON A LATHE.

To determine what gears to use, take the numbers of threads to the inch which the lathe will cut with even gears—that is, gears of same size on stud and screw—for the number to be used on stud, and take the number of threads per inch desired to be cut, for the number to be used on screw, or any other numbers which are in the same proportions to each other as these two. For instance, the lathe cuts three threads per inch with even gears, and we desire to cut seven. To do this, we use gears on stud and screw which are in the proportion to each other that 3 is to 7, as 18:42, 24:56, 30:70, 36:84, and so on.

When the stud makes the same number of revolutions as the spindle, which is the case with most lathes, the lathe will, with even gears, cut screws of the same pitch as the lead screw.

In cutting a double-threaded screw, it is best to change alternately from one thread to the other, if convenient, especially with the finishing cut. This can be done by opening the nut and moving the carriage, or turning the lathe so as to bring the point of the tool in the other thread, provided the pitch of the screw on work in the lathe is an even number of times greater than the pitch of the lead screw, as 2, 4, 6, etc., times.

Or it may be accomplished by disconnecting immediately below the gear on stud, and turning the lathe, together with the stud, one-half revolution, and placing the gears again in mesh.

It is well to chalk two teeth which bear against each other before disconnecting, and mark a tooth on the stud directly opposite the first mark, so that there may be no trouble in changing one-half revolution. Should the stud and spindle not revolve at the same speed, it is the spindle which must be turned one-half revolution, letting the stud revolve as far as it may.

In cutting a thread on a lathe which is without a reversing belt, and where the vent will not drop into the lead screw at every point and correspond with the work, the following is a safe practice:

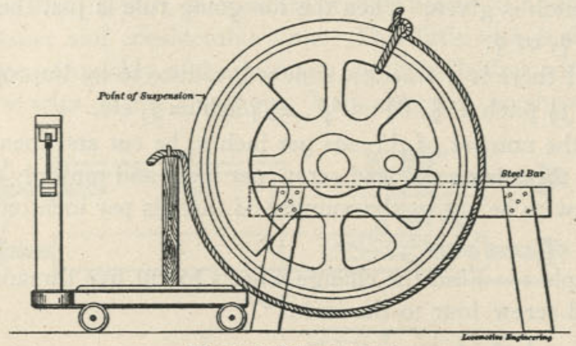
When the tool has run sufficiently far beyond the end of the thread for clearance, stop the lathe and make a chalk mark on shears of lathe opposite a corner projection, or mark on carriage. Make another lathe somewhat further back than the length of the screw on work. The distance between the marks must be the shortest distance, or multiple of the same which will contain a whole number of threads on lead screw and a whole number of the threads on work. Open the nut and move the carriage back to the latter mark; close the nut and go ahead, stopping lathe again at former mark, and repeat.

Example.—We have a four-thread lead screw lathe and no backing belt. We want to cut eleven and one-third threads to fit 2-in. gas pipe. In this case, after stopping the lathe, we move the carriage back 3 ins., which will contain exactly twelve threads on lead screw and thirty-four threads on work in the lathe.

HOW TO COUNTERBALANCE A DRIVER.

When a bad-riding engine has had her valves altered a few times, her spring rigging overhauled, and a few other well-known home remedies applied without result, the following rule will be found a very good guide to go by:

For Main Wheels.—Take one-third the weight of cross head, piston and front end of main rod; add weight of back end main rod and front end of side rod; multiply this by half the stroke, and divide this by the distance from center of axle to point of suspension. (If tires are on, the point of suspension will be outside of tire.)



WEIGHING A COUNTERBALANCE.

For Back Wheels.—The same as main wheels, but leave off weight of back end of main rod.

Note.—Pin on opposite wheel from one being weighed must be exactly plumb. Trestles must be exactly level both ways.

Example.—Weight	main rod	351 lbs.
"	side rod	291 lbs.
"	piston and crosshead	324 lbs.
		996 lbs.

$996 \div 3 = 322 \times 12 = 3864 \div 30$ ins. radius of wheel $= 129$ lbs. — 129 lbs. being the proper weight for counterbalance.

ABOUT SCREW CUTTING.

I have worked in several shops, and I found that most of the workmen, and even some of the foremen, did not know how to figure out a set of change wheels.

The easiest method I ever saw is to multiply the pitch of the thread to be cut by the number of threads to the inch on the lead screw, and then multiply the product by any number to bring it to the required answer, according to the change wheels.

To find the pitch of any complete screw, take the number of threads to the inch, and place oue above it. For example: The screw is six threads to the inch; place one above the six equals one-sixth the pitch; one thread is one-sixth of an inch.

Where the screw has a fraction, as $2\frac{1}{2}$ threads per inch, reduce to an improper fraction and invert it. Example: $2\frac{1}{2}$ reduced $= \frac{5}{2}$ inverted, $\frac{2}{5}$, the pitch.

When the thread is one to every one, two, three or four inches, the exact pitch is given. Then the foregoing rule is just the reverse, thus, $\frac{1}{1}$, $\frac{2}{1}$, $\frac{3}{1}$, or $\frac{4}{1}$.

And if there is a fraction annexed, reduce to an improper fraction, thus, $3\frac{1}{2}$ pitch $= \frac{7}{2}$, $8\frac{3}{4} = \frac{35}{4}$, $2\frac{1}{4}$ pitch $= \frac{9}{4}$, etc.

Find the number of threads per inch to be cut and then find the number of threads on the lead screw per inch, and multiply the pitch of the screw to be cut by the number of threads per inch on the lead screw.

Example 1.—Find the change wheels to cut five threads to inch with a lead screw four to the inch.

The pitch is $\dfrac{1 \times 4}{5} = \frac{4}{5} \times 6 = \frac{24}{30}$, 24 on spindle, and 30 on lead screw.

Example 2.—Required the change wheels to cut six threads to inch, with lead screw two to inch.

The pitch is $\dfrac{1 \times 2}{6} = \frac{2}{6} \times 10 = \frac{20}{60}$, 20 on spindle, and 60 on lead screw.

Example 3.—Find the change wheels to cut $2\frac{1}{2}$ threads to the inch, with lead screw six to inch.

The pitch is $\dfrac{2 \times 6}{5} = \frac{12}{5} \times 5 = \frac{60}{25}$, 60 on spindle, and 25 on lead screw.

Example 4.—Required to cut a thread to every one inch, with lead screw two threads to the inch.

The pitch is $\dfrac{1 \times 2}{1} = \frac{2}{1} \times 20 = \frac{40}{20}$, 40 on spindle, and 20 on lead screw.

Example 5.—Required to cut a thread to every $2\frac{1}{2}$ ins., with a lead screw two to the inch.

The pitch here is $\dfrac{5 \times 2}{2} = \frac{10}{2} \times 10 = \frac{100}{20}$, 100 on spindle, and 20 on lead screw.

TO CENTER DRIVING BOXES.

Figs. 1, 2 and 3, Plate A, show views of a very handy tool for centering driving boxes and laying out the chucking line *T*, Fig. 3.

The fitting of a stick in a box and placing on it a strip of tin and locating on that, in turn, an accurate pricked center, is a job requiring skill, patience and considerable time. This little tool enables a box to be centered quickly and accurately, with no bother with the carpenters or trips to the tin shop. It is clamped, as shown, by the

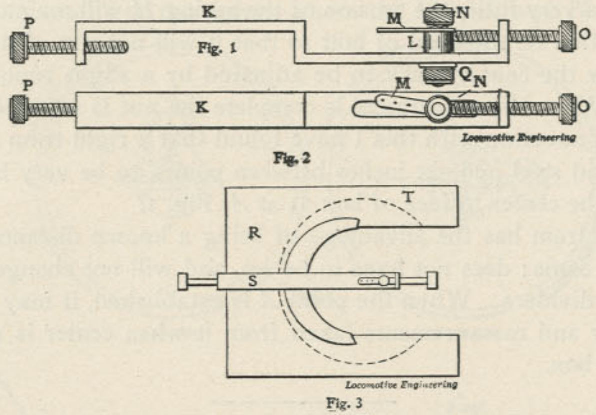


PLATE A.

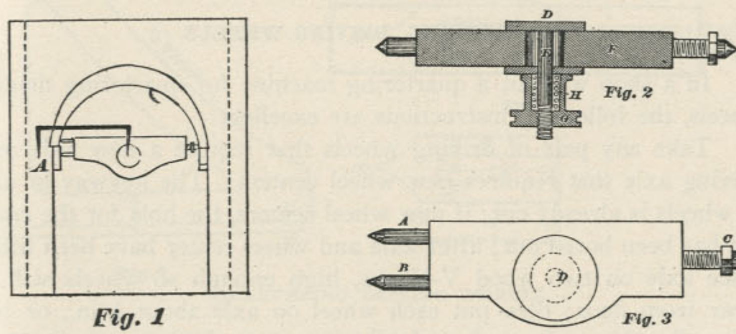


PLATE B.

thumb screw *P* and the stud *L* set at a short distance below the probable location of the center, and clamped by the thumb nut *Q*. The piece *M* is held by the friction of a short coil spring under the nut *N*, or it can be solidly clamped by the same. It has a number of prick marks for the divider points, so that with the available side motion of this piece, and the judicious use of the adjusting screw *O*, the center can be quickly found and the chucking line drawn.

Another good device for centering driving boxes is illustrated here also. The steel points *A* and *B*, Fig. 3, Plate B, are firmly set against one side of the bore of the box by screwing the set screw *C* against the opposite side. This gives a bearing at three points, and holds the body of the tool very firmly in its place.

A fine center *D* is made on the flat head of the steel bolt *E*. The hole through the body *F* is one-half an inch larger than the stem of the flat-headed bolt, so as to allow a lateral adjustment of the same. It is held fast by the milled thumb nut *G*. By loosening the grip of this nut, a very little, the tension of the spring *H* will maintain sufficient friction on the head of bolt so that it will not slip of itself, but will allow the center mark to be adjusted by a slight touch of the finger. When the adjustment is complete the nut is screwed tight.

In connection with this I have found that a rigid tram made of ¼-in. round steel and six inches between points, to be very handy to transfer the center to face of box as at *A*, Fig. 1.

This tram has the advantage of being a known distance; is always the same; does not have to be set, and will not change as will a pair of dividers. When the point *A* is established, it may be used thereafter and measurements taken from it when center is removed from the box.

QUARTERING DRIVING WHEELS.

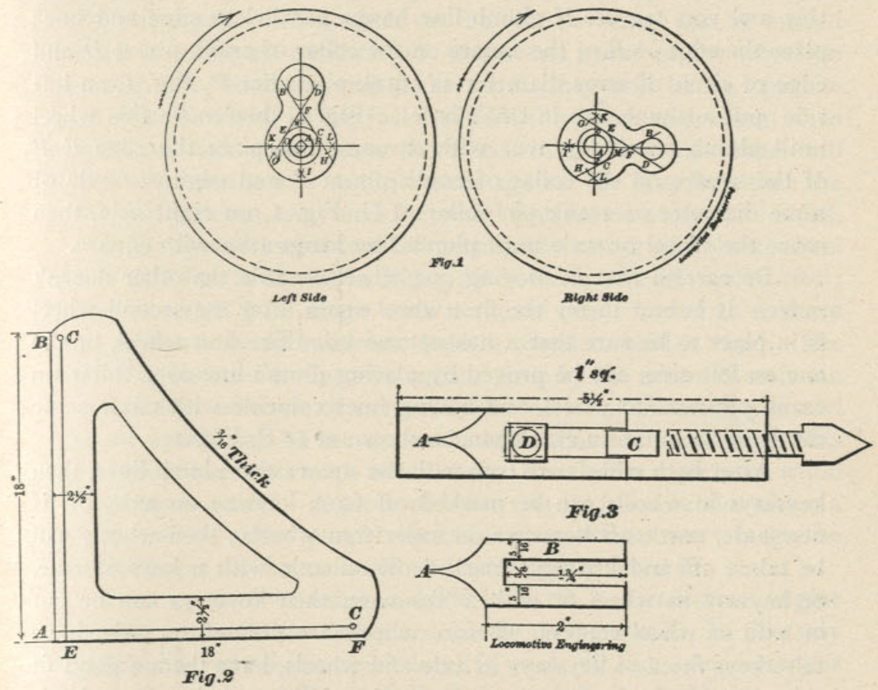
In a shop without a quartering machine for quartering driving wheels, the following instructions are excellent:

Take any pair of driving wheels that require a new axle or a driving axle that requires new wheel centers. The keyway in axle or wheels is already cut; if new wheel centers, the hole for the crank pin has been bored out; after axle and wheel center have been fitted, place axle on two wood V-blocks, high enough so wheels will be clear from floor; then put each wheel on axle about ½ in., or just enough so keyway can be marked on axle, or if it is a new wheel center, keyway can be marked from axle onto wheel.

When putting wheel centers on axle put them on so crank pins will be as near right angle to each other as can be done with the eye: be sure the leading crank pin is put on the proper side; on all locomotive engines that I have seen, the crank pin on the right side was the leading one, when running forward. After the wheels are on axle get the centers of the wheel fit on a small piece of tin, fastened to a small piece of wood that is tight in hole where axle fits in wheel

centers as shown at *A*, Fig. 1, or better, use a tool made as shown at Fig. 3—as all sizes are given it can be easily made.

Take a straight edge, put one edge against collar on crank pin, or hole for crank pin, at *B*, Fig. 1, and the other end of the straight edge of hole where axle fits at *C*, draw a straight line from *B* to *C;* put straight edge at *P* and *E* and draw another straight line, where these lines bisect at *F* make a small center-punch mark; then put one point of a pair of dividers at *F*, and the other point a little distance below points *C* and *E*, and make the lines *G* and *H;* make small center punch marks at the points where the lines *G* and *H* bisect the



QUARTERING DRIVING WHEELS.

lines *D E* and *B C*, then with dividers from the points *G* and *H* make the two lines at *I*, make a small center punch mark at this point; draw a straight line from *F* to *A* and to *I*—this line could be got without the point *I* by drawing the straight line from *F* to *A* and continuing it to the point *I*—when the point *I* is got from the points *G* and *H* and coincides with the points *F* and *A*, it proves that the points *F*, *A* and *I* are correct. From the center of wheel *A*, with a radius *A* to I, draw the arc of a circle *M;* where this line bisects the line *F A* make a small center punch mark, draw a line at *A* right angle to the line *F I* by using the points *I* and *M* and drawing the arc of a circle at *K* and *L*, make a small center punch mark at these points *K* and *L*, draw a straight line from *K* to *A* and *L*; this line should be at right angles to line *F A I*. From the center *A* draw a circle with a diameter equal the diameter of collar on crank pin next to wheel, as shown at *O* and *P*; get all these lines on both wheels.

With a square made as shown at Fig. 2, the small holes at *C C* are for a plumb line to be put in—draw a line on square from *C* to *E* and *C* to *A*, have these lines parallel with the edge so when using this tool you can see if plumb line hangs parallel to edge and line; place the edge *A B* of the square on the collar of crank pin at *D* and edge of circle of same diameter as crank pin collar *P*, Fig. 1, on left side; put a plumb line in small hole *C*, Fig. 2, then move this wheel until plumb line hangs true with square; then place the edge *E F* of the square on the collar of crank pin at *B* and edge of circle of same diameter as crank pin collar at *O*, Fig. 1, on right side, then move the wheel on axle until plumb line hangs true with square.

Be careful that in moving one wheel on axle the other doesn't move. It is best to try the first wheel again after the second wheel is in place to be sure that it has not moved. The first wheel, or the one on left side, can be proved by placing plumb line over collar on crank pin next to wheel, and having lines coincide with circle same diameter as collar on crank pin, as shown at *O P*, Fig. 1.

After both wheels are true with the square and plumb lines, then keyways in wheels can be marked off from keyway on axle, or, if new axle, mark off keyways on axle from wheels; then wheels can be taken off and keyways marked off on axle with a keyseat rule, or keyway in wheel fit with a T-square, then keyways can be cut in axle or wheel centers. Before wheels are pressed on axle, have false keys fitted to keyways in axle and wheels, have them a good fit sidewise so wheel cannot move on axle. When putting the wheels on axle to mark off keyways, have them go on axle same distance all around, have them stand parallel with each other; they can be held together, and on axle, by three $\frac{3}{4}$-in. rods and clamps bolting the two wheels together.

After the driving wheels are pressed on the driving axle they can be tried to see if they are correct by scribing from center of axle with a ball center on one point of a pair of dividers, a circle on each end of axle, of same diameter as collar on crank pin next to wheel; then place the wheels with one crank pin on the top, so when plumb lines are placed over collar on crank, pin will coincide with circle on end of axle of same diameter as collar on crank pin; then place square, shown in Fig. 2, on crank pin collar of wheel on opposite side, and edge of circle on end of axle of same diameter as collar on crank pin; if plumb line hangs true with square, then wheels are correct; if not true, press one wheel nearly off and take false key out and file enough off from false key on side that fits next to wheel, so wheel can be moved around on axle so crank pins will stand at right angles to each other; then put false key back in keyway and press wheel on axle a little so pressure will hold it, then set a jack under one spoke of the wheel on the side so wheel can be moved around on axle; set another jack under one spoke of the wheel on opposite side; have the two jacks set so they will be on opposite sides of each wheel, so the jacks will "lift" against each other when screwed up tight; then press the wheel on axle and the wheel will turn around on the axle until it comes against the false key, then the jacks can be taken away and the wheel pressed on as far as needed.

A handy and useful tool for getting the center of hole in wheel where axle fits, is shown in Fig. 3; it is made of 1-in. square steel; in one end is a $\frac{3}{8}$-in. screw with a square head, turned to a sharp point so it can be screwed into hole in wheel to hold it rigid. The piece *B* is fastened to the 1-in. square piece by the screw *D* so it can be set at edge of circle of same diameter as collar on crank pin, and edge of square can be set against it and collar on crank pin. This little tool makes the work much easier than when a piece of wood is used for a center. A piece of brass can be fitted in slot *C* for a center, and as center punch marks for a center get worn large the piece of brass can be removed and a new piece fitted in.

I am opposed to using a spirit level on a locomotive engine whenever a plumb line or square can be used instead. In this way of quartering wheels no spirit level is used; all that is necessary is that the two sides *A B* and *E F* of the tool shown in Fig. 2 are on an angle of 90 degrees, and be careful about drawing the lines and making center punch marks.

A CRANK-PIN TEST GAUGE.

Mr. Allen McDuff, general foreman of the Burlington, Cedar Rapids & Northern Railway shops at Cedar Rapids, Iowa, describes and illustrates a very useful device of his invention, as follows:

I find by practical experience that crank pins in locomotive driving wheels frequently get twisted in the pin hub from severe strains of service, and also that the pin hub itself sometimes becomes twisted from the same cause. Shrinking very heavy tires very tight on driving wheels, sometimes distorts the crank-pin hub. Defects of this character are nearly always mistaken for a bent crank pin, the result being that the pin is driven out, and a new crank pin put in without producing any improvement. Sometimes the old pin is put in the lathe and found true; then the machinist who judged the pin bent is blamed for careless measuring. The man is not generally to blame. The mistake made resulted from want of proper measuring tools. My experience is that the expense and delays resulting from misunderstandings about the real condition of crank pins can be avoided by the use of this simple form of crank-pin testing apparatus.

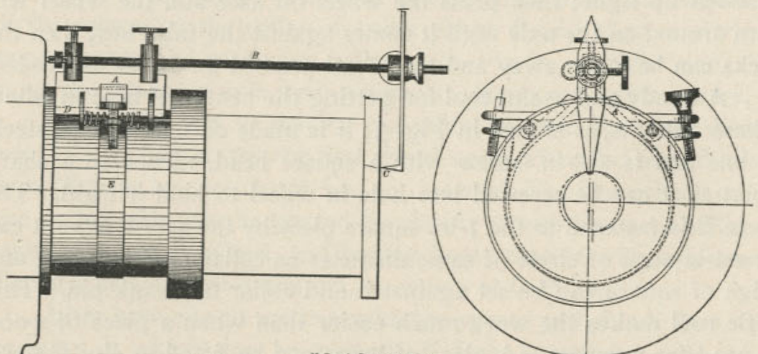


Fig. 1. McDuff's Crank-pin Gauge. Fig. 2.

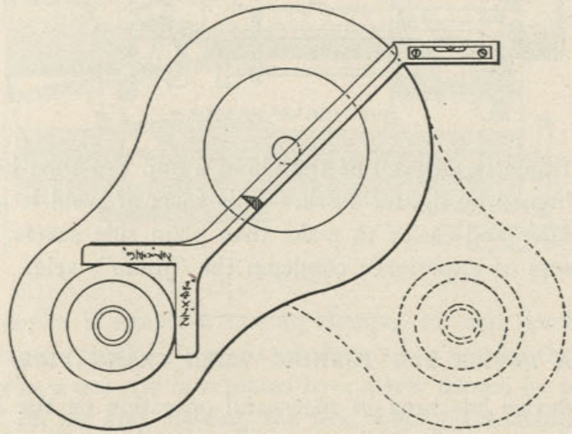
The tendency of locomotives is to wear the crank pins eccentric with the original center of the pin. This causes a very dangerous defect, yet it is very difficult to identify by the ordinary methods of testing crank pins. I have found crank pins from $\frac{3}{16}$ to $\frac{1}{4}$ in. eccentric from the true center of the pin, yet they were declared by skilful machinists to be all right. The journal was smooth and truly cylindrical, as found by calipering. In ordinary practice, pins in this condition are sent out with connections nicely fitted up, and those in charge cannot understand why the shearing of rod bolts follows, and keys enough are lost to pay for new crank pins in six months. If an engine in this condition does not break a crank pin or a side rod, it is more by good luck than good management.

The crank-pin gauge hereby illustrated was designed to detect defects of crank pins, and it performs the duty very successfully. The principle of the device is the making the crank pin carry and control

two marking points, which describe a circle on the crank-pin hub, and on the end of the crank pin, these circles supplying the means of showing whether or not the crank pin is parallel with the axle, and how it stands in relation to its original center. Referring to the engraving, Fig. 1, shows a side elevation of the device as it appears when set on a crank pin, and Fig. 2 is a transverse section of the gauge. The foundation of the device is a right-angle iron plate *A*, which presses on the crank pin, and carries the marking connections. The marking rod *B* is held parallel with the crank pin by suitable attachments. The tension rod *D* pushes the angle plate close to the hub of the crank pin, and *E* is a flexible strap which encircles the crank pin and holds the angle plate secure in its place. This gauge can be applied in a few minutes, and one revolution round the crank pin accurately detects any defects of crank pin.

QUARTERING TEST GAUGE.

The gauge shown herewith for testing driving wheels and crank pins to determine the accuracy of quartering, or whether the pins are sprung, was designed by Mr. D. J. Limlin.



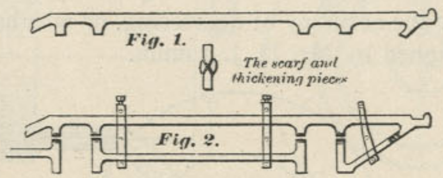
QUARTERING TEST GAUGE.

This tool is made of steel, $\frac{3}{4}$ in. wide and $\frac{1}{2}$ in. thick, with an arm at 45 degrees with the square at lower end. This arm is beveled on the outer face to a sharp edge at the inside, as seen in section, and its upper end is fitted with a spirit level that is true with the lower edge of the upper limb of the square.

In use the tool is applied as shown, with the pins on the lower eighths, the square against the collar on the pin, the beveled edge passing through the center of the axle, and the bubble in the spirit level in the middle of its travel. With this side for a base of comparison the tool is placed on the opposite pin, showing at once how near the wheels are in quarter. We are indebted to Mr. Ralph E. State for the particulars of this useful device.

FORGING A FRAME.

The Southern Pacific at their Sacramento shops have a very successful method of forging a locomotive frame. They forge the upper and lower rail separately, welding on or drawing out parts of the pedestals on each piece as shown in Sketch 1. These pieces are placed together and held by clamps while being welded together. The ends of the jaws and braces are scarfed sideways on each side, so that they meet only at the points. Triangular pieces are then laid into the depressions on each side, a welding heat taken, and the whole frame welded up entirely by side blows from a steam hammer. This



FORGING A FRAME.

done, the frame is relieved of the clamps, and can then be finished and straightened by lighter work. This form of weld is said to be much stronger and easier to make than plain side scarfs, while all frame makers of experience condemn the "jump" weld.

A DEVICE FOR TURNING WORN CRANK PINS.

This device has been in successful operation on the Boston & Albany for some time and is an auxiliary to the quartering attachment of a driving-wheel lathe, by which to true up worn crank pins while the latter are in the wheels.

Fig. 1 of our illustrations of the device shows the application of it to the work in hand, with all the parts necessary to its operation, and showing their relation to each other. Fig. 2 is an end view, with the pin in section, looking toward the face plate, and Fig. 3

is an enlarged view of the crank pin, quartering spindle and foot slide, with a cut in progress on the pin.

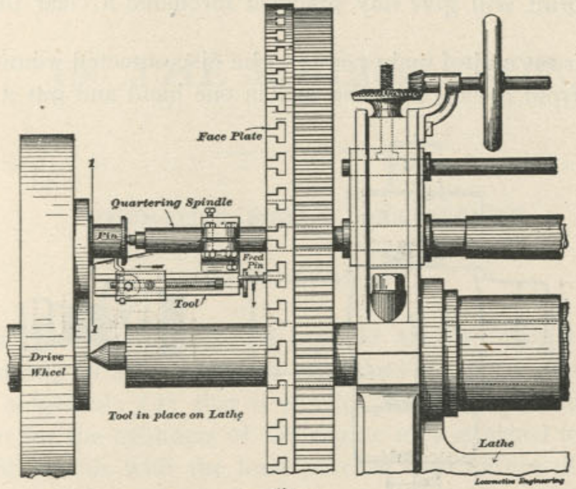


Fig. 1.

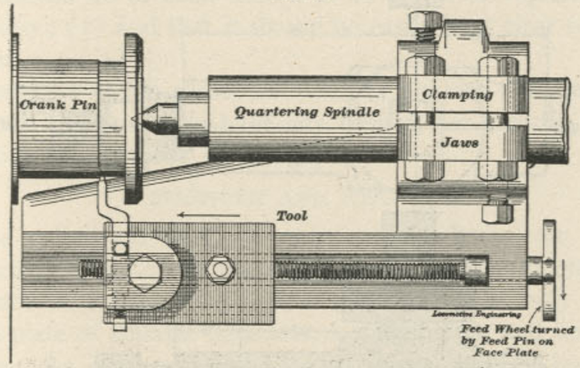


Fig. 2.

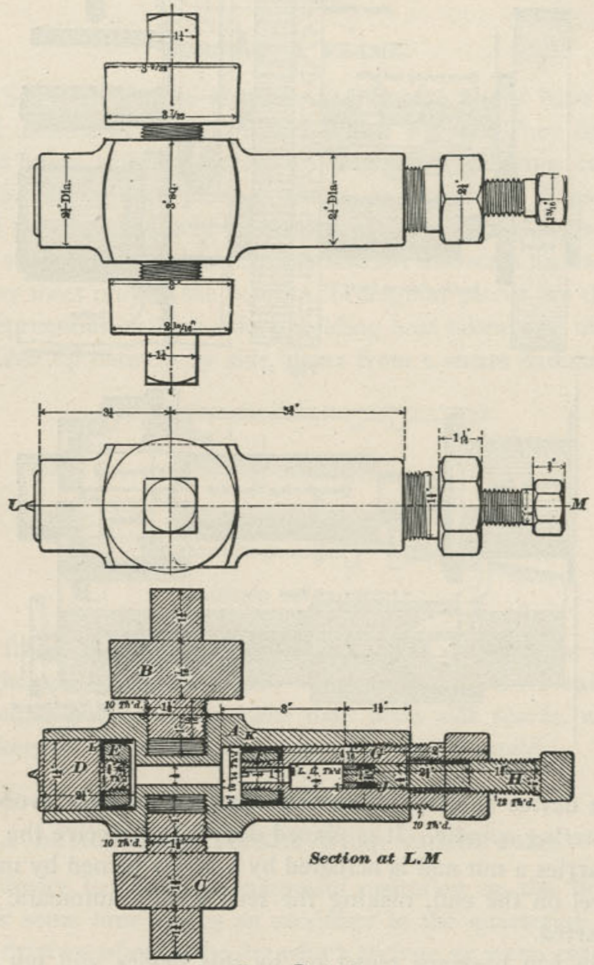
The device is simply a casting clamped to and revolving with the quartering spindle. It is planed dovetail to receive the tool slide which carries a nut and is actuated by a screw turned by means of a star wheel on the end, making the feed wholly automatic after the cut is started.

Main rod bearings trued up by this device will not have the excuse for a pound, that they could fall back on after the roundhouse doctor had tried to get them into a circular section with the file and other working tools of his profession. This kind of a tool should receive a wider recognition from shop managers, and be classed with the actual necessaries of a plant.

A PISTON-ROD REMOVER.

The tool illustrated can be applied to all classes of locomotives and this print will give any practical mechanic a clear idea of its use.

The front end of main rod is to be disconnected, remove plugs *B* and *C* from device, take the tool in one hand and put it between



PISTON REMOVER.

cross head sides, so *D* will point to center of piston rod, screw *B* from the outside of wrist pin hole, *C* from the inside of the same, and apply the power as indicated by *H* and G. The large piston to move up quickly, the smaller one for power.

IN THE BOILER SHOP.

LOCOMOTIVE BOILER CONSTRUCTION.

BY W. F. DIXON.

The chief requirements of a boiler are (1) that it should be amply strong in all its parts to withstand the pressure to which it will be subjected; (2) that it should provide an abundant supply of steam for the cylinders of the engine it is attached to; (3) that it should do this with the least possible expenditure of fuel; (4) that it should be of such design as to admit of repairing cheaply and readily; (5) and that it should be easily kept clear of scale and sediment.

First cost within reasonable limit is a minor consideration that should not be allowed to have any weight, for broadly speaking a locomotive boiler cannot be too good.

STRENGTH AND WEAKNESS.

The cylindrical part, or waist, of the boiler can readily be constructed to stand the maximum strain coming upon it with a fair factor of safety; five is good practice. It is only a question of good plate of suitable thickness, a strong seam and honest workmanship. As soon as the boiler is put in service, however, deterioration begins, and it is the retarding of this as much as possible that should be considered in the design. There is no doubt whatever that when the butt joint is used, corrosion along the seam is much less than with the lap joint. Why this should be is not altogether clear. The most plausible hypothesis is that with the butt joint the strain due to the steam pressure is uniformly disturbed over the whole circle, while with the lap joint when the boiler is under steam there is a tendency for the plates to straighten out, the result being that the plate bends to some slight degree each side of the lap; this tendency causes scale that may be deposited there to flake off and leave the surface of the plate exposed to furrowing or corrosion. Another theory is that chemical action takes place more rapidly when the plate is subjected to a high tensile strain, and if this is really so, and there is much ground to show that it is, then it is easier to understand why corrosion would be most active when the bending strain is greatest, viz., at the laps; and although a lap joint can be made that will give as high a percentage of strength as the butt joints, yet the established fact that the butt joint lessens corrosion warrants its adoption in most cases, especially with large boilers carrying high pressures.

The fire-box end of the boiler is where the greatest danger lies, and it is this that claims the major share of attention of boiler designers.

Sheets that require severe flanging, such as the throat and top connection on flat-sided wagon-top boilers, should always be made $\frac{1}{16}$ inch or $\frac{1}{8}$ in. thicker than the others so as to make up for the thinning out arising from the operation of flanging.

BREAKAGE OF STAY BOLTS.

The most troublesome things about a locomotive boiler are the stay bolts, broken stay bolts, after low water and hot crowns, being the most prolific cause of explosion that there is. When fire boxes were small, broken stay bolts were not such a pest as they are at this day of large boilers and high pressures. As is well known, stay bolts usually break close to the outer sheet, and may generally be found broken in the two or three upper rows along the sides except toward the ends of the box where they extend down as far as the sixth or eighth row from the crown. They are very rarely found broken near the mud ring. The cause of their breaking is generally understood to be due to the constant bending backwards and forwards they undergo due to the difference in expansion between the fire box and shell sheets. The outer or shell sheet being thicker than the inner is more rigid and consequently the stay bolt naturally breaks there. How to remedy this trouble is one of the most perplexing problems that confronts the boiler maker of to-day; indeed, it seems improbable that we shall ever be free from broken stay bolts. Various ball-and-socket joints for the ends of the stay bolts have been tried, and all have so far either failed in their mission or proved themselves such unmitigated nuisances in the way of leaking that they were discarded. A step in the right direction seems to be increasing the diameter of those bolts which are most liable to

fracture. Wide water spaces are also advantageous, as they make a long stay bolt necessary, and the longer the stay bolt the less will its angle of deflection be as the fire box expands and the longer it will last.

SUPPORTING CROWN SHEETS.

There are three systems in common use for staying the crown sheet, (1) the crown bar, (2) the radial stay, and (3) the Belpaire.

The crown-bar boiler has long and deservedly enjoyed a wide popularity, and when a boiler is small, the pressure comparatively low, say 140 lbs. per square inch, and the water tolerably good, there is probably no better method of staying a crown sheet extant.

When bad water has to be used—water that is loaded with impurities that are precipitated freely—then the difficulty experienced in keeping the crown free from sediment is much increased by the obstruction that the crown bars offer. This trouble is appreciated in regions where bad water prevails, and on that account alone many roads have abandoned the crown bar in favor of the radial stay. When we come to large boilers having wide crown sheets and carrying high pressures, then the crown bar is insufficient to carry the load without the assistance of a large number of sling stays. When putting in the slings it is well nigh, or I may even say quite, impossible to so hang them that each individual one shall have its own proper quota of load, no more and no less. When the boiler is under steam some will get an excessive strain while others will be almost inoperative, and the trouble of it is that you cannot tell anything definite about it; there is nothing positive except the continual presence of the unpleasant element of uncertainty, and if the crown sheet should even start to come down, all the sling stays that could be got into a boiler will not hold it—down it will come. For this reason I consider crown staying the most unsafe of any when, as I have just stated, the boiler is large and the pressure high.

The radial stay system has come into quite general use of late, more especially since the advent of the extended wagon-top boiler, and it has much to recommend it; at first there was, and still is for that matter, considerable apprehension felt as to its security owing to the angle at which many of the stays must necessarily pass through the sheets, some stays being so pitched that but one full thread could be obtained in the sheet, and although on the face of it this certainly looks like a weak point, yet when the work is carefully and honestly done there appears to be no ground for alarm on this score, as many boilers so built have been in successful operation for years; in fact, I have yet to hear of a single instance of this style of staying giving out under ordinarily fair conditions. The general construction of this type of boiler is so well known as to require no special attention, except that I may say in passing that the center six or more rows of stays down the length of the fire box should be fitted with button heads under the crown sheet, so that in the event of low water and a hot sheet the stays will prevent the crown from dropping as readily as it would were there nothing but the screw threads and riveted over heads to hold it.

BELPAIRE BOILERS.

Within the last fifteen years the Belpaire type of boiler, first introduced by and taking the name of M. Belpaire, at one time at the head of the motive-power department of the Belgian state railways, has come into extended use in this country. When properly designed and well constructed this style probably presents the best solution of the problem of crown staying yet brought forward. The crown sheet is comparatively unobstructed, and may readily be kept clear of sediment. The staying is positive, all the stays having good bearings in and on the sheets. All the strains may be accurately calculated and provided for, and all the stays may if desired be made of one length, an advantage that is appreciable. The two main objections that have been raised against it are the difficulty of keeping the crown stays tight in the neighborhood of the ends of the braces running from the back head to the top of the fire-box shell owing to the constant downward pull of these braces. This trouble may be overcome in several ways: (1) By dispensing with the round back-head braces and substituting in their places gussets or plate braces attached to the roof sheet by long angle irons, thus distributing the strain over a large area and preventing its localization; (2) by running the braces forward to the waist of the boiler, a plan which is in many cases impossible owing to their number; (3) by running the braces clear forward and attaching them to the front flue sheet, a plan I would not recommend owing to the difficulty in keeping the ends tight, the incessant vibration tending to cause leaks; (4) by riveting heavy angle irons crosswise of the roof sheet as close as possible to where the brace ends take hold, thereby stiffening the sheet and preventing it "giving."

The second objection to this type of boiler is the difficulty experienced in some quarters of keeping the top corners of the throat of Belpaire sheet tight where they join the shell. These corners have been a thorn in the side of the mechanical department of more than one road. The trouble in the majority of cases appears to be caused by not allowing the flue sheet sufficient room in which to expand vertically. After a boiler is fired up, the fire box, being at a higher temperature than the shell surrounding it, expands more. The two are rigidly connected together at the bottom by the mud ring, so that the only direction in which the firebox sheets can expand is upwards, the result being that the crown sheet is slightly higher above the center line of the boiler when it is hot than when it is cold. As the flue sheet is more rigid in an up and down direction, owing to its flat shape, than the side sheets, which are more or less arched or curved, it seems plausible to suppose that a greater strain is brought to bear on the crown stays in closest proximity to it than on those further back.

If the first row of crown stays is close up, the flange uniting the flue and crown sheets, say 1½ or 2 ins. from the edge of the flange to the center of the stays, the crown is hardly able to give at all, and the stays are carried up the amount the flue sheet expands. This, of course, tends to distort the top of the shell at a point close to where it is riveted to the waist of the boiler. The constant moving up and down which takes place every time the boiler is cooled off, and, indeed, whenever the fire door is opened, permitting a current of cold air to strike the flue sheet, causes the seam to work or loosen and allow more or less serious leakage to occur. If, however, the first row of crown stays is kept well back from the flue sheet, say 5 ins. from the edge of the flange to the center of the stays, the intervening portion of the crown, while amply strong to withstand the steam pressure, has a chance to bend or give slightly, with the result that the upward thrust on the stays and the consequent distortion of the shell are lessened. If in addition to throwing the centers of the stays back, a heavy bar-iron brace running crosswise of the shell top and well down the sides is riveted on just back of the throat or Belpaire sheet seam, the trouble with leaky top corners can be reduced to practically nothing. There is another advantage in throwing the first row of crown stays back from the flue sheet as far as is consistent with absolute safety, which is that the expansion strains in the flue sheet itself are lessened, and the chance of cracking the sheet between the flue holes is reduced.

There is one objection to the Belpaire boiler, and indeed any straight boiler, apart from any question of boiler making, to be found more especially in the case of eight- and ten-wheel engines, and that is the unduly large percentage of the total weight of the whole machine that is thrown on the leading truck.

With the ordinary wagon top, crown bar, or radial stay boiler with the fire box down between the main and back axles, the drivers of an eight-wheeler get on an average about 64 per cent., and of a ten-wheeler about 74 per cent. of the total weight, but if the Belpaire boiler is used this percentage in the case of the former sinks to about 61 and in the latter about 68. The reason of this is that with the wagon-top boiler a sufficiently large space can be obtained for steam room over the crown sheet, while keeping the waist of the boiler tolerably small in diameter, but the Belpaire, being straight on top in the great majority of cases, that is to say, without any rise at the back end, the waist must be increased at least four inches in diameter in order to obtain the necessary steam room. The larger the waist the larger the smoke box and front must be; the branch and exhaust pipes must be longer and heavier, and altogether the weight of the front part of the boiler, which comes directly on the truck, is materialy increased. Whether the Belpaire presents advantages sufficient to offset this disadvantage is a moot question.

The amount of grate area required is the factor that, more than any other influences, the main design of a boiler, and this factor is dependent upon the nature and the quality of the fuel that is to be used. Wood, for example, requires for its proper combustion a deep fire box, and as the requisite depth cannot be obtained except by placing the fire box down between the axles, the size of a wood-burning box is practically limited to the distance between centers that it is considered expedient to place the coupled wheels. Hard coal, on the other hand, requires a large shallow fire box in which to burn to advantage, consequently the fire box has to be extended over one or more axles according to the type of the engine. Thus we find we require for each of these two fuels a particular kind of fire box; for wood, a deep one, and for hard coal, a shallow one. We know that these are essentials, and that we cannot successfully deviate from them. But when we come to soft coal the case is different; it can be burned in either a deep or a comparatively shallow fire box, and it is generally the size of grate needed that determines which it shall be. We know that we can burn with a fair degree of economy about 120 pounds of coal per square foot of grate area per hour, although, when occasion requires, as high as 200 pounds can be consumed, but not economic-

ally. Knowing the service the engine is to be employed in, it is possible, by estimating the amount of steam required per hour, to calculate the quantity of coal that should be consumed and so get at the size of the grate. A safer, if less scientific way, is to base your calculations on what existing engines are already doing and be governed accordingly.

PROPORTIONS OF CYLINDERS, GRATE AREA AND HEATING SURFACE.

Taking the piston displacement, or the space swept through by the piston at each stroke of cylinder in cubic feet as a starting point, and dividing it into the number of square feet of grate area of a large number of highly successful soft coal-burning engines having cylinders ranging from seventeen to twenty-one ins. diameter, I have found the average result to be six, that is to say, the piston displacement of one cylinder in cubic feet multiplied by six gives the grate area of the boiler. For example, take an engine having 19×24-in. cylinders: The piston displacement of one of these is 3.93 cubic feet; multiplying these figures by 6 gives 23.58 square feet as the grate area required, which agrees quite closely with the best modern practice. After deciding what area of grate is necessary, the length and width may be readily found, and if the former is so long as to be prohibitive of a box between the axles, then the box must go over the back axle or axles, and either between or on top of the engine frames, as may be deemed most desirable. The amount of heating surface, both flue and fire box, may be obtained in a similar way. Taking as before a large number of engines now running, and dividing the piston displacement into the number of square feet of fire box and flue heating surface, the result in the case of the former is 36 and of the latter 370. Taking the 19×24-in. engine again as an example and multiplying its displacement, 3.93, by 36, we find that $141\frac{1}{2}$ square feet of fire-box heating surface is required, and 3.93×370 equals 1,454 square feet of flue surface required. The design of the engine determines how long the flues shall be, and when once this dimension and the diameter of the flues to be used is settled upon, it is an easy matter to find out how many flues you will need in the boiler.

FLUE SETTING.

In spacing the flues in a boiler they should not be brought closer together than $\frac{11}{16}$ in. in the clear, $\frac{3}{4}$ in. is better; placing them closer weakens the flue sheets, retards circulation and affords sediment a better lodgment. With regard to whether flues should be placed in vertical or horizontal rows, although a good deal has been said from time to time as to the merits and shortcomings of each plan, it is unnecessary to enter into any discussion of the subject at this time; suffice it to say that there is very little difference in the results obtained with either plan. When setting tubes in a boiler it is preferable to use a copper ferrule at each end instead of at the fire-box end only, as is often done, the advantage being that when the flues have to be taken out of the boiler for renewal it is a much easier job to get them and their coating of scale through the slightly larger holes in the front flue sheet that the use of the copper ferrules entail than it is if the holes are nominally the same diameter as the flues themselves. When about to put a set of flues into a boiler care should be taken that the holes in the sheets, the ferrules and the ends of the flues themselves are quiet clean and free from dirt of any description, so that a perfect metallic contact may be obtained, otherwise there is sure to be trouble from leakage.

CARE AND MANAGEMENT OF LOCOMOTIVE BOILERS.

By Henry J. Raps.

BOILER WASHING.

Anyone who has had anything to do with the washing out or care of locomotive boilers realizes the importance of keeping the lower part of the shell clear of sediment; for when this is filled up with deposit, the space between the flues fills up in a very short time.

The old way of inserting a bent nozzle into the shell from the pit, and then getting out and turning on the water and seeing the pressure turn the nozzle in some other direction from that in which it was intended to throw the water, was found to be not only conducive to profanity, but also to indifference. As a natural consequence bad results followed; for even when the nozzle was held in position with pipe tongs, it made the matter no better, for as soon as the grip was loosened the nozzle would be turned by the pressure and was always liable to fly out of the hole.

To overcome these difficulties and get better results, the nozzle shown in cut was made, and twelve of them have been in use for over three years on the Burlington, Cedar Rapids & Northern Railway, with very good results. The nozzle is made of 1-in. pipe, this size giving the best results for all pressures. Coupling *C* is a

common pipe coupling, and is loose at the lower end, so that the elbow may be turned in any direction. The rod by which the elbow is turned is made of ½-in. iron, the jaw being deep enough to clear the flattened end of the clamp on coupling *C* when elbow is being turned. The handle on the end of nozzle is for the purpose of holding the nozzle in position as well as changing its position.

The nozzle can be held in any position, and can be inserted through spokes of drivers or any other close place about a locomotive, the operator standing on the floor and running no risk of being wet to the skin, as he did by the old way. To use the nozzle successfully two or three holes are necessary in bottom of shell; 1¾-in. is large enough.

BOILERS TAKING CARE OF THEMSELVES—HOW TO WASH OUT BOILERS.

In these days of heavy trains, high speed and long runs, the locomotive boiler is a very important factor in railroad economy. No matter how good the engine may be, its efficiency is decreased to a great extent by a leaky boiler, and if the engine is in poor

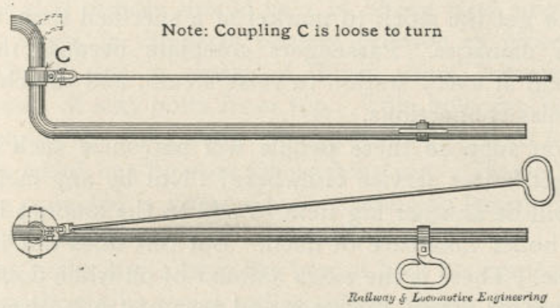


Fig. 1.

condition and pounding all over, a good tight boiler is the more necessary. As there is no question about this, let us see how we may keep the boiler in a safe, serviceable condition and in the highest state of efficiency at the least expense.

Let us take for our subject the common type of locomotive boiler with either a deep, short box, or a long, shallow one—either crown bar or radial stayed.

We will take up, first, its proper care and inspection while in service; next, how not to make heavy repairs; then, how to make both light and heavy repairs; and, finally, its disposition when unfit for further service on the road.

We will suppose the boiler is a new one, just from the builder, perfect as can be in design, material and construction, with steel fire box and shell, thoroughly braced throughout. We will also take it for granted that the water the boiler is to use contains carbonates and sulphates of lime, salt, alkali and other incrusting and corroding matter.

Now, don't say to yourself, "I will have a little comfort with that boiler; it will take care of itself for a long time." If you do, you never made a worse mistake. Do you know what it will cost a railroad company to have one hundred such boilers to take care of themselves for one year? It will cost from $10,000 to $15,000. Do you think the figure is too high? It is not a cent too high—not high enough. That boiler is taking care of itself, and as a natural consequence in five or six months it is bound to spring leaks, and the merchant complains because his car of goods had to be set out; the stockmen complain because they wanted to get all of their stock into market by the next morning, but a part had to be left up the road on account of boiler leaking, or they were late to market because hills had to be doubled or the engineer had to run for water; and if a contract was made with the railroad company to get the stock to market at a specified time, there is a chance for damages. Passengers complain because the engine must be held at every station to raise steam, and the chances are they will miss connections.

Do you suppose these people will patronize such a road if they can get better service elsewhere? Not by any means. And this loss will be another big item to add to the amount it costs to have that boiler take care of itself. But this does not include all the expense. There is the extra amount of oil while doubling hills and running for water, the wear and tear of track, tires and machinery, to say nothing of the overtime of engine and train crews. All these items, and others not mentioned, help to swell the amount it costs to have a locomotive boiler take care of itself.

The railroad officials will inquire from you why this engine is making such a bad record. They supposed she was the best engine they had. She is nearly new. You will probably tell them that you can't account for it; it must be the bad water, or faulty construction, or the engineer has abused her.

It's not so. Don't you know that this is the engine that is taking care of herself, and isn't she doing it with a vengeance?

Let us see how all this trouble and expense could have been avoided.

The engine has made her first 600 miles, and is to be washed out. The boiler washers will be inclined to say, "Ah, here's a snap—a brand-new boiler; we'll just take out half the wash-out plugs and show her the hose."

Don't allow it! Have her washed out as thoroughly as though she was the dirtiest engine on the road.

To do this properly you will need plenty of water and a sufficient amount of pressure. A 1-in. nozzle will give the best service under all conditions. The pressure at the pump should be at least 80 pounds, and if the mains are small and long, or there is more than one gang of boiler washers, 100 to 120 is necessary.

The boiler should have two wash-out holes in the top of shell, 10 or 12 ins. from front tube sheet, and the same distance on either side of the center; two holes in the top of connection, 12 or 14 ins. on either side of center; two or three holes on either side of wagon top, according to length of fire box (no two holes should come opposite one another); three or four holes in back head, according to its width, on line with opening under crown bars. If crown is radial stayed, these holes should be 3 or 4 ins. higher. Two holes should be in the bottom of back head, one on either side; the lower side of hole should be 1 in. above mud ring; two holes in throat sheet, in the same relative position as those in bottom of back head; one in center of throat sheet, between first and second rows of stay bolts from top. This hole can be dispensed with if engine has circulating tubes, provided there is a hole opposite tubes which can be used for washing out. Two or three holes should be provided in either side (according to length of box), just below swell, and three holes in bottom of shell.

If the boiler has a long fire box, a hole for inspection of side water legs should be put in either side of throat sheet, from 20 to 24 ins. from mud ring, and on line with side water space; $1\frac{1}{2}$ ins. in diameter is large enough.

All other holes in boiler, except those in bottom of back head and throat sheet, should be $1\frac{3}{4}$ ins. in diameter, unless brass sleeves and cap are put in shell. Should brass plugs be put in bottom of back head and throat sheet instead of hand hole plates, they should be $2\frac{1}{4}$ ins. in diameter, to facilitate getting out large pieces of scale. These holes should be put in the straight part of sheet and not in the bend, where it is impossible to keep them tight.

All holes should be put in where they will not be covered up (as they often are) by hand railing, air pump, driver brake cylinder, injector, gauge-cock dripper, reach rod, pipes, etc., making it utterly impossible to do good washing out.

On a number of roads, four tubes are left out of boiler; the holes in back tube sheet are plugged or left out when a new sheet is put in. The holes in front tube sheet are tapped out and brass wash-out plugs put in. These holes are used for washing tubes and should be located on either side of nozzle and inside of a circle the diameter of door, making it unnecessary to take down front when tubes are washed. Deflector should be hung on hinges, and made to raise and lower conveniently.

To wash the tubes properly through these holes, make a nozzle of $1\frac{1}{4}$-in. pipe long enough to reach back tube sheet. Weld a plug in one end and cut a slot in one side (as near the welded end as possible) $1\frac{3}{4} \times \frac{1}{2}$ in.

If a long nozzle is convenient to use, or there is not room enough in front of engines, make the nozzle in two pieces.

A nozzle of this description, made of 1-in. pipe, is also a good thing to use on the crown sheet of a crown-bar boiler. To wash out bottom of shell, the nozzle illustrated and described in Fig. 1 will be found very effective and convenient. A straight nozzle of 1-in. pipe, 12 to 16 inches long, and several bent nozzles of various shapes, will usually complete the boiler washer's outfit, as far as nozzles are concerned.

And now we are ready to give the new boiler its first washing. We will blow off the steam and cool the boiler by taking out one of the top plugs in front end of shell, insert the nozzle, and turn on the cold water; this is quicker than cooling through the injector. Fill the boiler until the glass is nearly full, and keep the water at that level until the boiler is cold, either by opening blow-off cocks or taking out one of the plugs or hand-hole plates in bottom of water leg. When the boiler is the same temperature as the water it is to be washed with, shut off the hydrant and empty the boiler. Start to wash on the crown sheet; don't begin to wash it from the back end, but start in front through the holes in top of connection in order to keep the deposit off the tubes; wash the back end of tubes down at the same time. Next wash the crown sheet from the sides and as much of the side water space as possible. Then wash the crown from the back end and as much of the rear water space as possible, also the door ring. Now wash the tubes down from holes in top of shell at front end. If boiler has

wash-out holes in front tube sheet, wash the tubes from front end next; begin at back end (top holes), and work forward, continually turning nozzle with either a pipe tongs or lever clamped on nozzle. When the tubes are washed clean, wash bottom of shell with nozzle illustrated in Fig. 1; begin at front end and work back. Then wash side legs through holes below swell; next, the front leg through hole in center of throat or through circulating-tube plug, and finish by washing bottom of leg through lower holes in back head and throat. If boiler has circulating tubes, wash them out when washing crown from the back end.

Do not hold the nozzle in one position when washing, but change it constantly in order to wash all parts of the boiler accessible from the hole through which you are washing.

You will need no cleaning rods at the first washing, but they will be needed soon thereafter. Make these out of $\frac{1}{2}$-in. and $\frac{3}{8}$-in. steel of suitable lengths, chisel pointed and hardened, with an eye turned on one end.

In order to make sure that the washing out has been thorough, inspect the boiler. "What!" some one says, "inspect a new boiler?" Certainly. Start in the right place—at the beginning. You will not find any scale, only a very thin coating; but at each subsequent inspection you will notice just how fast it will accumulate, and also any unusual collection of scale, which is not only liable, but sure to occur, and you may possibly find a lot of bolts or other material left in by the builders. The writer has taken twenty-three different articles out of one boiler; among them was a pair of rivet tongs and a pint cup.

If you haven't any torches suitable for inspection, make several of different lengths of $\frac{1}{4}$-in. steel wire. Turn an eye on one end and crimp the other, or turn a small eye, and tie on this end, with copper wire, a piece of waste, lamp-wick or asbestos. Dip in oil—and you have some very good torches. Make the inspection as thorough as possible. A hole in either side of back head, 10 or 12 ins. from top of crown, will be found very convenient for inspecting upper part of side water spaces.

In order to make boiler washing as effective and systematic as possible, keep a record of all washing. A very good system of keeping records and making reports is in operation on the Burlington, Cedar Rapids & Northern Railway system. A record is kept in the boiler shop of all engines washed, noting the date, mileage, condition, name of inspector and station. A separate record is kept of engines washed at each station, noting date, engine number and mileage. At the end of each week a report is made to the assistant master mechanic, of the number of engines washed at each station, and the average mileage. Report blanks are shown below. Table 1 is the blank used by boiler shop in making report to the assistant master mechanic. Table 2 is used by roundhouse foremen in making report to foreman of boiler shop.

Table 1.

Below find report of boilers washed during week ending:

Station.	No. Engs.	Mileage.
Cedar Rapids........................	....	....
Estherville........................	....	....
Iowa Falls........................	....	....
Muscatine........................	....	....
Ellsworth........................	....	....
Rockford........................	....	....
Albert Lea........................	....	....
Burlington........................	....	....

....Foreman.

Table 2.

Station..

Report of boilers washed during week ending..............

Date.	Eng. No.	Mileage.		Remarks.
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....

The foreman of roundhouse also has a record of each engine washed, showing date of washing and mileage. The boiler washers have a record for their own convenience of all engines washed, showing the date of washing.

HOW NOT TO MAKE HEAVY REPAIRS ON LOCOMOTIVE BOILERS.

In this age of invention a large number of tools have been made to facilitate the construction and repair of the locomotive boiler, and the all-important question with both builder and repairer is—how to do the work as quickly and cheaply as is consistent with safety, good construction and permanency of repairs. For the builder this is a very proper question, and also for the repairer, when repairs are necessary; but there is a question of still greater importance to the repairer, and that is—how not to make repairs, or, to modify it, how to avoid making extensive or heavy repairs.

To illustrate this, we will go back to the new boiler. It has been in service for two or three months; has had the best of care; has been washed regularly every 500 or 600 miles—more or less—as circumstances and the condition of water demanded; has been inspected regularly; while the scale has been getting thicker all over the inside of the boiler, you have noticed no unusual accumulation; yet the boiler maker comes to you and reports three or four stay bolts leaking, or possibly only one. You begin to think there is nothing in washing out after all—it's a laborious, dirty job all the way through, and unsatisfactory in the end. You try to study out the case of the bolts leaking. Are the stay bolts spaced too far apart? Were they put in too tight or too loose? Were they hammered too much or too little? Are the heads too large or too small? Was the thread partly stripped in putting in the stay bolts? Is it on account of poor material in the bolts or is it poor material in the sheet, and has a crack developed on account of it? Is it on account of bad water? Has the blower been used too much on the road or on the clinker pit? Were the dampers left open after fire was drawn? Was the furnace door opened on the road to check the fire?

These or other possible reason may be assigned by you as the cause of the bolts leaking. You are wrong in each case. If any of these reasons could be assigned as the cause of the bolts leaking, why are not more leaking? But, you argue, poor workmanship or a stripped thread may be the cause. You forget the engine has been in service two or three months, and if this was the cause the bolts would have leaked before this. Well, you say, bad water will cause the bolts to leak. That is true; but never a few in one locality. All the bolts below swell will leak more or less, and if the water is very bad, all the bolts in the fire box will leak; and not only the bolts, but the tubes and crown-bar rivets as well. But now you have it—it must be on account of the misuse of the blower, or dampers left open after fire was drawn. Wrong again. The misuse of blower and damper will cause bolts to leak, especially in the lower part of the box; but never a few in one locality.

Well, you say, no matter what the cause, it is plain the bolts are leaking, and you will have them caulked, and that will end the trouble. Let us follow the matter up and see. The bolts are caulked and remain tight for several trips, and you congratulate yourself on having applied the proper remedy and curing the case, even though you did not diagnose it correctly. But here comes the boiler maker; he looks very sad, and approaches you slowly. He appears to have had bad news, and probably wishes to break it gently. It's the same story you have heard before—stay bolts leaking in the new boiler—same bolts that leaked before, and possibly you get angry and say, "Just what I expected." Locomotive builders don't build engines like they used to; the engines of to-day are much inferior to those built years ago. The boilers are too heavy for the frames, and therefore an extraordinary amount of strain is thrown upon the boiler. Or, you say, what else can you expect? Competition is so keen between builders that they are obliged to throw the work together in order to make any profit out of it, and it's a wonder the boiler has done as well as it has. It's not your fault, anyway, for you have done the best you could—had it washed out regularly and thoroughly, and inspected properly, and you are sure nothing more can be done.

You order the boiler maker to caulk the bolts again, and keep them caulked. You never want to hear of them leaking again. Ready to do your bidding, he caulks them and does not trouble you any more. The boiler is doing fairly well. There is an occasional report on the work book of stay bolts, crown-bar rivets and tubes leaking; but they do not trouble you, as they are a common occurrence.

The engine has been in service for ten or twelve months, and the tires are to be turned. It is necessary to take down pan and grates, and you conclude this is a good time to inspect the fire box. And what a sight it is! Instead of three or four stay bolts leaking, there are from fifty to seventy-five on either side, and from fifteen to twenty small cracks have developed on either side; a half dozen stay bolts have the head and thread nearly stripped; thirty to forty crown-bar rivets leaking; the crown and sides bulged, and the tube sheet is nearly as bad. There are a few cracks in the door ring, and altogether the fire box is in a sad plight.

You hold up your hands in horror, and exclaim: Just what I expected. It's a poor grade of steel; manufacturers of steel have worked up a good reputation and are selling a low grade of steel on a high-grade reputation. Or, if the boiler has been using bad water, the water is blamed. You never saw such bad water; it is ruining all the boilers; it pits the tubes and shell; it grooves the bottom of shell next to the seams; it grooves both the inner and outer sheets of water leg next to mud ring; it causes the fire-box sheets to bulge and crack, frequently bulging away from the stay-bolts and crown-bar rivets or radial stays; it causes tubes to collapse, and, through the repeated stretching of tubes beyond their elastic limit, causes the front tube sheet to bulge, and on account of this bulging, the tube sheet develops a crack around the bottom at the bend. But the boiler must be put in good condition again. Possibly you have new half side sheets put in the fire box, a patch put on the door ring, tubes taken out, safe ended and reset, and the crown-bar rivets caulked.

And now you know you have put the boiler in the best possible condition, and will have no trouble with it. But in two or three weeks the crown leaks as bad as ever, and grows gradually worse. Cracks develop; the sheet bulges worse than before. In two or three months the stay bolts begin leaking—two or three to begin with—and grow gradually worse, and at the end of the second year the boiler needs a new fire box. The bad water is blamed again; or, if the fire box is long and shallow, it comes in for its share of the blame.

Let us see what there is in the bad water. It is a well-known fact that in some localities it is impossible to keep tubes and stay-bolts tight for any reasonable length of time, but this trouble is only local. In general the greatest trouble experienced is from incrusting matter, the principal one being carbonate of lime, which is held in solution by free carbonic acid. As the water evaporates, the acid is released and the carbonate is precipitated, forming scale. When the scale becomes thick enough between the stay bolts, crown-bar rivets or tubes to make trouble, its presence is shown by particles of coal burned on the sheet; as the scale becomes thicker the water is removed farther and farther away from the sheet. The result is, the sheet becomes so hot that it loses its strength and is forced out by the pressure upon it; the scale is loosened slightly, allowing the water to rush in and cool the sheet. The heated sheet, however, has been stretched beyond its elastic limit and retains the bulge. New sediment is added to the scale already formed; it again adheres to the sheet and the bulging process continues. The sheet is distorted around rivet or bolt holes, causing rivets and bolts to leak, and if the scale is not removed, the sheet will bulge away from the rivets and bolts and sometimes will strip the beads off the tubes.

When an unusual amount of scale forms around stay bolts on fire-box sheets, its presence is shown by a white ring around stay-bolt head. As the scale becomes gradually thicker the bolts leak slightly at first, growing worse as the scale increases, and finally through repeated overheating and cooling the sheet becomes brittle, local strains are produced, the sheet cracks and is distorted at the hole, the threads and head are gradually stripped, and the sheet is forced away from the bolt. When a large number of cracks develop, it becomes necessary to either remove a part or whole of the sheet or sheets affected and renew them or take out the whole fire box and renew it. As this is expensive, let us see how it can be avoided or put off for a number of years.

We will go back to the new boiler and to the time when the boiler maker made his first report of stay bolts leaking. There were only a few, and very little was thought of it; as the boiler was being washing thoroughly it was not thought possible that scale enough had formed to make trouble, but let us look into the water space.

Possibly the boiler has a long, shallow box and no wash-out holes were put in below the swell. They were not deemed necessary on account of the shallowness of box. The water leg was washed from holes in wagon top and from either end. In washing from the top the water strikes the outer sheet on account of the fire box being narrower on the bottom than top, the force of the water is broken and the inner sheet derives no benefit from the washing.

In washing from the ends the force of the water is broken by the stay bolts, with the same result—no benefit to the bolts or inner sheet in the center of water leg. It has been merely a change of water. To prove this let us look into the water space. As the leaks around stay bolts usually develop near the center of that part of side sheets below the swell and between the wash-out holes, both in shallow and deep boxes, we will have to drill a hole in outer sheet opposite the leaky bolts, and then we insert a torch and inspect the bolts. What a surprise is in store for us! For around the bolts, next to the inner sheet, layer upon layer of scale has accumulated until it is from 2 ins. to $2\frac{1}{2}$ ins. in diameter and from 1 in. to $1\frac{1}{2}$ ins. thick. How wonderfully it is formed, as though an unseen hand had held it in position until it fastened itself upon the bolts and sheet. We insert a cleaning rod and find the outer scale is still soft, while next to the sheet it is hard and requires a little effort to remove it. We remove all of the scale, caulk the bolts lightly, and they give us no more trouble unless scale is allowed to accumulate again, and this will invariably happen, especially on those parts that are not open for inspection, such as central portion of side sheets and crown sheets of crown-bar boilers.

Should scale on the crown make its presence known by lime around the rivet heads or by particles of coal adhering to the sheet, have dome cap and stand pipe removed. If all of the scale cannot then be removed, have dry pipe taken out, and then the scale can certainly be removed. It is less expensive to do this than to allow the crown sheet to be ruined and make its removal necessary.

The crown sheets of radial-stayed boilers are often neglected. On account of their convex surface and the fact that they are usually lower behind than in front, they are expected to take care of themselves. The result is, scale is formed around the bolts at the crown sheet, and if allowed to accumulate the same trouble will be had that was experienced with the stay bolts in side sheets.

The fire door also furnishes its share of trouble, frequently on account of too much lap on the inner flange, causing the inner door sheet to crack around the bend. Should scale accumulate on the top of door, it will make its presence known by lime forming along the seam and around rivet heads. When this makes its appearance a hole should be drilled in back head and scale removed.

Had the stay bolts, door and crown sheet of the new boiler received the proper care, they would not have needed any repairs for four years, and then only light repairs, for the proper care of a boiler is just as essential to its efficiency and longevity as good material, construction and workmanship, and it is only by constant, untiring vigilance that the repair of the fire box can be avoided or put off for a number of years. To sum it all up in one sentence, it is simply to take the stitch in time.

HOW TO MAKE LIGHT REPAIRS ON THE LOCOMOTIVE BOILER.

We will assume that the boiler has been cared for properly—has been washed out at regular intervals, say every 500 or 600 miles. All unusual accumulations of scale have been taken care of. The stay bolts and crown-bar rivets or radial stays have not caused any trouble, but the tubes are becoming troublesome, they will not remain tight more than a trip or two. If the tubes are close together, say $\frac{1}{2}$ in. to $\frac{5}{8}$ in., this will take place from 10 to 12 months after boiler is put in service. If tubes are from $\frac{7}{8}$ in. to 1 in. apart, they should not give any trouble for from $1\frac{1}{2}$ to 2 years—the closer together the tubes are, the faster they will fill up with scale.

You may possibly worry along with the tubes in this condition for a year or two longer, but it is not good policy to do so; there is no money in it, only a lot of grief for the engineer and fireman, for the officials and also for the boiler maker.

As scale accumulates in sufficient quantity to cause the tubes to leak, particles of coal not only adhere to the tube sheet, but also to the tubes, partially or wholly closing them and impeding the draught. The cinders passing into the tubes are saturated with moisture from the leaky tubes, the moistened cinders adhere to the inner portion of tubes, closing them up, and reducing the amount of heating surface—making it impossible for the fireman to keep up steam—reducing the efficiency of boiler and engine.

True, this can be partially remedied by cleaning the honeycomb off from the tubes, but in this case prevention is worth more than the cure.

The water from the leaky tubes is constantly running over the tube sheet, corroding it and making it brittle. It also corrodes the stay-bolt heads and eventually causes them to leak, also causing the sheet to crack at the stay-bolt hole. The repeated caulking of the tubes wears away the bead, and in a short time a groove is worn into the sheet by the caulking tool. The constant extraordinary expansion of the tubes on account of the formation of scale has made the tubes brittle and eventually the beads crack off, making it necessary to insert a copper thimble and plug. These will remain tight for a short time. When they leak it is necessary to caulk them with a beading tool, which gradually cuts away the copper thimble; the result is that the beading tool cuts into the sheet deeper and deeper, until it is distorted and nearly cut through.

The expansion and contraction of tube sheet on account of scale also causes the sheet to crack through the bridges, and its general condition, when engine is brought in for repairs, is such that it is unfit for further service, and its removal follows.

But this is not the most expensive part of allowing tubes to

run beyond their safe limit, sooner or later your superior is likely to thrust a message under your nose something like the following:

Had to double....hill account of tubes leaking, laid out 45 minutes.

........Engineer. Engine No.....

When the engine comes in you have an extra good job done on tubes, and they do tolerably well for three or four days, when you receive a message something like this:

..........Station.

Had to set out eight cars, account of tubes leaking; obliged to plug four tubes.

........Engineer. Engine No.....

Still you trust to luck and try it again. The engineer starts out with a full train; he proceeds twenty miles, and wires back that he has lost fifteen minutes, account of tubes leaking; engine wouldn't steam. He is obliged to set out four cars. He goes another twenty miles, and again wires saying he has lost one hour plugging tubes. He is obliged to set out five more cars.

At the end of the next twenty he wires that he is unable to proceed farther with train. He is instructed to return with light engine, and has covered half of the distance, when the official is startled by the following:

..........Station.

Cannot proceed farther; tubes very bad; cannot keep water in boiler.

........Engineer. Engine No.....

It is necessary to tow engine in—a complete failure.

This is invariably the outcome of allowing tubes to run beyond their safe limit, and it is this sort of grief that causes railroad officials to exclaim: "How long is the destiny and welfare of this road to be controlled by the boiler shop? And what will be the final result? Will it be bankruptcy?"

Very likely you are feeling very sore yourself about having all this odium cast upon the boiler shop, and you wish to remedy the trouble.

In the first place, have the tubes in all the boilers tested with a hammer to find out their exact condition in regard to the formation of scale and the amount formed; repeat it every six months (oftener if found necessary); keep a record of each engine, noting date, condition of tubes and number of tubes necessary to be removed to clean out scale from between tubes. Have roundhouse boiler makers report any unusual leakage, also any troublesome accumulation of scale.

When the tubes are likely to make trouble—not after the trouble has been made—remove a sufficient number to clean the tubes and shell. The usual manner is to remove an inverted V-shaped section from the bottom of tubes—taking out fifty or sixty —more than the necessary number of tubes are removed without accomplishing the desired result—the removal of scale between the tubes.

A far better plan is, to take out every other tube in each alternate row, as marked by small circles in illustration on next page, Fig. 2. It will readily be seen that it is possible by this method to remove all the scale between the tubes—accomplishing the purpose for which they were removed.

It may not be necessary to remove all the tubes marked; the illustration merely shows the plan which should be followed.

It will not be necessary to remove steam pipes; exhaust pipe only should be taken out. It may be necessary to remove a few extra tubes on either side, in order to shift the outer tubes over far enough to clear steam pipes.

Should engine have circulating tubes, it will be necessary to remove one in order to take out and replace tubes conveniently. Possibly one of them is in bad condition and needs to be renewed; this one should be taken out, as it makes no difference which one is removed, as far as taking out tubes is concerned.

If the tubes have not been allowed to run too long, the scale may be removed in a few hours, otherwise it may take 1½ to 2 days, and even then it is much less expensive than to allow the tube sheet to deteriorate to such an extent as to cause its renewal, or the engine to fail causing grief and disappointment all along the line.

In washing out avoid filling the front water leg with scale, as it is very hard to dislodge, when once packed in solidly.

At this time crown sheet, water legs and stay bolts should be inspected and all scale removed. Grate bars should be removed and all leaks about mud ring attended to. Rust and ashes should be cleaned off from mud ring rivet heads, and those that have leaked should be caulked. All leaky wash-out plugs should be taken out, holes retapped, plugs chased and replaced.

Should it be necessary at this time to remove dome cap and stand pipe in order to clean off crown sheet, all braces and brace pins, which are accessible, should be tested and thoroughly inspected, and those that are cracked, broken or dangerously corroded removed and new ones put in place.

These will likely be all the defects requiring attention, except possibly a crack or two in the bend of door ring, on account of too much lap on inner flange; if there are such, they should be drilled

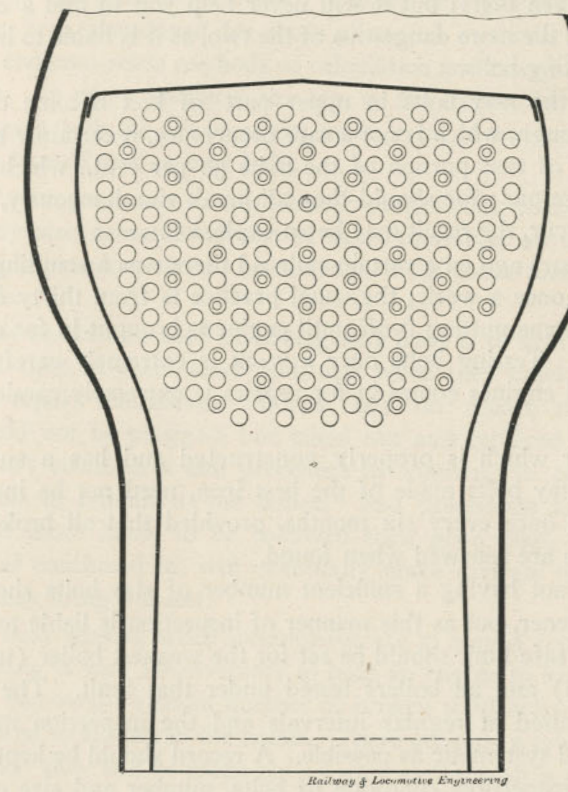


Fig. 2.

out, the hole tapped and an iron plug inserted, care being taken that not more than one or two threads of the plug project through the sheet.

If there is a stud hole in back head through which plug can be held on, it should be utilized for that purpose, and also to upset plug from the inner side with a steel pin. If there is no such hole, the plug should be lightly fullered and caulked.

At this time the stay bolts should be tested to find out if they are broken or cracked.

The inspection of stay bolts is a very important feature in the care of the locomotive boiler. Various methods are employed to discover broken bolts, with good, bad and indifferent results.

On some roads 30 to 40 pounds pressure is put on the boiler with compressed air or steam, after letting out water, in order to force the ends of the broken bolts apart. This aids slightly in discovering broken bolts; but it will never help you to find a cracked bolt, which is the more dangerous of the two, as it is liable to be overlooked in testing bolts.

Should the stay bolts in upper part of box become cracked half way through, which is not a rare occurrence, it certainly reduces the strength of that portion of the bolts 50 per cent., which is extremely dangerous; for should they all break simultaneously, which is liable to occur, the result may be an explosion.

Some years ago on a certain railroad there was a standing order to test bolts once a week; the usual practice is from thirty days to six months, some putting it off until engine is brought in for general overhauling. Testing bolts once a week is extremely careful, and waiting until engines comes in for repairs is extremely careless and dangerous.

A boiler which is properly constructed and has a sufficient number of stay bolts made of the best iron, need not be inspected oftener than once every six months, provided that all broken and cracked bolts are renewed when found.

Boilers not having a sufficient number of stay bolts should be inspected oftener, but as this manner of inspection is liable to create confusion, a safe limit should be set for the weakest boiler (unless it is reinforced) and all boilers tested under that limit. The jacket should be raised at regular intervals and the inspection made as thorough and systematic as possible. A record should be kept showing date of inspection, condition of bolts, number and size of bolts taken out and put in, kind of material, mileage and name of inspector.

The ordinary way to test stay bolts is to let out the water and have them held on one end with a light sledge and tap them on the other with an ordinary chipping hammer, and judge from the sound which ones are broken or cracked.

A broken bolt which has its two ends separated is very easily detected by the hollow sound which is emitted when the bolt is tested. A broken bolt, whose ends are still in contact, can be detected by the dull, vibratory sound emitted; a cracked bolt will have the same sound but not so pronounced, depending on how badly it is cracked.

It is impossible to detect all bolts that are cracked by the sound test.

It is this fact that makes the sound test unreliable, and, therefore, unsafe, and too much dependence should not be placed upon it.

Since the demand for higher pressure by railroad companies, more attention has been paid than formerly to the design and construction of the locomotive boiler. Unsafe and questionable practices have been abandoned for more advanced methods, which experience, common-sense methods of calculation and tests have proved to be safe. In many instances the care of the locomotive boiler has not kept pace with the advancement made in its construction; this is especially true of testing stay bolts.

If higher pressures demand better construction than formerly, they surely also demand the best of care; therefore, all unsafe and questionable practices should be abandoned for those that are absolutely safe.

By far the best method of testing stay bolts is to drill a 3-16-in. hole 1 in. deep in their outer end, and when they crack or break they will report themselves. When they do report themselves, they should not be plugged, but taken out and replaced with new ones. Don't establish a bad precedent by allowing a cracked or broken bolt to remain in the boiler. Bad precedents are usually easier and more liable to be followed than good ones, and loose methods, if continued in, will eventually make careless men; careless men may bring disaster.

In a busy season, when locomotives are in almost constant service—making it very inconvenient to hold an engine to have broken stay bolts removed—a small number of broken solid bolts are sometimes allowed to remain in the boiler. There are only a few, and will do no harm; they will be taken out as soon as the rush is over. But the rush sometimes continues; new duties demand and receive attention, and the bolts are forgotten until the boilermaker brings in a forcible reminder in the form of a report saying that the upper part of one of the side sheets has a bulge in it the whole length of the fire box and 8 ins. or 10 ins. wide—the result of all the bolts in two or three of the upper rows being broken.

It sometimes happens that broken, hollow or drilled bolts are plugged when an engine is badly needed.

These are very bad practices, and cannot be too strongly condemned. It is fortunate, indeed, if such indifference and carelessness does not make procrastination the murderer of men as well as the thief of time.

HOW TO MAKE LIGHT REPAIRS ON THE LOCOMOTIVE BOILER.

The boiler has arrived at that stage when it is necessary to remove all of the tubes, if they are close together, say, $\frac{1}{2}$ in. to $\frac{5}{8}$ in., this will be from two and a half to three years after engine was put in service; should they be $\frac{7}{8}$ in. to 1 in. apart, it will be three and a half to four years, provided that the boiler is using the ordinary run of water. Should the feed-water be such that considerable scale is formed of a hard, stony nature—impervious to water—the life of the tubes between settings will be shortened from six to eight months.

Rainy seasons also shorten the life of tubes between settings, especially in boilers in which scale has formed to a considerable extent.

The soft water loosens the scale which has formed on the tubes and it is lodged between the tubes; at every successive rain more scale is loosened and lodges between the tubes, until finally all the space is filled up, making the removal of tubes necessary.

The usual method of making repairs at this time is to remove tubes, make a cursory examination of the external portion of the shell—if lagging is removed—and caulk all leaks. If any stay bolts are broken they are renewed, a few rivets taken out of mud ring and replaced with new ones, and seams in fire box caulked where necessary.

If stay bolts and radial stays or crown-bar rivets are not leaking (they should not be if boiler has received proper care), no attention is paid to them. The mud and loose scale is thrown out of the boiler, it is given a rinsing, the tubes are replaced, and the boiler is "just as good as new" and ready for service. This is by no means an exceptional way of making repairs.

When a boiler needs no other repairs than the changing of tubes the greatest amount of labor should be put on the inner part of the boiler. You will want your best man to do it, not necessarily the best mechanic, but a man with patience, endurance and perseverance, plenty of stick is what is needed. Furnish him with all kinds of cleaning rods, a scaling pick, hammer and chisel, a few torches made of $\frac{1}{4}$ in. steel wire, wrapped at one end with asbestos, and a can of oil to replenish torch; can should have neck large enough to allow the insertion of torch. Have all the scale cleaned from sides of water leg, stay bolts, crown sheet, crown-bar washers, crown bars and shell. Do not expect to have the labor performed in a few hours; it will take five or six days to do it properly. When the scale has been loosened, the boiler should be thoroughly washed; this cannot be done properly in an hour or two, but will take six or eight.

As all parts of a locomotive boiler are not open to inspection it is impossible to keep all parts cleaned alike; you may find here and there the water space nearly filled with scale, and, although it has made no trouble, the trouble was not far off.

The cleaning process should be begun at the lowest part of water space and continued toward the top. Especial pains should be taken with the inner end of stay bolts, inner side of water leg, crown sheet and crown-bar washers, as these are the parts that make trouble on account of scale formation. The bottom of shell should also be cleaned thoroughly its whole length and about thirty inches wide in order to ascertain its condition in regard to pitting and grooving. As a rule, the shell will be pitted most just below the checks; the pits are not readily discovered, and must be cleared out with a chisel. If guide-yoke or frame-brace angles are fastened to shell with either rivets, studs or tap bolts the pitting is invariably worse around these than elsewhere. The pitting and grooving of shell should not be dangerous at this time.

All braces, brace pins, brace lugs, crows feet and angles should be thoroughly inspected. If the boiler is sufficiently braced, these should still be in good condition. However, this should not be taken for granted, as the safety of life, limb and property depend as much on good, sound braces as on sound stay bolts.

It may be that the brace lugs and crows feet, instead of being forged from the solid bar, are made of two pieces jumped together, and that some of these are pulling apart in the weld. They should be removed and replaced with braces forged from the solid bar. Should back tube sheet have crow-foot braces riveted solid to tube sheet, they should be taken off, holes in pad or flat end welded up, a piece of 1-in. pipe 1 in. long put between brace and tube sheet, new holes drilled in pad and braces reriveted. This manner of bracing allows the water to circulate between brace and tube sheet, keeping the sheet cool and preventing cracking and distortion around the rivet holes.

Should the long tie rods extending from back head to front tube sheet or to lugs riveted to shell pass under the crown bars, they will likely be found sagged down on crown sheet. These should be tied up with ⅝-in. hook bolts and straps laid across upper braces.

A bad form of bracing followed by some is to put crows feet on either side of wagon top opposite crown bars and running braces across with jaw at either end, fastened with pin and cotter. It is almost impossible to remove these braces when broken or to replace broken pins without removing crown bars. On account of their bulk at the crows feet they also accumulate considerable scale and prevent loose scale from dropping through into the water leg where it can be washed out.

A better plan of bracing is to put in tie rods, tapped into both sides of wagon top and hammered over. The lower side of tie rods should be on line with lower side of crown bars in order to make all the room possible for washing of crown.

The wagon top should be so strong that it will need a rod through only one-half of the spaces between crown bars, leaving every other space clear for the removal of scale and washing and inspection of crown. Should more than this number of rods be required another row should be put in above these.

Should crown be radial stayed it is probable that the upper seam of tube sheet has become distorted on account of the rigidity of the stays. Further distortion may be prevented by removing the two front rows of stays, inserting eye bolts in both upper and lower sheets and fastening a flat bar of iron on either side of them with pins and cotter. They should be fastened together in the center with a ⅝-in. bolt, a washer the same thickness as eye bolts being inserted between them; the upper holes in braces should be slotted lengthwise ½ in. longer than diameter of pins to allow the tube sheet to expand, as in firing up the front part of box expands more than balance of box or outer sheet of water leg, causing distortion of the tube sheet if no allowance has been made for it. The upper flange will crack sooner or later on account of the bending action. The cracks may be drilled out and plugged or cut out and a patch put on, but the final outcome is usually the removal of the tube sheet.

It may be that we are too presumptuous in assuming that the fire box needs no other repairs at this time than the removal of scale from its outer parts. It may be that cracks have developed at some of the stay-bolt holes on account of scale accumulation, or rather on account of carelessness in not removing the scale. If the cracks are not too numerous—not more than six or eight in one

sheet, and not more than one crack at a stay bolt nor more than 1 in. in length—they may be drilled out and plugged successfully, should the general condition of the sheet warrant it.

The stay bolt should first be removed; the first hole should be drilled next to the stay-bolt hole; ⅛ in. (or less, if it can be done successfully) of metal should be left between the holes. The hole should be tapped with a 14-thread taper tap; an iron plug inserted and screwed in tight, then marked with a chisel where it is to be cut off, allowing 1½ to 2 threads for hammering over. It is then removed and nicked with a hack saw on two opposite sides, leaving stock enough to screw plug in steam tight. Should plug project through sheet more than 1½ threads the end should be sawed off. The plug is again inserted and twisted off. Should a second plug be necessary to take out balance of crack, the drill should be set so that it will cut into the first plug as far as the root of thread. The same process is gone through as with the first plug. They are then held on, on the inside, with sledge, and hammered from the outside with a round-ended steel pin through stay-bolt hole and finished by holding on through stay-bolt hole and hammering from inside. The stay-bolt hole is then tapped out, stay bolt put in and hammered.

There are those who will say that it is not necessary to describe the drilling out and plugging of cracks in fire-box sheets, as it is a very common practice. Very true; but practiced, usually, as a makeshift to keep an engine running until she can be brought in for repairs. Very little attention is usually paid to the length of plugs; they are allowed to project into the water space and accumulate scale which in time makes it impossible to keep plug tight. Iron plugs put in as described in a sheet not entirely worn out, will give as good or better service than a patch.

If the sheet has been badly mud burnt, and is seamed or cracked between several of stay bolts in one locality, the affected part should be cut out and a patch put on. The method usually followed is, to cut out the affected part with a cape chisel and ripper. A cut ⅛ in. deep is taken with a cape chisel, and the balance of the metal is cut out with the ripper, whose face should be ¾ x $\frac{3}{16}$ in. The stay bolts are drilled on the outside, a punch inserted in the hole, and the bolts broken. The patch is then marked off by placing the old upon the new and drawing a line upon the new piece 1 $\frac{1}{16}$ ins. from the edge of the old, for the seam.

Allowing $\frac{5}{16}$ in. for the thickness of chisel, this makes the lap on old sheet ¾ in. from the center of holes. The holes should be spaced 1¾ ins. apart, center to center, and punched ¾ in. The patch should then be trimmed on the outside, allowing ⅞ in. from center of holes for lap. It is then annealed, bolted to fire-box sheet through stay-bolt holes; holes in seam drilled 25/32 in. and tapped ⅞ in., 12 thread, with taper tap. Holes in patch are then reamed 29/32 in. and countersunk to an angle of 45 degrees; the bulk of the metal being cut out with a drill and finished with a rose bit. All burrs and oil are removed; holes in sheet are tapped with straight tap, and patch put on with patch bolts, which should not be over ⅞ in. long. When the bolts are screwed in up to head, the patch should be hammered up around the bolts with punch and hammer, the bolts again screwed in, and the process repeated until all parts of the seam are brought in contact. The bolts should then be nicked with a chisel under the square head and twisted off; the stay bolts tapped; bolts put in and hammered over; the patch bolts fullered and caulked and the patch chipped and caulked, finishing the operation.

Should the patch extend down to mud ring, it may be put on with rivets by bending the patch up at the bottom far enough to admit a wedge bar for the purpose of holding on the rivets.

Patches may also be put on with tapered plugs. The process is to punch holes in patch, bolt it to sheet and drill the holes, then taking off patch and removing burrs and oil, patch is again bolted on, hammered up at one of the holes, hole tapped out with a taper tap, a steel tap bolt put in which has the thread cut off from upper part of body a little farther from head than the thickness of patch so that it will pull patch up to sheet. The patch is then hammered at the hole on either side of bolt, the holes are tapped, plugs inserted, nicked and twisted off, and the process repeated until all the plugs are put in. They are then fullered and caulked. In tapping, just enough oil should be used to prevent stripping the thread. Should the patch extend down to mud ring, it should be bent up at the bottom (provided the patch is large enough to warrant it), and plugs held on with a wedge bar hammered as they are put in.

When the patch is to be bent back into place, enough thin washers should be put in water space at the lower stay-bolt holes to make up for width of space, to prevent the patch from buckling into water space while being bent back to place. The practice in some shops is to offset patches next to seam from ½ in. to 1 in. to stiffen the seam and prevent leakage; another practice is to insert copper between the seams for the same purpose. The latter usually results in grooving of sheet next to seam.

Should the crown be warped on account of scale deposit, it should be heated and straightened before the crown-bar rivets are removed. If a patch is necessary it should be put on top of sheet and riveted.

In putting on bolt patches it is very important that all chips and grit be removed from seam, holes and bolts, that threads are full, that the lap is not too wide, that the body and head of bolt fit properly and all other details are just as important and should be given the closest attention, for upon the details depends the success or failure of the whole. A patch that is not a success when put on will always be a failure and a source of annoyance.

When the necessary repairs have been made on the fire box and internal portion of the boiler, the copper thimbles should be expanded in tube sheet and tubes replaced. The back end of tubes should be made large enough to require three or four smart blows from a 6- to 7-pound hammer to drive them in. The front end of tubes should be enlarged so that shimming will be unnecessary.

Assuming that the workmanship has been of the best, there is still one more requisite necessary to make the repairs successful, and that is proper care. Without it the best construction and workmanship is of no avail.

HOW TO MAKE HEAVY REPAIRS ON THE LOCOMOTIVE BOILER.

When the boiler has been in service from three to five years a large number of the heads of stay bolts in the lower portion of fire box will be found completely fatigued or burned out from exposure to the intense heat of the fire. Although the washing out has been as thorough as possible, a small ring of scale has gathered around the inner end of stay bolt ½ in. larger than diameter of bolt and become as hard as stone. As it is impervious to water, it naturally helps to increase the temperature of sheet and bolts, and, consequently, is, in part, the cause of the fatigued condition of the stay-bolt heads. Here and there a head will be found which has the life completely burned out of it around the edge; if a chisel is inserted under that portion of the head which is hammered over the sheet it will crumble like so much burnt cast iron. An occasional leaky bolt will also be found that has been caulked so much that it is about lifeless.

As a rule, very little attention is usually paid to the stay bolts in the lower part of fire box. If they are tight, that is thought to be sufficient reason for not disturbing them; in some shops the practice is to rehammer the bolts when they arrive at this condition, but this is a makeshift and a bad practice, as the bolts will not remain tight for a reasonable length of time. The proper plan to follow is to remove all the bolts which have the heads burnt or which have been leaking and replace them with new ones. There will probably be 30 or 40 in either side and 10 to 15 in either end which will need renewing; they should be drilled from both sides when being removed, using an air motor to furnish the power. Holes should not be tapped larger than necessary, $\frac{1}{32}$ in. larger will usually suffice. The renewing of stay bolts in the lower part of fire box is a very important feature in the repair of the locomotive boiler and should not be neglected, as by it the life of the fire box will be doubled.

It may be that by this time the door hole has developed a number of cracks at the bend, on account of too much lap on inner flange, builders sometimes leaving as much as $1\frac{1}{2}$ ins. from center of holes. This keeps the water away from outer flange. It also leaves a very small space between the edge of inner flange and bend which is very soon filled up with scale, causing overheating and cracking.

If the number of cracks is large enough to warrant it, the outer flange should be cut out and a new door ring put in. If possible, the old flange should be cut out just inside the bend, so that the seam will come inside the stay bolts. The excessive lap on inner flange should be reduced to $\frac{3}{4}$ in. from center of holes. A number of points in the edge of inner seam should then be located on the back sheet with a pair of dividers, making witness marks with a center punch. This is done for the purpose of locating the edges of seam on the new piece. When the new piece has been flanged and annealed, it should be put in place and the edge of the seam marked off from the witness marks previously made on back sheet. The holes are then laid out $\frac{3}{4}$ in. from this line and $1\frac{3}{4}$ ins. center to center. The piece is taken out, holes punched or drilled, the edge trimmed $\frac{7}{8}$ in. from center of holes, patch replaced and holes drilled in old sheet through the holes in new piece, the holes in flange are then marked with a scratch awl through the holes so drilled, the patch is again removed, holes in flange punched or drilled, and the same process is then gone through with as with patch-bolt patch described in previous chapter. Should the mud ring be removed at this time on account of the renewal of side sheets, the greater part of the same may be riveted.

Should it be necessary to extend the patch beyond a number

of the stay bolts around door hole, the stay bolts should not be put in seam. If the stay-bolt holes are so located that they will come in the seam, the holes in inner sheet should be used for patch bolts or rivets, as the case may be, the outer holes plugged and bolts located at least 2 ins. from holes in seam. Should it be necessary to remove a number of bolts around door hole, the holes may be utilized for the purpose of marking off the holes in flange and also the edge of seam on inside.

In flanging the door hole the radius of bend should be made as large as possible in order that it may adapt itself to the various changes produced by expansion and contraction—due to the variations of temperature—without cracking.

After six or eight years of service it will be necessary to remove the lower part of side sheets in fire box and probably the back tube sheet. The horizontal seam of the half side sheets should be located above the swell, where it will give better results, on account of being removed from the intense heat of the fire. The sheets should be cut just above a row of stay bolts with a cape chisel and ripper, the rivets in vertical seams and mud ring are then cut out, mud ring removed, stay-bolt heads cut off, bolts drilled and broken and the sheets removed.

The upper part of sheets are straightened, the outer row of stay-bolts ends punched out, the old sheets are laid upon the new and holes marked off with a marking punch made of round steel the size of holes and having a raised center.

The horizontal seams should be lined off $\frac{11}{16}$ in. from edge of old sheets, allowing $\frac{5}{16}$ in. for thickness of chisel; this makes the lap on inner sheet of seam $\frac{3}{4}$ in. from center of holes. The first hole in seam should be 2 inches from vertical seam, in order that there will be ample space next to flange for driving the rivet; the balance of holes should be spaced $1\frac{3}{4}$ ins. center to center. When the holes are marked the old sheets are removed and stay bolts lined off with a chalk line and marked with a center punch. Before this is done, however, it should be ascertained whether or not the stay bolts are in alignment. If not, they should be adjusted.

All holes should be punched, punching holes for upper seam $\frac{3}{4}$ in. for $\frac{11}{16}$ in. rivets, stay-bolt holes should be punched $\frac{1}{8}$ in. smaller than diameter of bolts. The edges of sheets are then trimmed, allowing $\frac{7}{8}$ in. from center of holes at ends and top, and $1\frac{1}{8}$ ins. to $1\frac{1}{4}$ ins. on bottom, according to location of holes in mud ring. The corners of sheets are then scarfed and sheets annealed, straightened in the rolls, the upper part rolled the required shape, the sheets put in place in the fire box and the holes in upper seams drilled, using an air motor to furnish the power. After drilling, the sheets are removed and burr removed from inside of upper holes in old sheets with the burr reamer illustrated in Fig. 3, which may be made of an old flat file, a wooden handle inserted in the eye. The holes in flanges are countersunk, all excessive lap removed from edge of flanges, reducing it to $\frac{7}{8}$ in. from center of holes.

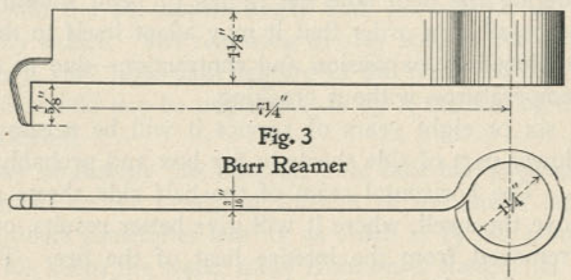


Fig. 3
Burr Reamer

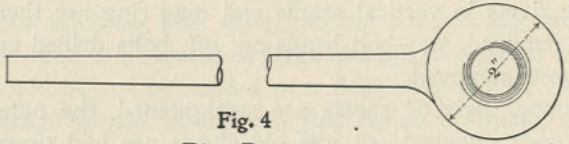


Fig. 4
Rivet Button

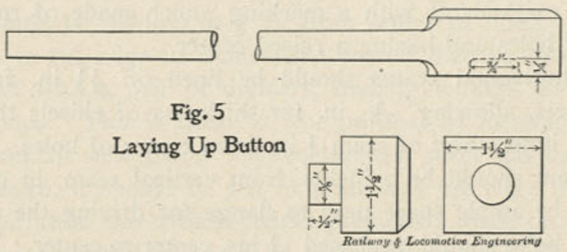


Fig. 5
Laying Up Button

The upper holes in new sheets are countersunk half way through, oil and burrs removed, sheets again put in place and riveted. A forked, wedged bar should be used to hold on rivets in upper seams, avoiding the necessity of cutting out the row of stay bolts above seam, as the bar will straddle the stay bolts.

A rivet button, as illustrated in Fig. 4, should be applied to the rivet head, and the wedge bar inserted between it and outer sheet. There should be a number of these buttons of different thicknesses, adapted to the difference in width of water legs; they should be made of steel, with $\frac{3}{8}$-in. iron handle.

A "laying-up" button, as illustrated in Fig. 5, will be found serviceable for those parts of seams that are not close enough to be brought in contact by driving the rivet. There should be a number of these also, of various thicknesses, made of steel. They should be inserted in the hole when necessary, with a pair of tongs, the wedge bar inserted and the seam hammered around the hole. When the work is under way this button should be applied just after the rivet has been plugged, as, if its use is put off until the rivet is finished, the rivet is liable to be loosened when sheet is hammered at the hole.

When the upper and end seams have been riveted the mud ring is put in place and riveted, the corner holes in box should be countersunk and rivets driven inside. Unless the mud ring is an extra heavy one the sides will be sprung out from $\frac{1}{4}$ to $\frac{1}{2}$ in. It should be straightened by heating it all over in a wood fire and drawing it together with rods. After riveting mud ring the outer sheets are straightened by inserting rods and drawing them together, the stay-bolt holes are then tapped, bolts put in, cut off and hammered over, the seams are chipped and caulked, finishing the operation.

Should the fire box be a shallow one, it will be found more profitable to cut out the whole side sheet and renew it, as, by putting in a half sheet, the upper seam is brought too near the intense heat of the fire and soon begins to leak, eventually developing cracks.

It is customary in some shops to renew side sheets without removing mud rings, especially in boilers that extend over the frame. In such cases, unless there is ample room in water space to hold on the rivets from the shell, the sheet is sprung away from the mud ring. The rivets in back seam and the greater part of the upper seam are held on from below, the balance are held on from the shell.

The most tedious and laborious part of renewing side sheets is the breaking of stay bolts. For the purpose of overcoming this, and to break the bolts more expeditiously, the stay-bolt breaker shown in illustration was designed.

Fig. 6 is a side elevation showing the supports *A A* bolted to end sheets of fire box through mud-ring holes; these supports have a jaw at upper end to receive the bar *B*, which serves as a track for the carrier, consisting of a $5\frac{1}{2} \times 1\frac{1}{2}$-in. sheave *C*, stirrup *D* and swivel *E*; the hook of swivel engages with the yoke *F*, which is bolted to a 12 x 12-in. driver brake cylinder *G*. *H* is an I-beam fastened to bottom of water leg with two hook bolts T T at either end, a piece of rubber K to cushion the recoil and a strap of iron L.

Fig. 7 is an end elevation showing a section of the I-beam H, on the lower flange of which the traveling fulcrum is suspended, consisting of two $2\frac{1}{2}$ x $\frac{5}{8}$-in. sheaves N, and two stirrups A_1 and B_1, which are connected by a rivet which allows them to turn on one another as desired; the lever C_1 is hung in the stirrup B_1 with a $1\frac{1}{2}$-in. pin, the long end of the lever C_1 is connected with the piston rod, the short end of the lever terminates in a downwardly projecting nose rounded on the bottom; it is bifurcated or forked so as to straddle the T-headed breaker hook D_1, made of $1\frac{1}{2}$-in. steel. The upper side of head is concaved so that when in operation the hook

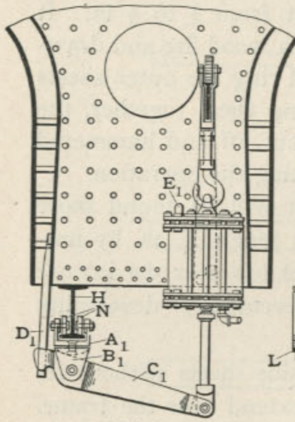


Fig. 7

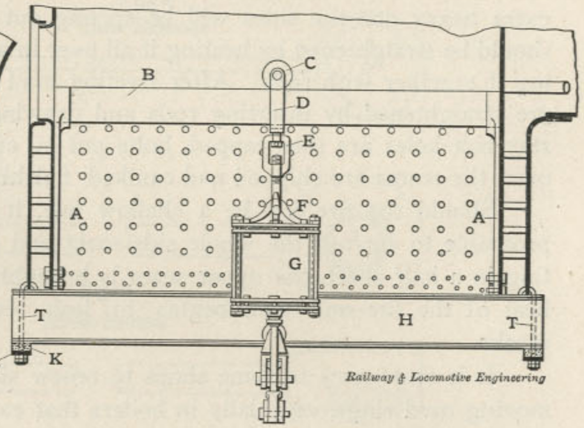


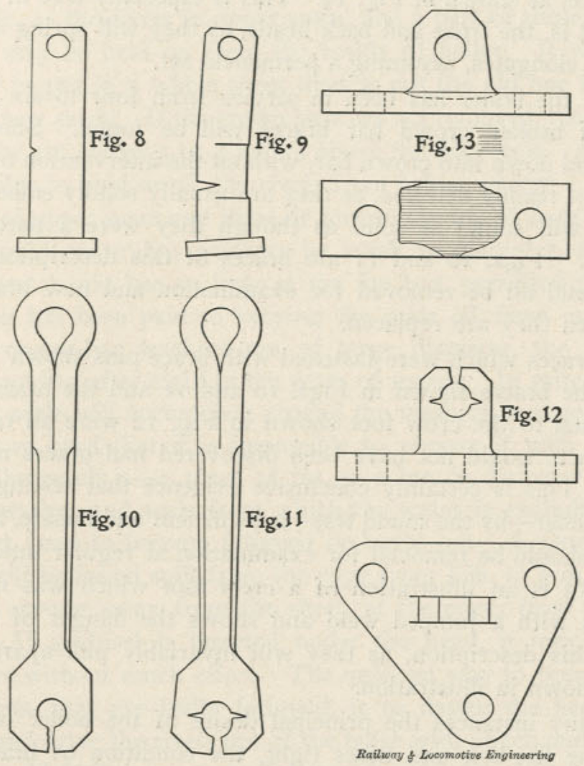
Fig. 5

and lever cannot disengage. The hook is beveled on the inside to give it a cutting as well as a breaking action. The breaker hooks are made of various lengths to suit the location of stay bolts, any slight variation is made up by inserting a mule shoe between the head of hook and lever. A mule shoe is shown in the details.

In the upper cylinder head is placed a check valve E_1. It contains a small valve and a coiled spring just strong enough to support the valve. When the piston descends air is drawn into the cylinder, the air is compressed when the piston ascends—forming an air cushion to counteract the shock when the bolt breaks. Compressed air is the power used. It is admitted and exhausted through a three-way cock.

Should the back tube sheet need renewing at this time a pattern should be made for it of Nos. 16 or 14 sheet steel (provided there

are a number of boilers of the same class), the tube holes, stay-bolt holes, brace and mud ring rivet holes should be located on pattern as well as flange and shear line. The mud ring and brace rivet holes, stay-bolt holes and holes for tit of tube hole counterbore should be punched in sheet before flanging. After flanging the lower corners should be shaped to fit mud ring. The sheet is then annealed and holes marked on flange, either by putting sheet in place and marking with a scratch awl or by transferring the loca-



tion of holes with a piece of hoop iron. The holes in flange are either drilled or punched, then countersunk, the tube holes counterbored, the straight parts of flange beveled in planer, the balance chipped. The lap on lower part should be $\frac{5}{8}$ in. from center of holes, upper part 1 in. After cleaning off all oil and grit the sheet is put in place and riveted, stay bolts put in, cut off, hammered over, and the sheet chipped and caulked. When putting on the braces a piece of 1-in. pipe 1 in. long should be put between brace and tube sheet.

All the braces in the boiler should again be examined. The method often followed of testing braces with a hammer and pronouncing them in good condition if they are taut, is not thorough enough. A brace may be taut and have a dangerously corroded pin, as shown in Fig. 8, or the pin may be cracked, bent or partly sheared, as shown in Fig. 9, or the brace may be cracked out at the hole, as shown in Figs. 10 and 11. The brace may be taut with the end of crow foot cracked out from the hole and the hole elongated in consequence, as shown in Fig. 12. This is especially true of the end sheets, that is, the front and back heads, as they will spring outward as the hole elongates, assuming a permanent set.

When the boiler has been in service from four to six years a number of broken crown bar braces will be found. Should the brace extend down into crown bar, without the intervention of a link, they are not readily detected, as they are usually solidly embedded in scale and will sound as solid as though they were a part of the crown bar. Figs. 10 and 11 are braces of this description; these braces should all be removed for examination and new brace pins put in when they are replaced.

The braces which were fastened with brace pins shown in Figs. 8 and 9, the braces shown in Figs. 10 and 11 and the brace which was fastened to the crow foot shown in Fig. 12 were all taut; the affected parts would not have been discovered had braces not been removed. This is certainly conclusive evidence that testing braces with a hammer—by the sound test—is inefficient and unsafe, and that all braces should be removed for examination at regular intervals.

Fig. 13 is an illustration of a crow foot which was made of two pieces with a jumped weld and shows the danger of using a brace of this description, as they will invariably pull apart at the weld, as shown in illustration.

In many instances the principal desire of the boiler maker is to have the fire box and tubes tight, the condition of braces and stay bolts being a secondary consideration. The braces and stay bolts of a boiler in good condition should receive more attention than those in a leaky boiler, as the maximum pressure is a more constant factor in the tight boiler than in the boiler that is leaking, subjecting the braces and bolts to a greater strain.

The old saying of letting well enough alone is often applied to a boiler which outwardly, at least, is in good condition. A boiler is not good enough until all its parts have been not only thoroughly inspected, but also their strength calculated and found to be sufficient. Should the inspection or calculation prove any part of the boiler unsafe it should be put in good condition. It is always more profitable to keep in mind the saying, "Better be sure than sorry."

With proper care, the back sheet of fire box should last until the box is renewed, with possibly the exception of that part of sheet around fire-door opening. However, it sometimes happens that it has deteriorated to such an extent that its renewal is made necesary at the time the lower part of side sheets are renewed. Should it be necessary to remove the crown bars, a whole sheet should be put in, as the rivets in upper seam, and a part of those in vertical seams, may be held on from the inside of boiler. It will also be cheaper to put in a whole sheet than to cut the old one in two and make a new seam. If the crown bars are not removed, the back sheet should be cut across 3 or 4 inches above the door hole. It will then be possible to hold on all the rivets from below, except a few in the middle of upper seam and three or four in the top of door hole.

Should crown-bar washers be small in diameter, the crown-bar rivets should last as long as the fire box, provided that proper attention has been paid to keeping the scale off from crown sheet. If the crown-bar washers are of large diameter, the rivets will need renewing after eight or ten years of service. In spite of the best of care, scale will accumulate around the washers next to sheet, and become so hard that it is impossible to remove it with a cleaning rod. The result is—a space $1\frac{3}{4}$ ins. to 2 ins. in diameter is covered by the washer and scale from which the water is excluded, causing the rivet head to become fatigued or burnt out. A number of the heads will be found split from the edge from $\frac{1}{4}$ in. to $\frac{3}{8}$ in.; they will also be sprung away from the sheet, at the edge, from $\frac{1}{32}$ in. to $\frac{1}{16}$ in. If a chisel is inserted under the head, it may be broken in pieces without much effort. The quickest way to remove crown-bar rivets, that are badly fatigued, is to flatten the heads with a sledge and drive the rivets out of the holes with punch and hammer.

Should it be necessary, for any reason, to renew crown-bar rivets that are in good condition, it will be found advisable to drill them out, using an air motor to furnish the power. They should be drilled through the counter sink and driven out with punch and hammer.

A very good washer to insert between crown bar and sheet is made of a piece of 1-in. pipe, and a flat washer of $\frac{1}{4}$-in. steel; the piece of pipe is put next to sheet, and the flat washer placed next to crown bar. These are cheaper, and far superior to the cast-iron washer commonly used, as they take up less room, thereby facilitating the cleaning of crown sheet. Old pipe and refuse plate may be used for the washers, entailing a nominal expense for material.

It occasionally happens that the renewal of crown sheet is made necessary before the fire box is renewed—usually on account of being mud burnt. The most successful way to remove the crown sheet is to cut out all the rivets from the seams of crown, and the upper rivets in one of the side flanges of tube sheet as far down as the swell. Remove ten or twelve stay bolts from the upper front corner of side sheet, on the same side of box; pull the corner of side sheet out with bolts, and the corner of tube sheet in with a turn buckle fastened to front tube sheet. The crown sheet can then be removed with very little trouble.

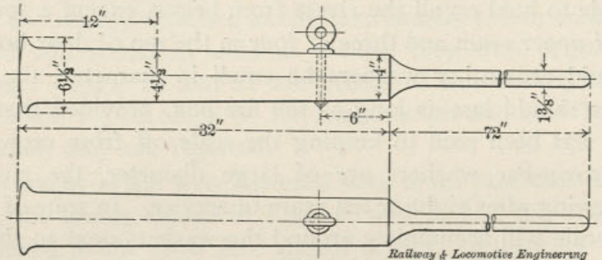


Fig. 14

Should the tube sheet be renewed at this time, the crown bars may be left on sheet, and removed more quickly and with less trouble after sheet has been taken out. The crown-bar rivet holes should be punched in new sheet before it is flanged; after flanging, the corners should be shaped to fit the corners of tube and back sheets, respectively. The sheet is then annealed. The rivet holes in ends and flanges may be located by putting sheet in place and marking the holes with a scratch awl, or they may be laid out by cutting a thin lath to the shape of end sheets and marking the location of holes upon it, then transferring them to crown sheet. The holes in side sheets may be marked on a stick and transferred to flanges. They are then punched or drilled; those in flanges countersunk; edge of flanges beveled in planer; sheet put in place, riveted, chipped and caulked. The crown bars are then put on and riveted, and braces replaced.

The lap on crown sheet should not be more than $\frac{7}{8}$ in. from center of holes. The corners of sheet should be reduced, so that, after

scarfing and flanging, they will not project beyond balance of flange; this will save considerable trouble when putting sheet in place.

After twelve or fifteen years of service, the whole of fire box will need renewing. The stay-bolt heads should be cut off and the bolts drilled in the thickness of outer sheets. The countersunk rivets in head and ring should also be drilled, as well as the ends of tie rods extending through wagon top, the rivets being then cut out of back head and bolts broken. If there is no stay-bolt breaker, they may be broken with a punch and hammer, or the ends may be cut out with a cape chisel. The braces are then loosened and head removed; the mud ring is then removed, and balance of stay bolts broken. The bolts in sides (and crown, if boiler is radial stayed) may be broken with the ram illustrated in Fig. 14, if there is no stay-bolt breaker. Its weight should be from 180 to 200 pounds; it should be hung so that its center of gravity will be about 6 ft. from back end of boiler. A gang of three men will be required to operate it successfully; one man to hold the bar in position, and two to operate the ram. The stay bolts in tube sheet may be broken from inside of shell with bar and sledge. The braces are then taken off of crown bars, and box removed.

It is likely that by this time the corners of mud ring are badly cracked. If such is the case, new corners or new ends should be put in, and the sides straightened if necessary.

When laying out the rivet holes in new box, the holes in flange of back sheet should be located $2\frac{1}{4}$ ins. from outside of sheet and $2\frac{3}{8}$ ins. in tube sheet, on the assumption that the edge of flange on back sheet is $3\frac{1}{8}$ ins. from outside of sheet and $3\frac{1}{4}$ ins. on tube sheet; this leaves $\frac{7}{8}$ in. from center of holes for lap.

Two patterns should be made the thickness of side sheet—one of them bent the shape of end sheets to lay outside flanges, the other left straight for laying outside sheets; a flexible strip of wood the thickness of side sheet will answer the same purpose. The upper hole in side flanges should be located $1\frac{3}{4}$ ins. from top of sheet, and the upper seams in side sheets lined off from these points. Assuming that the edge of flange on crown sheet is $3\frac{1}{8}$ ins. from outside of sheet, and the sheet is $\frac{3}{8}$ in. thick, this will leave 1 in. from center of holes for lap.

In laying out the side sheets, we will take the length of mud ring on the inside; we will assume that it is 72 ins., and make the fire box $\frac{1}{8}$ in. shorter, so that the mud ring may be inserted without much trouble. The holes in back sheet have been located $2\frac{1}{4}$ ins. from outside of sheet, and those in tube sheet $2\frac{3}{8}$ ins. These added together equal $4\frac{5}{8}$ ins., plus $\frac{1}{8}$ in. equals $4\frac{3}{4}$ ins. This deducted from 72 ins. equals $67\frac{1}{4}$ ins., or the distance between the end seams, which are then laid out with the template previously made.

In laying out the rivet holes for mud ring, we will assume that the first hole is $1\frac{3}{4}$ ins. from end of ring on the inside, when brings it $\frac{9}{16}$ in. outside of back seam and $\frac{11}{16}$ in. from front seam. The holes in ring may be located on a stick and transferred to sheet.

In laying out the stay-bolt holes, we will draw lines with a chalk line across the holes in lower part of outer side sheet in a vertical direction, extending the lines to bottom of sheet, locate the position of these lines relative to mud-ring holes upon a stick, and transfer to sheet.

To locate the position of stay-bolt holes on these lines, the shape of flange on back head should be drawn full size, also the shape of flange on back and tube sheets in the same relative position that they occupy when in place.

The shape of back head may be obtained by bending a piece of iron over the outer side sheet. The position of stay-bolt holes and mud-ring holes should be marked upon it. They may then be transferred to drawing, and lines produced from these points normal with contour of back head to meet the line which represents flange of back and tube sheets; these points may then be marked on a piece of hoop iron. Holding the hoop iron a distance equal to half the thickness of side sheet away from the line, these points are then transferred to first vertical row of stay-bolt holes in front and back of side sheet; lines are struck across the sheet with chalk line from these points, and the work of laying out the side sheets will be finished, except marking the shear line. This should be $\frac{7}{8}$ in. from center of holes in the ends, and 1 in. on top will usually be sufficient to meet end of crown bar, and $1\frac{1}{8}$ in. to $1\frac{1}{4}$ in. on bottom, according to location of holes in ring. The sheets are then punched, bevel sheared or planed; lower corners scarfed, then annealed, straightened and bent in the rolls to fit back and tube sheets.

The two ends and sides are then bolted together, crown put in place, and holes marked. Holes are then punched, edges planed, or they may be bevel sheared before flanging.

The second rivet hole from ends in flanges should be countersunk on the inside, so that rivet may be driven flush to make room for caulking end sheets. The crown is then replaced, and box riveted and caulked. The crown bars are then put on and riveted. The fire

box is then put in the boiler, lowering it as much as possible in order to hold on the rivets in upper part of back head conveniently. It should also be put forward as far as possible, so that the rivets in lower part of back head may be held on without trouble.

The back head is put in position and riveted, after which the fire box is put in place and the door hole riveted. The mud ring is then inserted and riveted. The pneumatic "holder on," shown in Fig. 15, will be found very convenient for holding on the mud-ring rivets. It is an 8-in. air-brake cylinder hung on a $\frac{3}{4}$-in. pipe, through which a $\frac{5}{8}$-in. rod has been inserted, the rod also being inserted through water space. When used on sides of box, it is hung on a bar of $1\frac{1}{4}$-in. round iron, which is put through fire-door opening and into one of the tube holes.

In operation a number of the holes are hammered up and reamed or drifted. When the rivet is inserted, the button or cup is applied

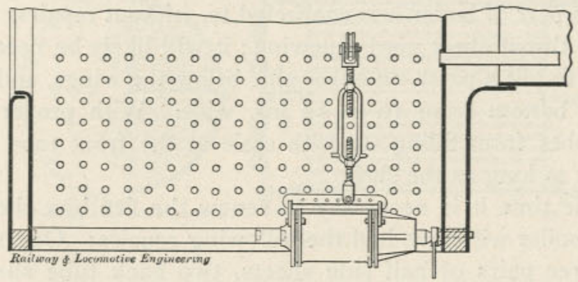


Fig. 15.

to the head as shown. It is given a smart blow or two with piston rod of holder-on; the rivet upset and snapped. The holder-on should be made the proper length for sides of box, and an extension used for ends, as shown. Compressed air is the power used, which is admitted and exhausted through a three-way cock.

After the mud ring has been riveted, the braces are put on tube sheet and riveted; plugs put in outer corners of the ring; stay-bolt holes tapped, bolts put in, cut off and hammered over; tie rods and braces replaced, or renewed where necessary.

Should the bottom of shell be dangerously grooved at seams, patches should be put on outside. If there is considerable internal pitting, a liner may be put on bottom of shell. It will probably need to be from 24 to 30 ins. in width.

The bottom of front tube sheet will likely be cracked by this time along the bend. If it is at all dangerous, it should be patched on the outside; the patches should be riveted. It is very probable that the throat sheet will also need a patch or two—cracks usually developing just below the wing. If there is an old sheet about, the patches may be fitted over it before they are put in place.

Should cracks be developing in the back head in the bend of flange, they may be patched on the inside. The holes should be countersunk, and rivets driven flush. A patch may also be necessary across the bottom of head, on account of grooving along the top of mud ring. It is very seldom that the back head needs to be renewed, or, rather, is renewed, for when the boiler has arrived at this stage in its decline, the expense of the necessary repairs is so great that it is unprofitable to make them. Should the head be renewed, the new sheet may be flanged over the old one (if there is no flange block to fit), and the flange set in the necessary amount afterward. All stay-bolt holes, brace and mud-ring rivet holes should be punched before flanging.

If the dome has been properly constructed, it should last as long as the part of boiler it is connected to, without repairs. Neither should the throat sheet need renewing; it will likely be necessary at some time to put a patch on either side below the wings, and a patch across the bottom from 10 to 12 ins. wide. With proper care in keeping tubes from filling up with scale at the front tube sheet, it should last as long as the shell.

By the time it is necessary to renew the fire box the second time, the boiler will have had the following repairs: One fire box, two or three pairs of half side sheets, two back tube sheets, the back sheet of box renewed twice (either entirely or partially), possibly one crown sheet, crown bars removed twice, a number of bolts in lower part of box renewed twice, a number of broken braces and stay bolts renewed, the tubes reset six to eight times, the bottom of shell lined inside, a patch on the bottom of one or two of the girth seams, a new bottom in front course of shell, a new bottom in smoke arch, a patch on bottom of front tube sheet, three patches on throat and one or two on back head. These repairs, with probably an occasional patch on fire box and outer side sheets, will usually be sufficient to carry the boiler through to its twentieth or twenty-fifth year, and the expense of the necessary repairs to put the boiler in a serviceable condition is so great that the boiler is taken out of service.

If the boiler is still in good condition for low pressure, it may be utilized as a stationary boiler; tube sheets should be renewed and tubes of a large diameter put in. It may also be advisable to cut down the water leg, especially if the height of door hole makes firing inconvenient.

Should the boiler be "scrapped," it is possible that a portion of the shell is still in a fair condition, and may be used for a feed water heater, as shown in Fig. 16. A hoop of 2½-in. angle is riveted to end of shell, and outer heads bolted to it, as shown. The partition *A* is surrounded by strips of pine, which, when they become swelled by the condensed water, make a steam-tight joint.

Should the heater be placed in a horizontal position, the partition should be placed as shown, so that the condensed water may run off through the tubes into opposite chamber, and thence into drip pipe. The outlet and inlet water pipes should be removed as far as possible from one another, to create all the circulation possible. The heater should be provided with wash-out holes, blow-off cock and safety valve.

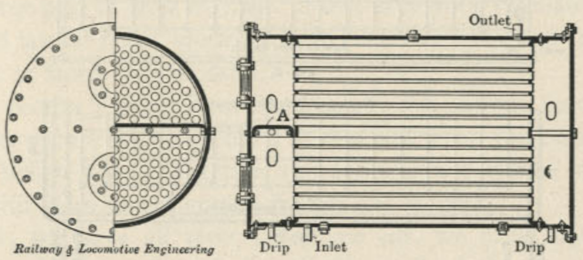


FIG. 16.

The shell of the old boiler may also be used for a compressed air reservoir, by putting a head in either end. These should be braced by running rods through the drum, putting nuts on the outside. Pieces of pipe should be put on the rods between the heads; old tubes will answer the purpose.

It is impossible to lay down a hard and fast rule to determine the life of a boiler; a safe plan to follow is to "scrap" the boiler when it has deteriorated to such an extent that it is unfit to carry the pressure desired.

If the boiler is cut up and the courses of shell and wagon top straightened out, it will be interesting, if not surprising, to notice the condition of the plates. A number of cracks will be opened up to view next to rivet holes, from ½ in. to 1 in. long; some of them running across from one hole to another. It will be impossible to detect these until plates are straightened out; yet they are there, and slowly but surely they would have grown worse, and possibly have led to an explosion.

The natural consequence of keeping a boiler in service after it is about worn out, is, that at some time it will throw itself away in a very decided and unpleasant manner.

HOW TO LAY OUT A BOILER.

BY JAMES HERON.

I am well aware that there is no trade that is less understood by the men working at it—the rank and file—than my own. The few who do learn how to lay out and plan work usually keep it to themselves, and the average apprentice rarely gets further than the riveting hammer and the calking tool. This is especially true of

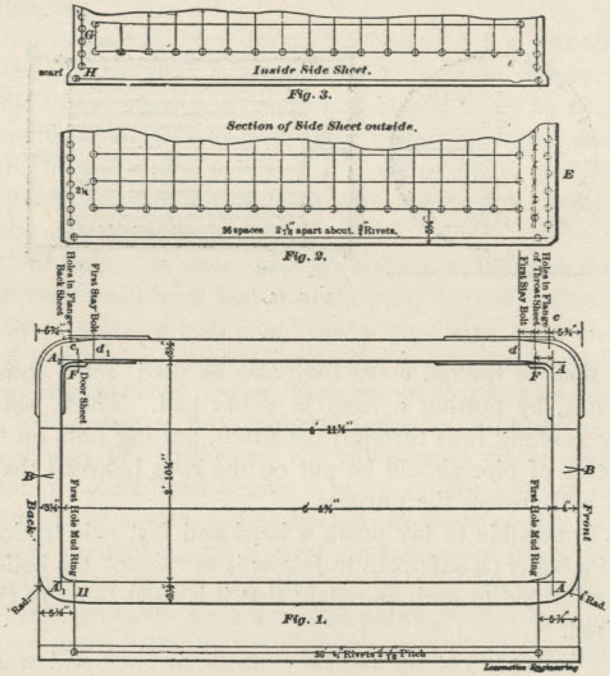


Fig. 3.

Fig. 2.

Fig. 1.

large shops, such as locomotive works, where the best results are obtained by having a specialist for each part.

Fig. 1 shows the mud ring, or foundation of a locomotive boiler with section of inner and outer sheets at boiler.

To make a boiler of standard dimensions, this ring must be square and of the proper size. To prove this and get the holes in proper place, I use the following method:

Take a straight edge and line off from inside of ring as at A A 1, do the same back and front. Now set your trams to center where side lines cross end lines. If one side is longer than the other this will show it. Then tram diagonally, always working from front end, scratch with trams as at A 1. If you strike both back centers, your ring must be square. If you should find ring out of square, say, one-eighth of an inch, it will be of no consequence, as that can be worked in to flange by putting the holes that much nearer the roof, or nearer the edge, as the case may be, but your starting point or first hole in front end of mud ring must be square with opposite side, or your stay-bolt holes will not be in line in inner and outer sheets, and your sheet and fire box would be twisted. This done, with A A as ends, find center of ring at ends as at B. This will be your center hole at ends of ring. Now, take your regulator or template, and lay off holes, working from center at ends, and from starting point at front ends at sides.

The reason I work from front end is this: If you have not got side sheets square with each other at that end when you come to build up your boiler, your connection and cylinder will not be straight or in line with sides where engine frames are secured.

Now, we have all rivet holes laid off, we must lay off stud holes for ash-pan and grate-bar rigging, also holes in corners, of which I shall write later, and our mud ring is laid out.

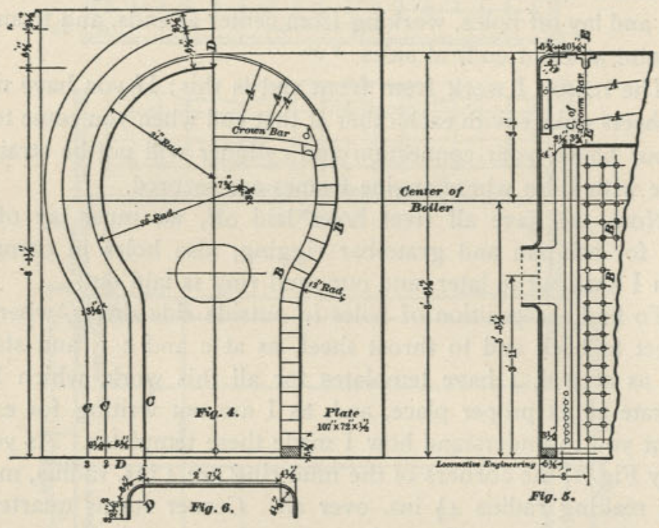
To find the position of holes in outside side sheets, where they connect to back and to throat sheet, as at c and c 1, and stay-bolt holes as at d d, I have templates for all this work, which I shall illustrate at its proper place, and, as I am not writing for experts, I want you to understand how I made these templates. As you can see by Fig. 1, the corners of the mud ring are 4 ins. radius, material $\frac{1}{2}$ in., making radius $4\frac{1}{2}$ ins. over all. Corner forms quarter of a circle. The sides are flat and must not lap over circle, so we must allow $1\frac{1}{4}$ ins. for lap of side sheet, added to the $4\frac{1}{2}$ ins. radius, making $5\frac{3}{4}$ ins., which bring us to first hole in side sheet as at E, Fig. 2. The same applies to back and front corners; now you have the length of outside side sheet from center to center of holes. Note double row in front end.

Now, locate first row of stay bolts; the sketch will explain the rest. Now we have length of side sheets, and stay bolt holes laid off one way, we will go to Fig. 3 or inside side sheets, and you will note at H, that first holes for mud-ring rivets are not on line with holes for flanges. My reason for this is that I prefer a short flange at corners, with rivet as close up in corner as I can get it. Then the man with the big hammer and little knowledge of his business cannot wedge off the sheet from mud ring, when a leaking corner is reported. F F gives you the length of this sheet from center to center of hole for flanges, less ½ in. at top, back where door sheet slopes in. This will also be the length of crown sheet, c to c of holes, less ½ in. back end.

Note, 3½ ins. water space at bottom and 4 ins. at top of door sheet, d d, gives position of stay bolts.

LAYING OUT THE BACK HEAD.

The large engraving shows the boiler we will lay out in the course of these articles, one piece at a time, and is used here the



better to show the student what is aimed at. Fig. 4 shows plate 107 x 72 x ½ ins. This sheet is to form door sheet, or what is called the back head. On this plate I lay down full view of a boiler looking from back. By this means I can locate all holes in proper place and see that all parts clear each other, such as vertical and lingitudinal braces, as at A A, Figs. 4 and 5, also wash out, gauge cock; in fact, all holes that have to be put in inner and outer door sheets. This means a saving of labor, as there are no holes to be drilled by hand when the boiler leaves the boiler shop.

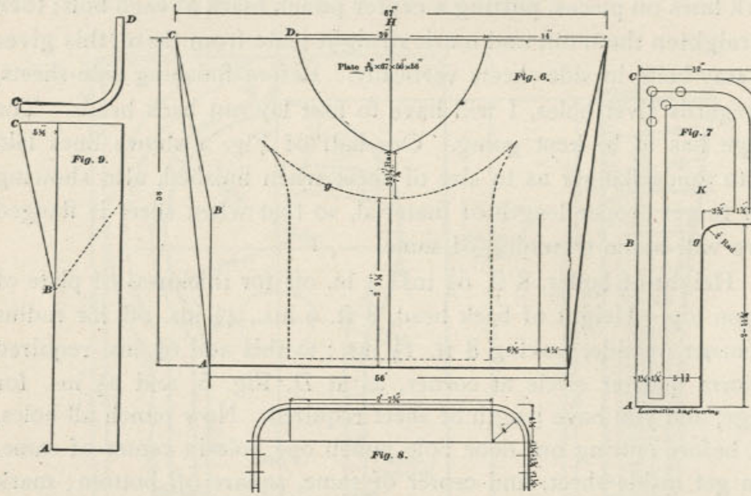
There is no necessity to locate stay-bolt holes on sketch, as, in any well-regulated shop, your blue print will show them. If not, you have to use your own judgment. What I want to point out to you is how to get at your starting points.

I want now to show you how to get stay-bolt and rivet holes vertically. I lay lines down representing center of stay bolt, always following surface of sheet, as at B B, Fig. 4, so as to have half square with surface of plate. Note that lines are not the same distance apart in inner and outer sheets. Now I get two pieces of iron, 1 x $\frac{5}{16}$ in., and 1 x ½ in., one of each; this represents thickness of plate to be used for side sheets. I bend one to shape of back flue sheet, the other to shape of back head. I lay these on stay-bolt lines, Fig. 4, and mark lines on pieces, putting a center punch mark at each bolt; then I straighten them out and mark straight plate from them, this gives me stay bolts in side sheets vertically. Before finishing side sheets, as regards rivet holes, I will have to first lay out back heads. The flange has to be kept going. One-half of Fig. 4 shows lines laid off to guide flanger as to size of sheet when finished, also showing how to get proper length of material, so that when sheet is flanged there will be no trimming of same.

Height of boiler, 8 ft. 6½ ins., ½ in. off for thickness of plate of wagon top. Height of back head, 8 ft. 6 ins., 4½ ins. off for radius of corner outside, leaving 8 ft. 1½ ins.; to this add 6⅝ ins. required to form quarter circle at corner, as at *D*, Fig. 6, and 2½ ins. for flange, and you have length of sheet required. Now punch all holes, and before cutting out door hole punch one hole in center of same, then get inside sheet, find center of same, square off bottom; mark center mud-ring hole and center of door hole; punch these two holes and bolt inner and outer sheets together, and mark off stay-bolt and door holes. These must come opposite when boiler is fitted up. *E E*, Fig. 5, gives starting point for crow feet and first crown bar, of which I shall write later.

Fig. 6 shows plate to form throat sheet. By referring to engraving of boiler you will find the height of this sheet where it connects to belly of boiler to be 2 ft. 11¾ ins.; the height to top of wing C D is a matter of taste. Some boiler makers run them up to center of boiler. I prefer to make them as short as possible, as it requires less manipulation in flanging and less riveting, and makes a stronger and neater job; this sheet when flanged should be the same width as back sheet, as in Fig. 6. But as we have a double row of rivets in flange, $1\frac{3}{4}$ ins. more must be added, each side, as double rows of rivets have $1\frac{3}{4}$ ins. between center, as at Fig. 8.

To lay out circular part of sheet, I give height to where $\frac{1}{4}$ circle commences as at g, Figs. 6 and 7, to find the height; the sheet we are working on is $\frac{4}{16}$ in., but to simplify matters, I make it $\frac{1}{2}$ in., height from bottom of mud ring to belly of boiler, or bottom connection sheet, 2 ft. $11\frac{3}{4}$ ins.; radius of corner as at g, Fig. 7, 2 ins. inside, $2\frac{1}{2}$ ins. outside; 2 ft. $\frac{1}{2}$ in. from 2 ft. $11\frac{3}{4}$ ins. will be the height, as at g, Fig. 6. Now you want to find amount of material required to form $\frac{1}{4}$ circle and straight part of flange. Where you find the abbreviated radius, it means radius in all cases where you get a given inside diameter, you must add thickness of material to diameter to find



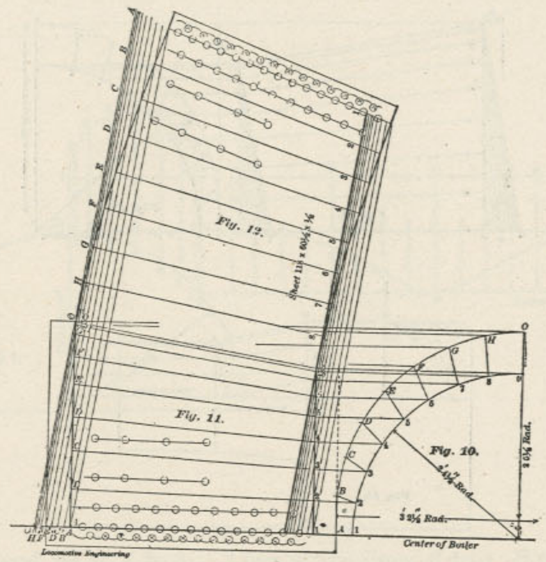
circumference. We have here an inside radius of 2 ins., which means a diameter of 4 ins., adding thickness of material $\frac{1}{2}$ in., or the equivalent decimal .50, makes $4\frac{1}{2}$ ins., or $4.50 \times 31.416 = 14.137$, or $14\frac{1}{8}$ divided by four, as we only require length of $\frac{1}{4}$ circle $3\frac{1}{2}$ ins., to this add $2\frac{1}{2}$ ins. for laps and $1\frac{3}{4}$ ins. for center, between knitholes; length required, $7\frac{3}{4}$ ins.

Note radius at H $32\frac{1}{4}$ ins., plan of boiler, shows a radius 2 ft. $5\frac{3}{4}$ ins.; this should be the radius of circle when finished, but I have added $2\frac{1}{2}$ ins. to that radius because my line on sheet is to guide flanger showing him where his bend commences.

I would call special attention to the method of flanging the sheet, and the reason I lay it out in this form, and, if followed up,

you will never have a throat sheet give out at bend of wing as I have seen hundreds do. I have used this method for the past ten years and I have never had one to give out from any cause at that point.

Fig. 9 shows sheet after sides have been flanged in clamps. I do not flange it down quite to right angles as shown. I have been given similar sheets to flange where there has been but 18 ins. cut out in center at top where I have 38 ins. and sides of sheet were square with bottom. Now, the difference in the two methods is this: When flanger puts his sheet on flange block to flange circular part, and comes down with the mauls—or what is more generally to the deterioration of the material, sledges—on point D, Fig. 9, down



goes the wing at point C with it, and I have seen sheet heated four times after flange was down to hammer back that wing so as to have edge straight as at A B C, Fig. 7. Now this is the cause of so many throat sheets giving out at point marked K, Fig. 7. That is the point where the sheet has the most strain in flanging, as it has to stretch both ways—down and out. Then knocking wing back, point K, as a center, has to stand the brunt of all the hammering, and is very often burned at that point in trying to get material as hot as possible, so as to get wing back to its place with least amount of work, which is no easy job.

Now, by having sheet wider at top and cutting to shape as at A B C, Fig. 6, point B is a weak point and when flanger strikes on point D, Fig. 9, wing at point C goes down with D and I have the material there to let it go, so needs no knocking back.

I insist on flanger bringing point C straight with A B; to do this he has to come down with heavy sledges at C on edge of plate. It is plain to see the $5\frac{1}{2}$ ins. at point C has to be upset in flange where it has to stretch the most, and sheet is not reduced by heating so often. By this method of flanging you can scarcely perceive a difference in thickness of material when calipered.

TAPER CONNECTION SHEET.

Fig. 10 shows front elevation of taper connection sheet, large and small ends. Radius of large end 2 ft. $6\frac{1}{2}$ ins. and 3 ft. $2\frac{1}{2}$ ins.

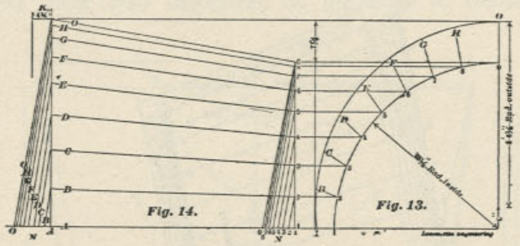


Fig. 14. Fig. 13.

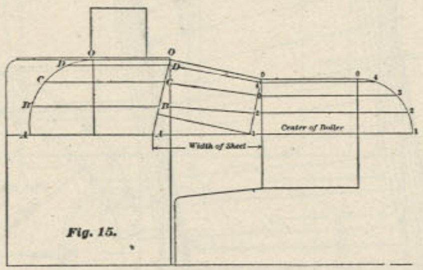


Fig. 15.

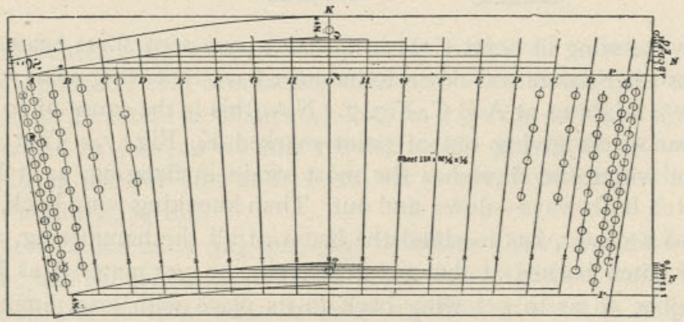


Fig. 16.

outside, and of small end, 2 ft. $4\frac{1}{2}$ ins. inside. Note that the large end is not a true circle. The radius for top of boiler is struck 6 ins.

from center of boiler and radius for side $3\frac{3}{4}$ ins. above and $7\frac{3}{4}$ ins. to one side of perpendicular center line. This is done to avoid having a flat place on side and to strengthen same by getting as near a circle as possible. I am aware that this is a hard problem for amateurs to work out, but if the boiler maker trying to work it out perseveres he will find it simple enough.

Now, you must study Fig. 10 well before going to other figures. Fig. 10 shows edges of plate, back and front, after being bent to proper shape. I show but half view, as the other half would be the same. Now suppose you divide your small end into eight equal parts, by spacing off on edge of sheet, as at 1 to 0, then do the same

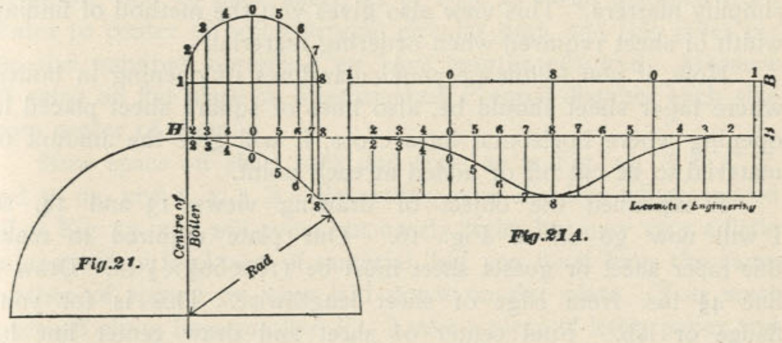


Fig. 21. Fig. 21 A.

with large end, as at *A* to 1. Then strike lines *A* to 1, *B* to 2, and so on; then your front elevation is complete. I speak of edges of plate in connection with this figure, to give an idea of what these lines are for and why this elevation is required to be laid down in order to lay out flat plate.

Fig. 11 shows side elevation of taper connection. Note that Figs. 1, 2, 3 to 0 are parallel with Figs. 1, 2, 3, to 0, Fig. 10 or small end of taper sheet. The large end is the same, but I have not drawn all the parallel lines as it would not leave side view so clear.

Fig. 12 shows one-half of plate when flat, and taking 0, 0 as center, as shown. Were it of light material that could be bent by drawing same over Fig. 11, all lines and letters, figures and holes would meet the corresponding letters, figures and holes.

LAYING OUT BOILER SHEETS.

Figs. 13 and 14 are the same as Figs. 11 and 12, but made more plain. Fig. 15 will show why we require a sheet the shape of Fig. 16 when flat, to form Fig. 13. Suppose we take a sheet and roll it up to radius required without cutting to shape, which has been and is still done in many places, while others make templates by using light iron and getting shape from boiler and marking plate from template so made. Fig. 15 shows this plate in place. You will see by lines you have too much stock at back end and not enough at front. My object in giving this figure is to help you to more clearly see through Figs. 13 and 14. *A, B, C, D, O,* and 1, 2, 3, 4, 0, Fig. 15, shows the same view as Fig. 13, but I made sectional view of boiler, and lined the same off back and front and divided into four parts instead of eight, as Fig. 13, to simplify matters. This view also gives you the method of finding width of sheet required when ordering material.

Now, if you follow perpendicular lines of opening in boiler, where taper sheet should be, also lines of square sheet placed in opening where horizontal lines cross, it will give the amount of material to be cut off or added at each point.

I explained the object of drawing views 13 and 14, so I will now go on to Fig. 16. Our plate required to make this taper sheet or gusset sheet must be $118 \times 60\frac{1}{2} \times \frac{1}{2}$ in. Draw a line $4\frac{3}{8}$ ins. from edge of sheet lengthwise. This is for your flange or lap. Find center of sheet and draw center line by squaring from line at edge. This will be back end of sheet. Plan of boiler shows double row of rivet holes in this sheet, so that the first thing one must do is to allow $4\frac{3}{8}$ ins. for flange at this edge, as we require that much for lap of inner and outer sheet and space between centers of holes. As at *K*, Figs. 14 and 16, measure distance from *O* to *A*, Fig. 13, and measure off same distance along center line, Fig. 16, as at *A. O.* Draw line full length of sheet. At this point do not draw line $4\frac{3}{8}$ ins. from edge full length. A short line or center mark is sufficient. I should have told you to take measurement at *O* to *A*, and strike that line the full length of sheet, and square your center line from that, as the other line would confuse you at ends of plate, and is of no use, as you can see by the engraving. Mark your line *A O*, as on sketch. Make distance *O O*, Fig. 16, the same as *O O*, Fig. 14. This means the full length of line on slope, not including lap or space added for flanging.

Get distance from 1 to *O*, as at *N*, Fig. 14; mark off along center line. Make center marks at all points you have measured off. Strike or draw line full length of sheet at last center found. This will give you points *K, O, A,* 1, 0 on center line.

Now we want length of sheet. We find radius of small end, $28\frac{1}{2}$ ins. inside or 59 ins. diameter, to which we must add thickness of plate $\frac{1}{2}$ in., making diameter $59\frac{1}{2}$ ins. or $59.50 \times 3.1416 = 186.92 \div 2$. We only require length of half the circumference, which is 93.46, or $93\frac{1}{2}$ ins. nearly. The length of large end can be found in a similar manner, but we have two radii to figure on and have to find the area of a circular sector, which is too lengthy a calculation to do here. The method I use is quicker and simpler and just as accurate. This plate when rolled and flanged is same size and shape as back sheet from center of boiler up. When I lay down view of back sheet, as at Fig. 4, I run distance from center to center of boiler around circular part, and this gives me the size required, assuming we have lengths required. Measure off same on flat plate on lines marked *P* equal distance each side from center of sheet.

Now space off sheet back and front as at Fig. 13, *A B C D*, and so on, and 1, 2, 3, 4. By setting your dividers where spaced off at Fig. 13, you will come out nearly right, but may vary a little on account of thickness of material, but you must have the same number of spaces on view laid down on flat plate. You must space off along lines marked *P*. I take a piece of letter paper and mark lines *A* to *O* and 0 to 1 as at *N*, Fig. 14, and carry paper to flat plate as at N, Fig. 16. Take paper to other end of plate and do the same. Mark letters *A O* and 0 1 on your plate and paper so that your paper letters, or letters on paper will correspond with letters on sheet, and not get your paper wrong way about. Now draw your lines from marks you transferred from paper parallel with sheet, and where your lines cross make center marks. This will give you the regular line of curvature. Draw your line of curvature by holding flexible straight edge at center marks. Now you must get your lengths of sheet along this line of curvature, then draw end lines, which will be your center of boiler and top row of rivet holes in lap. The row of holes shown above is for welt strip as shown in plan of boiler. Those still above that are for crow feet, to brace irregular circle.

Note hole back and front on center line of flat plate. These holes correspond with holes on center line on top of wagon top and cylinder of boiler. This must bring every part to fit accurately. To make this matter as clear and simple as possible I left half of view of flat plate without curvature line, so that it would be more easily understood.

LAYING OUT DOME SHEETS.

Figs. 17 and 18 show front and side views of dome on boiler. To lay out a dome sheet it is not necessary to lay down Fig. 17, but when you want aperture, or dome hole, very accurate, then you must use that figure. Strike radius of segment of a circle, the size called for on drawing, draw center line *OD*. Height of dome is of no importance. I have put it full size to make it more plain. Strike radius or semi-circle on top. The dome of boiler we are laying out is 30 ins. inside diameter. Thickness of material, ½ in., so as to have our lines an equal distance apart on semi-circle on top of dome, Fig. 18. And on flat plate, or Fig. 19, we must strike our

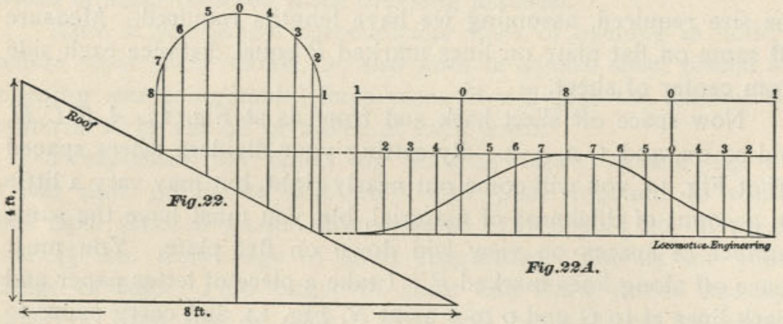


Fig. 22. Fig. 22A.

radius 15¼ ins. or 30½ ins. diameter of dome. Divide semi-circle into any number of parts, the more parts or spaces the more accurate will be your line of curvature. But four spaces, as on sketch, will answer all practical purposes, as at 1, 2, 3, 4, 0. Strike perpendicular as from 1 to 1, 2 to 2, etc., intersecting radius of boiler. Strike line on top of boiler parallel with center of boiler. The distance from where your perpendicular lines cut parallel line to radius of boiler, is the space to be added at corresponding numbers on flat plate. Now we roll up a plate to form a dome, with all edges square with each other, and put it on top of boiler at points marked 1 on Fig. 19. Square sheet at center of boiler, plumb the sides. Then you would find you were short of stock as from 1 to *s*. Now, suppose we set divider that distance and scratch a line on dome, by letting dividers follows a radius of boiler, we would have to cut dome away at 0, the distance from 1 to *s*, to make sheet fit boiler. Repeat with all

the numbers measuring from parallel line down to radius of boiler on the lines as numbered, and from parallel line down at flat plate at corresponding numbers; this will give you your line of curvature. Now you must allow for flange and laps all around your sheet and the plate is complete.

Fig. 20 shows method of finding shape of aperture, or dome hole, in plate when flat; you will note that hole is not round when plate is flat, but will be when rolled. *K H F E O* are the same distance apart as corresponding letters at Fig. 18. Fig. 19 shows plate when flat, laid out to form dome sheet. Inside diameter 30 inches, plate ½ in. or 30½; 30.50×31.416=95.95, or 96 ins. nearly. Divide this into four equal parts, as at 1, 0, 1, 0, 1. Sub-divide these quar-

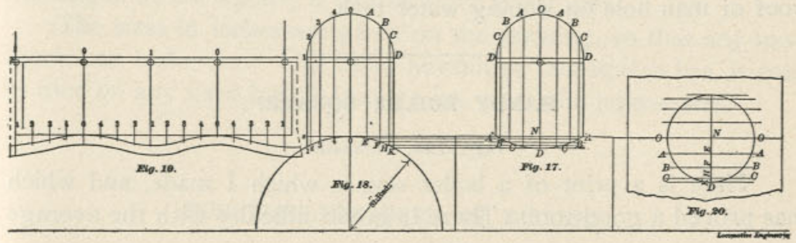


Fig. 19. Fig. 18. Fig. 17. Fig. 20.

ters into four parts or spaces, as at 1, 2, 3, 4, 0. Now, by setting your dividers at 1, Fig. 18, and marking the distance there on all where you are to locate dome. Set dividers from *N* to *D*, Fig. 20, mark distance from *N* to *N*, Fig. 20; do the same from *N* to *A*, on line marked *AA*. Do the same on lines *BB*, *CC*, *D;* this will form your aperture.

HOW TO LAY OUT BOILER WORK.

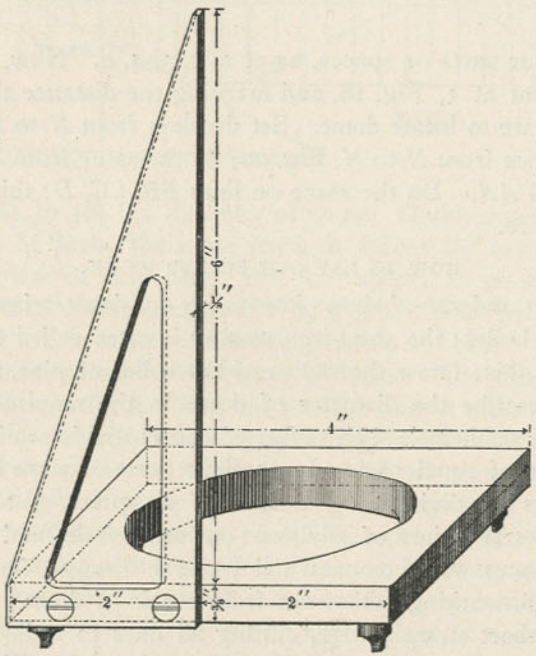
Figs. 21 and 22—*A* shows how to lay out dome, when placed on one side of boiler; the sheet-iron worker is often called on to make a piece like this: Draw the radius of the boiler or pipe, as the case may be; describe the diameter of dome in the required position, describe the semi-circle with radius of dome; divide semi-circle into any number of equal parts—I use eight parts—square lines down from points of division. I never use a square, but put small center marks at points of division on semi-circle and take distance of spaces with compass and transfer distance found to line marked *H* 8, working both ways from center of dome; then strike lines with short straight edge, cutting all lines to radius of boiler. Now, take the plate of which dome is to be formed as Fig. 21*A* and square plate to length required, allowing for laps at ends of plates. Strike a line the full length of sheet; distance from top of sheet must be the same as from 1 to *H* or 8 to 8, Fig. 21, and as at *BB*, Fig. 21*A*. Divide plate into four equal parts from center of holes at ends of plate; quarters are marked 1 0 8 0 1. Divide quarter into same number of parts as shown on semi-circle, Fig. 21. Now, by setting your compass at points marked 8-8, 7-7, 6-6, etc., and transferring lengths found at these points on Fig. 21 to points with corresponding numbers, Fig. 21A, or flat plate; this will give you your line of curvature. You must now allow for flange and your job is complete. The rule to lay out Figs. 21 and 22 is the same as shown in Figs. 18 and 19.

Figs. 22 and 22*A* are the methods I use for laying out jack for roof or man hole on sloping water tank.

HANDY BOILER SQUARE.

By Wm. Foster.

Here is a print of a boiler square which I made, and which has proved a good tool. There is great difficulty with the average



HANDY BOILER SQUARE.

mechanic in drilling holes in a boiler to get them central, and in putting valves in on the boiler circle unless they are central—they look bad—and if the tapping is not properly done, one-sided work is the result. Having seen a great deal of it, and realizing the difficulties, and seeing a number of styles of boiler squares, all imperfect, for the reason of the difference in the size of boilers, necessitating a different square for each size. To overcome all difficulties I made this square, which will enable anyone to drill holes and tap them central with the boiler. The sketch explains itself, the projecting feet on bottom being of equal length, when placed on the circle of the boiler, squares itself, as the tongue of the square is exactly in the center and square with the feet. Now if the tap is brought on a line with the tongue of the square, it will be right every time.

The sizes in inches are given on the drawing, so that any mechanic can make one. One other advantage this square has, it can be used on any sized boiler, from 10 ins. up to the largest size.

BURSTING PRESSURE OF BOILERS.

A subject which nearly all engineers and mechanics want to understand is how to figure out the bursting pressure of boilers. The following article makes the matter plain to all who can work the first four rules of arithmetic:

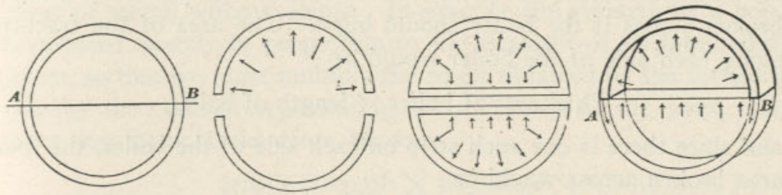


Fig. 1. Fig. 2. Fig 3. Fig 4.

BURSTING STRENGTH OF BOILERS.

Fig. 1 shows an end view of such a shell, with the thickness purposely exaggerated. Let us assume that when the shell bursts it will separate along the line *A B*, so as to come apart in the manner indicated in Fig. 2. Now, although the steam pressure acts perpendicularly to the curved shell at every point, as indicated by the arrows, yet, so far as blowing the two halves of the boiler apart is concerned, the effect is the same as though the steam pressure acted vertically against a flat plate equal to the boiler in length, and equal in width to the diameter of the boiler. To make this plain, let us consider Fig. 3, which shows each half of the boiler with a flat plate welded to it along its open side. Now, it is a matter of common experience that a structure like one of these halves will not move upward or downward when steam is admitted to its interior. That is, if it were put on a pair of scales the pressure of the steam against its inner surfaces would not make it weigh less or more than before. It follows, therefore, that the total upward pressure of the steam against the shell is precisely equal to the total downward pressure against the flat plate; the greater area of the curved shell being exactly compensated by the obliquity of the pressure against it.

Let us now consider Fig. 4. The total upward pressure of the steam against the upper half of the shell is equal, as we have seen, to the pressure against a flat plate, such as that shown in the cut, extending across the middle of the boiler. That is, it is equal to

Pressure per sq. in. $\times$ area of flat plate.

But the area of the flat plate is equal to the length of the boiler multiplied by its diameter, so that the total upward pressure, tending to blow off the upper half of the boiler, is equal to

Pressure per sq. in. $\times$ diameter $\times$ length.

This upward force is assisted by the strain on the boiler shell, as indicated by the arrows at *A* and *B*. The total strain on the shell is equal to the strain on 1 square inch of sectional area multiplied by the number of square inches of sectional area that would be broken across if the boiler should burst. The area of the fracture along each side of the boiler would be

Thickness of boiler $\times$ length of boiler,

and since there is one such strip on each side of the boiler, the total area broken across would be

$2 \times$ thickness $\times$ length,

and, therefore, the total strain at *A* and *B*, tending to hold the boiler together, is

$2 \times$ strain per sq. in. of section $\times$ thickness $\times$ length.

So long as the boiler does not burst, the force tending to blow it apart must be exactly equal to the force tending to hold it together; so that

Pressure per sq. in. $\times$ diameter $\times$ length $= 2 \times$ strain per sq. in $\times$ thickness $\times$ length.

This is equivalent to saying that

Pressure per sq. in. $\times$ diameter $= 2 \times$ strain per sq. in. $\times$ thickness.

And this, again, is equivalent to saying that

Pressure per sq. in. $\times$ radius $\times 2 = 2 \times$ strain per sq. in. $\times$ thickness.

That is,

Pressure per sq. in. $\times$ radius $=$ strain per sq. in. $\times$ thickness.

Now, when a boiler bursts, it does so because the strain on the shell has become equal to the tensile strength of the material; so that in this case our last formula becomes

Bursting pressure $\times$ radius $=$ tensile strength $\times$ thickness.

This is the ordinary rule for finding the bursting pressure of a cylindrical boiler, except that it is usually expressed in the following slightly different manner:

$$\text{Bursting pressure} = \frac{\text{tensile strength} \times \text{thickness}}{\text{radius}}$$

The bursting pressure of a boiler shell, therefore, is found by multiplying the tensile strength of the material in pounds per square inch, by the thickness of the shell in inches, and dividing by the radius in inches.

In this demonstration we have assumed the shell to be a solid sheet of metal, without joints. In practice the strength of a boiler is reduced exactly in proportion to the strength of its longitudinal joints, so that we must multiply the result obtained by the foregoing rule by the decimal representing the efficiency of the joint. The foregoing formula, therefore, becomes

$$\text{Bursting press} = \frac{\text{tensile strength} \times \text{thickness} \times \text{efficiency of joint}}{\text{radius,}}$$

which means that in actual boilers we find the bursting pressure by multiplying the tensile strength of the material by the thickness of the plate and by the efficiency of the joint, and then dividing by the radius.

In conclusion we shall give a few numerical examples of the use of the foregoing formula and rule:

Example 1.—What is the bursting pressure of a steel boiler (tensile strength 55,000 lbs.), 48 ins. in diameter and $\frac{5}{16}$ in. thick, with single-riveted longitudinal joints whose efficiency is 56 per cent.? Ans.—The radius of this boiler is 24 ins., so that the rule gives

Bursting pressure $= 55{,}000 \times \frac{5}{16} \times .56 \div 24 = 401$ lbs. per sq. in.

Example 2.—What is the bursting pressure of a steel boiler (tensile strength 55,000 lbs.), 60 ins. in diameter and $\frac{3}{8}$ in. thick, with double-riveted longitudinal joints whose efficiency is 70 per cent.? Ans.—The radius is 30 ins., and the rule gives

Bursting pressure $= 55{,}000 \times \frac{3}{8} \times 70 \div 30 = 481$ lbs. per sq. in.

Example 3.—What is the bursting pressure of a steel boiler (55,000 tensile strength), 66 ins. in diameter $\frac{3}{8}$ in. thick, with triple-riveted longitudinal joints whose efficiency is 75 per cent.? Ans.—The radius of this boiler is 33 ins., and the rule gives

Bursting pressure $= 55{,}000 \times \frac{3}{8} \times .75 \div 33 = 469$ lbs. per sq. in.

Example 4.—What is the bursting pressure of a steel boiler (tensile strength 55,000 lbs.), 72 ins. in diameter and $\frac{3}{8}$ in. thick, with double-welt butt longitudinal joints whose efficiency is 87.5 per cent.? Ans.—The radius is 36 ins., and the rule gives

Bursting pressure $= 55{,}000 \times \frac{3}{8} \times .875 \div 36 = 501$ lbs. per sq. in.

After we have found the bursting pressure, the safe-working pressure may be found by dividing the bursting pressure by a suitable factor of safety. We consider 5 to be the best factor of safety when all things are considered, though we sometimes allow $4\frac{1}{2}$ when the workmanship is known to be first class, and the materials of which the boiler is made have been carefully selected and tested. With a factor of safety of 5, the safe-working pressures in the foregoing examples are as follows: Example 1, $401 \div 5 = 80$ lbs.; in Example 2, $481 \div 5 = 96$ lbs.; Example 3, $469 \div 5 = 94$ lbs.; and in Example 4, $501 \div 5 = 100$ lbs.

BOILER EXPLOSIONS.

MASTER MECHANIC'S THEORY ON.

In a report on boiler explosions made to the Railway Master Mechanics' Association the sentence occurs: "Explosions occur from over pressure: it matters not whether the whole boiler or a portion is too weak to resist the pressure." That sentence was written in 1869, and all the years that have passed since that time with the vast experience gained concerning boilers, has corroborated the great truth expressed. At that time numerous wild theories were rife, to the effect that boiler explosions were frequently due to some mysterious agency that human care could neither provide against or control. The good sense displayed by the Master Mechanics' Association on this question did much to disseminate rational views concerning boilers, and very few people now believe there is more occult cause for the explosion of a boiler than there is for the breaking of a valve stem. We are sometimes asked to discuss theories concerning mysterious causes of boiler explosions, but we think it would be waste of printers' ink.

CAUSES THAT WEAKEN BOILERS.

We decline to publish irrational theories about boiler explosions, because they do not have a place in the gospel of sound engineering, and we are apprehensive of our readers falling into heretical beliefs on a subject so important to their worldly welfare. Our motto is: "Keep the steam gauge correct, do not meddle with the safety valves and see that vigilant inspection is made to detect broken stay bolts." It is a safe plan to see that there are two gauges of water in the boiler. Leaks about the boiler are evidence of weakness or decay, and the cause ought to be carefully examined. The usage to which a locomotive boiler is subjected in ordinary service is sufficient to bring about deterioration, which will have a destructive effect if not properly remedied.

THE BOILER BENDS IN SERVICE.

The frames of the locomotive are regarded as two girders, and are supposed to be strong enough to bear the weight of the boiler and all that is on it without yielding, but this is not entirely correct.

The boiler and frames are secured to each other by the expansion braces at the fire box end, the cylinders at the front end, and by belly braces at intermediate points along the barrel of the boiler. The boiler and frames being bound to each other in the manner they are, it is the supposition that that combination is self-sustaining, but such is not the fact, as the boiler itself indicates. Keen observers, who are responsible for the care of boilers, know that the boiler yields by its own weight when it receives heavy shocks. Where the belly braces are riveted to the barrel of the boiler, which has run any length of time, it will be found that around the edge of the rivets, inside the boiler, the sheets are grooved. Grooving is nearly always a result of sheet movement. If these braces are not riveted, but are brought up to the boiler so as to fit around the under side, the working of the engine will show the chafing of the braces on the boiler, indicating the resistance it must offer.

Another sign of destruction is the small cracks that take place in the upper side of the throat sheet. These are generally supposed to be effects caused by some obstruction to the expansion of the boiler. When the upper corner stay bolts and others next to the flange of the throat sheet are found leaking, it is evidence of the strain put upon them when the boiler bends up or down. There is some spring between the flange and these stay bolts, but little or none in the upper sides, where the cracks take place. This spot may be looked upon as the fulcrum of the lever, as it receives the direct crushing effect, alternating as the boiler bends. The weight of the barrel and its contents, with the cylinder bolted to the smoke box, acts like a weight on the end of the lever, keeping that end of the boiler down and binding it to the frames.

These destructive strains mentioned may be regarded as mechanical while at the same time there are still some serious strains caused by the unequal expansion and contraction, due to heating and cooling. We have heard it said that certain boiler explosions were due to the act of God, but as a rule the neglect of inspection and proper reports by the men in charge are the real origin of the disaster.

THE ENGINEER IS WRONGLY BLAMED FOR LOW WATER.

As a rule, injustice is done to the man in charge when a boiler explodes. A worn out boiler, that has received no systematic inspection or repairs, but has held together with mysterious persistency, goes to pieces one day, and all those who are really responsible for the death trap being where it could do harm, shout with one accord: "The water must have been low." This cry of low water is nearly always raised as a fog to hide the real culprit. Hot plates are weaker than cool ones, and boiler explosions have resulted from overheated furnaces; but cases of this kind have been very rare compared to those that have resulted from broken stay bolts and corroded sheets.

PROGRESS OF DETERIORATION.

There is some excuse for people thinking that something mysterious must have been at work to tear a boiler into pieces. The boiler has been working under the same pressure day after day without showing any signs of distress, and it suddenly goes to pieces without any warning. That seems strange when the whole

particulars of the case are not properly understood. Although no weakness has been apparent, there have been stay bolts breaking gradually, or there may have been a crack on the edge of a seam, working deeper and deeper with every infinitesimal bend due to change of pressure or physical shock. A time comes when the stayed surface or the cracked plate becomes too weak to resist the pressure within, and the explosion is too sudden to give warning. The people sometimes found, who allow a leaking hollow stay bolt to be plugged, or who patch a crack without finding out the extent of the weakness, criminally neglect fair warning.

FAILURES OF MECHANISM.

Unexpected and inexplicable failures or breakages are quite common in all lines of industry, but they do not attract so much attention as boiler failures because the effects are not so destructive or conspicuous. A link in the chain of a crane breaks under a lighter load than it lifted two hours before. A crank shaft breaks, not with the engine working at its maximum power or speed, but under comparatively light duty. A locomotive axle breaks when the engine is jogging along at a quarter of the speed made the day before and sustaining much lighter shocks. Every man familiar with the handling of tools or familiar with appliances subject to shocks and severe strains, remembers cases of unaccountable breakage. These things are strange, but few people believe that Satan or some other evil power had a hand in the failure. They are not sufficiently striking to engender susperstition. It is only when a boiler explodes that mysterious agencies are thought of. The most careful investigation may fail to identify the broken stay bolts, the cracked sheet, the corroded seam or brittle plate, but those who are given to reasoning between cause and effect will certainly abide in the faith that one of these or some other natural cause has brought the boiler to grief, for the weakest point measures the strength of any apparatus or boiler.

EXPLODING BOILERS FOR KNOWLEDGE SAKE.

A series of experiments with boilers were made by the United States Government years ago that gave very valuable data about boiler explosions. One of the experiments was with flat-stayed surfaces that would very well represent side sheets or crown sheets secured by stay bolts. Heat was applied with plenty of water over the heating surface until the vessel exploded from over pressure. Dr. Coleman Sellers, who was present, describing this explosion, wrote: "It was fired up, and when the steam reached 125 pounds we left the boiler and retired to a safe place. In about five minutes, with about 180 pounds gauge pressure, it exploded. The sheets went out in the form of dishes, each part where the stay bolt was presenting an indentation like a mattrass. Every stay bolt was drawn out of its hole. No stay bolt was injured in the slightest degree on its thread, but every hole, from which a stay bolt was drawn, was enlarged sufficiently to allow the stay bolt and its head to come out."

This is information worthy of consideration by people who act as experts before the courts when boiler explosions happen. The writer was present at a law suit once over an exploded boiler, and the attempt was made to prove that the accident was caused by low water. We heard several so-called experts testify that the sheets must have been hot because the stay bolts were pulled through the sheets without tearing off the threads.

LOW WATER SELDOM CAUSES EXPLOSIONS.

The belief exists among many people that a boiler will not explode so long as it contains a good supply of water. Properly conducted experiments have repeatedly disproved the correctness of this theory. An easily made experiment is: Take a piece of steam pipe 3 ins. diameter and 3 ft. long. Screw a steam tight cap on one end and put water in the pipe till it is two-thirds full. Then drive a pitch-pine plug into the other end until it is within 3 ins. of the water, giving room for expansion. Put the pipe on a bright fire and get out of the way, for an explosion will follow in a few minutes. If all the water was converted into steam there would be no violent explosion. The violence of a boiler explosion is directly in proportion to the amount of water ready to flash into steam when a rupture is made great enough to suddenly release the pressure.

INJECTING WATER UPON HOT SHEETS.

Another unfounded belief about steam boilers is that injecting feed water upon heated plates is likely to cause an explosion. Iron and steel boiler plates do not act that way, although a hot cast iron plate might crack when quenched with water. If a piece of iron or mild steel is made red hot and quenched in the coldest water it will be annealed instead of cracked. For this reason there should be no hesitation in putting on the feed when the water in a boiler is found to be low. The most harm that can be done will be

that the sudden shrinkage of the sheets will cause the seams to leak.

The Pennsylvania Railroad Company, years ago, carried out a series of experiments with locomotive boilers that prove most of the statements made. A locomotive which was condemned to be scrapped, was run out on a side track in the woods near Altoona, and experiments made upon it. The plan was to fill the boiler with water, raise a high pressure of steam, then run off the water until the crown sheet was exposed, permit it to become red hot and then pump cold water into it, to find out the effects. In the first experiment the boiler exploded before they had time to blow off any of the water. They then took another old engine whose boiler stood the steam of unusually high pressure. After steam was raised the water was drawn off until it was below the crown sheet. They waited long enough for the crown sheet and the upper part of the fire box to become red hot, then they forced a supply of water into the boiler by means of a powerful fire engine, and nothing happened except that the seams leaked and the steam went down. This was repeated several times, always with the same result. The boiler was damaged by the overheating, but no accident happened.

COMPOUND LOCOMOTIVES.

COMPOUND ENGINES.

FIRST COMPOUND ENGINE.

When thoughtful men studying the operation of the steam engine noted the high proportion of heat wasted by passing out of the cylinders in the form of exhaust steam, they naturally asked the question. Is it not possible to make use of the energy represented by this exhaust steam? The stationary steam engine had not been long in use when a practical attempt to utilize the exhaust steam was made in the invention of a compound engine. That was in 1781, and the inventor was Jonathan Hornblower, whose patent claim reads: "I employ the steam after it has acted in the first vessel (cylinder), to operate a second time in the other, by permitting it to expand itself, which I do by connecting the vessels together and forming proper channels and apertures, whereby the steam shall occasionally go in and out of the said vessels."

CAUSE OF FAILURE.

As the boiler pressure in those days seldom exceeded 10 lbs. to the square inch, there was very little heat loss prevented by expanding the steam through two cylinders; in fact the cylinder condensation resulting from the increase of cylinder area operated through wasted steam, and so the first compound engines were failures, although the principle which the inventor tried to work out was based on sound engineering.

Although Hornblower's attempt to improve the steam engine was not a success, he had pointed in the direction of advancement, and his discernment of possibilities led his successors to work in the same line. During the first half of last century many compound engines were built, and they became noted for their durability, which was due to the strains of action being more evenly

distributed than they are in simple engines; but there was no decided economy in the use of steam in the compounds built in Europe during the first half of last century, which was due to the low boiler pressure in vogue. American engine builders used considerably higher boiler pressure than what prevailed in Europe, and they had it in their power to make compound engines that would effect saving of steam.

FIRST AMERICAN COMPOUND ENGINES.

As early as 1825, James P. Allaire, of New York, built compound engines for marine service that gave a horse power on less steam than any engines that ever had been worked up to that time; but American marine engineers were prejudiced in favor of the light, high-pressure, high-speed engines that had become the national type, and Allaire's ingenuity, skill and enterprise did nothing to convince the engineering world that the compound had the inherent right to become the steam engine of the future.

ELDER'S SUCCESS.

In 1854 the forerunner of the successful compound engine was built under the direction of John Elder, a member of a well-known ship building firm in Glasgow. Elder was a leading spirit among a group of Scots mechanical engineers, who were laboring to lead their profession away from beaten paths into new fields of enterprise. He was an accomplished engineer and an industrious investigator into the peculiarities of heat phenomena, which guided him on the safe way to work out improvements on the marine engine, then doing its work on a coal consumption of about 6 lbs. of coal per horse power per hour. Elder perceived that the compound engine had proved itself more efficient than the single-cylinder engine, only when the pressure of steam carried and the extent of expansion exceeded the practice customary at that time. Following the obvious teaching of this fact, he applied high steam pressure and a high ratio of expansion to well-designed compound engines, and reduced the coal consumption from about 6 to 3¼ lbs. per horse power per hour. As boiler pressures were still further increased and various improvements effected on the mechanism, the coal consumption was steadily reduced till now, with quadruple expansion engines very little more than one pound of coal produces a horse power.

The change introduced by Elder was the greatest improvement effected on the steam engine since the separate condenser was applied, and made possible the high speed now common with steamboats.

UNREASONING OPPOSITION TO COMPOUND ENGINES.

When the compounding of marine engines was demonstrated to be a fuel reducing operation, the principle was gradually extended to stationary engines; but the improvement was effected very slowly. The introduction of the compound engine excited surprising opposition. The opponents of the change acted more like politicians eager to defend the spoils of office, than like business men considering the merits of an engineering problem. The cost of power is, however, such an expensive element in manufacturing, that an engine capable of cutting the coal accounts in two was bound to make its way and so the compound itself conquered all opposition.

WHY COMPOUND LOCOMOTIVES CAME SO SLOWLY.

The owners of locomotives and the men having charge of railway motive power, were by no means precipitate in trying to secure the benefits that others had derived from the use of compound engines. There were good and sufficient reasons for this. The simplest form of a compound locomotive added some parts to the simple engine, and moved by the lessons that come from long experience railway motive power men have been a unit against complexity in locomotives. They understood that a compound locomotive that failed to take out and in trains as regularly as simple engines would be unsatisfactory, no matter what saving of fuel they might effect.

FIRST SUCCESSFUL COMPOUND LOCOMOTIVE.

Attempts were made by various inventors to produce a compound locomotive even before the compound marine engine was made a decided success; but they were all commercial failures until Anatole Mallet, a French engineer devoted himself to working on the problem. In 1876 the Bayonne & Biarritz Railway Company had two locomotives built according to Mr. Mallet's designs. They were small experimental engines, but they were the seed that produced the abundant crop of compound locomotives found all over the world to-day.

FIRST CROSS COMPOUND.

The first railway official to follow Mr. Mallet's lead was Mr. Von Borries, mechanical superintendent of the Hanover Railway, who built a number of compound locomotives modified in various details to meet his own views. This was followed by Mr. T. W. Worsdell, locomotive superintendent of the Great Eastern Railway of England, who designed and applied an intercepting valve that became a pattern for other designers of two-cylinder compound locomotives. The leading features of the Worsdell compound locomotives were a single high-pressure and a single low-pressure cylinder connected to cranks set at right angles, with a cylinder ratio of about 1 to 2. Slide valves were used to cut off steam at the points considered most desirable for economical working. A receiver intervened of about the capacity of the high-pressure cylinder, and it was located in the smoke box, with the view of having the steam heated by the smoke-box gases. This type of compound has come to be called cross compounds in the United States.

WEBB'S COMPOUND.

Two years after the Mallet compounds were put into service, Mr. F. W. Webb, locomotive superintendent of the London & Northwestern Railway, built a two-cylinder compound, following Mallet's lead, and it was found to work satisfactorily. Mr. Webb is a man of such strong personality that he could not be satisfied to imitate any design of a railway appliance, so he brought out a three-cylinder compound with one inside cylinder acting as low-pressure cylinder for two outside high-pressure cylinders. The influence of the inventor was sufficient to put a great number of these engines into service, and in 1889 the Pennsylvania Railroad Company imported one of these engines to find out how well it was adapted to the hauling of trains in the United States. The engine was by no means a success, but it seemed to introduce among us a prejudice in favor of compound locomotives, which created a demand that was readily supplied. It is not necessary to enter into details of the history of compound locomotives in the United States. I shall only comment on the reasons why a compound locomotive should do a certain amount of work with less fuel than a simple engine.

PRINCIPLES OF STEAM ENGINEERING.

The fundamental purpose of all improvers of the steam engine has been to convert an increased proportion of the heat energy of the steam that passes from the boiler into the mechanical energy available for performing useful work. An axiomatic principle recognized by all engineers conversant with thermo-dynamics is "The higher the temperature of the steam when it enters the cylinder and the lower that which it reaches before the exhaust occurs, the greater will be the efficiency of the engine, if the reduction of temperature has been caused by the conversion of heat into useful work." The engine that will best perform this function, transforming the energy of heat into useful work, will in the end prove most efficient.

Locomotive improvers have adhered very closely to a certain sound principle in steam engineering and generation after generation have moved in cycles, working on the problem of admitting the steam quickly into the cylinders at near boiler pressure, cutting it off at the shortest point consistent with the work to be done, and expanding it as low as practicable before opening the exhaust. That is, they do their best to provide for the maximum expansion of steam in the ordinary cylinders. Mr. D. Kinnear Clark, the eminent engineer, who wrestled long with investigations into the most economical methods of operating locomotives, came to the conclusion more than half a century ago that "expansive working was expensive working"; yet his discoveries did not deter others from laboring to perfect means for admitting and cutting off steam quickly, with a view of obtaining a high ratio of expansion in locomotive cylinders; but the labors in this direction have uniformly resulted in disappointment. Clark, who first demonstrated that a high ratio of expansion in locomotive cylinders was not conducive to economy, discovered and explained the cause, and at the same time furnished a rational solution of the difficult question, why a compound engine providing for a higher ratio of expansion than a simple engine might yet be more economical.

CYLINDERS ACTING AS CONDENSER AND BOILER.

This discovery was to the effect that the cylinder of a steam engine acted alternately as a condenser and as a boiler, condensing a portion of the steam during admission and revaporizing the resulting water of condensation during the period of expansion and exhaust. This is due to the interaction of the metal of which the cylinders are made, and is inevitable with material that forms a good conductor of heat. When the steam becomes water in the cylinder it loses its power to do mechanical work; therefore, the percentage of steam that condenses, through the interaction of the cylinder metal represents so much loss of power. A portion of the steam condensed becomes spray and helps to dampen the steam entering the cylinders, vitiating its capacity for doing work.

This may appear to be a fine-spun theory to those who have not studied steam matters closely; but it is a theory founded upon the discoveries of highly practical men. The serious heat losses that occur in the steam engine through cylinder condensation and re-evaporation are well known and acknowledged by the best authorities. They have been as clearly proved as anything belonging to steam engineering; yet few railroad men act as if they realized the importance of the matter. There are probably few locomotives that lose less than 25 per cent. through condensation of the steam used. Locomotive cylinders are more exposed to refrigerating influences than the cylinders of any other form of engine, yet very little attention is given to keeping them protected.

WHY A COMPOUND ENGINE SAVES STEAM.

An impression prevails that steam is saved in a compound engine because it is used in more than one cylinder, thereby utilizing as much as possible of its expansive properties. That increase of expansion would probably cause actual loss through excessive cylinder condensation were it not that extremes of temperature are prevented by using two or more cylinders, giving a low average pressure in each. Take, for instance, the cylinder of a simple engine using steam at 200 lbs. gauge pressure. That steam has a temperature of 381.6 degrees Fahr. on entering the cylinder, and it would drop to about 25 lbs. gauge pressure when the exhaust was open. The temperature of the latter pressure would be about 240 Fahr., a difference of 141.6 degrees. The cylinder metal would naturally drop toward the temperature of the exhaust steam, making it ready to condense the incoming steam at the return stroke. That same steam used in a compound cylinder would, in ordinary working, be exhausted into the receiver or into the low-pressure cylinder at a pressure of about 70 lbs. pressure, making the extremes of temperature from 381.6 to 303, a difference of only 78.6 degrees, as compared with 141.6 degrees. The changes of temperature in the low-pressure cylinder are comparatively small for the steam will pass in at about 300 degrees Fahr. and be exhausted at about 240 degrees, a drop of about 60 degrees, which is comparatively small.

Another advantage gained by the compound in the use of steam is that part of the condensed vapor passing out with the exhaust steam is re-evaporated by drawing heat from the cylinder walls or by what is called the interaction of the cylinder metal, and becomes real steam. In a simple engine that regenerated steam passes out with the exhaust or helps to increase the back pressure; in a compound it passes into the low-pressure cylinder and does useful work.

DESCRIPTION AND DIRECTIONS FOR OPERATING THE CROSS COMPOUND LOCOMOTIVE AS BUILT BY THE AMERICAN LOCOMOTIVE COMPANY, SCHENECTADY WORKS.

With the arrangement of valves shown in Plates 1 and 2 the engine can be started and run either compound or simple, and can be changed from compound to simple, or from simple to compound, at the will of the engineer.

General Description.—As the throttle is opened, steam from the boiler, through the dry pipe, is admitted directly to the high-pressure steam chest, and at the same time to chamber E, surrounding the reducing valve L, Plates 1 and 2.

The exhaust from the high-pressure cylinder, by means of the receiver pipe, passes to chamber surrounding the intercepting valve, and thence to the low-pressure steam chest when working compound, intercepting valve in position shown on Plate 2, or to the atmosphere, through separate exhaust valve and stack, when working simple, valve in position shown on Plate 1.

The low-pressure exhaust passes directly to the stack at all times.

The intercepting valve opens and closes the connection between the two cylinders.

The separate exhaust valve opens and closes the connection between the high pressure cylinder and the atmosphere.

The function of the reducing valve, which operates only when the engine is working simple, or starting, is to control the admission of steam from the boiler to the low-pressure cylinder, in order that the pressure of steam admitted to the low-pressure cylinder shall have the same ratio to the steam in the high-pressure cylinder as the volume of the high-pressure cylinder is to the volume of the low-pressure cylinder.

The oil dash pot insures a steady movement of the intercepting valve without shock.

The intercepting and reducing valves operate automatically by means of the steam pressure acting on the difference of areas of the ends of the valves. The movement of the reducing valve is cushioned by the small air dash pots shown. The separate exhaust valve is operated by the engineer, by means of a three-way cock in the cab. To open the separate exhaust valve the handle of the three-way cock is moved to the position provided for admitting pressure against the piston A, Plate 1. Moving the handle in the opposite direction relieves the pressure against A and the spring, which is shown in the figures, shuts the valve. The separate exhaust valve can be so connected as to operate either by air or steam.

OPERATION.

Starting Simple. Plate 1.—The handle of the three-way cock in the cab is moved by the engineer so as to admit pressure through the pipe D against the piston A, forcing it and the valves B and C to the position shown on Plate 1. As the throttle is opened steam is admitted directly from the boiler into the passage E, forcing the intercepting valve into the position shown (Plate 1), thence the steam passes through the intercepting valve by the ports K K, and the passage G G, through the reducing valve to the low-pressure steam chest; at the same time steam from the boiler is admitted directly, by means of the steam pipe, to the high-pressure steam chest. The exhaust from the high-pressure cylinder passes to the atmosphere by means of the receiver passage H and the separate exhaust valve B. Steam from the low-pressure cylinder is exhausted directly to the atmosphere.

To Change from Simple to Compound. Plate 2.—Having started simple, to change to compound, the handle of the three-way cock in cab is turned so that pressure is released from the piston A. The separate exhaust valve will then be closed by the spring I. The pressure in the receiver, due to the exhaust from the high-pressure cylinder, will rise and force the intercepting valve to the left, that is, to the position shown in Plate 2, thereby opening the passage for the exhaust steam, from the high-pressure cylinder, through the receiver, to low-pressure steam chest. The movement of the intercepting valve, to the left, also closes the passage G G, thereby shutting off the admission of steam directly from the boiler to the low-pressure steam chest.

Starting Compound.—To start the engine compound the separate exhaust valve is left closed as in Plate 2. As the throttle is opened the steam pressure in the passage E will force the intercepting valve to the right or to the closed position, at the same time steam directly from the boiler will be admitted to low pressure steam chest through ports K K and passage G G. The high-pressure cylinder will exhaust into the receiver until the pressure is sufficient to force the intercepting valve to the left as shown in Plate 2, when the engine will work compound. The change to compound working takes place at from one-half to three-quarters of a revolution of the driving wheels.

Compound to Simple.—With the engine working compound,

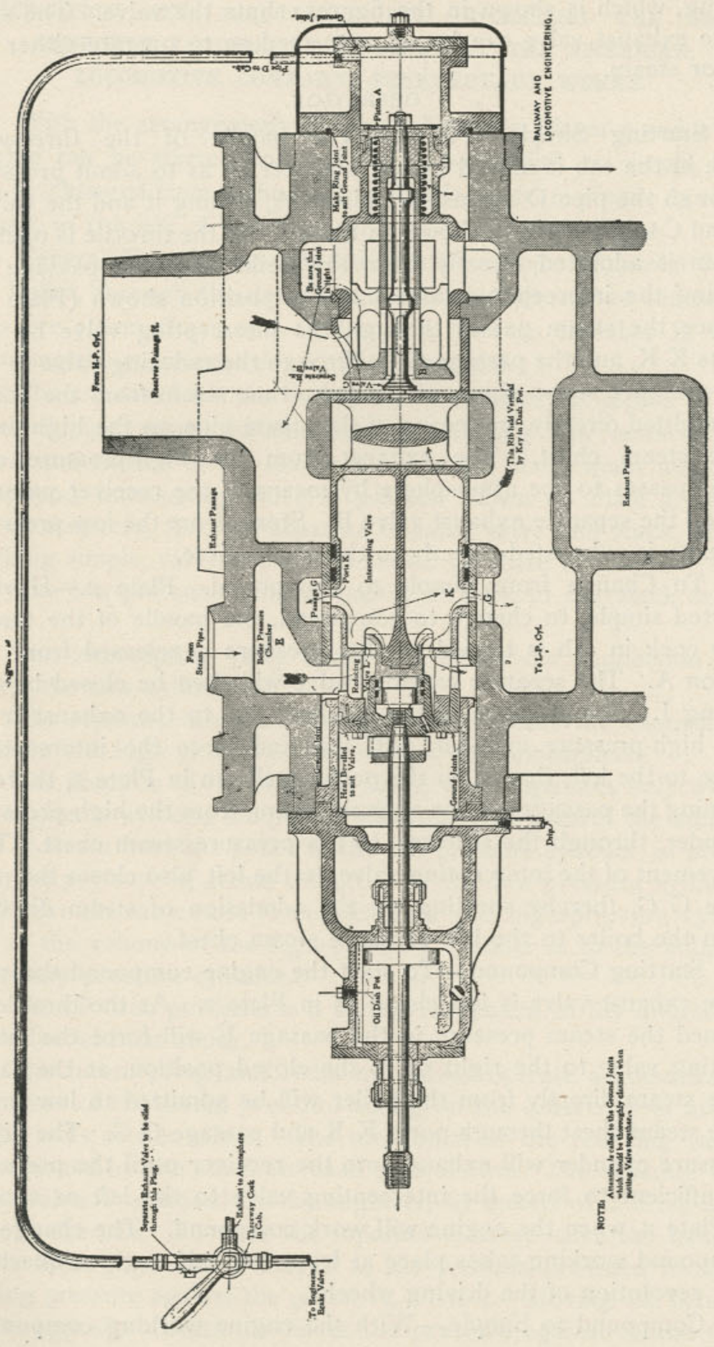


PLATE I.

if the engineer wishes to run the engine simple to prevent stalling on a heavy grade, the handle of the three-way cock should be placed in same position as for starting simple. This opens first the small bleeding valve C, Plates 1 and 2, and then the separate exhaust valve. The bleeding valve relieves the pressure and thus permits the main valve B to be operated more easily. As soon as the separate exhaust valve is open, the pressure in the receiver drops and the intercepting valve is forced against the seat to the right, by means of the pressure in chamber E, and the engine works simple as before. Engines should be worked simple no longer than absolutely necessary.

Lubrication.—A pipe from the sight feed lubricator located in the cab leading directly to chamber E is provided, by means of which both the intercepting and reducing valves are lubricated. One drop per minute is sufficient for these parts. A small oil cock in three-way cock located in cab, provides for lubricating the separate exhaust valve and attendant parts, and oiling once a day with a small quantity of cylinder oil provides sufficient lubrication.

When using steam it is good practice to feed about two-thirds of allowance of cylinder lubrication to H. P. cylinder. When drifting down long grades this should be reversed on account of the larger surface to be lubricated on L. P. side. Always run with lubricator steam valve wide open.

By-Pass Valves.—Some of the compound locomotives recently built are equipped with by-pass valves, provided to admit of engines drifting more freely. These valves, more particularly on the low-pressure side, should be examined occasionally, by removing the cap, to insure that they are in good working order. On new engines the by-pass valves should be cleaned frequently, as their free movement is liable to be hindered by gumming or the presence of core sand.

Should a by-pass valve become broken or in any way defective, take off the valve body and insert a blind gasket between it and the cylinder.

Carrying Water.—Most of the later compound locomotives are equipped with piston valves, and it is very necessary that the cylinders should be kept free from water. Great care should be taken to open cylinder cocks when starting and before opening throttle after drifting down grade. Careful attention should also be given to avoid carrying water too high in boiler. Carrying water high in the boiler, and thus causing wet steam in cylinders,

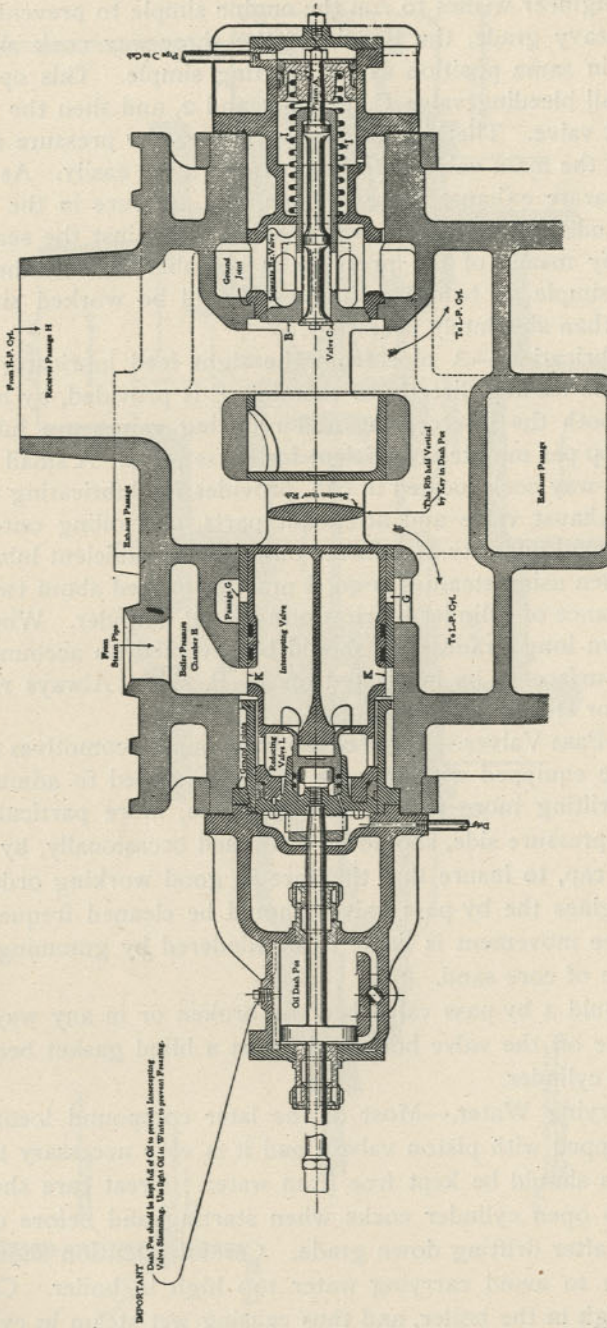


PLATE 2.

is injurious to compound locomotives, no matter whether slide valves or piston valves are used.

Oil Dash Pot.—This should be kept full of oil to prevent intercepting valve from slamming. Breakages of intercepting valves are nearly always due to neglect of this rule.

Dash pots should be filled with common car or engine oil, thinned with kerosene when necessary, in winter.

The dash-pot stuffing boxes should be kept packed, to avoid leakage of oil.

Drifting.—In drifting the three-way cock should be in simple position whenever it can be done without too much loss of air by leakage of separate exhaust valve or piping. Most of the recent compound locomotives are provided with a small drifting valve, in main throttle valve so arranged that it can be opened with a slight movement of the throttle lever. It is considered good practice to admit a little steam to cylinders when drifting, through this valve, or, if not provided with a small drifting valve, by a slight opening of main throttle.

Examination.—Enginemen should ascertain if separate exhaust valve is in good working condition before starting out with train by trying the engine simple and compound before coupling to the train. The separate exhaust valve should be examined at intervals so that the spring and other parts are kept in proper condition. Should the engine refuse to move after the throttle is opened it will usually be found that it stands on center on high pressure side (in position to take steam on low pressure side) and it will be due to either the intercepting or reducing valve sticking, which is always the result of lack of lubrication for intercepting valve, or carrying too much water in the boiler. Which of these valves are sticking can be ascertained from the position of the intercepting valve stem. In starting the engine if the intercepting valve stem extends clear out about seven inches it would be the intercepting valve, and unless some of the ports are broken a slight tap on the end of the stem, with throttle open, would send it ahead. If it was found that the stem had already moved ahead so that it extended out about three inches it would be the reducing valve. Usually one or two sharp blows on intercepting valve back head with throttle open, will loosen it. In either case live steam would then be admitted to low-pressure cylinder for starting.

Should the engine refuse to work compound after the three-way cock had been placed in compound position, and continue to work as a simple engine, it would indicate that the separate exhaust had not closed. This trouble can usually be traced to enginemen using engine oil for lubricating separate exhaust valve chamber, and can sometimes be overcome by a dose of kerosene, which should in all cases be followed up with valve oil.

Relief Valves.—Combined pressure and vacuum relief valves on low-pressure steam chest and single-pressure relief valves on low-pressure cylinder heads should be set at 45 per cent. of the boiler pressure, and the high-pressure cylinder-head relief valves set at twenty pounds above boiler pressure.

Dampers.—Dampers should be closed when drifting down long grades.

BREAKDOWNS AND LOCATING BLOWS ON TWO-CYLINDER TYPE OF COMPOUND LOCOMOTIVES.

Disconnecting.—In case of break downs the engine can be disconnected as readily as a simple engine. Should the high-pressure side become disabled, disconnect, block, cover the ports, and open separate exhaust valve same as when running simple. Should low-pressure side become disabled, disconnect, block, cover the ports, and open separate exhaust valve.

In case the engine should be without air for the operation of separate exhaust valve a block, preferably of wood about three inches thick, should be inserted in the valve cylinder by the removal of the head and the latter again replaced over the block.

To locate blows or leaks through the valves or cylinder packing on the two-cylinder type of compound locomotives, precisely the same manner of procedure is followed as on a single-expansion engine. These tests should be made when the cylinders are warm, well lubricated, running slowly, and engine working as a single expansion.

In case of breakdown, if it is necessary to run in on one side, the engine can be disconnected as readily as a single-expansion engine and in exactly the same manner; the main rod should be taken down, cross head blocked and valve placed in central position to cover all ports.

In all cases, regardless of which side is disabled, the intercepting valve must be in the position to allow the engine to work as a single-expansion engine.

All the different makes of compound locomotives are so arranged that live steam can be admitted to the low-pressure cylinder, so that the power may be increased for starting trains, and to keep them moving on grades, where a single-expansion engine

would stall. This feature on the Vauclain compound is governed by the starting valve and has been previously referred to. On the two-cylinder type of compounds, this feature is controlled by the movement of the intercepting valve. One position of this valve allows the live steam to enter the low-pressure cylinder and the engine to work as a single-expansion engine. If the position of the valve is reversed it closes the opening for live steam to the low-pressure cylinder, and opens a passage that allows the exhaust steam from the high-pressure cylinder to enter the receiver and the low-pressure cylinder.

The movement of this intercepting valve is at all times under the control of the engineer by a small lever in the cab, and by the movement of this lever the engine can be made to work single expansion or compound at any part of the stroke.

From the fact that this method of using live steam in the low-pressure cylinders is to be found on all makes of compound locomotives, the engineer has therefore the same duties to perform when operating any class or make of these locomotives; he should be careful not to abuse the engine by carelessness in handling the starting valve, or the intercepting valve, as the economy of fuel and maintenance depends in a large measure on the proper use of these valves.

BLOWS IN TWO-CYLINDER COMPOUND LOCOMOTIVES, SCHENECTADY AND RHODE ISLAND SYSTEMS.

Blows in two cylinder compound engines are developed through wear of packing rings in intercepting valve and separate exhaust valve, and in rings of the piston valve and cylinder packing. To determine if intercepting valve is blowing, place right hand crank on upper quarter, and reverse lever in center of sector, bringing main valve central over its ports. Intercepting valve to be closed and separate exhaust valve open, as when starting simple; if intercepting valve blows, steam will pass through separate exhaust valve and appear at exhaust nozzle. There is no way to visibly detect a blow in the Rhode Island intercepting valve. If such a blow exists the steam passes to the low pressure steam chest, whether working simple or compound.

To test piston valve, place crank on upper quarter on side tested, and reverse lever in center of sector. The valve being on center of its seat and covering both steam ports, will show steam at one or both cylinder cocks if rings are blowing. This test applies to valves of either outside or inside admission. To test cylinder packing rings, leave crank on upper quarter, and place reverse lever in full forward or back gear, opening either steam port full. If packing rings blow, steam will appear at cylinder cocks. If piston valve packing blows on high pressure side, the effect is to let steam through the exhaust port into the receiver, and also to the opposite side of piston. If cylinder packing of high-pressure piston blows, the effect is to let steam pass to the opposite side of piston and out through exhaust port into receiver. Blows in piston-valve rings or cylinder-packing rings have no effect on the operation of by-pass valves for the reason that steam-chest pressure is always greater than the wire-drawn pressure due to blows.

The separate exhaust valve remains stationary when running except as actuated by pressure on its piston to open, or tension on its spring to close. If spring in separate exhaust valve is weak, the result will be closed by receiver pressure. This action applies to the Schenectady compound. The separate exhaust valve of the Rhode Island compound, in case the spring is too weak to close the separate exhaust port, will be forced open by the receiver pressure when working compound, diverting the exhaust from low-pressure steam chest to exhaust pipe and engine will work simple.

DESCRIPTION AND DIRECTIONS FOR OPERATING TANDEM COMPOUND LOCOMOTIVES, BUILT BY THE AMERICAN LOCOMOTIVE COMPANY.

Cylinders.—The general arrangement of cylinders and of pistons and valves is shown in Fig. 1, in which the high-pressure cylinder is forward of the low-pressure cylinder, with both pistons on the same rod. The steam chest is common to both high and low-pressure cylinders, being open from end to end and serving the purpose of a receiver.

The valves are hollow and permit an unrestricted flow of steam through the steam chest. There being no receiver pipe on these engines, the smoke box is fitted up with steam pipes and exhaust pipe exactly the same as in simple engines.

Piston Valves.—On the high-pressure cylinders the valves are arranged for internal admission, and on the low-pressure cylinders for external admission. An examination of Fig. 1 will show that this design of valves allows steam to be admitted to the same side of each piston by means of the crossed ports on the high-pressure cylinder, the valves being shown as admitting steam.

Low-Pressure Cylinders.—The saddle and cylinders are shown in Fig. 2 in front view and vertical section, in which the coring is shown for steam and exhaust passages. The saddle has an opening cored into the steam-pipe passage, extending from front to back on each side, where there is a circular flange for connection to the short length of steam pipe which extends from front of saddle to the high-pressure cylinder. Coring this passage through from end to end of saddle makes the cylinders interchangeable for use on either side.

Starting Valve.—To work the engine, simple or compound,

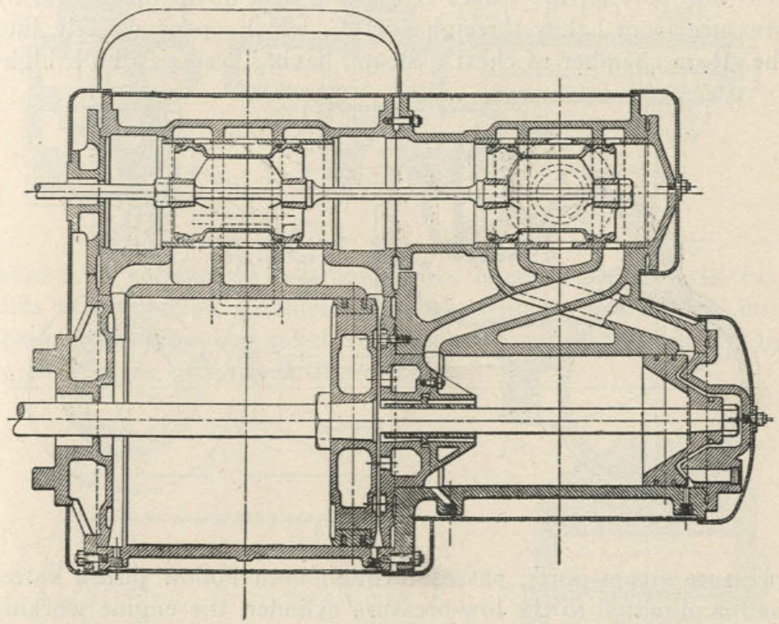


FIG. 1

at will, the starting valve shown in Fig. 3 is used, this valve being secured to the side of steam chest over the high-pressure cylinder, and having direct communication with the steam passages into that cylinder. The by-pass valves for the high-pressure cylinders are also contained in the casing of this starting valve and are worked in connection with the latter.

By-Pass Valves.—For the purpose of relieving the low-pressure cylinder of excessive pressure when working steam, or freeing the same cylinder from back pressure when drifting, the bypass valves shown in Fig. 4 are used. These by-pass valves are bolted to the side of the steam chest near each end of low-pressure cylinder, and furnish communication between the steam chest and steam ports in cylinder.

Operation Working Simple.—To start the locomotive simple —that is, to admit live steam directly to the low-pressure cylinders —the starting valve A is placed in position shown in Fig. 3 by means of a lever in the cab. Steam is admitted to high-pressure steam chest through the short steam pipe connecting saddle and chest, and passes through ports D and H, which register with the high-pressure steam ports in steam chest. From D the steam is admitted to ports E and G, and passes around the by-pass valves B B into port H, the valves B B being held up to their seats by pressure from below through port C, which opens directly into the steam chamber of chest. Steam, having access to both high-

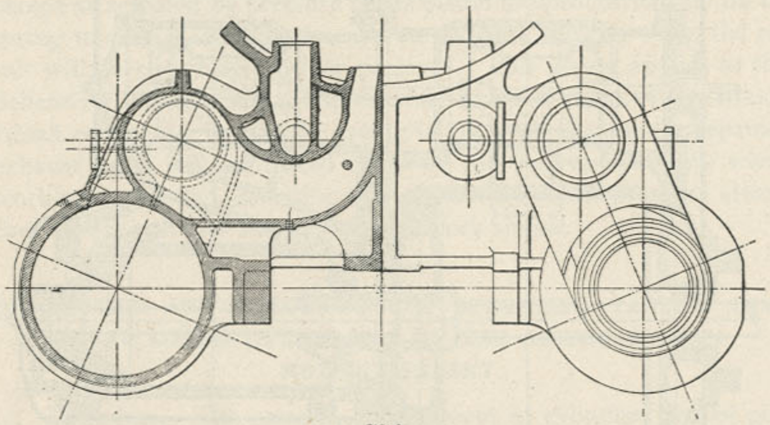


FIG. 2

pressure steam ports, passes through both hollow piston valves and is admitted to the low-pressure cylinder, the engine working as a simple locomotive.

Working Compound.—When working compound, the starting valve A in Fig. 3 is brought to lap on port E, shutting off high-pressure steam from its passage into the low-pressure end of steam chest. Under these conditions no steam can reach the low-pressure cylinder, except from the exhaust of the high-pressure cylinder.

Drifting.—When drifting or not working steam, the by-pass valves B B in Fig. 3, being in a vertical position, fall away from their seats by gravity and give a clear opening between the two ends of the high-pressure cylinder. The by-pass valves in Fig. 4 for the low-pressure cylinders are also in a vertical position, and are held to their seats by the steam-chest pressure when working

steam. When running with closed throttle, the by-pass valves (Fig. 4) are raised from their seats by any pressure on the lower side, assisted by the spring under valve. With the valves raised

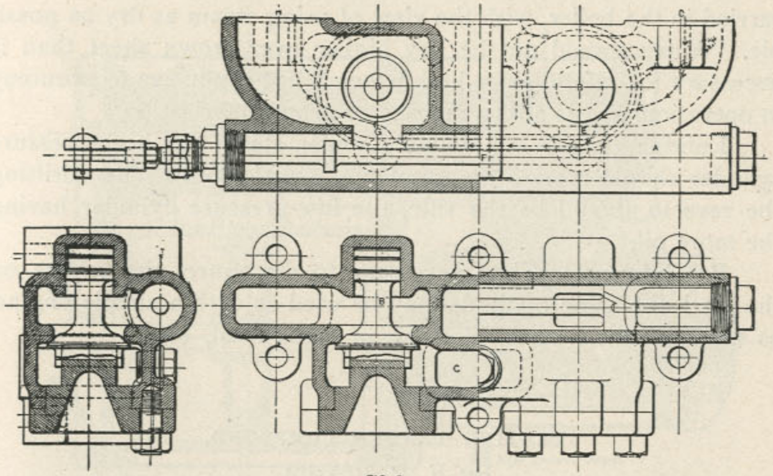


FIG. 3

from their seats there is a continuous opening between the two ends of low-pressure cylinder through cylinder steam ports into steam chest, providing relief from back pressure when drifting, by equalizing the pressure in the cylinders.

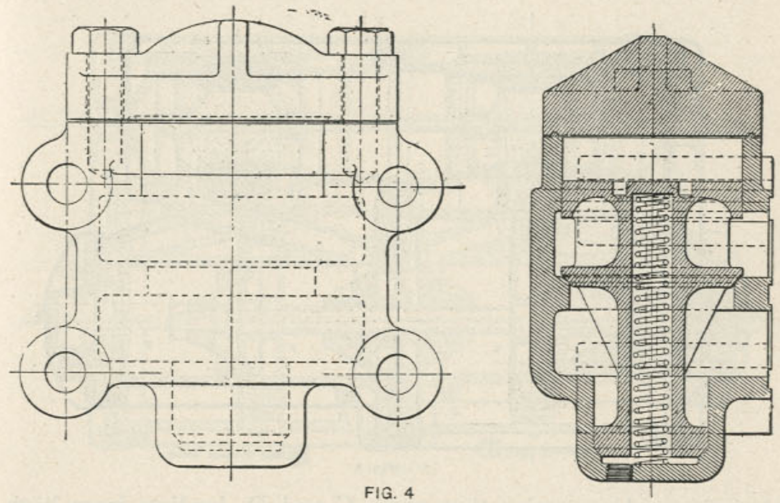


FIG. 4

Starting.—Any compound engine will do more economical and satisfactory work operated as a compound, and should therefore never be worked as a simple engine except in starting, or when likely to stall on grades, and then only long enough to overcome the resistance of the train.

Water.—Attention should be given to the quantity of water carried in the boiler, with the view of using steam as dry as possible. Water should not be any higher over crown sheet than is necessary for safety, since high water is not conducive to economy in operation, and is also a menace to proper lubrication.

Lubrication.—When running under steam the high-pressure cylinder should receive the greater amount of oil. When drifting the reverse should be the rule, the low-pressure cylinder having the more oil.

Breakdowns.—When necessary to disconnect the engine on the road, the same methods may be used as with a simple engine, as to removal of parts, blocking of cross head, etc.

TESTING TANDEM COMPOUND.

BY F. P. ROESCH.

The figures show sections through steam chests, valves and cylinders, with valves in various positions for testing.

It will be noticed that high-pressure valve, A, is central or internal admission, while low-pressure valve, B, is external or end

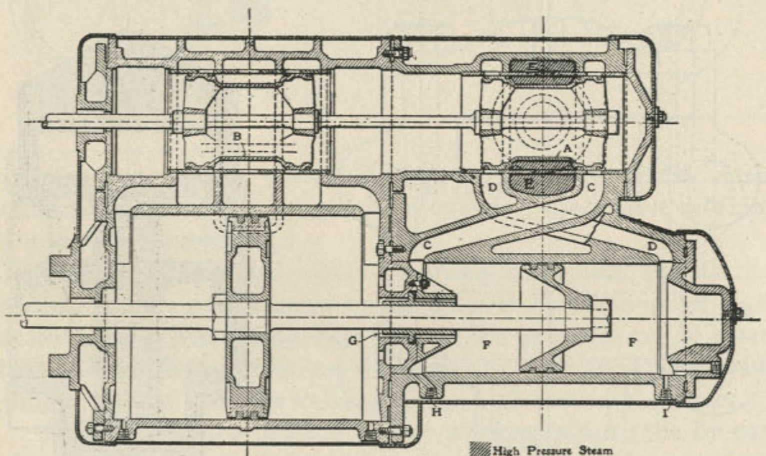


Fig. 1

admission. Also notice that ports C and D, leading from high-pressure steam chest E to cylinder F, are crossed. Both valves A and B, and cylinder packings and piston-packing sleeve G, can be tested on each side of engine by simply moving reverse lever.

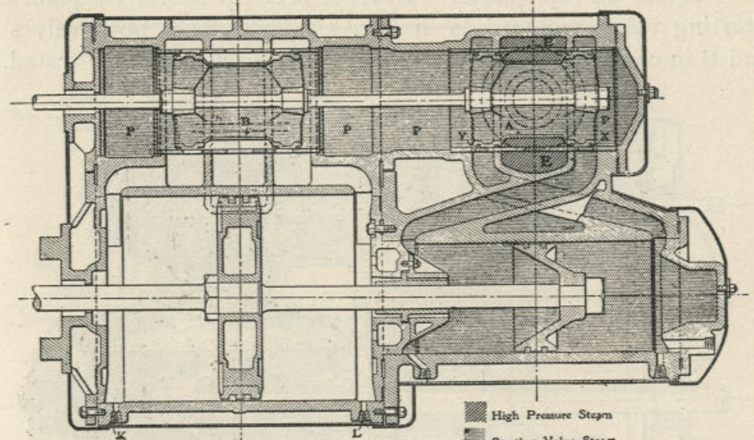


Fig. 2

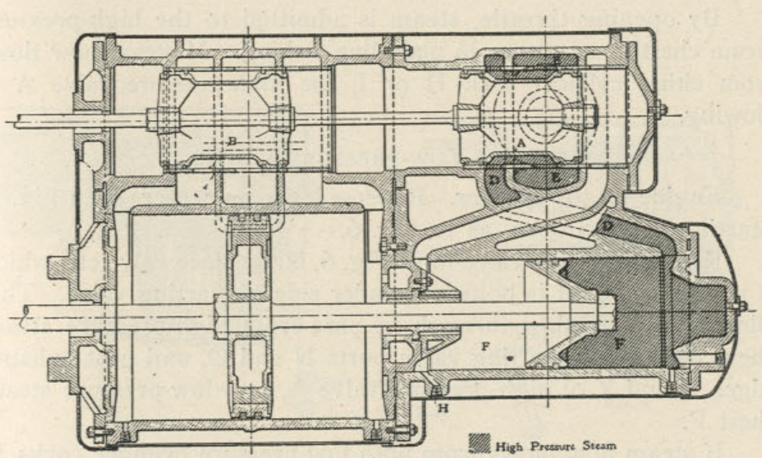


Fig. 3

To make tests, place the engine on quarter on side to be tested and proceed in manner designated on following pages.

TESTING HIGH-PRESSURE VALVE.

Engine on top quarter. Reverse lever in center of quadrant. Starting valve S closed as in Fig. 7. This places both valves A and B in central position, covering all ports on side to be tested.

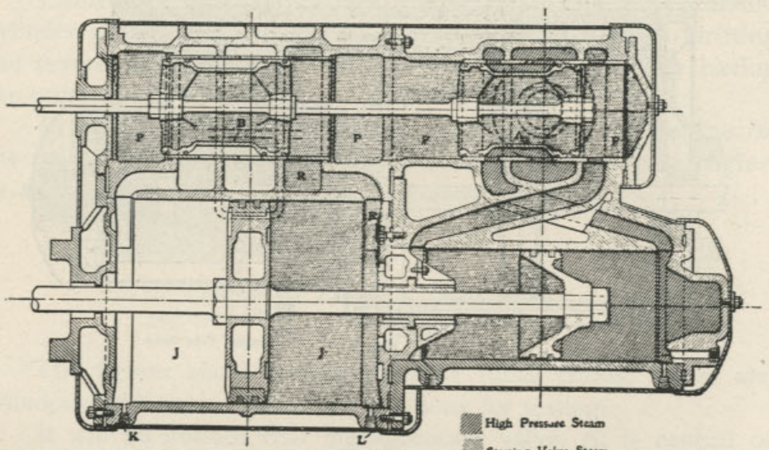


Fig. 4

By opening throttle, steam is admitted to the high-pressure steam chest E, as shown in plain line etching. If steam now flows from either cylinder cock H or I, the high-pressure valve A is blowing.

TESTING LOW-PRESSURE VALVE.

Engine on top quarter. Reverse lever on center, as in Fig. 1. Starting valve S open, as in Fig. 6.

Remove by-pass valve M in Fig. 6, but replace valve cap which is not shown, as it is bolted to under side of starting valve. This allows steam to flow through by-pass from high-pressure steam chest E, through starting valve ports N and O, and past exhaust edges X and Y of high-pressure valve A, into low-pressure steam chest P.

If steam now blows from both low-pressure cylinder cocks K and L, the low-pressure valve B is leaking.

TESTING HIGH-PRESSURE CYLINDER PACKING.

Engine on top quarter. Starting valve S closed, as in Fig. 7. Reverse lever in back motion.

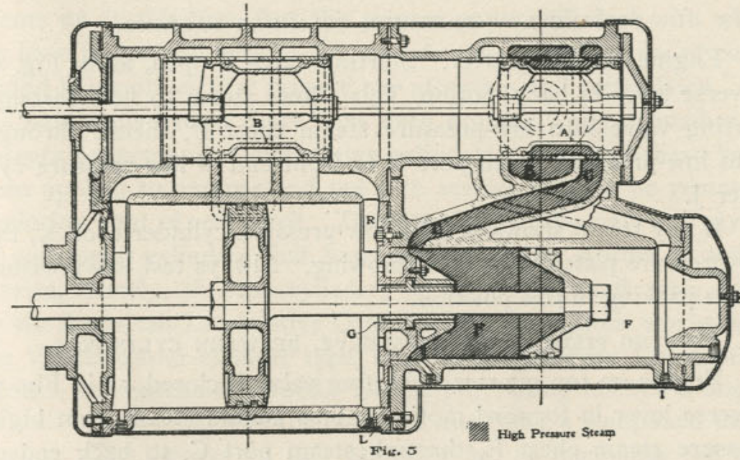


Fig. 5

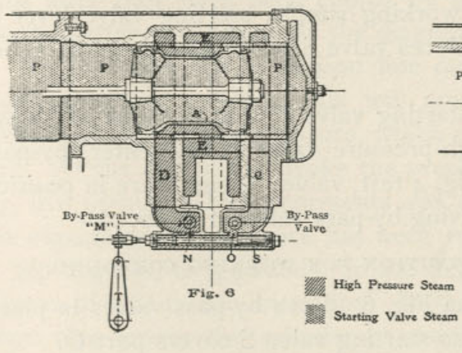


Fig. 6

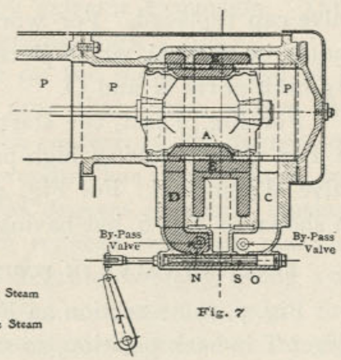


Fig. 7

This admits steam from high-pressure steam chest E, through steam port D, to front end of high-pressure cylinder F.

If steam now blows from back high-pressure cylinder cock H, the high-pressure piston packing is blowing.

TESTING LOW-PRESSURE CYLINDER PACKING.

Engine on top quarter. Starting valve S open, as in Fig. 6. Reverse lever in back motion. This allows steam to flow through starting valve into low-pressure steam chest P, thence through front low-pressure steam port R to front end of low-pressure cylinder J.

If any steam shows at back low-pressure cylinder cock K, the low-pressure piston packing is blowing. Always test low-pressure piston packing in this position.

TESTING PISTON PACKING SLEEVE, BETWEEN CYLINDERS.

Engine on top quarter. Starting valve S closed, as in Fig. 7. Reverse lever in forward motion. This admits steam from high-pressure steam chest E, through steam port C, to back end of high-pressure cylinder F only.

If steam now flows from front low-pressure cylinder cock L, the piston sleeve G is worn and leaking.

STARTING VALVE IN POSITION FOR WORKING SIMPLE.

Figure 6 shows section through high-pressure valve, steam chest and starting valve. By-pass valve M removed, but having valve cap replaced. For working simple, starting valve lever T should be vertical, which places valve S in forward position, opening both ports N and O.

For Fig. 2 test, the starting valve S is in position as shown in Fig. 6, but having high-pressure valve A on center, by-pass valve M removed. For Fig. 4 test, valves A and S are in position as shown in Fig. 6, but having by-pass valve M replaced.

STARTING VALVE IN POSITION FOR WORKING COMPOUND.

Fig. 7, same section as Fig. 6. Both by-pass valves in place. Lever T in back position, so starting valve S covers port O.

For Fig. 1 test, starting valve S as in Fig. 7. The high-pressure valve A on center.

For Fig. 3 test, valves A and S in position as shown in Fig. 7.

For Fig. 5 test, starting valve S as in Fig. 7. High-pressure valve A in forward motion.

PROPER HANDLING OF COMPOUND LOCOMOTIVES.

(Paper by W. J. McCarroll, Read Before the Traveling Engineers' Association.)

It does not seem necessary to go back to the original design of compound locomotives and carry along the history and developments up to this time, but the present paper will deal with what we have to contend with to-day, as referring to the classes of compound locomotives that require our attention and supervision. In the past twelve years there have been granted a great number of patents on compound locomotive cylinders. Many of these have been applied to engines and put into service only to be removed again for want of real merit. There are practically only two styles of compound cylinders that have weathered the storms of active service, namely, the two-cylinder, or cross-compound type, built by the American Locomotive Company at their various works, and the Vauclain four-cylinder type, built by the Baldwin Locomotive Works, and extensively used. Before proceeding further it might be well to ask what was the object of designing a compound locomotive. The answer to this can only be, to economize the expense of fuel. This economy is the result of passing the steam through two or more cylinders, with the object of obtaining, by a succession of expansions, more work from a given quantity of steam than can be obtained from the use of steam through one cylinder, and by reducing, to a certain degree, the condensation in the cylinder, by retaining the heat required to warm the cylinder walls after they have been cooled by extreme expansion. This may be better understood by the diagrams, Figs. 1 and 2.

In following the expansion line on the indicator card of a single-expansion cylinder, you will note that steam enters the cylinder at 200 pounds pressure, which represents 387 degrees of heat. At the end of the stroke the pressure has been reduced to, say, five pounds, which represents 228 degrees of heat. During this expansion the pressure has been reduced from 200 pounds, or 387 degrees, to 5 pounds, or 228 degrees, thereby losing 159 degrees of heat in one expansion. In the compound cylinders the steam also enters the cylinder at 200 pounds pressure, or 387 degrees, and is expanded in the high-pressure cylinder down to about 80 pounds, or 323 degrees. This 80-pound pressure becomes the initial pressure for the low-pressure cylinder, which is again expanded down in the low-pressure cylinder to 5 pounds, or 228 degrees, or a total loss of 159 degrees of heat, same as in a single-expansion cylinder, but with this loss of heat degrees on a compound cylinder we have the gain of the additional expansion in the low-pressure cylinder. In other words, the steam acts on the piston of a single-expansion cylinder for one stroke, or half a revolution, while in the compound it is distributed through two strokes of the piston, or a complete revolution. As previously explained, the object of using compound cylinders is to allow the steam to be expanded further than it is possible to do in single-expansion cylinders.

In compound locomotives there is an obstacle to be overcome with which the designers of stationary engines do not have to contend. In locomotives the exhaust pressure must be depended upon to create a draught for the fire. Therefore it is impossible to expand the steam down to such a low pressure as practical in marine or stationary engines, which ordinarily use condensers. In order to obtain a maximum expansion of the steam through two cylinders of a compound, and still have sufficient exhaust pressure

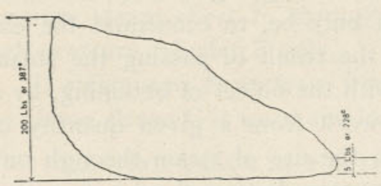


FIGURE 1

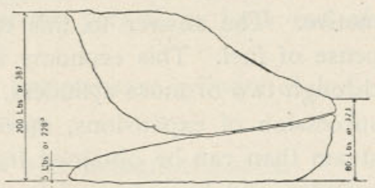


FIGURE 2

left to cause a draught upon the fire, it is necessary to carry a higher steam pressure in the boiler than in a single-expansion locomotive.

It is not expected that a compound locomotive should haul a heavier train or at higher speed than a single-expansion locomotive of the same weight and class. No locomotive will haul more than its adhesion will allow. The compound will, however, keep a train moving at slow speed on heavy grades, where a single-expansion locomotive will stall. This being accounted for from the fact that the pressure on the crank pin is more uniform throughout the stroke.

The starting valve, which is the valve used to allow live steam to pass from the high-pressure steam port to the low-pressure cylinder when starting, should be used judiciously. This valve is only intended for admitting live steam into the low-pressure cylinder when starting a train, or use in a case of emergency, when about to stall on a grade. Live steam should not be used in low-

pressure cylinder, after the speed of four miles per hour is attained. The neglect to close this valve, after the train has been started, or continuously operating the engine with live steam, will soon result in excessive repairs, and will be direct evidence of carelessness on the part of the engineer. There will also be a loss of fuel, and the locomotive will be logy. This valve should be closed, and the engine working compound before the reverse lever is hooked back.

Figure 3 shows the connection to this starting valve. By following the openings or pipe connections in this diagram you will

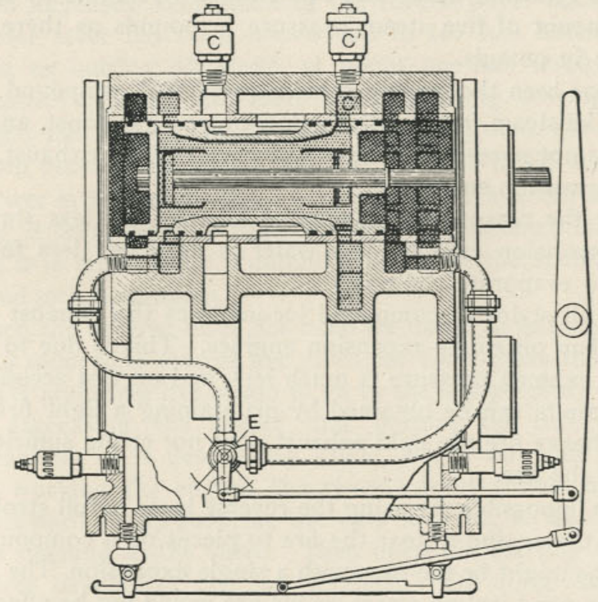


FIGURE 3

observe the position of the main valve is such that steam from the boiler is entering the high-pressure cylinder port; and the pipe connections, when the starting valve is open, will allow steam to pass through the pipes up through the main valve into the opposite end of the low-pressure cylinder, thus increasing the pressure there and making the engine more powerful.

Exhaust nozzles, you will find, are very sensitive points on compound locomotives, indeed, a great deal more so than any one would suppose. The size of the exhaust nozzle is very often lost sight of by many men when regulating the engine to steam. I have frequently noticed, when an engine is reported as not steaming, the first thing done to remedy this fault is to reduce the size of the exhaust nozzle regardless of any other conditions, or without even trying to locate the direct source of the trouble. This is poor practice to follow on any class of locomotives and should be the last remedy resorted to. First examine, and be sure all other parts having an influence on steaming are properly arranged. In all cases avoid reducing the nozzle and aim rather to increase the size, then the working of the engine will be much smoother. A restricted exhaust nozzle invariably results in increasing the back pressure in the cylinders. This condition is objectionable, as it is a retarding force and can only be overcome by using the same amount of live steam pressure in pounds as there is back pressure in pounds.

It has been thoroughly demonstrated that compound locomotives make steam freely with the low-pressure exhaust, and, therefore, it is not necessary to have a sharp sounding exhaust, as on a single-expansion engine.

For the reason that compound engines use less steam than single-expansion engines, less water is used and less fuel is required to evaporate the water.

On all styles of compound locomotives the exhaust is much milder than on single-expansion engines. This is due to the fact that the exhaust pressure is much less, and on this account much better results can be obtained by maintaining a light fire. With a deep, heavy fire the mild exhaust does not create sufficient draft to work the fire.

It is impossible, by using the reverse lever in full stroke, or in slipping the engine to tear the fire to pieces on a compound locomotive, as might be the case with a single expansion. The fireman, therefore, need feel no alarm, as his fire would not be affected.

It is also noticeable that when a compound locomotive is properly adjusted and fired, the great annoyance of cinders, black smoke, sparks, etc., is overcome to a very great extent. In drifting down grades the ash-pan dampers should be kept closed.

From the experience an engineer has in handling a single-expansion engine, he should not require any further introduction to the reverse lever, but he should use it for what it is intended. The reverse quadrant on all compound locomotives should be so arranged that it cuts off steam in the high-pressure cylinder at about one-half stroke; shorter cut off will result in excessive compression in the high-pressure cylinder.

We will assume that the engine is coupled to a train ready to start; the reverse lever at this stage should be in full gear. If

the train is heavy and at difficult starting point, place the starting valve lever in position to allow live steam to enter the low-pressure cylinder. On engines where the starting valve is connected to the cylinder cock lever, the lever has three positions; the normal position is central, when cylinder cocks and starting valve are closed; in the forward position cylinder cocks are open; rear position, starting valves are open, live steam entering low-pressure cylinder. When the train has been started, and a speed of four or five miles per hour is attained, shut the starting valve, and, as the speed increases, keep hooking the reverse lever back. After the reverse lever has been hooked up to the last notch on the quadrant, or cutting off steam at about one-half stroke in the high-pressure cylinder, and more power is being developed than is required, partly close the throttle, so as to regulate the speed.

When ascending a grade, and the speed is being reduced or more power is required, drop the reverse lever a notch and keep dropping it from time to time, to retain the momentum of the train, as it is much more economical to retain the speed than to lose it and pick it up again.

When the reverse lever has been let down to full stroke, and the speed reduced to four or five miles per hour, move the starting valve lever and allow live steam to go to the low-pressure cylinder, thereby increasing the power and keeping the train moving. When running on a descending grade, where the train will run without working the engine, the reverse lever should be in full gear backward or forward, as the case may be, so as to give a full port opening to the valve. Then open the starting valve, so that a free circulation can be obtained. On long descending grades, it is recommended to use just sufficient steam to keep relief valves closed, thus giving a freer and smoother motion to the engine; besides, this will aid in lubricating the cylinders, and is considered the best method to follow on large single-expansion engines.

A point of importance might here be mentioned in regard to handling high-speed trains. It is a well known fact that compression and back pressure increases as the speed increases; it also increases as the reverse lever is hooked back and point of cut off is shortened. Compound locomotives have more power at high speed when run with the throttle partly closed and as long a cut-off as possible. Long cut off gives a larger port opening and a later exhaust opening. By partly closing the throttle the steam is wire drawn and reduces the compression. If compound locomotives could be run by the reverse lever, it would be preferable to do so, but, with a short cut off, the compression increases at high speed. There is but one way to get the required cylinder power, and that is to use a longer cut off and wire-draw the steam through the throttle to a point where the boiler can keep up the supply of steam.

Care should be taken never to reverse a compound or single-expansion locomotive when equipped with piston valves, except when moving slowly, as it is destructive to packing rings and piston rod packing. With piston valves there is no release for the pressure, as the piston valves cannot rise and allow pressure to escape as with a plain (D) valve, which can lift, and allow the pressure to escape from the cylinder when increased by reversing.

Cylinders of compound locomotives should not require any more lubrication than a single expansion. This is due to the fact that sufficient particles of oil remain suspended in the steam after passing through the high-pressure cylinder, which will properly lubricate the low-pressure cylinder.

When switching, it is advisable to use all styles of compound engines with the starting valve open, or as a single-expansion engine.

LOCATING BLOWS ON A VAUCLAIN FOUR-CYLINDER COMPOUND ENGINE.

At times it is necessary, in order to make an intelligent report, to know how to locate any defect or any derangement of parts in the compound cylinders, such as leaking of steam past the various packing rings of the valves and pistons. It may at first appear puzzling to know just how to locate troubles of this sort, but with a little careful observation any of the usual defects can be located.

On the Vauclain four-cylinder engine, when it is observed that the engine is going lame or exhausts unequally, about the first inspection necessary would be to examine the starting valves and connecting levers. Place the starting valve handle in the cab in central position, then get down and observe the position of the lever on the starting valve. If this is central, that proves these valves to be exactly right. If one side is central and the other side is front or back of central position, the connecting-lever rod should be lengthened or shortened, as the case may be, to make it central. Should the lameness still continue, a rigid inspection of the motion work for defects, such as bent eccentric rods, loose eccentric rods, bent transmission rod, loose rocker boxes, etc., should be looked for.

With this make of engine there need be no alarm about eccentrics slipping, as they are all securely keyed to the axle, and this key cannot possibly get out of position without seriously deranging the motion. If the motion work is in no way deranged, and the lameness continues, it is then necessary to test the valve-packing rings and cylinder-packing rings.

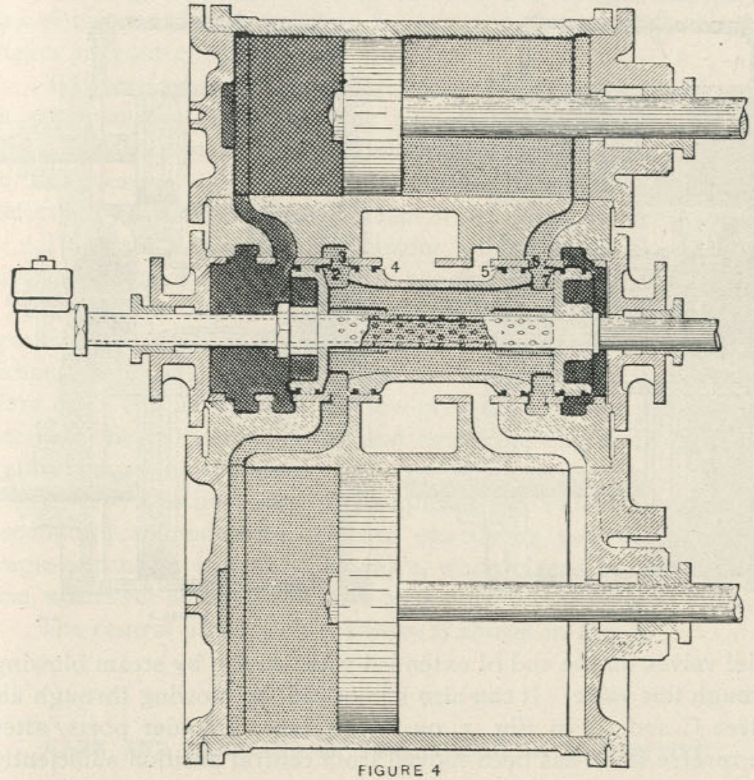


FIGURE 4

It will be noticed in Fig. 4 (a sectional cut of cylinders and valves), that the valve-packing rings are numbered and referred to in the following manner: The rings governing admission and release of steam to high-pressure cylinder are 1, 2, 7 and 8, and those to low-pressure cylinder are 3, 4, 5 and 6. For convenience in referring to the diagrams, dark indicates live, or high-pressure steam, and light low-pressure steam, or exhaust from the high-pressure cylinder. The final exhaust from the low-pressure cylinder is not indicated by color. Rings 1, 2, 7 and 8 can be tested as follows: Place the reverse lever in central position, thereby covering all the ports, then open the throttle and admit steam to the ends of the valves. If rings 1 and 8 leak, the steam will blow through, filling both ends of the high-pressure cylinder and central cavity of the valve. The leak can be noticed by steam escaping in a steady blow at high-pressure cylinder cocks, or by removing indicator plugs (if cylinders are so arranged), or on engines having

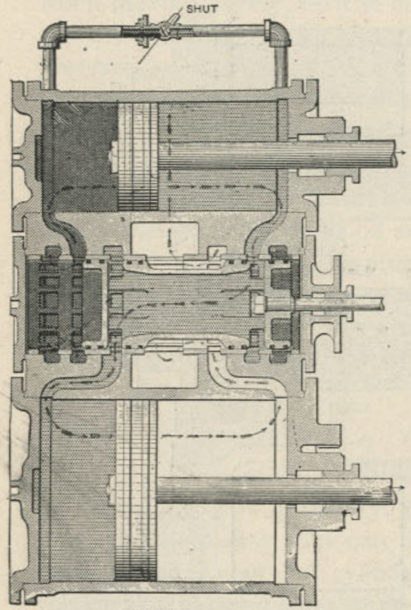


FIGURE 5

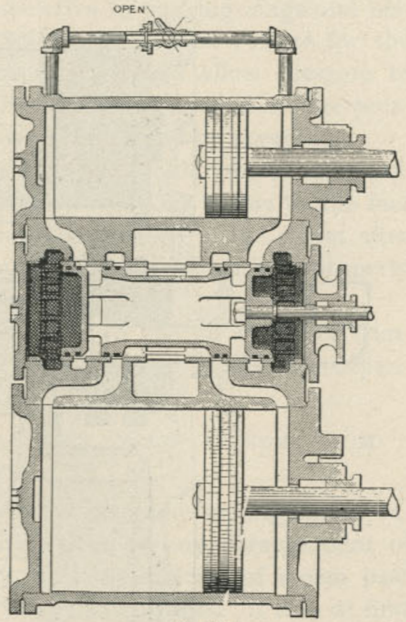


FIGURE 6

relief valves on the end of extended valve stems, by steam blowing through this valve. It can also be noticed, by blowing through air valves C and C', in Fig. 3, on low-pressure cylinder ports, after the reverse lever has been moved from central position sufficiently to get the lap opening on valve to low-pressure cylinder. If these rings do not leak, no steam should escape from these points.

If rings 5 and 6 to low-pressure cylinder leak, it can be noticed by a steady blow through the exhaust at the same test made for rings 1 and 8. If there should be a small leak through rings 1 and 8, the steam will not be entirely lost, as it goes to do useful work in the low-pressure cylinder.

To test rings 3, 4, 5 and 6, governing the admission and release to low-pressure cylinders, place reverse lever in full gear,

with starting valve open and driving brakes on. Open throttle and if these rings leak it will be indicated by a steady blow through the exhaust nozzle.

To test high-pressure cylinder packing rings, place engine at about quarter stroke, so that valve is open and steam enters high-pressure cylinder at front end, as shown in Fig. 5. Keep starting valve closed and driving brakes on. Open throttle and admit steam. If the packing rings leak the steam will pass the ring, and down through the center of the valve to the forward end of the low-pressure cylinder, and can be detected by a steady escape of steam at front cylinder cock.

To test low-pressure cylinder rings, keep engine and valve in same position as testing the high-pressure cylinder packing rings, but open starting valve, which gives an increased pressure in low-pressure cylinder. If the packing rings leak it will be detected by a steady escape of steam at the back cylinder cock.

The testing of valves and pistons for leaks and blows should always be done when cylinders are hot and well lubricated.

Should the high-pressure cylinder packing leak, it would increase the pressure in the low-pressure cylinder, consequently the exhaust would be heavier on this side and sound as if the valves were out. A leak through the low-pressure cylinder packing will decrease the exhaust pressure and cause the engine to have two light exhausts on this side.

In case it is necessary to disconnect the Vauclain engine, on account of a breakdown, proceed exactly as you would with a single-expansion engine. The valve, when placed in central position, will cover all ports the same as is done by the plain D valve.

The central position of the valve is shown in Fig. 6.

CARE AND HANDLING OF THE COMPOUND LOCOMOTIVE.

In the paper read before the Traveling Engineers' Association by Mr. A. L. Beardsley, of the A., T. & S. F., on "Care and Handling of the Compound Locomotive," the speaker laid down the principle at the outset that before the men whose duty it is to care for and handle the machine can get good results they must first have an engine designed and built for the service expected. He put in a plea for the proper use of the starting valve. He said "the fact that this device adds to the tractive force of the locomotive is often taken advantage of and the engine is overloaded, causing the starting valve to be used and the engine to be run 'simple,' which is very hard on any compound." There is no question but that the economical point at which to work a compound locomotive is in one-half stroke, or a little more, but we often find times in the service when this is not practicable.

In the matter of detecting blows, Mr. Beardsley said, when on the road:

"Two heavy exhausts on one side generally come from high-pressure packing blowing, caused by the rings being broken. This, however, may be caused by a leaky valve, a loose bushing, cracked bridges, a leaky starting valve, or any defect that will increase the pressure in the low-pressure cylinder, cavity of valve or low-pressure steam chest. Two light exhausts on one side may be caused by low-pressure packing blowing, which is very hard to detect while running, because the steam is admitted to the low-pressure cylinder at a greatly reduced pressure. The same result may be caused by packing rings in the valve being broken, which will allow part of the steam to escape to the atmosphere while it is passing through or around the valve to the low-pressure cylinder, or by loose bushing, cracked bridges, etc.

One loud exhaust with the Vauclain engine may be caused by either rings No. 1, 2, 3, 6, 7 or 8 being broken. Rings No. 1 or 8 broken gives us more port opening at the end of the high-pressure cylinder that ring is broken on, and, of course, more volume of steam in the high-pressure cylinder. This goes to the opposite end of the low-pressure cylinder and gives us one heavy exhaust. If rings No. 3 or No. 6 are broken the volume of steam admitted to the low-pressure cylinder is increased and the effect is practically the same. Rings No. 2 or No. 7 being broken will give one loud exhaust on that side of the engine for the reason that steam will blow by the ring from the live steam way directly into the hollow of the valve when the steam port at the opposite end of the valve is open.

If you have one heavy exhaust from the front end on the right side, it may be caused by ring No. 8 in the valve being broken, or perhaps ring No. 2 is broken. In either case the volume of steam, or the pressure, is increased in the low-pressure cylinder and you have one heavy exhaust. This point must be considered when testing for a high-pressure packing blow on the Vauclain engine, as explained later.

The tandem compound may have one heavy exhaust from rings No. 5 or No. 8 being broken, which will increase the port opening to the low-pressure cylinder. Rings No. 2 or No. 3 broken in a tandem merely increases the volume of steam in high-pressure cylinder and low-pressure steam chest, and gives two loud exhausts. If rings No. 1 and 2 or No. 3 and 4 are broken it increases the pressure in the low-pressure steam chest, and anything that increases the pressure or volume of steam in the high-pressure cylinder or low-pressure steam chest gives two heavy exhausts on that side of the engine.

If rings No. 5 and 6 or No. 7 and 8 are broken we have two light exhausts, because part of the steam from the low-pressure steam chest or receiver is blowing by them to the atmosphere. Assuming that we have found which side the blow is on, and that the starting valve is in good order, we should make a standing test to locate the trouble, as follows:

STANDING TEST FOR BLOWS—VAUCLAIN COMPOUND.

Place the engine on the bottom quarter on side to be tested. Block drivers or set brakes and remove both indicator plugs on the high-pressure cylinder. If the engine is not equipped with these plugs, remove pops or water relief valves on the cylinder heads. Give the engine steam and in doing this be sure that you open the throttle enough to set the packing rings out against the bushing. These packing rings will leak a little, but if you can cover ports it shows that rings No. 1 and 8 are in good order. In testing for high-pressure packing blow put the reverse lever in forward motion, which opens front port to the high-pressure cylinder. See that the starting valve is closed and indicator plug or pop is out at the back end of the high-pressure cylinder. Give engine steam, and if it blows out of the indicator plug the high-pressure packing may be blowing on ring No 7 in the valve may be broken.

To determine which this is, replace the indicator plug in back end and remove the front one. Put the reverse lever in the back motion and make same test. If it is the high-pressure packing that is blowing it will show; while if it is ring No. 7 it will not show.

To test for low-pressure packing, put the reverse lever in forward motion with all the indicator plugs in except the one in back end of low-pressure cylinder. Open the starting valve, which will admit steam to back end of high-pressure cylinder, hollow of valve and front end of low-pressure cylinder. If the low-pressure packing blows you will note it at the back indicator plug. In this same position if rings No. 3 and 4 or No. 5 and 6 are broken, steam will blow through the stack. The blow in either case, however, will be very light, as the steam, you must remember, had to pass through the starting valve.

STANDING TEST FOR BLOWS—TANDEM COMPOUND.

Place the engine on the bottom quarter, on side to be tested, block the wheels or set the brake and cover ports. Remove the indicator plugs on high-pressure cylinder. Give the engine steam, using the same precaution to set out the packing rings. If you can cover the ports, it merely shows that rings No. 2 and 3 are tight. To test low-pressure valve, leave the engine in the same position and open the starting valve. Replace indicator plug in high-pressure cylinder and remove those in the low-pressure cylinder, also remove by-pass valve and screw the cap nut down. If rings No. 5 and 8 are blowing, it will blow through the stack and out of the plug. Test high and low-pressure cylinder packing the same as you would with the Vauclain engine. We have one blow, however, on the tandem that we do not have on the Vauclain engine; this is the sleeve or bushing between the high and low-pressure cylinders, and is tested by admitting steam to back end of high-pressure cylinder with starting valve shut. If this sleeve blows it will show through front cylinder cock or indicator plug in the low-pressure cylinder and blow through the stack. Some authorities advise to place the engine on lower forward eighth in testing for blows. With the compound engine we find the largest part of the cylinder in the extreme and there is nothing gained by placing the engine on the eighth.

In testing for blows we find it very unsatisfactory to go by the cylinder cocks, and for that reason I recommend removing the indicator plugs on the side of cylinders, or the water-relief valves on cylinder heads. Some roads are putting indicator plugs in all cylinders. This is, you will find, an improvement, not only as a help in locating blows, but to assist in lubricating when it is necessary to tow the engine in. If for any reason the locomotive is disabled and has to be towed in, there will be no bad effects if you remove all the indicator plugs and the plugs over the valves, and lubricate valves and cylinders well. This is quite an advantage, as it would be a hard matter to take down the main rods on the large engines.

In fact, some roads now instruct their enginemen not to take down the main rods in cases of this kind. It would be much easier to remove cylinder heads, and I find from experience that it is not necessary to take down main rods. The engineer, being on the

ground, should, however, use good judgment in handling his engine, and must be held responsible for its condition. If the engineer is careful in watching the engine work while pulling a train over the road, and makes a standing test on completing the trip, he will generally find what is wrong; but there are so many different blows that have the same effect that we often hear the engineer criticized for not reporting the work right, when he is not at fault. The machinist who does the work should look for loose bushings, etc. This can generally be detected by tapping the bushings over the bridges with a light hammer. He should also look for cracked bridges and cylinders.

OPERATING LOCOMOTIVES.

BREAKDOWNS.

BY JOSEPH A. BAKER.

The object of this chapter is to give the easiest and quickest way of making temporary repairs to a disabled locomotive with the few tools supplied and at the engineman's command.

Some of the instructions given a decade ago are fast becoming obsolete, as the frequent and fast trains on our trunk lines of to-day demand the clearing of the main line with as little delay as possible to prevent a blockade. With this object in view, the writer, who until a few years ago was in the harness himself for twenty-odd years, will endeavor to present the subject of breakdowns as plainly as possible, so as to make it possible for the man of ordinary education to understand.

In order not to confuse, let it be understood that a locomotive consists of two complete and independent engines, so that in case of disablement of one the other can still perform its work. Much valuable time can be saved in knowing how and just what parts to disconnect in certain breakdowns, and this is where the up-to-date engineman shows his value to his employer. A good engineman will carefully inspect his engine before starting on a trip, whether pooled or regularly assigned, to avoid accidents of this nature. With the heavy power of to-day some of the temporary repairs insisted upon in former years are abandoned, and many of the tools furnished engines formerly are removed from them now.

1. DISCONNECTING ONE SIDE.

Aim to do as little as quickly as is consistent with safety. Never remove a main rod unless absolutely necessary. Pinch bars are of very little use to move the large engines of to-day, and a main rod left up will, with a little thought, supplant the pinch bar

and do it more effectively. In removing the forward section of side rods on some makes of ten-wheel, mogul or consolidations, care must be exercised where blocking of cross head back is necessary. Very often the crank pin will interfere with the piston rod key in cross head. When this is the case cut off the key flush with the cross head or block the cross head forward.

2. BROKEN MAIN ROD.

Remove the broken parts, block cross head back to within one-half inch of clearance to keep the cylinder packing out of the counter bore, disconnect cylinder-cock rod on disabled side and block cocks open. Shift valve in the same direction as piston if a slide valve or outside-admission piston valve, and in the opposite direction if an inside-admission piston valve. An easy way to remember and distinguish a direct from an indirect motion is in the position of the rocker arm. With the indirect, one arm is above and the other below the rocker box; with the direct both arms are either above or below the rocker box. In moving valve give it just enough opening to show steam at the cylinder cock, which will take the pressure off of the blocking.

3. BROKEN SIDE ROD.

Remove the broken rod and the same section opposite. If the break is on the forward section of a ten-wheel or mogul and the knuckle pin on the rear section, take down all side rods. If the break is on the knuckle-pin section, take down only those sections. If the intermediate section on a consolidation, take down all sections; if on a forward or back section take down only those sections.

4. BROKEN VALVE YOKE.

This is not so hard to locate as one imagines. Generally the engineer in attempting to locate the heavy blow places the engine on the good side on the dead center unintentionally, and is then unable to move her either forward or back. First inspect your eccentrics and blades, and if found intact go to the side on the quarter. A little thought will tell you that if this side were not disabled it would move the engine off the center on the other side. If your chest has a release valve, don't take up the cover. Disconnect the valve stem and take out release valve. You can then shift the valve to cover steam ports and also help your good side off the dead center. When covering ports, insert a plug in the release valve of sufficient length to hold the valve central from one end and with the valve rod from the other. Don't take down main rod, you may want it to help you off the center again. Block cylinder cocks open on that side, and with a very little admission of steam through valve the cylinder will get sufficient oil to prevent damage. The Vandalia railway has a record of a passenger engine making 86 miles this way and no damage to cylinder.

5. BROKEN PISTON ROD.

If the broken rod has taken cylinder head along with it, disconnect valve rod only and cover ports. Take in as much of a train as you can.

6. BROKEN PISTON OR VALVE GLAND.

If this break happens near the stud, place a large washer on either side of the lug over the stud and tighten nuts against them. With a broken valve gland, use the clamp generally provided to hold a disconnected valve central, and bend the beak out of the way to clear the valve-rod key. Where stud has pulled out, changing end for end sometimes will answer. You can generally find a nut around your engine that will answer for this purpose. Sometimes a little canvas wrapped around the gland and forced into the stuffing box will hold.

7. BROKEN CYLINDER HEAD.

In most instances there is a heavy leakage of steam around the head to give warning, and if it is a forward head it may be saved from total destruction. The writer on several occasions of this kind placed heavy blocking against the head, and with a screw jack placed against the pilot timber, brought in his train a distance of 100 miles without any further mishap. With the back head broken in such a manner as not to interfere with the guide block, it is generally safe to run with the main rod up, but if there is any liability to damage, take down rod and cover steam ports.

8. BROKEN STEAM CHEST OR COVER.

When the break is not a bad one, wedging between the chest and bolts is sometimes successful, but where the break is a bad one, remove the cover, block the supply ports, which on modern engines are at each end of cylinder, with blocking of sufficient thickness to be held down by cover, disconnect valve stem only, block the cylinder cocks open, and proceed on one side. The same method applies to a broken cover.

9. BROKEN RELEASE VALVE.

This does not imply that the valve is entirely useless. Remove release valve casing from chest and insert a wooden plug in casing and screw back in. Better still, if you have a spare washout plug on your engine, remove the casing and screw the plug in instead. A modern engine should be supplied with such emergency appliances and a modern engineer will provide himself with such appliances.

10. BROKEN CRANK PIN.

With a broken main crank pin, any class of engine, take down all side rods and be sure that the crank pin on the forward wheel does not interfere with the cross head in blocking the latter. With the back crank pin on a consolidation or a ten-wheel engine, proceed as with a broken side rod (see chapter on side rods), but if the crank pin of an intermediate, otherwise known as driver No. 2, take down all side rods and run in light with main rods up. Remember that taking down one section and not the other on the opposite side is dangerous; there is nothing to pull the wheel on the good side off the dead center. In only one case is this permissible when the eccentrics are on the first or leading, and the main rod on the second or main drivers. In this instance if the forward section, with a solid end, breaks, the other side is left up so as to control the valve motion on the good side; but the valve gear on the crippled side must be disconnected.

11. BROKEN CROSS HEAD.

If the break is with a four-bar guide or a Laird guide with yoke, block ahead and let main rod rest in yoke; but the butt end brass and strap must come down, otherwise the rod would interfere with main pin. If the cross head is of the alligator type and yoke secured near middle of guide, block back and take down main rod. It is always a good plan to allow enough port opening in blocking valves central, to admit a little steam against the piston in the direction you are blocking. Remember also that an outside admission valve is pushed in the same direction as the piston and an inside admission in the opposite direction.

12. BROKEN ECCENTRICS, STRAPS AND BLADES.

With a broken go-ahead eccentric or blade take down the back up also. If the back up is not disturbed the link lifter must be taken down. With a broken back-up eccentric, strap or blade, the go ahead need not come down, but the engine must be run with a full cut off and no attempt made to bring the lever back to center of quadrant. The above suggestions are only to be used where the distance to a siding is short and you want to clear the main line. At any other time if you break one, take down the other also and cover steam ports. Don't take down main rod.

13. BROKEN GUIDE YOKE.

If a bad break, take down main rod, disconnect valve stem and cover ports.

14. BROKEN ROCKER BOX OR ARM.

With the bottom rocker arm broken there is more or less danger of catching the link or blade on the rocker box, if the link motion is considerably worn. Take no chances but take down both eccentric straps and blades and cover ports. If the top arm is broken, remove broken part and cover ports.

With a direct-motion valve gear remove transmitting bar and broken arm and cover ports. By transmitting bar is meant the rod that conveys the motion from the link to the rocker arm. For a broken rocker box or sheared bolts, if no repairs are possible or no bolts at hand of nearly the same diameter as the old ones, take down both eccentric straps and secure the link to link lifter, and remove rocker box if bolts are sheared.

15. BROKEN LINK LIFTER.

Place the lever in quadrant at a point where you can comfortably start your train. Cut a block of wood to fit between the top of link block and link, also one to fit between bottom of link block and link. Fasten them securely. Blocking for the forward motion, never drop the lever below the point of cut off selected, as the lifting arm on tumbling shaft may interfere with link. You can cut the lever back toward the center without danger and work steam expansively on the good side, but this will give you two light and two heavy exhausts. Don't attempt to reverse your engine without first removing the blocking from below the link block and placing it on the top of the link block.

16. BURST FLUE.

Generally in a case of this kind the engine is dead in a very few minutes. Draw the fire and in freezing weather open blow-off cocks, let out all of the water, take down hose connections between engine and tender and be prepared to be towed in. Do no disconnecting and oil cylinders in freezing weather with light oil. With the extension front end of to-day it's next to impossible to reach a flue without removal of draft plates, and the time consumed would not justify repairs on the road.

With leaky flues the conditions are different. Most injectors of to-day have the heater cocks so arranged that they can easily be removed. If bran or sawdust can be had, start the injector first, then take out the heater cock and put a small quantity of the bran through this opening while the injector is working. The current will carry it to the boiler without any difficulty. Too much bran will cause the engine to foam. By this method you can bring in a full train without any further trouble. Gauge and water glass cocks must be opened often, however, to keep from clogging.

17. BROKEN EQUALIZER OR STAND.

If an equalizer post or equalizer breaks run the back wheels up on a frog and block between the main driving box and frame. Next put the frog at the main driver and run main driver up on the frog and block between box and frame on rear driver. Take down all loose parts that are liable to give trouble and run slowly as the drivers will heat very fast otherwise.

18. SPRUNG LINK.

On certain classes of engines with a 4-wheel truck and the lever in the extreme forward notch the links are in such close proximity to the truck that invariably from any cause of derailment the links are generally badly damaged or sprung. With the solid link you have no other alternative but to disconnect the valve gear. With the sectional link unless too badly damaged, slack off the nuts on top and bottom of link bolts, partly withdraw the bolts and insert a washer of sufficient thickness to allow the free movement of link block in the link when reversing the lever. Tighten bolts again and you are free to go on with your train without disconnecting.

19. DISCONNECTED OR BROKEN THROTTLE ROD.

This depends entirely upon the nature of the break. With a throttle valve open reduce the steam pressure down to a point where you can handle part of your train without slipping your engine. It is always safer to have some cars in your train to get the benefits of the brakes than to run in with just an empty engine. Sometimes what is considered as a disconnected throttle valve proves to be a cocked valve. If the rod connections are badly worn and a full throttle opening given, a cocked valve often results, and is mistaken for a disconnected throttle. Tapping the throttle rod will bring it back, with a closed throttle valve, conditions on your line must govern your actions. On a line burdened with frequent trains arrange to be towed in without disconnecting any part of the engine. If your line requires you to make repairs, blow off the steam, remove dome cap and make repairs. Generally you will find it a bolt that has worked out. Your oil pipes will not supply sufficient steam to bring in the engine of to-day.

20. BROKEN WHISTLE STAND.

A broken whistle stand means a dead engine. Remove the broken part from the dome. A handy thing to have around an engine is a washout plug and several sizes of reducers. In the absence of a washout plug use the reducer in the dome cap, then take the nipple and angle cock off of an air-braked car and insert into the reducer. This takes but very little time and I have seen an engine under steam again in thirty minutes. You can't rely on wooden plugs.

21. BROKEN DRAW BAR BETWEEN ENGINE AND TENDER.

Do not attempt to pull a train with the safety couplings, unless the grade is in your favor. If a chain can be used insert the link in the deck-bolt pocket for draw bar and secure the other end to body bolster of the tender, taking out all of the slack between engine and tender.

22. BROKEN REACH ROD OR LEVER.

Block over one link only with a point of cut off that will enable you to start your train and maintain a slow speed. With some classes of engines you can use a bar under the lifting arms of the tumbling shaft by placing the bar across both frames, and not block the link.

23. BROKEN TUMBLING SHAFT LIFTING ARM.

Use same manner of temporary repairs as for broken link lifter.

24. BROKEN LINK SADDLE PIN.

Use same method as for broken link lifter.

25. BROKEN LINK BLOCK PIN.

Disconnect valve stem and cover steam ports. Don't disturb main rod.

26. BROKEN VALVE SEAT.

Place the engine on the quarter on the side you think it is on, set your brakes and give her steam with lever in forward and back motion so as to admit steam to each end of cylinder alternately. If the blow is at one end only it indicates a broken valve seat or section broken out of valve. Disconnect the valve stem and move it central if it is a broken bridge between the steam and exhaust cavities. If it is the section between the supply and steam port move the valve in the opposite direction, with the cross head and piston in the same direction of the valve. This closes the exhaust and admits the steam under full port pressure against the piston. Disconnect main rod. With a valve badly broken, remove the valve and block on the top of steam ports with sheet iron and wood at your command. With a balance valve where the space between the valve and valve table is from $\frac{1}{16}$ in. to $\frac{1}{8}$ in., use sheet iron on the face of valve and blocking at either end. Take out cylinder cock valves and leave main rod up. For a broken piston valve if the break is not a bad one shift valve enough to stop the blow and clamp valve stem at one end and extension rod at the other end. Where there is no extension rod, block between valve and forward head.

27. BROKEN CENTER CASTING.

If the truck is a standard 4-wheel truck a short rail put across the top of the truck equalizer and under the center casting will bring you in safely, or in the absence of rails, block with hard-wood blocking over truck frame and under cylinder saddles. Run slow and carefully.

28. BROKEN DRIVING AXLE.

This occurs usually close to the wheel and outside of the driving box. If a broken main driving axle, all rods on the disabled side and all side rods on the good side must come down. With any other driving axle only such rods should come down as would give trouble to the rest of the rods. See chapters on broken crank pins and rods. To block up the axle on the broken side remove the cellar and put a wooden block between the axle and the binder brace. If an hydraulic or screw jack is handy, raise the axle and driving box, if it has an overhung spring and block under spring saddle above the frame to take the weight off of driving box. Use sponging on the sides of blocking under axle or, better still, your hot main pin grease.

29. BROKEN FRAME.

For a broken frame ahead of main driver disconnect the valve stem on disabled side, cover ports and leave up main rod. Bring your engine in light with the good side. If the break is behind the main driver take down side rods on rear section only if a consolidation. With a mogul type and the knuckle pin on forward section of side rod, take down all side rods.

30. KEY OUT OF FRAME SPLICE OR CYLINDER SADDLE.

Unless the key has been lost, try and put it back with the use of liners to secure it snugly. The cylinder saddle key is a taper affair, while the frame key is a square one, and with the latter a rod key driven in and watched occasionally will bring in the engine without shearing frame bolts. With nothing to replace saddle key, disconnect valve stem and cover port on that side.

31. BROKEN DRIVING BRASS.

Run the wheel upon a frog or wedge and block up between the frame and spring saddle to take weight as much as possible off of box.

With an engine having underhung springs there is no saddle to block under, and in a case of this kind place a jack under equalizers nearest to broken brass, then block the other end between frame and equalizer and remove the spring under broken brass if possible.

32. BROKEN EQUALIZER BETWEEN FORWARD DRIVER AND ENGINE TRUCK ON MOGUL OR CONSOLIDATION.

If the break is at the forward end, get a jack and raise that end as high as possible; lay a rail across the frame and secure the equalizer with the chain to the rail. If the rear end, or the hanger connecting the equalizer to the cross equalizer is broken, raise the equalizer the same as in the other case and secure it with a chain to a rail placed on the frame behind the cylinders. Bring the cross equalizer down from the boiler and block between the boiler and cross equalizer also.

33. BROKEN ENGINE TRUCK WHEEL OR AXLE.

This is an aggravated case and requires considerable judgment. If it is a broken tire or a broken wheel, jack up the front end of the engine to take the weight off the truck. Take out the cellar and block with a V-shaped block of wood between the axle and pedestal brace. Jack up the truck frame high enough to allow broken wheel to clear the rail and secure the truck to the engine frame with a chain.

BLOWS AND POUNDS IN SIMPLE LOCOMOTIVES.

BLOWS.

These affect the steaming qualities of the engine and are often harder to locate than the pounds of which we treat in the next subject. A valve blow is often confounded with a cylinder packing blow, especially with the balanced type or one with supplementary ports. The most prolific cause is improper adjustment of the valve table or the proper dimensions of the valve. The distance between the table and valve of the Richardson balanced valve should never be over $\frac{1}{8}$ in. If this distance is exceeded broken balance strip springs are usually the case, particularly where an inferior spring is used. The balance strip, otherwise held up by the spring, settles down in the valve groove, steam passes over it and out of the small hole in top of valve to the exhaust. This hole is essential under normal conditions, as it permits any steam that may escape to pass out of it. Without this hole the valve would lift off of its seat. With any of the strips down the lever handles with a hard, jerky motion when the valve makes the return stroke on the defective side. A valve blow from a cut valve seat and valve will give a wheezing, intermittant sound, while the blow from a valve strip stuck down or broken gives off a clattering, vibratory sound.

A leaky or cut piston valve in addition to a blow will give a much heavier exhaust on the side the trouble is on and make the engine sound out of square. When a valve blows only when at one end of travel with the lever down in either the forward or back notch and ceases as soon as the lever is cut back towards the center, the valve overreaches the valve seat and is often due to a bent or loose tumbling shaft arm. In testing for cylinder packing it has been customary to test one side at a time. Both sides can be just as easily tested at the same time by placing the main pin on the right side on the forward top eighth. This brings the left main pin to the back top eighth so that both valves admit steam to their respective cylinders. Admitting steam to the cylinders with the engine in this position and cylinder cocks open, should steam escape from all four cylinder cocks it is conclusive evidence that the cylinder packing of both pistons are worn or broken and need prompt attention. In this case the packing will blow when engine passes either center. Should the blow occur when passing only one center it's an indication of a hole in the follower plate or spider, or a broken follower. In this it differs from a valve overreaching in that the blow takes place at all points of cut off.

Loose exhaust stand, tip or leaky steam pipes are always detected by their action on the fire. Instead of a bright, white fire, it is always of a dull red, with a tendency to drive the heat out of the fire door with each exhaust of the engine. Leaky steam pipes or exhaust stand are mostly due from loose saddle bolts causing the cylinder saddles to work.

POUNDS.

Some very annoying pounds are ofttimes encountered in the simple locomotive type that at times are hard to locate by the novice and old enginemen. Some require immediate attention to prevent damage to machinery and rolling stock. The remedy is often very simple when properly located. While the subject may be old to some, still the host of men who are preparing to supplant the present generation of locomotive engineers are anxious to succeed in their chosen calling. We will begin our subject with a loose follower bolt. Old engineers have allowed the piston to destroy the cylinder head through their inability to locate the pound. A loose follower bolt can only give trouble at one end of cylinder, the forward end, and then only when the piston reaches the fordward end of stroke. The first warning comes with the closing of the throttle when the engine is drifting. As soon as the throttle is opened and the lever cut back towards the center, pounding ceases as the steam forming a cushion takes up the lost motion in the rods. No time should be lost in coming to a stop. Remove the cylinder head and if the bolt can not be tightened remove it entirely. This same pound may also occur with defective rod work, but will manifest itself as soon as the engine leaves the roundhouse. If the rod has been made too long the pound will be on the forward head, and if too short on the back head. A loose piston head on the rod will pound the forward head and generally takes place when steam is exerted against the piston and the first indication will be a heavy knock when the engine is passing the back dead center and a click in passing the forward center. If the piston is secured to the rod with a nut that can not be tightened or has a key to secure it, remove it from the cylinder entirely, as safe repairs can not be made.

A loose piston rod in cross head will pound the forward head. Stop at once, and if it is found that the cross-head key is not the proper taper or the key is bent, remove the piston rod from cylinder.

Pounds in rods and driving boxes are found by placing the engine on the top quarter and blocking the wheels. Admit just enough steam to produce a movement of the boxes and rods when the lever is moved backwards and forwards. If it is found in the rods it may be due to a loose key or a badly worn brass. If the pound is in the forward end of main rod, hot main pins are always the result.

Pounds in boxes may be attributed to worn brasses, improperly fitted shoes and wedges, or improper adjustment of wedges by the engineman or inspector. The most pernicious practice is that of some enginemen, who, finding an opportunity to set up a few wedges on a side track, do so without giving the

others the proper attention. The result is the drivers are thrown out of tram, tire flanges are cut, driving-box brasses are pounded out of true and the engine gives continual trouble until she enters the shop for general repairs.

UNDERHUNG SPRINGS.

The method of hanging the driving springs and the equalizers of any locomotive is always of interest to the engineer, because he is, as a rule, desirous of knowing the extent of the effect which the failure of a spring or hanger will have in causing delays, when such failures occur on the road.

Nearly every engineer knows that the object of hanging the weight of the boiler and its attachments on springs is to permit the engine to be run smoothly at almost any rate of speed of which it is

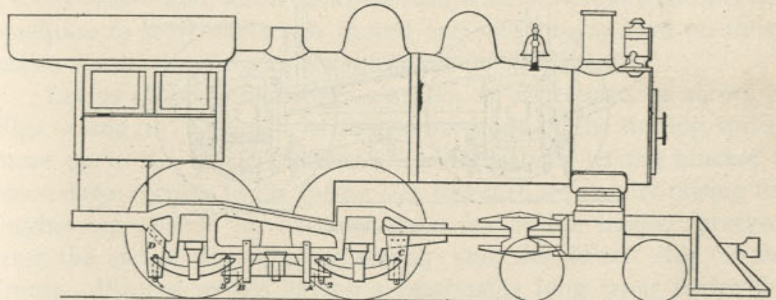


Fig. 1

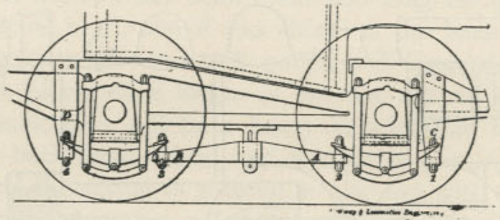
capable, over rough and uneven spots in the track, without severe jar or shock.

When it was the rule to employ much lighter engines than we have nowadays it was customary to place the driving springs over the driving boxes, allowing them to rest on spring stirrups, that in turn rested upon the top of the driving box, and then by means of hangers and equalizers to suspend the weight of the boiler from them.

As the demand for heavier engines and more boiler capacity increased, the space above the driving boxes, which had been used for the springs and hangers, had to be given up to make room for the larger boiler, which now generally spreads out over the frame at the firebox end, and a location under the driving boxes is now, in many modern designs of locomotives, used for placing the driving springs, hangers and the equalizers.

On eight-wheel engines the arrangement of the springs and equalizers when underhung is not radically different from what we find it when they are overhung, as may be seen by reference to Figs. 1 and 2 accompanying this article, except that it requires an entirely different scheme from that of the ordinary spring stirrups, or saddle, for holding the driving springs in place and for transferring their load to the driving boxes.

Fig. 1 shows the form of hanger, or we might term it underhung spring saddle, that is employed on some engines. It is attached to the driving box, extends downward and encircles the spring at the band. This form of spring saddle prevents the removal of the driving box cellar when it is necessary to pack the driving box, unless the engine is jacked up; otherwise it has proved very satisfactory.



UNDERHUNG SPRINGS

FIG. 2.

In Fig. 2 the springs are underhung, but the weight of the engine is all transferred to the top of the driving box on account of the long hangers that are connected to the equalizer beams that rest on the top of the driving box and from which the weight is suspended.

A little study of the figures will make clear the manner in which the weight is distributed to, and equalized on, the driving boxes. There are many other methods of hanging the springs under the driving boxes and different designs for the frame hanger brackets, but in principle they are all similar to those shown in the figures.

One thing may be said of the underhung spring, and that is, if it breaks, or if any of its hangers break, there is not the likelihood of the end of the spring getting far out of place or of the equalizer flying up so far that it will be a difficult job to get it back where it belongs. The most difficult part of fixing up a broken spring or

hanger on the road, on engines that have underhung springs, so as to get in without heating the driving boxes, is jacking the engine up high enough to get the required amount of blocking in between the top of the driving box and the frame, when necessary to hold the engine level, or in between the frame and the end of the driving spring, or frame and the end of the equalizer, as the case may require.

A few words here as to how to raise the engine up when it is necessary to do so, will not be out of place.

Time is, next to safety, the most important consideration on a railroad as elsewhere; therefore, before doing a whole lot of unnecessary work, look the situation over carefully to determine just how much is needed to be done. It may so happen that if a hanger breaks, or a spring, if your terminal is not far away, you can get along without jacking up or blocking up, and so need not cause any serious delay to your train. But if you find that it is necessary to jack up, then I believe in using a wedge to raise the engine with; a screw jack—well, screw jacks nowadays are seldom in good enough condition to work the screw in and out without any load on them, not to speak of raising a 50-ton locomotive with them.

Let us suppose the hanger 1 breaks, in either plan, as shown in Figs. 1 and 2. This will let the forward end of the driving spring move up in the hanger bracket *C*, or rather will let the bracket *C* move down relative to the spring. In this case we can, by raising the engine up, block in between the sides of the hanger bracket, over the end of the driving spring and the lower side of the frame. Place a wedge having a reasonably long taper under the forward driving wheel, and run this wheel upon it, remove the broken hanger and the gibs, and pry down the end of the driving spring, and fill all the space between the top of the hanger bracket, the lower side of frame bar, and the top of the driving spring with blocking. The spring cannot get away, and you can proceed, having the use of the other spring, and with your equalizer in proper position. If hanger No. 2 breaks, raise the engine the same way, level up the equalizer, and block it in position between the end *B* and the lower side of the frame; pry the back end of the spring down as close to the proper position as you can get it, and block there, placing your blocks over the top of the back end of the spring, between it and the jaw of the driving box. A chain could be used here to chain up the end *A* of the equalizer to the frame. Should either of the hangers 4 or 3 to back driving spring break, the same method of blocking as described for hangers 1 or 2 may be used, and to raise the engine run the back driving wheel up on the wedge.

Should the equalizer itself break, the engine may be raised by running first the forward driving wheel up on the wedge, then the back wheel, and each time that the wheel is raised fill the space between the frame and the top of the driving box with hardwood blocks until you have the engine high enough, so that you are able to pry the ends of the equalizer down to where they belong, and to block them there by placing hardwood blocks between the frame and the tops of the ends *A* and *B*. Then the blocks may be moved from the tops of the driving boxes, and you can proceed, having the use of both springs; but your equalizer will not perform its duty, namely, equalize the weight on the driving boxes, as the engine moves over uneven places in the track.

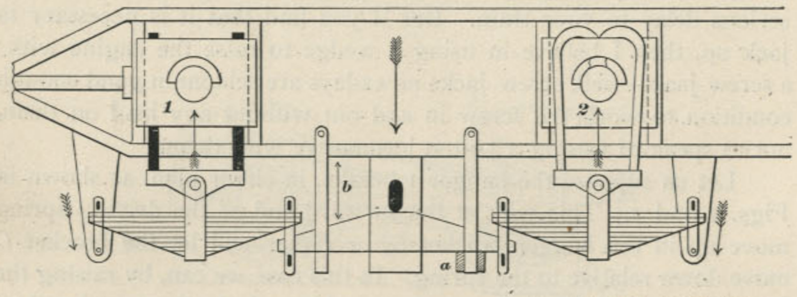


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FIG. 3.

In some cases of equalizers breaking, when the engine is moved up on the wedge, no blocking can be placed between the frame and the top of the driving box, as the equalizing beam is in the way, as shown in Fig. 2. In such cases the equalizer would have to be blocked while the engine was raised on the wedge.

Perhaps the most serious failure to the underhung spring rigging would be that of breaking the hangers that are suspended from the driving boxes, as shown in Fig 2. If one of these should break—say it was from the forward driving box—the frame of the engine would settle down on top of this driving box and rest there.

To get out of such a difficulty, it would be necessary to remove all parts of the driving box hangers and the spring, raise the engine by means of the wedge, block the end *A* of the equalizer down to its proper position, and block up over the top of the driving box until the frame of the engine is about level.

In some designs of underhung spring arrangement the equalizers

are provided with safety straps, as shown in Fig. 1, and some do not have them, as is the case in the arrangement shown in Fig. 2.

However, whether they are provided with safety straps or not, in case of failure of springs or hangers the equalizer is not likely to get badly out of place, as the ends cannot get higher than the lower bar of the engine frame.

We should suggest as a further means to become familiar with the underhung spring to make a skeleton sketch of an engine, similar to those we illustrate and study the direction of the forces on the springs as indicated in Fig. 3. By following this rule one can take

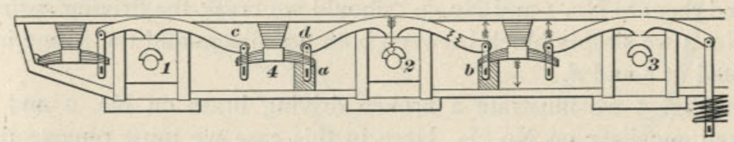

FIG. 4.

any type of underhung spring and master easily that which at first seems a very difficult problem and dispel the constant fear of not knowing what one would do in case of a breakdown.

In Fig. 3 we show two styles of hangings from the driving boxes, showing the direction of the stresses on the center and ends of the springs. No. 1 in Fig. 3 has four bolts passing through the box near the flanges and terminate in a cross bar from which the spring is suspended. No. 2 in Fig. 3 shows another arrangement

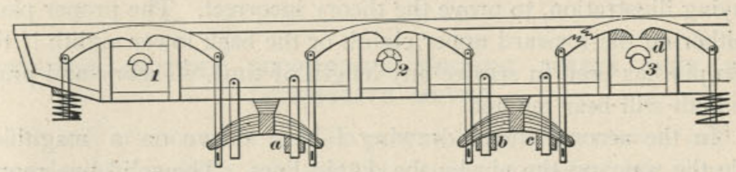

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FIG. 5.

favored by some designers and consists of two heart-shaped hangers resting on the top of the box and placed on both sides of the frame and extending down below the driving box to the spring similar to No. 1. It is the uncertainty on the part of the engineman as to the direction of the forces that confuses him and makes him dread a breakdown with an underhung spring.

In No. 2 driving box, Fig. 3, we show a broken brass and where to block in a case of this kind. If the engine is provided with safety brackets over the equalizer, raise the equalizer with a jack or bar a sufficient height to take the weight off the box and block at *a*, between safety bracket and bottom of equalizer. If there are no safety hangers, block between bottom of frame and top ot equalizer indicated at *b*. The arrows in Fig. 3 show the direction of the forces.

In Fig. 4 we have another type of underhung spring and equalizer. Here the driving-box brass and equalizer over No. 2 are both broken. If we block at points *a* and *b*, as shown, we have removed the weight off of the box and strain off of the equalizer and transferred them to No. 1 and No. 3. Should we break the driving spring at No. 4 we simply block between both equalizers and the frame indicated at *c* and *d*.

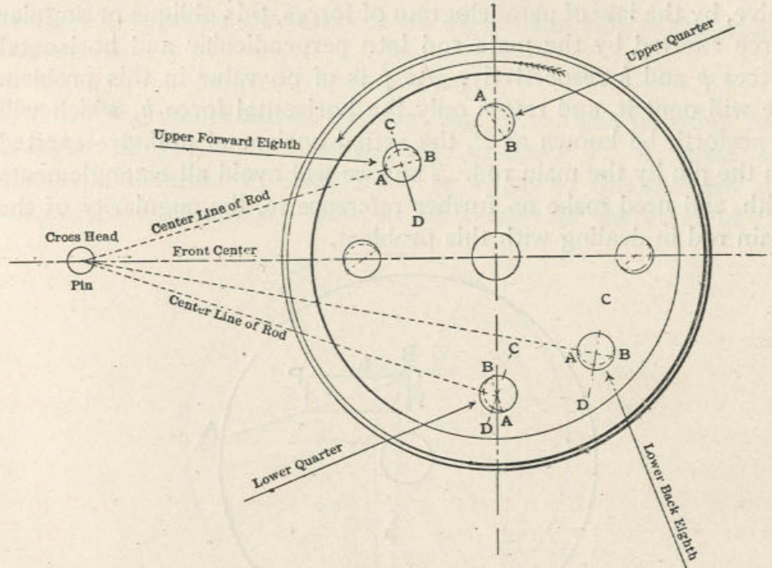
In Fig. 5 we illustrate a broken driving brass on No. 2 and a broken equalizer on No. 3. Here in this case we must remove the broken equalizer over No. 3 and block on the top of driving box. We next raise the spring at *a* and block between the safety hanger and spring, performing the same operation at *b* and then *c*. This saves the tedious work of removing the springs, hangers and equalizers and No. 1 and No. 3 will carry the load.

KEYING UP MAIN ROD.

As the question of keying up the main rod on the quarter is advocated by many mechanical men, I shall endeavor, by the accompanying illustration, to prove the theory incorrect. The proper place is either on the forward upper eighth or the back lower eighth if the main pin has been in service any length of time. Theory and practice both will bear me out.

In the accompanying drawing I have shown on a magnified scale the wear on the pin by the dotted lines. The solid line represents a perfect round pin, while the dotted lines a worn pin. Now we will key up the rod on the bottom quarter, as some claim is the proper place. The dotted lines *A B* show the greatest diameter of the pin, new or old. If the brasses (the dividing line between the two halves being *C D*) are keyed snug on either quarter they will be keyed on a diameter of the pin which is not its greatest diameter, and when the engine is moved so as to bring the pin on the lower back eighth or on the forward eighth, at which points the greatest diameter of pin will be at right angles to the dividing line C D,

between the brasses, the brass will pinch the pin and the result will surely be a hot running journal and a continual annoyance. But if the keying is done on either the upper forward eighth



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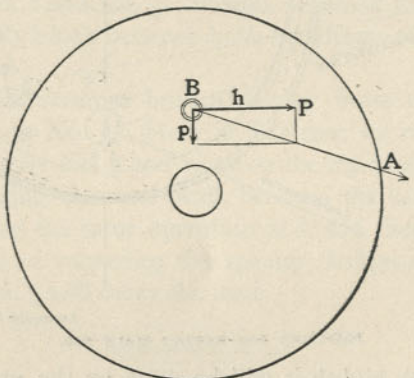
POSITIONS FOR KEYING MAIN ROD.

or the lower back eighth it will be done on the greatest diameter of the pin which is at right angles to the dividing lines, between the two brasses, and as a consequence the brasses cannot be keyed so as to at any point pinch the pin.

LEVERAGE OF THE LOCOMOTIVE DRIVING WHEEL—WHY THE LOCOMOTIVE MOVES.

I will try to make it plain why a locomotive moves, and for the sake of simplicity will ask the reader to confine his observations to one side of the locomotive only. What you wish to know is, how is the power applied to the wheels during an entire revolution? With a stationary engine the front and back cylinder heads form the resistance for the steam to push the piston, but what you want to know about a locomotive is, what are the points of the lever on the wheel when the pin is on the bottom quarter going ahead, and is the fulcrum at the axle the crank pin or the point of contact with the rail? I will try to make this clear by the following diagrams.

Fig. 1 shows the direction of the force applied by the main rod *A* on the pin *B*. As we are concerned only with horizontal forces in the movement of the locomotive along the track, we can resolve, by the law of parallelogram of forces, this oblique or angular force exerted by the main rod into perpendicular and horizontal forces p and h respectively. As p is of no value in this problem we will omit it, and retain only the horizontal force h, which will henceforth be known as P, the actual horizontal pressure exerted on the pin by the main rod. Thus we will avoid all entanglements with, and need make no further reference to, the angularity of the main rod in dealing with this problem.



Locomotive Engineering Fig. 1

LEVERAGE OF THE DRIVING WHEEL.

Fig. 2 shows the driving wheel acted upon by P, the force at the pin, P_1, the driving box resistance, and P_2, the force at the point of contact between the wheel and rail. The arrows indicate the direction the forces are acting, viz.: P and P_2 are forward and P_1 is backward. Thus we have a lever of the second class, whose arms are respectively 12 and 30 inches, and which is fulcrumed at P_2. The force exerted on the pin, we will say, is 10,000 pounds. Now we know the two lever arms and the force P, and will proceed to find the two unknown forces, P_1 and P_2. At the instant before the wheel starts to revolve there is an equilibrium of forces about the fulcrum point, P_2; *i. e.*, force P multiplied by its lever arm (the distance between P and P_2, which is 42 inches) is balanced by the opposing force P, multiplied by its lever arm (the distance between P_1 and P_2, which is 30 inches).

This we will state by the equation.

$$P_1 \times 30 = P \times 42, \text{ or}$$

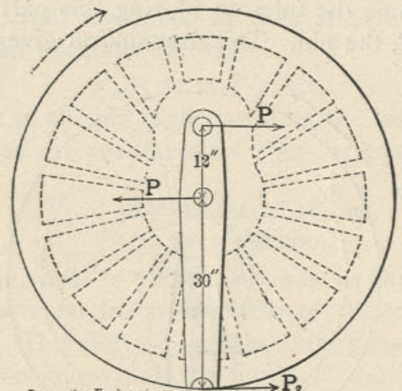
substituting together the known value of P, which is 10,000 pounds, we have

$$P_1 \times 30 = 10{,}000 \times 42, \text{ or,}$$

multiplying together the terms in the right-hand side of the equation, we have

$$P_1 \times 30 = 420{,}000.$$

Now, P_1 is an unknown quantity, but we can find its value, for we know, as the equation states, that 30 times P_1 is equal to 420,000. Therefore P_1 itself must be equal to one-thirtieth of 420,000, which is 14,000. Now, as we know that the value of P_1



Locomotive Engineering Fig. 2

LEVERAGE OF THE DRIVING WHEEL.

is 14,000 and of P is 10,000, we will put the figures instead of the letters in the equation:

$$P_1 \times 30 = P \times 42,$$

and we will have

$$14{,}000 \times 30 = 10{,}000 \times 42, \text{ or}$$

performing the multiplication, we have

$$420{,}000 = 420{,}000.$$

Thus equilibrium is proved.

Now that equilibrium of the forces has been proved, what have we accomplished that is useful? The answer to this question is that we have a proof that at the instant before the wheel begins to revolve the forward acting force of 10,000 pounds on the pin at the upper end of the lever just balances the backward acting force of 14,000 pounds on the axle at the middle point of the lever. Now, that this is proved, another step can be made. We will add enough more steam pressure to the piston to increase the force on the pin to, say, 10,001, instead of the even 10,000 as before. Now equilibrium is broken (for 10,001 times the lever arm, 42, equal 420,042, and is greater than 14,000 times 30 inches, which equals 420,000), and the lever will start to rotate about its fulcrum, P_2, and move in the direction of the greater force, which is to the right. Thus the wheel begins to roll to the right, and the engine moves forward.

Let us return for a moment to the lever held in equilibrium, as shown in Fig 2, for we have not yet found the value of P_2, the adhesion between the wheel and the rail. To find the value of P_2, we will assume the fulcrum (during this part of the computation) to be at P, the pin. This assumption gives a forward force

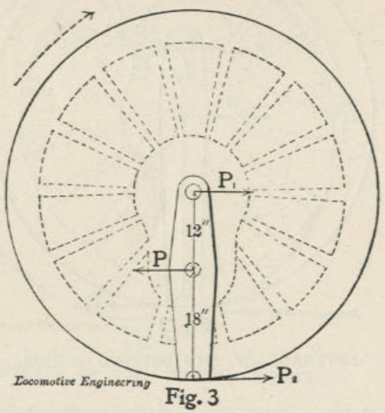


Fig. 3

LEVERAGE OF THE DRIVING WHEEL.

of P_2 multiplied by a lever arm of 42 inches balancing a backward force, P, multiplied by a lever arm of 12 inches. Putting this in the form of an equation, we have:

$$P_2 \times 42 = P_1 \times 12.$$

But P_1 has a value of 14,000 pounds, as proved. Putting this in, we have the equation

$$P_2 \times 42 = 14{,}000 \times 12, \text{ or,}$$
$$P_2 \times 42 = 168{,}000.$$

We do not know the value of P_2, but we do know, as the equation states, that 42 times P_2 is equal to 168,000 pounds. Hence P_2 must be the one forty-second part of 168,000 pounds, which is 4,000 pounds. To prove this, and also to prove our right to assume the fulcrum to be at the pin during this part of the computation, the forces directed forward must balance those directed backward, *i. e.*, $P + P_2$ must equal P_1, or $10{,}000 + 4{,}000 = 14{,}000$. This is done, and is therefore proved.

We will now rotate the wheel ahead one half revolution, as shown in Fig. 3, which places the pin on the lower quarter. This gives us a lever of the third class, where the force P is applied at the middle point of the lever and the fulcrum is still at the point of contact between the wheel and the rail. Again, at the instant before the wheel starts to revolve and the lever to rotate about the fulcrum P_2, the forces are in equilibrium; *i. e.*, the forces pointing to the left multiplied by their lever arm must equal those pointing to the right multiplied by their lever arm. Putting this in the form of an equation, we have:

$$P_2 \times 30 = P \times 18.$$

As the pressure at the pin is the same on the lower quarter as on the upper, we can replace the letter P in the equation with 10,000 pounds, thus:

$$P_1 \times 30 = 10{,}000 \times 18, \text{ or,}$$
$$P_1 \times 30 = 180{,}000.$$

If 30 times P_1 is equal to 180,000 pounds, as the equation states, then P_1 itself is equal to one-thirtieth of 180,000 pounds, which is 6,000 pounds. Therefore P_1 equals 6,000 pounds.

Now that we know both the forces P and P_1, we can easily determine P_2; for $P_1 + P_2$ together oppose and hold P in equilibrium. Hence P_2 is the difference between 10,000 pounds and 6,000 pounds (P and P_1), or 4,000 pounds. Thus it will be seen that the forces on the pin and the rail above the centers are the same as those on the pin and rail below the centers. One notable difference, however, is the pressure of the axle in the driving box, which is greater while the pin travels through the half revolution above the centers than that below. This is true whether the engine be running forward or backward.

Thus we learn that while the pin travels through the upper half revolution, we have a lever of the second class, which gives the same pressure on the pin and pull on the rail as that had during the revolution through the under half, when the lever is of the third class. The progress of the engine through space should, therefore, be uniform.

Beginning at the back center, as the engine moves ahead one half revolution of the driving wheels, the cylinders, frames and other fixed parts of the locomotive move forward through space a distance equal to one-half the circumference of the driving wheels, which is equal to one-half the diameter of the wheel multiplied by 3.1416 (30 $\times$ 3.1416), or 94¼ inches. During this half revolution the piston pulls away from the back cylinder head, and, with the second-class leverage in the wheel, pulls the locomotive along. The absolute travel of the piston through space is therefor 94¼ inches plus 24 inches (the stroke), or 118¼ inches.

As the wheel completes the revolution, moving the pin from the forward center through the lower half revolution to the back center, the fixed parts of the locomotive move through 94¼ inches more space, making 188½ inches in all. The piston, through this half revolution, now loses 24 inches, and travels, therefore, but 70¼ inches forward. Through this half of the revolution the piston forms the resistance, moving forward more slowly than the cylinder head, which pulls ahead while the piston forms the resistance. The pressure on the piston through the lower half revolution is exerted on the third-class leverage in the wheel.

The only times during the revolution that the piston stands absolutly at rest (in relation with the ground) is at the two dead centers.

STRESSES ON PEDESTAL JAWS.

The average man naturally supposes that the stresses on the front and back jaw are equal when a locomotive is exerting her utmost power in moving a train. That this idea is wrong I will endeavor to prove, and, by an inspection of the following diagrams, you will note the points of my proof:

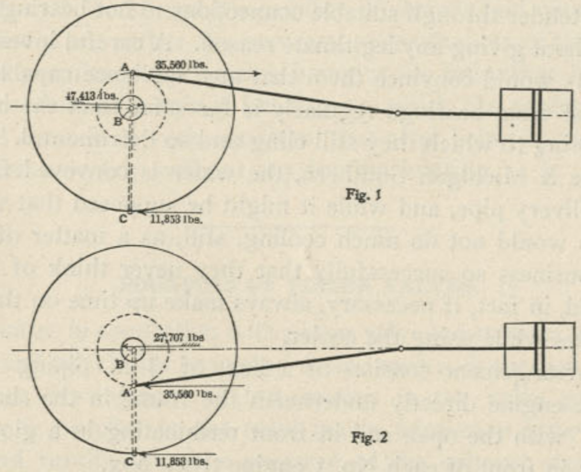
Suppose an engine having 18 x 24-in. cylinders, 72-in. drivers and carriyng 175 lbs. of steam. The engine is, by hypothesis, pulling a train, and we will further suppose that it is running slowly, so as to be in full gear. Then the maximum pressure on the pedestal jaws will be approximately when the crank pins are on the upper and lower quarters. The area of an 18-in. diameter piston (neglecting the rod) is about 254 sq. ins. With 175 lbs. boiler pressure we may realize 140 lbs. on the piston. Multiplying 254 by 140 gives 35,560 lbs., the thrust on the piston rod. Consider now this as a force, applied in a line parallel to the track to the crank pin on the top quarter.

If the center of the crank pin and the point of contact of the wheel with the rail be considered the extremities of a lever *A C* 4 ft. long, the fulcrum is at the rail *C*; the application of the force to the pedestal jaw is at the axle *B*, 1 ft. from the crank pin *A*, and the lever is one in the second order. The lever arms are here 3 to 4.

Consider the forces in equilibrium and we have a stress of 35,560 lbs. acting at the crank pin end, 1 ft. from the axle, or 4 ft. from *C*. Multiplying 35,560 by 4, the length of the lever arm *A C* in feet, and dividing by 3, the length of the other lever arm *B C*, we obtain 47,413 as the number of pounds exerted at the axle against the front pedestal jaw.

The difference of these two forms, or 11,853 lbs., gives the force acting at the end of the lever, which in this case is resisted by the friction between the wheel and rail.

Consider now the fact that not only is the steam pushing the piston forward in the cylinder, but that it is also pushing on the



STRESSES ON PEDESTAL JAWS.

back cylinder head with a force of 35,560 lbs. This is transferred by the frames, and as it is in an opposite direction to the force pushing forward on the front pedestal jaw, the difference of these two, or 11,853 lbs., must be taken as the net pull transferred to the draw bar.

Let us now proceed to the other position, with the crank on the lower quarter. Here we have a lever *B C*, 3 ft. long, one of whose ends *B* is the center of the axle, and the other the point of contact of the wheel with the rail C. The fulcrum is at the latter point as before, but the lever is now one of the third order.

With a force of 35,560 lbs. on the crank pin *A*, as before, one-third of this will go to the rail and two-thirds to the axle, the forces being divided inversely proportionately to the respective lengths of the lever arms. This gives 11,853 lbs. at the rail as before, and

23,707 lbs. against the back pedestal jaw. Remember, now, however, that the steam is also pushing against the front cylinder head with a force of 35,560 lbs., and this is transferred by the frames as before, so that the difference of these two amounts, or 11,853 lbs., is the net effort applied to the draw bar.

We therefore see that the stresses are double as much on the front pedestal jaw as they are on the back one.

USING INJECTOR TO COOL HOT BOXES.

Some lines are averse to the use of water carried either from the injector or tender through suitable connections to hot bearings on the engine, without giving any legitimate reason. A careful investigation of its merits would convince them that any appliance capable of removing heat from bearings regularly is far safer than the intermittent drenching to which they still cling and so detrimental. On the Lake Shore & Michigan Southern, the water is conveyed from the injector delivery pipe, and while it might be supposed that water as hot as this would not do much cooling, still, as a matter of fact, it does the business so successfully that they never think of losing a minute, and, in fact, if necessary, always make up time on their fastest schedules while using the cooler.

The arrangement consists of a line of $\frac{3}{4}$-in. piping running around the engine directly underneath the frame in the shape of a letter "U," with the open end in front terminating in a glove valve waste cock in front of each No. 1 engine truck box.

Connection to this pipe is made by a $\frac{3}{4}$-in. pipe tapped into each delivery pipe directly ahead of the injector, chocked to $\frac{1}{4}$ in. at the top and leading directly down to the $\frac{3}{4}$-in. pipe below, opened and closed by a globe valve in upper end.

Connection is made from the $\frac{3}{4}$-in. pipe to each driving and engine truck box by means of $\frac{1}{2}$-in. hose connected to the inside end of the cellar by nipples, into which are screwed from inside the cellar bent pipes which extend along the bottom of the cellar to the middle, where they rise on the side just as high as possible without touching the journal. Each hose is closed by a globe valve.

The cooler may thus be operated from either or both injectors, and will throw water sufficient for one or all the boxes on the engine. These hose are securely clamped to nipples to prevent being forced off by pressure.

A $\frac{3}{16}$-in. hole is drilled into the under side of each end of the main water line, from which there is a continuous flow of water while in operation. This insures a circulation of water throughout the pipe and prevents freezing.

A $\frac{3}{8}$-in. steam pipe, closed by a globe valve, is also run from the boiler to the water line, which is used as a heater while cooler is not in use. The method of using it in freezing weather is to open the waste cocks in ends of the water line until all water is blown out, after which they are closed and sufficient pressure maintained to insure a free flow of steam through the $\frac{3}{16}$-in. vent holes.

You thus have a cooler always ready for use at a moment's notice, and one which will handle any hot box at any speed.

It might be supposed that the use of this would naturally increase the number of "hots" and the number of chronic bad ones, but they do not find it so; rather the contrary, since the use of the water in the cellar permits of the bearing being at the same time freely oiled on top, so that, as a rule, a bearing on which the cooler has been used will come in in such condition that after being sponged it will run on the next trip without any further heating.

POUNDING OF PISTON VALVES.

A matter in connection with piston valve locomotives which is of interest, and which has prompted some inquiry, is the pounding and consequent development of lost motion in the valve gear. This pounding is peculiar to the solid inside admission type of piston valve, and results from the pressure of the exhaust steam which, passing up over the ends of the valve exerts a force sufficiently great to take up the lost motion in the valve gear with a jerk or pound, more or less, according to how the engine is being worked. The exhaust pressure, it will be understood, operates to move the valve in the direction in which it is traveling at the time. The lost motion in the valve gear being taken up by the effort of moving the valve, it is consequently free to be forced ahead the distance which the lost motion in the connections will allow. In the case of an engine considerably worn and being worked slow and in long cut off this pounding is excessive and results in rapid wear and increase of lost motion. This action soon becomes severe enough to crystallize and break valve stems and other parts. It also causes a certain irregularity in the admission of steam, since the valve jumps and then stops until the lost motion is taken up. This effect is perhaps not important, but the pounding is so detrimental to the gear as to probably preclude the use of solid piston valves, when the matter comes to be thoroughly understood.

CAUSE OF POUND OF PISTON VALVES WHEN DRIFTING.

The question was asked in a railway magazine, "What causes piston valve engines to pound when drifting with lever hooked up?" The answer given was that this pounding is caused by compression in the cylinders, on account of the early closing of the exhaust when valve is running in short travel. This is a mistake. The pounding, which is in the rod brasses, is caused not by compression, but by the lack of it, on account of the valve opening for admission, and thus permitting the air which is being compressed to escape into the steam ways. There then being no resistance, the momentum of piston and connected parts takes up the lost motion in rod brasses with a jerk. The pounding can be stopped either by placing the lever in the corner or on the center—or, which is the better, by keeping main rod brasses filed.

OVERLOADED ENGINES ARE EXPENSIVE.

"The overloading of engines is a most expensive practice, occasioning more repairs than ordinarily needed, and excessive fuel consumption, it lessens the capacity of a railway, and is expensive in overtime and is indirectly the cause of train accidents," so spoke Mr. G. J. Bury, general superintendent Lake Superior Division, Canadian Pacific Railway, at a meeting of the Canadian Railway Club.

The speaker referred to the increase of 101.91 average trainload tons between the years 1889 and 1901 on his road. Eased grades and heavier engines in part accounted for increase, but greater loads for engines accounted for the remainder. Transportation officers, he said, know that to use minimum staff in moving a given tonnage is the most economical way to do it. If freight trains average 15 miles an hour, train crews can make 5,000 miles a month, while if the average be reduced to 8 miles an hour, men cannot stand more than 3,000 miles a month. If they make 2,500 miles during slack times for, say, eight or nine months in the year, they would be able to make up to perhaps 5,000 miles for the few months of the rush. The economical plan is, if possible, to make the regular, trained staff handle a rush without dangerously overtaxing them. More men employed with trains traveling at slower speeds produces greater risk of accident, first, by introducing longer service hours, and, second, by the larger employment of new men.

Mr. Bury makes a calculation in which he shows that a 2-8-0 engine hauling a train weighing 1,100 tons (tare and contents) over 118 miles up and down several 1-per cent. grades at an average rate of 8 miles an hour, would cost $41.96, or 32.3 cents per thousand miles. The cost of a train of 1,000 tons (tare and contents) hauled by the same engine over the same division, but at 15 miles an hour, would come to $34.13, or at the rate of 28.8 cents per thousand miles. The lighter train also produces less wear and tear on the engine, and so reduces its maintenance account—just how much would have to be decided by actual tests extending over a given period of time.

The economical load is, of course, variable, but the speaker held that it was decidedly uneconomical to overload engines when traffic was dense, because, as he rightly said, "even one train staggering and doubling over a district will demoralize the trains following and those met, resulting in overtime, extra consumption of fuel and the risk of train accident, which increases when train and enginemen are long hours on duty."

OVERLOADING ENGINES.

Are the railway companies solving the problem of freight transportation successfully? Are they not sacrificing revenue in order to show up a big ton-mile haul? We know they are destroying the efficiency of their power by overloading and sending their engines to the repair shops long before they should be there, all on account of some official of high degree whose idea of economy got started on the wrong track.

The superintendent of motive power must slight his work because of the small amount allowed for repairs, and the condition of the engines is shown (on paper) as first-class when really far from it.

The enginemen are cut on valve oil so that the internal resistance of the machinery, which under favorable conditions is from 10 to 15 per cent., goes up to 25 or more. Not only does this mean a loss of horse power, but also a decided increase of coal consumption. An increase of oil means a decrease of coal consumption. The additional expense incurred for oil to secure the best results would be more than compensated for by the saving in coal. Suppose you give an engine one pint of valve oil valued at 7 cents to make a run of 125 miles, consuming 14 tons of coal at $1 per ton, and you then increase the oil allowance to one and a half pints, at a cost of 11 cents, and cut down your coal consumption to 13 tons (which is a fair inference based on personal experience), does this not show a net gain of 96 cents on the right side of the ledger?

Remember, when you cut the necessary supplies below what they should be, you encourage your employees to be dishonest.

Give an engine a fair rating, with an average speed of 20 miles per hour, and you will move more cars with her over her district in a week than you can, if you load her down, allowing no reserve power and cutting down the speed to 10 miles or less. While it is true that your ton mile per train will be less with the former, your revenue will be greater on account of the reduced time of freight in transit. For instance, if a car passes over a district in 10 hours, and returns to the starting point in another 10 hours, that car is earning just double as much as the car that consumes 20 hours going one way.

The argument may be made that by increasing the load per train we have fewer trains on the line, and reduce the danger of accidents, which looks very well in print, but let us look at the matter from another point, and see if it is not true that we increase the danger instead of diminishing it. Is an engineer's brain as clear and safe when he is on the road 25 or 30 hours as when he is out only 10 hours?

The passenger engineer working five or six hours has the right of track over the freight men, and the latter have to keep out of his way. The passenger man assumes no risk, the freight man all. The former has regular hours of rest after each trip, the latter none. The man with the longest working hours has the shortest rest.

The majority of railroad accidents are due to overworked brains, and, likewise, the overloaded engine is productive of the most failures. An engineer with an overworked brain is not only a dangerous risk to the public, but a financial loss to his employer.

The capacity of an engine for work depreciates according to the service she is put to, and the length of time she is kept in that service. Her rating ought, therefore, to be re-established from time to time.

Don't ask your enginemen to do the impossible with power that ought to be off the right of way. Have a pleasant word for them. Don't censure them for your mistakes.

Cut down your tonnage so that your enginemen can get over the road on schedule time. They would rather have rest than overtime. The results will show in increased revenue, and it is the large revenue a road earns and not big ton miles that makes the stock "gilt-edged."

WHY LARGE ENGINES FAIL.

The problem of overcoming the too frequent failures of the large engines has been the one absorbing thought of the builder, designer, and superintendent of motive power. Opinions from these different sources have been given to the public through the press of late, and in the majority of cases the cause of failure has been attributed either to the ignorance or indifference of the enginemen—due to the pooling system—or the employment of new engineers and firemen made necessary by the increasing traffic. While this is often the true cause, it is not by any means the whole reason for the failure of the big engines. Faulty design and bad water have contributed more to these failures than anything else. When engines break 500 stay bolts in five months, or an average of three and one-third per day, there is certainly a fault in the design. On many of our roads where stay bolts are tested only at wash-out periods, which come about twice a month, an engine breaking three stay bolts a day is a slumbering volcano, liable to create havoc any minute. Nursing an engine to please the superintendent of motive power is not the transportation department's idea. Their instruction to the engineman is, "Never mind the engine. She belongs to the company, and we want you to pull cars and get there." With this order, the "good" or the "indifferent" engineman has no choice.

Pooling engines has been a blessing to the careless and incompetent men and a curse to the energetic and competent.

Abridging water space in order to get more heating surface has been the prolific cause of leaky flues in the bad-water districts of the West.

Pressing "handy men" into service to do experienced boilermakers' work, in order to save expense, has caused many an engine failure, and is always an expensive sort of economy.

The engineman has no voice in the question of pooling, tonnage rating or the employment of repair men, yet much blame is laid on his shoulders. With the advent of the large engines came a change in fire-door design, some of our "battle ships" having two doors and so arranged that it is almost impossible for the fireman to operate them to advantage. The result has been that the fireman, unable to close the door after each scoopful of coal, and having to coax the monster with 25 tons or more of coal over the division, has adopted the opposite plan and left the fire door open until five or six scoops at a time have been shoveled into the fire. This always means disaster to the fire box. The indifference of some of our lines to these conditions is the cause to-day of so many of their old firemen leaving their service. Breaking in new firemen is expensive business. So long as railroads place so little value on the services of an experienced fireman, ignoring his needs in order to save a few dollars, just so long will the stockholders continue to wonder why the big engines earn so much less than they were expected to.

We must disagree with the builder who tells the public that the waters of the Western States are almost certain death to those who drink them. We are familiar with the waters of California, Colorado, New Mexico, and Kansas through years of experience, and know people who have been using them for twenty years without serious inconvenience. We must also disagree with the statement that 50 to 75 per cent. of cylinders in the old single-expansion engines in use ten or fifteen years are banded or patched, owing, of course, to this same deadly water. Bad water will convert a steam engine into one of the hydraulic kind very often, but many of the fractures mentioned were made by defective pistons or piston rods. Frequent inspection would have reduced the percentage. When those engines were built, we had no piston valves. Piston valves are not a success in bad-water districts, because they cannot free themselves of water so readily as the old slide valves. For the sake of argument, allowing the damage to cylinders on the engines with slide valves to have been 25 per cent., the damage to the piston-valve class, had there been any such, would have footed up 50 per cent.

The lack of facilities for repairs to the large engines is to be charged against the railroad companies. The lack of interest on the part of the engineers and firemen is also directly attributable to the nearsightedness of officials who failed to see far enough ahead to establish a thorough system of instruction and examination for their enginemen. Had this course been pursued, the careless and incompetent men could easily have been located and removed without wasting years in misplaced confidence. Later, when rush of business compelled wholesale promotions, some officials shut their eyes to plain facts and promoted men who passed a quasi-examination, but never made any effort to study the mechanism or management of a locomotive until the coming examination was announced.

If the large engines are to be a success, the needs of the enginemen must be considered, and they must be assisted in every way in the performance of their work. Periodical examination of firemen will give good timber to promote from. Coupled with these examinations there should be on every road a competent force of traveling engineers and firemen, masters of their business, thorough instructors and disciplinarians, with lots of patience to help those who show a disposition to help themselves. Many an indifferent engineman, with proper instruction and kind treatment, will develop into a first-class runner and careful student of mechanics.

RAILWAY GAUGES OF THE WORLD.

An interesting table prepared by the Baldwin Locomotive Works, of Philadelphia, shows the various gauges of railways for which they have built engines in all parts of the world during the years 1901 and 1902. They range from 18 ins. up to 5 ft. 6 ins. The table is as follows:

1 ft. 6 ins.	2 ft. 11½ ins.	3 ft. 9¼ ins.
1 ft. 9 ins.	3 ft. 0 in.	4 ft. 0 in.
1 ft. 11⅝ ins.	3 ft. 3⅜ ins.	4 ft. 1 in.
2 ft. 0 in.	3 ft. 4 ins.	4 ft. 8½ ins.
2 ft. 2¾ ins.	3 ft. 5 ins.	4 ft. 9 ins.
2 ft. 3.6 ins.	3 ft. 5½ ins.	4 ft. 9.07 ins.
2 ft. 5 ins.	3 ft. 6 ins.	5 ft. 3 ins.
2 ft. 6 ins.	3 ft. 7½ ins.	5 ft. 5.83 ins.
2 ft. 11 ins.	3 ft. 8 ins.	5 ft. 6 ins.

VALVE MOTION.

IRREGULARITIES OF CUT OFF WITH AND WITHOUT A ROCKER.

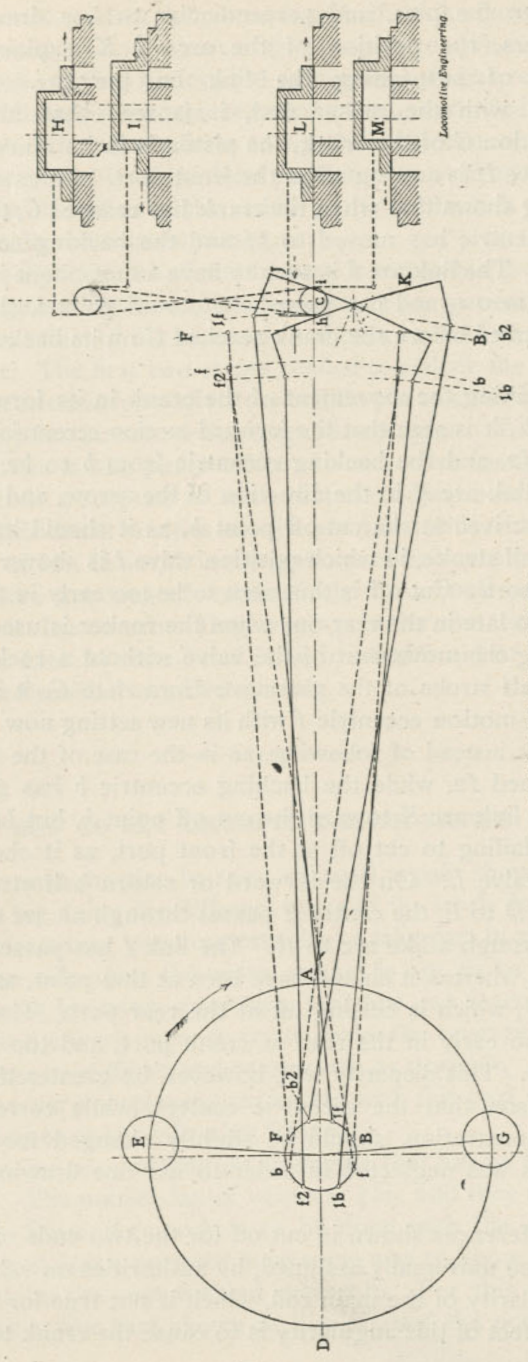
By O. H. Reynolds.

We will endeavor to show with the aid of the accompanying drawing the irregularities of cut off with and without the rocker arm, why the cut off occurs too early in one case and too late in the other. Our description and drawing will treat with a valve gear with the crank pins shown for the half-stroke position of the piston—the point usually selected to show inequalities of steam distribution to the best advantage. A rocker with arms of equal length and a center line of motion coincident with center of cylinder, is assumed.

The centers of eccentric are designated by characters corresponding to elements on which the link positions are drawn, as *F B* and *f b*, for the forward and backward eccentrics, and *1f*, *1b*, the same eccentric centers after advancing through the same angle traversed by the crank in passing from the forward center *A* to the half-stroke position *G*. *f2* and *b2* are location of eccentric centers when the crank has passed from the back center *D* to the upper half-stroke position *E*.

Arcs are drawn from these centers with a radius equal to the length of the eccentric rods, which is the radius of the link minus the distance from the link arc of the center of eccentric-rod pins back of the arc. The arcs thus drawn determine the position of the link, as the rod pins are resident in them. The arcs *F B*, *f b* locate the true position of the rocker and link block for the neutral or central position *c* of the valve over the ports. From *c* as a center a circle is described with a radius equal to the lap of valve, and points *h i* on the circle represent the steam ports opening or closing—that is, the steam edges of valve and port are line and line.

After having drawn the link arcs *J K* by means of a cardboard template cut to the correct radius—in this case 60 ins.—and which has the eccentric-rod pins properly located, together with a center



LAYING OUT A LINK MOTION.

line between the pins, and perpendicular to line drawn through their centers, the position of the arcs *J K* explains at once the effect of suspending the link on the arc. Considering the motion with the rocker first, it is seen that for the half-stroke position *G* of the crank, the piston is in its rearward stroke and the valve *H* is cutting off at the front port. An examination of the drawing shows that when the crank has reached *G*, the forward-motion eccentric has moved to *1f* and the backing eccentric has reached *1b*. The link arc *J* is seen to have a movement in the direction of the arrow, and has passed the cut-off point *i*, showing that cut off occurred before the crank reached *G* on its backward stroke from *A*.

Next taking the movement of the crank in its forward stroke from *D* to *E*, it is seen that the forward-motion eccentric has moved from *f* to *f2*, and the backing eccentric from *b* to *b2*, which has moved the link arc *K* in the direction of the arrow, and shows that it has not arrived at the cut-off point *h*, as it should have done to cut off at half stroke, in which position valve *I* is shown cutting off at the rear port. Cut off is thus seen to be too early in the forward port and too late in the rear one when the rocker is used.

Tracing the movement of the valve without a rocker, for the rearward half stroke of the piston, or from *A* to *G*, it is seen that the forward-motion eccentric *f* with its new setting now goes ahead of the crank instead of following, as in the case of the rocker, and it has reached *f2*, while the backing eccentric *b* has gone to *b2*, moving the link arc *K* toward the cut off point *h*, but falling short of it, thus failing to cut off at the front port, as it should do, as shown by valve *L*. On the forward or return half stroke of the crank from *D* to *E*, the center *F* passes through an arc *1f*, and the center *B* through a like arc to *1b*. The link *J* has passed the point of cut off *i*, whereas it should have been at that point, as shown by the valve *M*, which is cutting off at the rear port. The cut off is therefore too early in the rear or crank port, and too late in the foward port. This disparity will, however, be greater than shown, for the reason that the eccentric centers, while correct for the rocker demonstration, should be slightly changed for the direct motion; this was neglected in order to use one drawing for both motions.

The differences shown in cut off for the two ends of the cylinder have been universally assigned, by authorities on valve motion, to the angularity of the main rod, which is not true for a link motion. The effect of this angularity is to cause the crank to fall short of its true position when the piston is at half stroke during its rearward movement, and to overrun its true position when the piston is at half stroke during its forward movement. It has remained for Mr. F. A. Halsey, to discover and demonstrate that of all the errors to be corrected in order to have an equal distribution of steam, this one of the main rod is of the least importance; as a matter of fact, he found that the offset of the saddle pin from the link arc became less as the main rod was shortened.

The principal causes of disturbance found in his investigations were the angular vibration of the eccentric rods as next in importance, and the offset of the eccentric-rod pins back of the link arc as the greatest. The first two errors tended to reduce the last, and it then became necessary to offset the saddle pin to entirely overcome the knuckle-joint action of the eccentric-rod pins. To those who believe that the saddle pin is offset as a corrective for the main-rod error, it will be a surprise to learn that the adjustment of the saddle pin for this disturbance is outside and not inside of the link arc. The results of Mr. Halsey's investigations of link-motion errors referred to here are treated exhaustively in a book published by Railway and Locomotive Engineering under the title of "The Locomotive Link Motion," and is an invaluable aid to the student and advanced scholar on valve motion.

HOW TO SET LOCOMOTIVE SLIDE VALVES.

The present practice in most railroad repair shops of having special men for doing the different parts of the work does not give the apprentice a very good opportunity to take part in all the work, and the man who does the valve setting is apt to be thought of by the boys as knowing something that few can learn, and some men who do the work seem to try to make the operations of valve setting appear as difficult and mysterious as possible. That there is nothing so very perplexing connected with this part of the work we will endeavor to show in what follows.

Suppose we are working on an engine that has an indirect link valve gear. The outside lap of valves is $\frac{3}{4}$ in. and they are line and line inside. Since the work is to be done with the steam chest covers screwed down, we must have some way to know the position of the valve on the seat without seeing it. For this purpose we will use a tram like that shown in Fig. 20, and the points *a* and *b* on valve stem, and point *c* on steam chest stuffing box, all shown in Fig. 21.

Point *c* may be in any convenient place, but it is generally a little to the outside of the top of stuffing box. We will now find the points *a* and *b*, which must be done before the chest covers are put on. Slide the valve ahead until it is just beginning to uncover the back steam port. A piece of tin is usually slipped between valve edge and port edge to prove that the port is beginning to be uncovered. Then place the short point of the tram in the point *c*, Fig. 21, and with the long point scribe an arc across the top of valve stem. Draw a line on top of and parallel with the stem, then

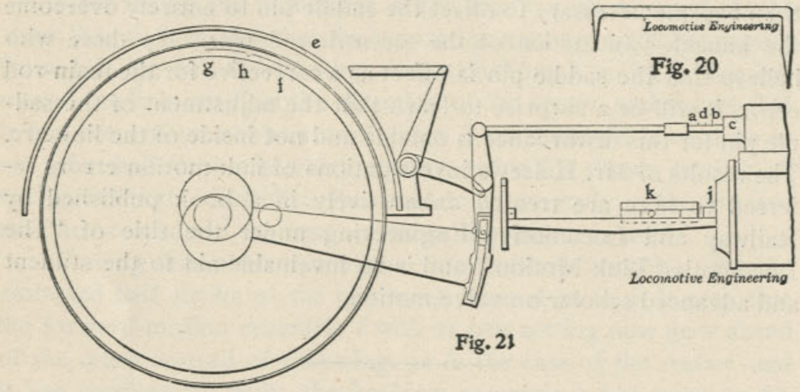


Fig. 20

Fig. 21

the point of intersection of the line and arc will be the point *a*, which should be marked with a small center punch mark. Now slide the valve back until the front port is just beginning to open, then proceed to get point *b* as *a* was found. The distance between *a* and *b* is equal to twice the lap of the valve. Before getting these points the valve stem gland should be in place, also the valve rod connected up, thus keeping the valve stem the same height, since any variation in the height of stem will cause the tram to extend a greater or less distance back of *c*. Hence the necessity for keeping the stem the same height as when it was marked. Theoretically, when the valve is on the center of the seat, the upper rocker arm should be at right angles to the seat, and the length of the valve rod should be such as will bring these conditions about. Otherwise the valve will not travel the same distance each way from the center of seat. Practically, the rod can be $\frac{1}{4}$ in. either way from this length without having any injurious effect on the valve's travel.

But it is well to know how to find the proper length of the valve rod. On the end of the rocker shaft scribe a circle, whose center is the center of shaft and whose diameter is the same as that of the hole for the pin in the top of arm, Fig. 22. Put the valve on the center of the seat, which position will be indicated by the tram reaching from *c* to a point *d*, midway between *a* and *b*, Fig. 21. Also put a line with a weight on each end of it over the valve-stem pin, as shown in the Fig., then lengthen or shorten the rod until the lines touch the circumference of the circle on end of shaft.

Before commencing to get the dead centers it is well to know that the driving wedges are properly adjusted. Also see that the eccentric rods are connected in the right way, that is, the forward motion rod to the top of link and backward motion to the bottom. Remember that with an indirect-link motion, such as we are dealing with, the eccentric that is controlling the valve always follows the crank pin, or when the pin is on the forward center the forward-motion eccentric will be almost above the axle, and the other almost below, and both will be advanced or turned toward the pin enough to overcome the lead and lap of the valve. We will not expect to get the eccentrics in exactly the right place at the start, but will set them as near as possible without doing any measuring, or, in other words, we will at first guess at their position.

Now proceed in the following manner to find the exact dead centers and length of eccentric rods. It is important that the dead centers be accurately located. While the cross head moves very little when the pin is near the center, yet the valve is at about half travel. Hence it is moving at nearly its greatest velocity, and a slight error in finding the dead centers will seriously affect the accuracy of the work.

It makes no difference which center is found first, but for convenience we will get the front one on the right-hand side. Suppose the pin to be above the center. Make a center punch mark at any convenient place on the wheel cover, say at e, Fig. 21. Then turn the wheels ahead until the cross head is about $\frac{1}{4}$ in. from the end of its travel. With one point of a tram, similar to Fig. 23 (which is made of $\frac{1}{2}$-in. steel and is about 12 ins. long), in the point e, scribe the arc *f* on edge of tire, and before moving the wheels, with the same tram, and with point *j* on front guide block as a center, scribe the arc *k* on cross head. Now turn the wheels ahead past the center far enough to bring the arc *k* slightly back of the tram point. When the other end of tram is in the center punch mark *j*, turn the wheels slowly backward until the arc *k* has the same position that it had when it was made, which position can be found by holding one point of the tram in *j* and stopping the wheels when the other point reaches the arc.

Now scribe the arc *g* on the tire, using *e* as a center. With dividers bisect the distance between *g* and *f* and get the point *h*. Perhaps it will be well to explain why when the wheels were turned until the pin passed the center they were turned enough to carry the cross head farther back than when the arc *k* was down. At that time the pin was pushing the cross head forward, and consequently the lost motion between the pins and brasses was taken up in that direction. If we had stopped the motion when the pin had passed the center and the cross head was traveling back, the lost motion would have been taken up in the opposite direction. Hence the arc *g* and also the point *h* would have been slightly away from the proper place. But when the cross-head was pulled back past the right place then the direction of the motion changed to

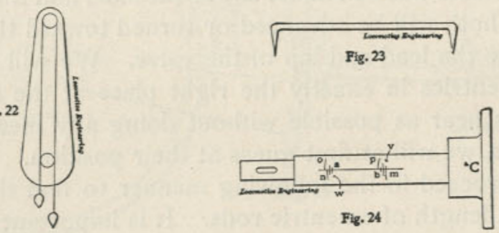


Fig. 22 Fig. 23 Fig. 24

bring it ahead again, the strain on the rod was the same as when the arc *f* was drawn.

We have found the point *h* and the pin is now a short distance below the center. Throw the reverse lever back as far as it will go, then turn the wheels backward until the tram will reach from *e* to *h*, then the pin is exactly on the dead center. With the short point of the valve stem tram, Fig. 20, at *c* scribe an arc *m*, Fig. 24, on the valve stem from the top to the outside.

The reason this arc is drawn from the top to outside of stem is because the backward-motion eccentric is moving the valve, and this eccentric is on the outside, or nearest the driving box. In this way it is easy to remember which marks were made for the backward and which for the forward motion.

After scribing the arc *m*, and before moving the wheels, make a mark across the outside edge of the outer guides opposite the end of cross head. This mark indicates the end of the stroke, and we will have occasion to use it later. Turn the wheels back enough so

that when they are turned ahead again all the lost motion in eccentric straps and other connections will be taken up in that direction, then put the reverse lever in full forward motion and turn the wheels ahead to the center. Now with the valve-stem tram scribe an arc on valve stem from the top to inside of stem shown at *p*, Fig. 24. We now know the position of the valve on the seat for both forward and backward motion when the pin is on the front center on right side. Get the other dead centers and positions of valve in the manner described.

We will now proceed to adjust the eccentric rods to the right length. Fig. 24 is a top view of the right valve stem after it has been marked as described above. The arcs *o* and *p* were made with the lever in the forward motion, and *m* and *n* with the lever in backward motion.

When the tram, Fig. 20, reaches from *c* to *a* or *b*, Fig. 24, the valve is at the point of cut off, and since the valve is to travel the same distance each way from these points, we can measure from *a* and *b* to the arcs to determine how much and whether to lengthen or shorten the eccentric rods.

First the forward motion: Suppose the distance from *b* to the arc *p* to be $\frac{1}{8}$ in., and from *a* to the arc *o* to be $\frac{3}{8}$ in., thus indicating that the valve is traveling farther ahead than back of the center of the seat, also that the forward-motion eccentric rod is too short, adjustment must be made. Since the arc *p* is back of *b*, and *o* is back of *a*, the amount to lengthen the rod is equal to half the sum of the distances *o a* and *b p*, or

$$\frac{\frac{3}{8}+\frac{1}{8}}{2}=\frac{1}{4} \text{ inch,}$$

provided the upper and lower rocker arms are the same length. If, as is often the case, the lower arm is the shorter, the length of the rod will not have to be changed quite as much as is indicated by the mark on valve stem. But we will suppose the arms to be of equal length, therefore will lengthen the rod under consideration $\frac{1}{4}$ in. The distance from *a* to *o*, before changing the length of the rod, was $\frac{3}{8}$ in. The change will shorten this distance $\frac{1}{4}$ in. and bring *o* $\frac{1}{8}$ in. back of *a*; *p* will also be $\frac{1}{4}$ in. farther ahead, which will put it $\frac{1}{8}$ in. ahead of *b*, or the same distance that *o* is back of *a*, thus "squaring" that side of the engine in forward motion.

The manner of finding the amount to change the length of the backward-motion eccentric rod is not quite the same, because one of the arcs is already back of and the other in front of the points *a* and *b*. The distance between *a* and *n* is $\frac{5}{16}$ in., and between *b* and *m* $\frac{3}{16}$ in., which shows that the backward motion rod is too short, and it must be lengthened half the difference between the distances *a n* and *b m*, or

$$\frac{\frac{5}{16} - \frac{3}{16}}{2} = \frac{1}{16} \text{ inch.}$$

This will bring *n* $\frac{1}{16}$ in. nearer to *a*, making the distance between *a* and *n* $\frac{1}{4}$ in.; and *m* will be $\frac{1}{16}$ farther from *b*, making their distance apart $\frac{1}{4}$ in., which will square the valve for backward motion. Now adjust the rods to length on the other side of engine in the same way.

Perhaps the following rule for determining the amount to change the length of eccentric rods will be helpful to some:

When the arcs on valve stem are both back, or both ahead of the points of cut off, the length of the rod should be changed an amount equal to half the sum of the distances between the points and arcs, or where one arc is back and the other ahead of the point of cut off, the length of the rod should be changed an amount equal to one-half the difference of the distances between the arcs and points.

If it is desired to give the valves $\frac{1}{16}$ inch lead in both forward and backward motion in full gear, and before setting the eccentrics it is necessary to have some marks on the valve stem to guide us. To get these points set a pair of dividers to the distance between the points *a* and *b*, Fig. 24, plus the lead, or in this case, $1\frac{1}{2}$ ins. plus $\frac{1}{16}$ in. equals $1\frac{9}{16}$ ins. Then with one point of dividers in *a* scribe an arc *v* across the top of valve stem in front of *b*, then with *b* as a center scribe the arc *w* back of *a*.

We will set the forward-motion eccentric first. Put the reverse lever in full forward motion, then turn the wheels ahead until the center is reached. Suppose it to be the front center.

When getting the length of eccentric rods we found that with the engine and lever in this position the valve lacked $\frac{1}{8}$ in. of closing the port; or, in other words, the valve had $\frac{1}{8}$-in. lead. Hence, it must be reduced to $\frac{1}{16}$ in.

This could be done by turning the forward-motion eccentric backward, but that would take up the lost motion in the opposite direction from what it is when the engine is running; hence the eccentric should be turned backward enough to take off all the lead, then turn it slowly ahead until the valve-stem tram will reach from *c* to *v*, Fig. 24. Fasten the eccentric in that position. Turn the wheels ahead about 6 ins.; put the reverse lever in full back gear, then turn the wheels back to the center and proceed to set the backward motion eccentric.

After getting the backward-motion rod the right length, we found that the valve had $\frac{1}{8}$-in. lead, which must be reduced to $\frac{1}{16}$ in., which can be done in the same way that the forward motion was adjusted.

The forward motion eccentric is set first because it is easier to get at than the other one; then if the backward-motion eccentric has to be changed enough to affect the lead in forward motion, the forward motion eccentric can easily be reset, and it will be necessary to move it so little that the backward motion will not be affected enough to require any further attention.

Now throw the lever ahead again and turn the wheels ahead to the front center on the other side; then in the manner described, set the eccentrics on that side. The engine is now square and has the right amount of lead all round; but, notwithstanding this, the valves may not—in fact, very seldom do—cut off the steam the same distance from the beginning of the stroke at each end of the cylinder, and one cylinder may be getting more steam than the other.

The cut off may be equalized for each end of the cylinder by changing the position of the saddle stud; but with case-hardened links and the saddle bolted rigidly to the link, this is not always practical, and some other means must be employed to adjust the cut off.

A very common way is to equalize the forward motion by changing the length of the backward-motion eccentric rods, which will affect the equality of the lead as well as the cut off in back gear.

Another method employed to a considerable extent is to give up equality of lead in both forward and backward motion for equality of cut off. But before we can use either plan, the points of cut off must be found; so we will proceed to find these points.

Suppose the engine to be on the front center on right side. Turn the wheels backward until the cross head has traveled, say, 6 ins. from the beginning of the stroke; then stop the motion and with the short point of the valve stem tram *c*, Fig. 21, move the reverse lever back of the center until the valve closes the port, or until the tram will reach from *c* to *b*. Put the lever one notch farther back, then turn the wheels backward until the tram shows that the point of cut off is reached. Now measure the distance from the beginning of the stroke to the front end of the cross head. Suppose it is found to be $7\frac{1}{2}$ ins.; mark this down with chalk on the front end of the outside guide. The outside guide is used for the backward motion because the backward-motion eccentric is on the outside. Turn the wheels farther back until the steam is cut off on left-side back end of cylinder.

We will assume that the cut off takes place at 8¾ ins. Turn the wheels back again until the right pin passes the center and the steam is cut off, say, at 8 ins. Turn the wheels still more back until the left pin passes the front center and reaches the point of cut off, will give the cut off for the four strokes. Here the cut off takes place at 9 ins.

According to the above, the cut off for the right cylinder takes place at 7½ ins. of the backward, and 8 ins. of the forward stroke. Left cylinder backward stroke, 9 ins.; forward stroke, 8¾ ins. To equalize the cut off on left side will shorten the backward-motion eccentric rod, and how much to shorten it can be found thus:

As stated above, the cut off for the forward stroke occurs at 8¾ ins., and for the backward stroke at 9 ins. The average is

$$\frac{8\frac{3}{4} + 9}{2} = 8\frac{7}{8} \text{ inches.}$$

We left the wheels with the left cross head at the point of cut off, or 9 ins. back of the end of the stroke, and it is desired to have the cut off take place at 8⅞ ins. Hence, turn the wheels forward enough to bring the cross head 8⅞ ins. back of beginning of stroke, and enough more to take up the lost motion, then turn them back until the cross head is at the place where the cut off is to occur. With the valve-stem tram make a mark on top of the valve stem; in this case it will be slightly ahead of *b*, Fig. 21. The distance between this mark and *b* shows how much too far back the valve is traveling; hence the eccentric rod will have to be shortened enough to throw the valve that much ahead. The other side of engine can be treated in the same way, which will make the cut off on left side at 8⅞ ins., right side at 7¾ ins.—considerable difference in the two sides, but this will be remedied later on.

Commencing with the backward stroke on right side, we will now get the cut off for the forward motion. Turn the wheels ahead until the pin passes the forward center and draws the cross head back, say, 6½ ins. Move the lever ahead nearly to the corner, then move it slowly backward until the valve closes the port, as indicated by the valve-stem tram, then put the lever in the first notch ahead of that position and leave it there until the cut off has been found for the four strokes. Now turn the wheels ahead until the point of cut off is reached. We will suppose it to be 8 ins. back of begin-

ning of the stroke. Mark this down on front end of right inside guide, then turn the wheels ahead and get the cut off for front end of left cylinder, which is at 7 ins. Again turning the wheels ahead find the back end of right side to be 8¾ ins., and the back end of left side to take place at 8 ins.

We will equalize the cut off on left side first. Cut off for forward stroke is 8 ins., and for backward stroke 7 ins., making an average of 7½ ins., and indicating that, in order to equalize the cut off, the eccentric rod must be lengthened. Turn the wheels back until the cross head is enough less than 7½ ins. from beginning of stroke to overcome all lost motion, then turn them ahead enough to bring the cross head the 7½ ins. from beginning of stroke.

With the valve-stem tram make a mark on top of valve stem. The eccentric rod must be lengthened enough to draw the valve back a distance equal to the distance between the mark just made on valve stem and the point *a*, Fig. 21.

Adjusting the right side in the same way will give an 8⅜-in. cut off on the right side, and the left side cuts off at 7½ ins. Notice that in back gear the cut off is latest on left side and in forward gear earliest on that side.

This inequality can be overcome by lengthening the link hanger on left side, or shortening the hanger on right side. We will lengthen the hanger on short side, but before doing so the amount to lengthen it must be found. To do this, put the reverse lever in the same notch of quadrant that it was in when the cut off in forward gear was found, and measure the distance from any stationary point directly above or below the upper-link hanger pin on left side to the center of that pin. Now turn the wheels ahead until the left cross head is as far from the beginning of the stroke as the right one is when the steam is cut off, or in this case 8⅜ ins. This is where it is desired to have the cut off take place on the left side.

Move the reverse lever ahead three or four notches, then move it slowly back until the steam is cut off as indicated by the valve stem tram. Again measure the distance from the same stationary point to the center of upper hanger pin. The difference in the distances between the point and center of pin is the amount the hanger must be lengthened to equalize the cut off on the two sides; or raising the tumbling shaft box slightly more than this on the right side would have the same effect as shortening the hanger on that side.

Let us see what effect this change will have on the back gear. The cut off in that gear took place at 8⅞ ins. on left side, right side at $7\frac{3}{4}$ ins. The nearer the link block to center of link the shorter the cut off. The change we have made in the hanger will throw the block farther below the center of link in forward gear; hence will delay the cut off. In back gear, lengthening the hanger as has been done will throw the block nearer the center of link, and will accelerate the cut-off, which is the effect wished for to make the two sides cut off nearer equal in back gear. The amount the hanger has been lengthened may not exactly equalize the cut off in back gear but it will be near enough, since the engine does very little work in back gear. In order to allow about the same volume of steam to be admitted to each end of the cylinder, the cut off should take place $\frac{1}{4}$ or $\frac{3}{8}$ in. later in the back than in the front end. This is owing to a part of the space between piston and cylinder head being occupied by that part of the piston rod within the cylinder. In the foregoing the equality of lead has been destroyed in both gears for the benefit of the cut off. Had it been desired to preserve the equality of lead in forward gear, it would not have been necessary to find the points of cut off in back gear, and the cut off for each end of the cylinders would have been adjusted by altering the length of the backward-motion eccentric rods.

The adjustment for each side of engine would have been made as has been described.

PISTON VALVES.

The use of the piston valve in locomotive work is not as modern as many seem to think, having been used as long ago as 1833 on the "Earl of Airlie," built by Carmichael, of Dundee, for the Dundee & Newtyle Railroad. Since that time there have been numerous revivals at various periods, but, like some vaccinations, they did not seem to "take," until within the past few years. Whether they became a fixture and forced the "D" slide valve to the "Field Museum" remains to be seen, but there are many now in use, and it is the present we have to deal with.

Judging from letters we receive, the compound locomotive and the piston valve have taken the mysterious places that were formerly occupied by the injector and the air brake. It seems best, therefore, to show, by a few simple drawings, what the piston valve is and how it differs from the "D" valve with which all are familiar.

In Fig. 1 is shown a plain "D" slide valve in its central position, with the exhaust cavity "line and line" with the ports and a liberal

lap on the steam ends. The amount of lap is not under discussion and is of no consequence to us at present.

In each case note carefully whether the steam is admitted to the cylinder by the outside or inside of valve, as this is of vital importance in setting valves. In Fig. 1, as in all "D" valves in use on locomotives to-day, the steam is admitted to cylinder by the outside edge of valve.

Fig. 2 shows a solid piston valve which also admits steam from outer end, and is, therefore, identical in action with the slide valve shown in Fig. 1. The setting of these valves would have to be the same, although performed somewhat differently owing to difference of construction.

Fig. 3 shows a solid piston valve with inside admission and outside exhaust. The steam pipe must supply the chest between

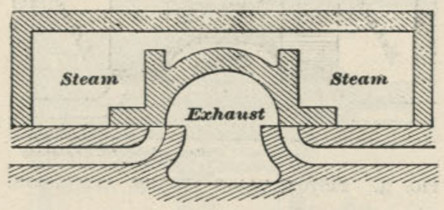


FIG. 1. PLAIN D-VALVE.

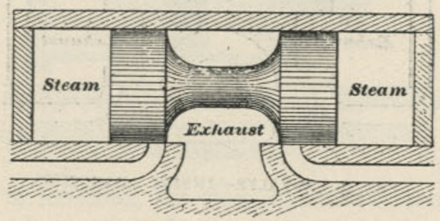


FIG. 2. PISTON VALVE—OUTSIDE ADMISSION.

the heads of the valves and the exhaust be taken out at both ends. The proportions in this figure are not such as are used. The idea is shown as nearly like a "D" valve as possible, so that there will be no difficulty in understanding the difference between them. To show this more clearly, Fig. 4 shows a "D" valve with inside admission. A top plate is added to prevent the live steam under valve from lifting it off the seat. The ports are spread or shortened and the clearance or volume of the ports correspondingly reduced. This valve would have to be set the same as the one shown in Fig. 3.

Some builders using piston valves admit steam at the ends the same as a "D" valve, among them being Baldwin in the Vauclain compound. This is a double valve controlling both high and low pressure cylinders and acting as two "D" valves. This is clearly shown in Fig. 5, where the live steam comes in at the ends, is admitted to high-pressure cylinder through the right-hand port. At the same time the exhaust from the high is flowing out the left port, through the center of valve to the low-pressure cylinder, while the low-pressure exhaust, flowing out of other port, goes direct to the stack.

Whether the admission is at center or at ends, the builder of piston valves makes them much longer than shown in the previous sketches, in order to make the ports leading to cylinders as short as possible.

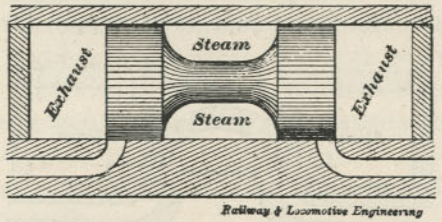


FIG. 3. PISTON VALVE—INSIDE ADMISSION.

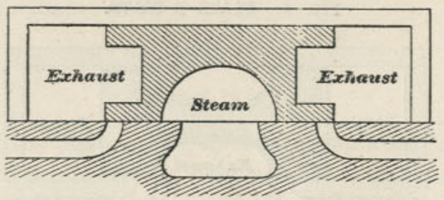


FIG. 4. D-VALVE—INSIDE ADMISSION.

Fig. 6 shows a modern piston valve with outside or end admission, having the same action as a "D" valve of the same dimension and made hollow for lightness. The steam is free to pass from end to end, but this does not affect the working in any way. In this, as in Fig. 7, a single, broad packing ring is shown at each end. This is not often used, however, but serves to show that in setting piston valves we must consider the edge of the rings as the end of valve instead of the valve body itself. It is the ring or rings which govern the admission and exhaust of the steam, and not the body of valve.

Fig. 7 shows the same valve as Fig. 6, except that it has inside admission such as is commonly used. Fig. 8 shows an internal admission valve partly open to admit steam to left-hand port while the right port is open to exhaust.

Ideas vary greatly in regard to packing rings, and they abound in great variety. The left-hand sketch in Fig. 9 shows a method used to some extent, consisting of a "bull ring" *B* which carries two packing rings *AA*. These are locked into *B*, as shown, which effectually prevents them springing out too far. As will be seen, the bull ring is held in place by the follower *F* being bolted to body casting *C*. These can be so made that both the bull and packing rings are free to move, or the bull ring could be clamped and the rings free to move. Some valves—especially in marine service—have the rings so made as to be locked in any desired position, making it virtually a solid valve. After they wear sufficiently to warrant

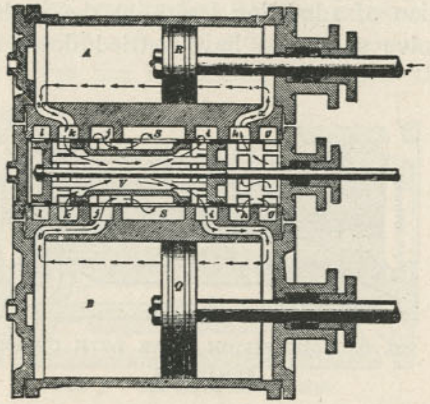


FIG. 5. PISTON VALVE USED IN VAUCLAIN COMPOUND.

it, the follower is loosened, the rings expanded as much as desired and again locked into place. This has all the advantages of the solid valve (except first cost) and also of being adjustable for wear. The right-hand sketch shows a hollow valve with a cast body *V* carrying two springs *RR* at each end.

Probably the first reason for adopting piston valves was to get away from the balancing of the slide valve. As will be seen in Fig. 1, the full pressure of steam is forcing the "D" valve to its seat and causing friction when it is moved. In Fig. 2, on the contrary, the steam is acting against each end, while in Fig. 3 the same principle holds good, being applied in center instead of at ends. In neither of these have we shown any valve rod, but it can be readily seen that a valve rod at one end will unbalance the valve by decreasing the pressure on one end by the amount due to the area of the rod. In some cases this has been balanced by putting an extended valve rod out the other end, but this introduces another set of rod packing, which is not altogether desirable.

The steam pressure being balanced, the only resistance to motion is that due to its weight and the friction caused by it. When spring packing rings are used, however, an element of friction is introduced, the amount depending on the construction of the rings. In some cases this has amounted to more than the friction of a slide valve and indicates clearly that piston valves are not necessarily frictionless. In nearly all constructions the steam works its way under the rings by hook or by crook and helps along the cause of friction.

The question of admitting steam at the ends or the center of a piston valve seems to have settled down to the latter in most cases. This has the advantage of having the most of the cooling surface of the valve chamber come in contact with exhaust steam, and the more valuable advantage of only having to pack valve stems against exhaust pressure. This is of considerable importance where high steam is used. There is still another advantage in making the joints with the heads of the valve chest, as the pressure is so much lower. In the case of a slide valve and steam chest it is still more important.

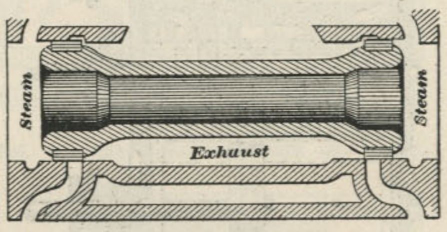


FIG. 6. LONG PISTON VALVE WITH OUTSIDE ADMISSION

So far nothing has been said regarding the movement of piston valves or the difference in this respect from the "D" slide valve. When a piston valve admits steam from the outside—as does the one shown in Fig. 2—its movement is the same as that of every "D" slide valve in common use, and it is set in the same manner. But when the steam is admitted from the center or inside the motion is just the reverse. This can be readily seen by studying Figs. 1 and 3 very carefully, or perhaps Fig. 8 would be better, as that is partly open.

In order to open the left steam port, the valve in Fig. 1 must move to the right, while the inside-admission valves 3 and 8 must move to the left or in the direction of the port it is to open. Valve 8 is already half open and steam is following the arrows shown. This opposite movement of the valve is one of the things that puzzle a man who has always been used to the "D" valve, but if he will give it a little attention there need be no difficulty.

This opposite motion can be obtained in two ways—by placing the eccentrics on the axle opposite from the usual position or by doing away with the rocker arm and connecting the valve rod direct to link block or a connection from it.

Fig. 10 shows the regular link motion in plain outline. The eccentrics are shown on axle and the crank pin is moving down as shown. This gives the lower end of rocker the motion indicated by arrow *A*, which is transferred at upper end to *B*. This would admit steam to right-hand port with an outside-admission valve, regardless of whether it is of the "D" or piston variety.

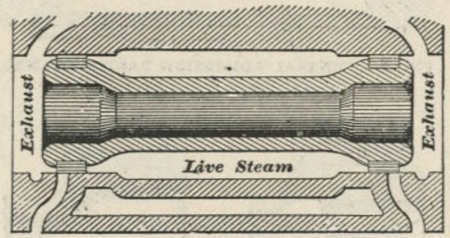


FIG. 7 CENTRAL ADMISSION.

Fig. 11 is the same valve motion with rocker removed and the motion transmitted direct, instead of being reversed as in Fig. 10. The valve rod can be supported as shown, by hanger *H* in dotted lines or in any other way desired, so long as the direct motion is not interfered with. A little thought will show that this motion would open the right-hand port of an inside-admission valve, making this a good form for a valve of this kind, and explaining why many piston valve engines have no rocker arm. This is better in some ways than using the rocker arm and reversing the eccentrics, although the general design of the locomotive sometimes determines which is best to use in that particular case.

Fig. 12 shows the regular link motion with rocker, but with eccentrics moved halfway round the axle or opposite the crank pin. As will be seen, this would move lower end of rocker as shown in arrow *A* and upper end like *B*, giving same movement to valve as Fig. 11.

These three figures, 10, 11, 12, will be of value in determining what kind of valves we are dealing with, and are more convenient than to take them out for examination. First note the relation of the crank pin and eccentrics. If they are together

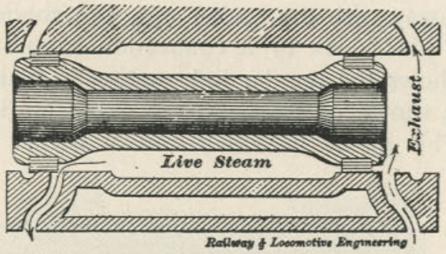


FIG. 8. CENTRAL ADMISSION PARTLY OPENED.

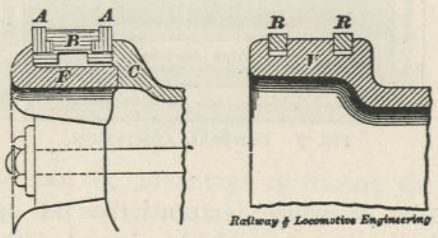


FIG. 9. TWO STYLES OF PACKING RINGS FOR PISTON VALVES.

or on the same side, as in Figs. 10 and 11, then see if the motion is direct or reversed with a rocker. In fact they may be summed up in three little rules or statements:

If the eccentrics and crank pin are together and there is a rocker arm which reverses the motion, the valve has outside admission (see Fig. 10).

If the eccentrics and crank pin are together and there is no rocker arm but the motion is direct, the valve has internal or central admission (see Fig. 11).

If there is a rocker arm which reverses the motion, but the eccentrics and crank pin are opposite instead of being together, the valve has internal admission (see Fig. 12).

So if you look your engine over and note the relative positions of the crank pin and eccentrics and get a good look at the rocker, if there is one, you can tell whether the valve is central (internal) or outside (end) admission. Knowing this, you also know what to do should anything happen that made resetting necessary.

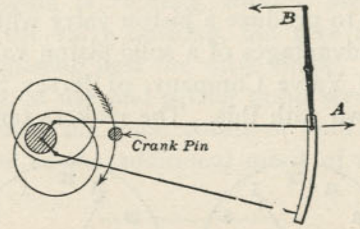


FIG. 10. REGULAR INDIRECT MOTION WITH ROCKER.

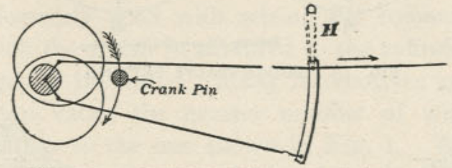


FIG. 11. DIRECT MOTION—NO ROCKER.

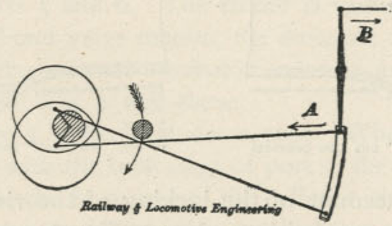


FIG. 12. "CROSSED" RODS WITH ROCKER ARM.

Valve setting on the road is a thing of the past (except in rare cases)—the first thing being to clear the right of way—but it is well to know how to go to work if necessary, and the first thing is to know what kind of a valve you have to deal with. A rough rule, and one which will get you home or out of the way of other trains, if it's only a case of slipped eccentric, is to set the eccentrics as indicated on the clock dials shown in Fig. 13. For valves with outside admission with a rocker or valves with inside admission without a rocker, use clock *A*, which shows the crank pin at 3 o'clock and the eccentrics at 1 and 5 o'clock with rods open.

For inside admission valves with a reversing rocker, set the eccentrics as shown in *B* with crank pin still at 3, but eccentrics at 7 and 11 and rods crossed.

THE "AMERICAN" PISTON VALVE.

The endeavor to produce a piston valve with expanding rings and yet have the advantages of a solid piston valve, led the American Balance Slide Valve Company, of Jersey Shore, Pa., to design the valve shown with this. The makers term it a "snap ring

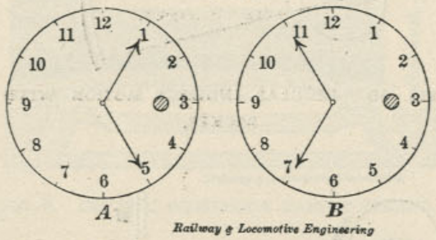


FIG. 13. ROUGH VALVE SETTING.

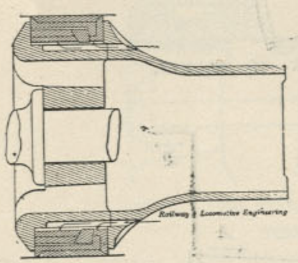


FIG 14. "AMERICAN" ONE RING COMPLETE

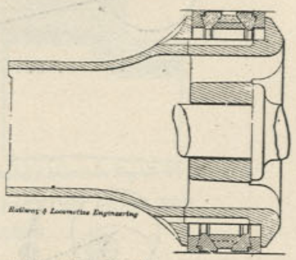


FIG. 15. "AMERICAN" TWO RING COMPLETE.

plug valve," on account of the locking of the rings by the pressure after being expanded into place. The sketches, Figs. 14 and 15, show the ends of a valve, one fitted with a wide ring, the other with two narrow rings.

This valve has internal admission and, as will be seen, the steam is also admitted under the rings. Ring 1 is the snap ring, and is in three sections in Fig. 11, the joints being lapped to prevent leakage. Ring 2 is solid—that is, does not expand with the steam. Ring 3 is split and is called the wedge ring.

Steam being admitted to chest, it goes under the rings 1, expanding them against cylinder walls. At the same time wedge

ring 3 is forced against solid ring 2, which locks rings 1 against head of valve and prevents any further tendency to expand; so that it is in effect a solid valve. The action is similar in the double ring valve, Fig. 16. There are two snap rings 1, 1, two solid rings 2, 2, and one wedge ring 3. Steam acts just the same as in the other case and locks the snap rings solid with the valve. As will be seen, a follower plate is used on each end.

When an engine is running without steam, the rings are not held against the valve bushing, but give relief while drifting by giving a free opening past the valve rings. A number of these valves are already in use and giving good service.

It seems to have the good points of both the solid and snap ring valve, as well as the additional merit of relieving an engine while drifting.

SETTING INSIDE ADMISSION PISTON VALVES.

By Ira A. Moore.

I have formerly dealt with setting the common form of slide valve, by which the steam is admitted to the cylinder past the front and back edges of the valve. Many locomotives are now equipped with the piston valve, the greater number of which are internal admission, similar to the one shown in Fig. 1. With this style of valve the steam comes from the boiler through the steam pipes into the cavity *s*, and is admitted to the cylinder past the rings 2 and 3, and through ports 5 and 6. The reader is cautioned to remember, that with an indirect valve motion, the eccentric always follows the crank pin, but the internal admission valve is an exception to the rule, as a study of Fig. 1 will show.

In the figure 5 is the front steam port. When the back side of ring 2 is in line with the back edge of port 5, the valve is beginning to admit steam to the front end of the cylinder, and the valve moves forward until the extreme travel is reached.

With the slide valve the valve is traveling backward while the front port is being opened. Consequently with the internal admission valve the eccentric controlling the valve leads instead of follows the crank pin and is as much more than 90° ahead as it is less than 90° back of the pin when the external admission valve is used, provided both valves have an equal lap and lead.

With the piston valve the marking of the valve stem is more difficult than with the slive valve, because the position of the live steam rings cannot be seen when the valve is in the chamber. The positions of the valve when steam is beginning to be admitted to the cylinder can be found by measurement, by the following method:

Before the valve is put into the chamber, place a straight edge across the front chamber head joint, as at *g*, Fig. 1, being particular to have the straight edge in line with the inner surface of the chamber wall. Fig. 2 is a strip of band iron, say $\frac{1}{8}$x1$\frac{1}{2}$ ins., with the end *g* made perfectly square.

On this strip lay off the distance *g a*, equal to *g a*, in Fig. 1. Similarly transfer the distances *g b*, *g c* and *g d* to the strip as shown at *b*, *c* and *d*, Fig. 2.

If this part of the work has been accurately done, the distance between *b a* and *d c* will exactly equal the width of the ports 5 and 6, Fig. 1, and the correctness of the measurements can be proved by setting a pair of calipers to the width of the port and then trying them on the strip of iron.

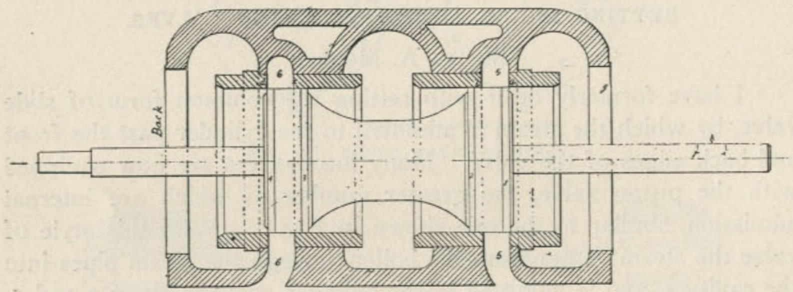


FIG. 1.

If the lines on the strip do not correspond to the calipers, the measurements should be taken again, to locate the error. Now lay the strip on its edge on the valve and parallel with the valve, placing the line *c* in line with the front side of the ring 3, Fig. 1, and then measure the distance between the line *b* and the back side of ring 2. This distance will be found, in this case, to be 2 ins., and the lap of the valve is one-half of this, or 1 in., or, when the valve is in its central position, it will have to move 1 in. either way before the steam port commences to open.

After ascertaining the steam lap of the valve, lay the strip on the valve again, with the line *d* in line with the back side of ring 4; then if the line *a* comes back of the front side of ring 1 the valve has exhaust lap and its amount is equal to one-half the distance between the line and front side of ring. But if the line *a* comes ahead of front side of ring 1 the valve has exhaust clearance by half the difference.

The valve shown in Fig. 1 is line and line on the exhaust side, or, in other words, the distance from the back side of ring 4 to front side of ring 1 is the same as the distance between the front edge of port 5 and back edge of port 6, or *a d* Fig. 1 is equal to *a d* Fig. 2.

The lap of the valve has now been found and it can be put in place in its chamber.

Before marking the stem, two gauges should be made for finding the positions of the valve when it is beginning to open the steam ports. Since the valve is line and line on the exhaust side, the distance from *g* to the front side of ring 1, Fig. 1, is the same as *g a*, Fig. 2, and since the valve has 1 in. steam lap, it will move 1 in. either way from its central position before the ports open.

On the strip of iron represented by Fig. 2, and 1 in. (the lap of valve) each way from *a*, draw the lines *m* and *n*.

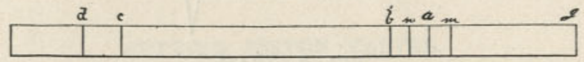


FIG. 2.—STRIP OF BAND IRON.

The distance *g m* is the distance the front side of ring 1 will be away from *g*, Fig. 1, when the front port is beginning to open, and the distance *g n* is the distance the front side of ring 1 will be back of *g* when the back port begins to open. Cut a piece of $\frac{1}{4}$-in. round iron to the length *g m*, Fig. 2, and another piece to the length *g n*.

Place one end of the shorter gauge against the back edge of straight edge at *g*, Fig. 1, and move the valve until the gauge will just reach between ring 1 and the straight edge.

The valve is now beginning to admit steam to the front end of cylinder and we will mark the stem in this position by means of a tram similar to Fig. 3.

At any convenient place on the end of the valve chamber make a center punch mark as at *h*, Fig. 1.

With the long leg of the tram at *h* scribe an arc *r* on valve stem.

Move the valve backward until the other gauge will just reach between the straight edge and ring 1, then with the tram scribe the arc *i*, as this indicates the valve's position when the back end of cylinder is beginning to take steam. The valve stem can be marked without the use of the gauges, and some workmen prefer not to use them.

Referring to the valve shown in Fig. 1, it was found to have

1 in. steam lap and to be line and line on the exhaust side; consequently, when the front side of ring 1 is in line with the front edge of port 5 the valve is at half travel, and the back side of ring 2 is 1 in. back of port 5, while the front side of ring 3 is 1 in. ahead of port 6. With the valve in this position the tram would reach from *h* to *k*, or midway between *i* and *r*.

Now, with dividers, set to the lap of the valve, or, in this case, 1 in., and with *k* as a center, scribe the arcs *i* and *r*, then, when the valve is moved enough to allow the tram to reach from *h* to *r* or *i*, the valve will be at the point of opening or closing, depending, of course, on the direction of its travel. Suppose the valve to have $\frac{3}{32}$ in. exhaust clearance, instead of being line and line. Then the front

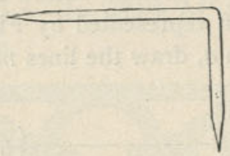


FIG. 3.—TRAM.

side of ring 1 would be that amount back of front edge of port 5 when the valve is central in the chamber, and this position could be determined without the use of the gauges mentioned above, by simply measuring between ring 1 and front edge of port 5.

Suppose, again, that the valve has $\frac{3}{32}$ in. exhaust lap. Then the front side of ring 1 is $\frac{3}{32}$ in. ahead of front side of port 5 when the valve is at mid travel, and, of course, the port is out of sight. Hence, to mark the stem when the valve has exhaust lap, move it backward until the edge of port can just be seen. With the tram make a mark on the valve stem, then move the valve forward the amount of the exhaust lap, when it will be at half travel, and the arc *k* can be drawn and the points *r* and *i* found with dividers as before.

Notice here that when the tram reaches from *h* to *i*, that the back steam port is beginning to open.

If the valve had external admission, or if *e e* were the steam and *s* the exhaust port, then *i* would indicate the valve opening to the front end of cylinder, or the forward point on valve stem would correspond to front end of cylinder, and *vice versa*, the same as when the common slide valve is used. But with the piston valve under consideration, the back point on the stem corresponds to front end and front point to back end of cylinder.

Again, when the valve has lead, the tram point will come the

lead back of *r* and in front of *i* when the crank pin is on dead center, the same as with the slide valve.

To increase the lead with the slide valve the eccentric is turned toward the crank pin. When the piston valve is used, the eccentric is moved away from the pin to increase the lead.

The manner of locating the dead centers, "squaring" the engine, and getting the engine to cut off the same in each cylinder is the same as with the slide valve, described on page 241. To equalize the cut off in each end of the cylinder the length of the blades must be changed opposite to the change when setting a slide valve, or to make the cut off take place earlier in the front end and later in the back end of cylinder with the slide valve, the blade would have to be shortened; with the piston valve the blade must be lengthened to produce this result.

A careful study of Fig. 1 will be helpful in getting these things fixed in the mind.

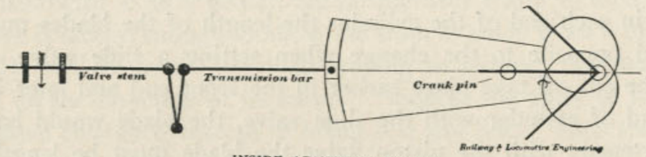
SETTING PISTON VALVES.

By George S. Hodgins.

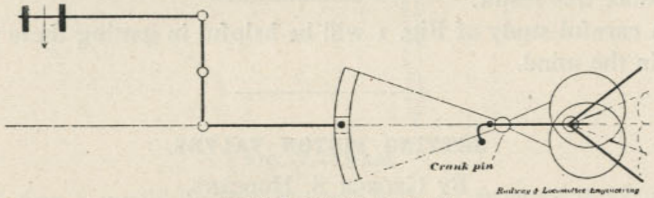
The setting of piston valves is, for some people, more or less surrounded by an atmosphere of mystery. There is, of course, no mystery about it, and at close range even the possible haze in the atmosphere disappears.

There are two classes of piston valves in use: those which admit steam to the cylinders from their outer edges or ends, and those which admit steam from the central portion, or from the inside of the body of the valve. The former may, for want of a better name, be called "outside" admission valves, and the latter "inside" admission valves. The outside valves are similar to the ordinary "D" slide valve, and other things being equal, they are set just as the "D" valve is set. These outside valves have the advantage, possessed by all piston valves, of enabling locomotive designers to make short steam passages, and to pretty evenly balance the valve itself. The inside admission piston valve is not exactly like the "D" slide valve, but it possesses the additional advantage over other piston valves, that it is more perfectly balanced, because the valve rod works only in exhaust steam and the valve chamber covers are only required to sustain intermittent exhaust steam pressure. The valve-stem packing has also an easier time of it, and lastly the central admission feature has the effect of holding hot live steam where temperature losses are less likely to occur.

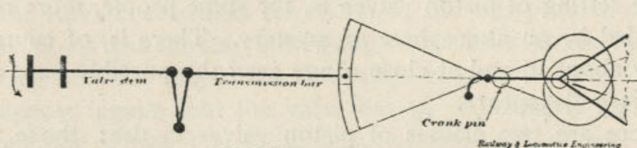
The setting of these outside and inside admission piston valves is modified by the method of connecting them with the links and eccentric rods. There are two ways in which this connection may be made. The first and most familiar in locomotive practice is with an ordinary rocker, pivoted in the center with one arm up and the other down. This rocker transforms a forward thrust of an eccentric rod into a backward valve movement, and is called indirect



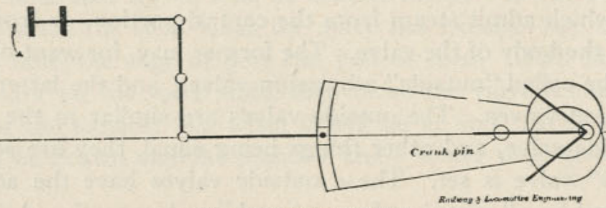
INSIDE ADMISSION—DIRECT



INSIDE ADMISSION—INDIRECT



OUTSIDE ADMISSION—DIRECT



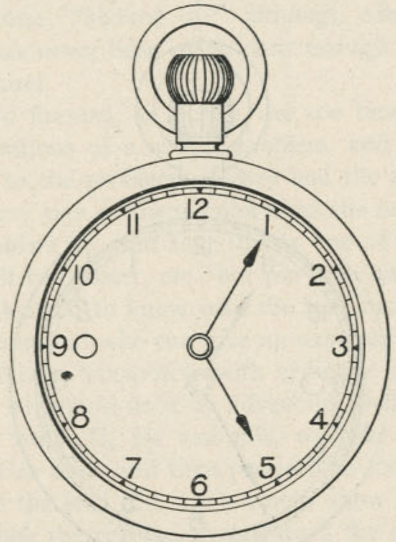
OUTSIDE ADMISSION—INDIRECT

connection. The other method, that of direct connection, is where valve stem and transmission bar (which latter terminates in the link block), are each attached to rockers the arms of which are both above or both below the pivot point. With direct connection a forward eccentric rod movement produces a like forward motion of the valve.

We have, therefore, before us, two types of valves, and two methods of connection. The old adage that "two and two make

four," holds good on railways, as it does elsewhere, and we have four possible combinations to deal with. Designating them by the names already used, we may have an outside admission, direct connected valve, or to put it concisely an "outside direct" valve. Then follows the inside direct, the outside indirect, and the inside indirect valves.

In setting any one of these piston valves it is necessary, first of all, to ascertain to which of the four classes the valve in question belongs. Knowing this, we further find that the position of the eccentrics, when the valve is of the outside direct type, is that the belly of each lies on the side of the vertical center line, farthest from the crank pin, or to put it another way, if the crank pin be repre-



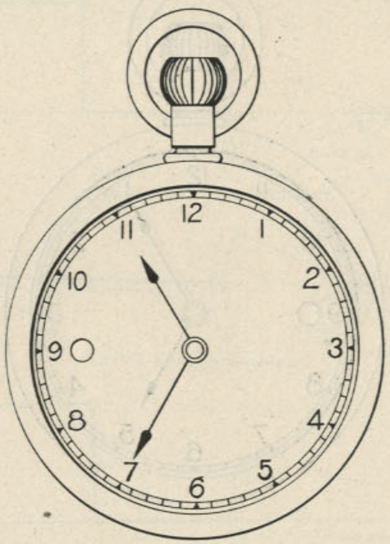
sented by the figure IX, on the dial of a clock, and the center lines of the eccentrics, by the hands, the latter will stand approximately at 5 minutes past 5; and this may be called the afternoon or P. M. style or setting. The outside admission valve, we have said, resembles closely the familiar "D" slide valve, but its direct connection, in this case, forces the eccentrics to conform to stationary practice. With the inside direct valve, the eccentrics lie on the same side as the crank pin, and their lines make, what we may call, a morning or A. M. setting, for with crank pin at IX on the dial, the lines through the eccentrics would mark approximately 25 minutes to 11. The outside indirect eccentrics also assume the same position, while the inside indirect eccentrics are set with lines suggesting the afternoon setting.

If one may summarize what has been said, it will be seen that the inside direct, and the outside indirect valves have eccentrics placed on the A. M. plan. If any one cares for a possible aid to memory on this subject, the following table may be useful:

Inside Direct	25 mts. to 11, A. M.
Outside Direct	5 mts. past 5, P. M.
Inside Indirect	5 mts. past 5, P. M.
Outside Indirect	25 mts. to 11, A. M.

The other two valves, the outside direct, and the inside indirect, follow the only method left, and place their eccentrics in the afternoon position.

In setting the Vauclain-compound piston valves measure the



valve very carefully, and place it so as to give the forward center-punch mark on the valve stem. This is done by examination, with the front valve chamber cover off. Then double the lap of the valve, and lay off that distance on the valve stem, from the front center-punch mark, and that point becomes the back center-punch mark. The valves are then set like ordinary slide valves, with this point always in the mind of the man doing the work, that if he is setting valves which require what we have called the P. M. plan, the valves must be moved *away from* the crank pin, to increase the lead, and *toward* the crank pin with the A. M. kind.

There has been an improvement made on a number of engines, which have valve stems extending through the front cover. In order to do away with gland and packing at the front end, inclose the stem in a piece of closely fitting wrought iron pipe, and plug the end. First cost, maintenance, charge, and general roundhouse trouble, is thereby materially reduced.

WHY LEAD INCREASES AS REVERSE LEVER IS HOOKED UP.

The reason why the ordinary link motion employed on locomotives increases the lead of valves as the reverse lever is brought from the forward notch towards the center, or, in other words, to use the engineer's phrase, "hooked up," although often explained by eminent writers, has never been made clear enough for the ordinary layman to understand.

Engineers and firemen, as a rule, are too busy to study these complex demonstrations of a simple problem, and their educations are seldom equal to the problems if they had the time.

Each and every one of them know that the lead does increase as the lever is hooked up, and that this is one of the reasons that the locomotive will run faster, etc., but pin nine out of ten of them right down, and demand to know *why* the lead increases, and there is not one in one hundred who can give an explanation off-hand.

Now, if we take a locomotive with ordinary link, and want to increase the lead, we would do it by advancing each eccentric in the direction it is to run. If, for example, we take the R.-go-ahead eccentric, mark it as at *a'*, and then proceed to move the eccentric ahead, to increase the lead, the mark would show a break as at *b'*. Now, when we hook the reverse lever toward the center, we do not move the eccentrics ahead on the shaft, but we do move the straps back on the eccentrics—which amounts to the same thing—the lead increasing the farther the lever is hooked toward the center, and the mark would show a break as at *b'*, the same as if the eccentric itself had been advanced on the axle. With locomotives having very long eccentric rods, the lead will not increase so much as with locomotives having very short blades, or rods—because the short rods make it necessary to move the straps farther around and back, on the eccentrics, while with the long rods the ends at the link could be raised from six to ten inches without moving the strap on the eccentric but a very little. This is not offered as a substitute for those explanations that describe the increase by the difference in the arcs the rods would describe if they embraced the axle instead of the eccentrics, etc., etc., but as a short, simple, easily-understood explanation for practical men.

CHANGING LEAD.

When necessary to change the lead of a modern locomotive it is a matter of considerable trouble, as all eccentrics are supposed to be keyed on the axle, and if the cut-and-try method is followed it necessitates the removal of the eccentrics from the keys in order to get them out of the axle and then the replacing of the eccentrics and straps and the coupling of blades to the links. Then follows the exasperating experience of the fellow in the pit endeavoring to move an eccentric a thirty-second of an inch, and not have it draw back in the old set screw marks. Anyone who has been in such a

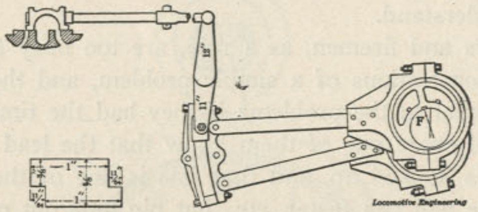


Fig. 2 Fig. 1

CHANGING LEAD.

non-get-at-able and trying place can appreciate the following method of getting the amount of offset to be given the keys without the laborious way described and without the errors caused by lost motion.

In Fig. 1 we have a diagram of a valve, rocker, strap and eccentric. Assuming that the valves of this engine have $\frac{7}{8}$-in. lap and it is desired to reduce it to $\frac{3}{4}$-in., it is necessary to reduce the linear advance an amount corresponding to the reduction of lap, planed from steam edge of the valves, or $\frac{1}{8}$ in. The upper rocker is 12 ins. long and the lower one 11 ins. long from center to center, throw of eccentric $5\frac{1}{4}$ ins., diameter of axle 8 ins. Now if the valve is moved $\frac{1}{8}$ of an inch the center of the lower rocker pin will be moved $\frac{11}{12}$ of this amount. Following on to the eccentric we find that the point *F*, which is the center of the eccentric will be moved this same amount, viz., $\frac{11}{12}$ of $\frac{1}{8}$ in.; but we want the offset to give the key and this lies in the surface of the axle outside of the travel line of the eccentric center.

Diameter of axle being 8 ins., radius equals 4 ins.; throw of eccentric being $5\frac{1}{4}$ ins., radius of eccentric path equals $2\frac{5}{8}$ ins.

So the offset will be multiplied by the ratio of $\dfrac{4}{2\frac{5}{8}}$, or $\frac{32}{21}$

Therefore, we have $\frac{1}{8} \times \frac{11}{12} \times \frac{32}{21} = \frac{11}{63}$, or practically $\frac{11}{64}$ in. offset.

For convenience the diameter of the axle and the throw of the eccentric can be used instead of their radii, which gives us the following simple formula:

$$O = \frac{A\,L\,D}{U\,T}$$

in which

O = Amount of offset
A = Amount valve is to be moved.
L = Length lower rocker arm.
D = Diameter of the axle.
U = Length upper rocker arm.
T = Throw of eccentric.

The offset key when planed will be as shown in Fig. 2, and when correctly set in the axle should be plainly marked so that no mistake can occur by getting it reversed at some future time.

VALVE LEAD.

It is not necessary to have lead to start trains, or to have engine work smoothly at or near full gear. By increasing the outside lap to 1 in. and giving the required clearance, an engine will run smoothly at a shorter cut off than with a valve that has $\frac{3}{4}$-in. outside lap and no clearance, if the same amount of lead is used with both valves. Consequently, the lead at 6-in. cut off can be increased to advantage in proportion to the outside lap.

The greatest disadvantage in too much lead is that it causes too much pre-admission when engine is worked near mid gear. When pre-admission is too great with the required lead, the best way to reduce it is to use valves with more outside lap.

Valves with 1-in. outside lap will reduce the pre-admission one-third over valves with $\frac{3}{4}$-in. outside lap, when engine is worked at 6 in. cut-off. Valves with 1-in. outside lap with $\frac{1}{4}$-in. clearance will stand $\frac{1}{4}$-in. lead at 6-in. cut-off, and with $\frac{3}{4}$-in. outside lap with no clearance should have only $\frac{7}{32}$-in. lead at 6-in. cut-off.

I consider inside clearance an advantage to fast-running engines, or engines with small wheels at a moderate rate of speed.

Negative lead allows steam to work longer in cylinder before being exhausted at full stroke. Advancing back-up eccentrics to produce a required lead, will give a longer cut off near mid gear in forward motion. With a 4-ft. radius there will be no lead required in forward or back gear to produce the best results. A 6-ft. radius would require a $\frac{1}{16}$-in. lead in forward and back motion to give $\frac{1}{4}$-in. lead at 6-in. cut off. An 8-ft. radius would require $\frac{1}{8}$-in. lead in forward and back motion to give $\frac{1}{4}$-in. lead at 6-in. cut off.

With the same travel of valves, viz., 5-in., and with the different radii of links ranging from 4 ft. to 8 ft., I would recommend eccentrics set as follows:

4-ft. radius—Valves set negative lead in forward motion full gear, and, if necessary to produce the required lead, advance the back-up eccentrics.

6-ft. radius—Valves set line and line forward motion, and back-up eccentrics advanced to give the required lead at 6-in. cut off.

8 ft. radius—Valves set with $\frac{1}{8}$-in. positive lead, in forward and back motion.

The old fallacy that a locomotive could not run freely unless the valves were set with considerable lead is slowly losing its adherents.

"It used to be the supposition that in order to make an engine work smoothly you must have a certain amount of lead. That this is not true is pretty well known now everywhere. This is pretty well illustrated by the smooth riding of an engine shut of at high speed. If properly balanced, the engine probably runs as smoothly as ever it did in its existence. Ten years ago it was the practice to give an eighth of an inch lead. It has been gradually cut down to a sixteenth and a thirty-second, and in some cases to zero. This has resulted in great improvement to the engine. There is no doubt that lead has been very injurious to the operation of engines. It has caused probably more wear and tear to the valve gear, and more expense for repairs than anything else. I have no doubt the practice of throttling engines is attributable to a great extent to excessive lead.

Some years ago Mr. Henry Bartlett, Supt. M. P. Boston & Maine, had some new engines built and gave this a great deal of attention. The engines in question had valves giving a $5\frac{3}{4}$-in. travel and one inch outside lap. With $\frac{1}{32}$ -in. lead in full gear forward and $\frac{5}{16}$-in. lead at quarter cut off they give excellent results.

Another point and an important factor with high-speed engines is inside clearance on back end of exhaust. The exhaust takes place

at unequal points, if the valve cuts off equally front and back, due to the angularity of the main rod. By advancing the exhaust on the back edge with the proper amount of clearance the compression is equalized in both ends of the cylinder.

LONG VS. SHORT ECCENTRIC BLADES.

Short blades are used to avoid a long, curved rod around the forward driving axle, or, what is worse, an intermediate rod around the axle and hung on links or guides at the rear.

The great trouble with the long, curved rod is its weight and consequent excessive friction on eccentric at high speed; then, its curve makes it, even when pretty heavy, a springy affair under heavy work. With it the rocker is carried close up to the steam chest, and, to avoid excessive wear of packing, a knuckle at the rear, and a horn on yoke, and an extension on the front of chest are needed; this objection also obtains where the intermediate rod is used.

The intermediate arm has an added objection, in its extra joints to get lost motion, and their proneness to break down.

The single objection to the short radius is the excessive lead when hooked up, but this, it seems, has never given any trouble except on paper, and in the imagination.

At high piston speed, more lead is necessary for quiet running, and we have yet to hear of trouble from this cause on a road using short radius links.

This plan makes the valve gear as simple as the simplest; the long valve rod can have a guide near its center to prevent trembling, and the vibration at the stuffing box is practically *nil.*

With the long eccentric blades the friction of the eccentric, multiplied by the leverage of the long blade, has too much chance to make the reverse lever dance, as well as the man who handles it.

LENGTH OF ECCENTRIC ROD.

The length of the eccentric rod affects the increase of lead from full to mid gear, as can be readily seen from Flg. 1. Shortening the rods increases the difference in lead between these points while lengthening them decreases it. The distance c c shows the increase for long eccentric rods and c'' c''' for short rods. As the effect of the increased lead is not particularly injurious, as we have seen, it is now considered preferable to have this than the long, crooked eccentric rods which always spring more or less and distort the motion more than the short rods. A fair length of eccentric rod is probably 60 ins. with extremes from 36 to 100 ins. depending on the construction of the engines. From the point of valve motion alone 60 ins. is long enough for good work and even 40 has been used on passenger engines with good results.

Lead is the amount of opening the valve has when the engine is on the dead center—or with the piston at the end of the stroke. As we have seen, the lead increases as the engine is hooked up and it has also been stated that most engines are now set so as to bring the desired lead in working position, leaving the lead at full gear to take care of itself.

As the valve is open by the amount of lead at the end of the stroke, steam is admitted during the time it is opening and before the piston has reached its extreme position. This is added to the

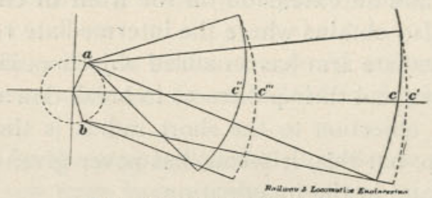


FIG. 1. LONG AND SHORT ECCENTRIC RODS.

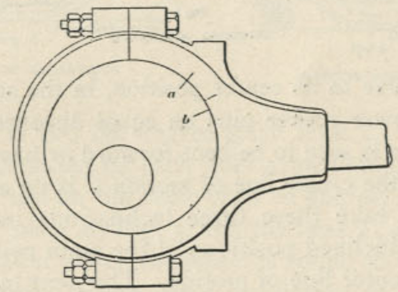
compression and makes more of a cushion—sometimes too much, if it is excessive. The effect of this is to warm up the cylinder and, if excessive, to retard the work of the engine too much.

Increasing the lead is the cure-all for engine diseases in some places and it is generally overdone. As increasing lead is accomplished by advancing the eccentrics as before stated, it will be seen that the effect is to make all the events earlier. The valve opens to lead, cuts off, opens to exhaust and closes for compression earlier than before. Some engines have more lead than others because of the ideas of the men having them in charge, but the days of excessive lead seem to be passing and engines are giving as good or better service than ever.

ANOTHER EXPLANATION OF INCREASED LEAD.

The reason why the ordinary link motion, or shifting link, employed on locomotives, increases the lead of the valves as the reverse lever is hooked up is of general interest.

If we take a locomotive with ordinary link, and want to increase the lead, we would do it by advancing each eccentric in the direction it is to run. If, for example, we take the R.-go-ahead eccentric and mark it as a', and then proceed to move the eccentric ahead, to increase the lead, the mark would show a break as at b'. Now, when we hook the reverse lever toward the center, we do not move the eccentrics ahead on the shaft, but we do move the straps back on the eccentrics—which amounts to the same thing—the lead increasing the farther the lever is hooked toward the center, and the mark would show a break as at b', the same as if the eccentric itself had been advanced on the axle. With locomotives having very long eccentric rods, the lead will not increase so much as with locomotives having very short blades, or rods—because the short rods make it



necessary to move the straps farther around, and back, on the eccentrics, while with the long rods the ends at the link could be raised from six to ten inches without moving the strap on the eccentric but a very little. This is not offered as a substitute for those explanations that describe the increase by the difference in the arcs the rods would describe if they embraced the axle instead of the eccentrics, etc., etc., but as a short, simple, easily understood explanation for practical men.

ADJUSTING ECCENTRICS WHEN WHEELS ARE NOT UNDER THE ENGINE.

If you were to be given the main driving wheels of a locomotive standing on the shop floor, whose old axle had been removed and replaced with a new one, and required that the four eccentrics be set and keyed before the wheels are put under the engine, so that they will have the correct angular advance according to lap and lead, the following advice will be of great value to you:

The first thing to be determined is whether the center of cylinder and cross-head pin is in line with the center of the axle. Fig. 1 shows that these centers are not in line; that is, that the center line *XX* of the cylinder and cross head is not coincident with the center line *AA* of the axle, but above it. It also shows that the inclination of the main rod, when the crank pin is on its front center *DD*, deviates from its inclination when the crank pin is on its back center *EE*.

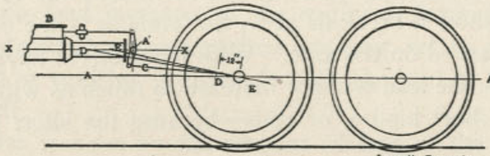


Fig. 1

ADJUSTING ECCENTRICS.

With the valve in its center position, in the steam chest *B*, and the upper and lower rocker pins an equal distance from the center *A'*, the lower arm is seen to be bent forward or have an offset, and it is also seen that the center line of motion *C* is on an incline. It will be necessary to take these three inclinations into consideration, namely, the two inclined positions of the main rod and the inclined position of the center line of motion. The next move is to find the amount of each inclination.

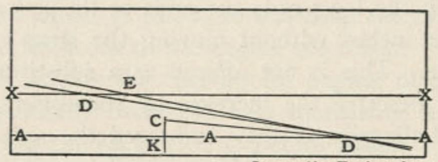


Fig. 2 *Locomotive Engineering*

ADJUSTING ECCENTRICS.

Take a pine board planed on one side and on lower edge, Fig. 2, and draw line *AA* to represent the center line of axles; after which, draw line *XX* parallel to it, and at a distance from it equal to the distance between lines *XX* and *AA*, in Fig. 1. The length of the main rod is then taken, to which is added 12 ins. for the length of the crank arm, and a line is drawn from center *D* to *D'*; also from center *D*, minus 12 ins. of the length of main rod, to center *E*, these lines giving the inclination of the main rod for the front and back positions of the crank pin.

The radius of link, which is the distance from the center of the axle to the lower rocker-pin center, when in its middle position, is next taken, and the arc *K* is drawn. The distance from the center line *AA* to center of lower rocker pin is next laid off, and the line drawn from *C* to *D* is the inclination of the center line of motion. Next, a square piece of wood is nailed under and parallel with each

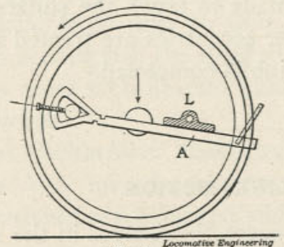


Fig. 3

ADJUSTING ECCENTRICS.

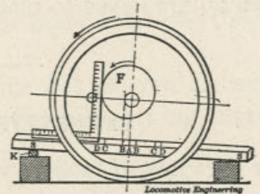


Fig. 4

ADJUSTING ECCENTRICS.

line, upon which is laid the degree spirit level *L*, by which to find the degree of inclination of each line. a memorandum of which is made for further use on the same class of engine.

The alligator plate *A*, Fig. 3, and the level *L*, are applied to the wheel as shown; after which the wheel is rolled so that the alligator plate will be brought to the same inclination as line *DD*, Fig. 2.

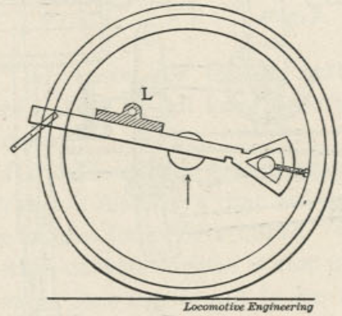


Fig. 5

ADJUSTING ECCENTRICS.

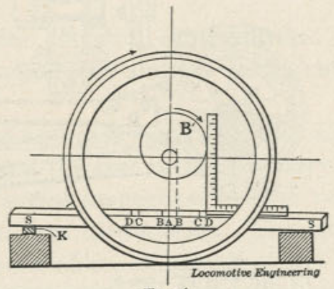


Fig. 6

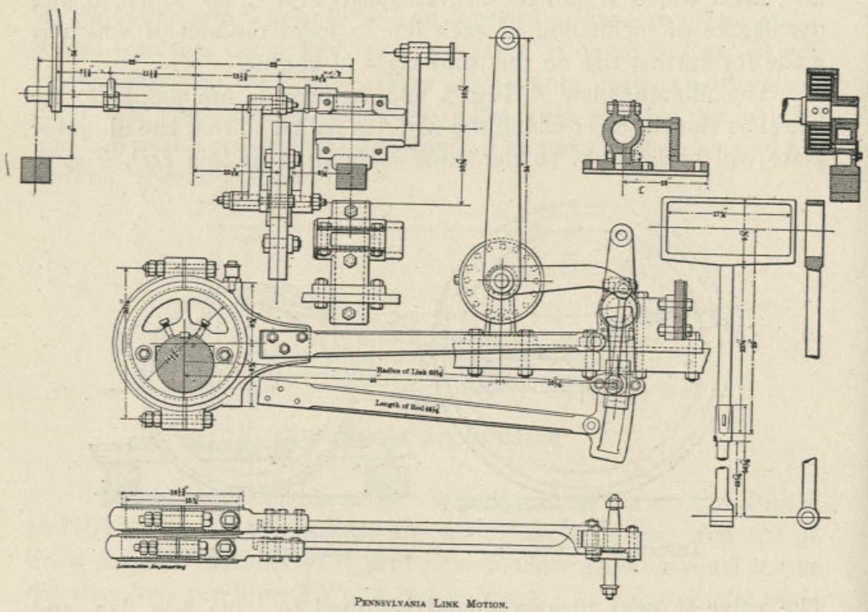
ADJUSTING ECCENTRICS.

The valve is next measured and is found to have $\frac{3}{4}$-in. lap, and the lead is taken at $\frac{1}{16}$ in. The straight edge *SS*, Fig. 4, is laid off, and as the rocker arms are of equal length, the distance *D C* is made in., which equals the lap and lead.

Straight edge *SS* is placed in position with the level *L* on it, and the former is, by means of the wedge *K*, brought to the same degree of inclination as the center line of motion *D C*, Fig. 2. Bringing mark *B*, Fig. 4, in line with the outside of the axle, the square is moved in line with mark *D*, and moving the forward eccentric *F* so as to touch the square, it will be in its proper position. Moving the wheel on its back center like Fig. 5, and bringing mark *B*, Fig. 6, in line with outside of axle, the square is moved in line with mark *D*, and the backing eccentric *B'* is made to touch the square, bringing it into correct position. The other eccentrics are treated similarly and when all are keyed to place the job is completed.

PENNSYLVANIA LINK MOTION.

For the class of readers who concern themselves in the study of valve motion, the annexed engravings are worthy of very close attention. It is the standard link motion for all the locomotives belonging to the Pennsylvania Railroad to which it can be applied. It



Pennsylvania Link Motion.

has been worked out with great care, and close attention has been devoted to eliminating as far as possible the leading defects of the link motion. All the dimensions necessary for transferring the motion to a drawing board or to a valve motion model will be found in the engraving.

BALANCED VALVES.

RICHARDSON BALANCED VALVES.

The subject of relieving the slide valve of steam engines of a portion or the whole of the excessive pressure to which the valve is subjected, while performing its work, has for many years engaged the attention of prominent mechanics, especially those connected with railroads. Various devices have been patented and put in trial from time to time, but in nearly every instance have failed to accomplish the desired object without developing inherent qualities more troublesome than the primary difficulty they sought to overcome.

The Richardson Balancing Device has proven an exception, and has fully met the expectations of those seeking after a perfectly satisfactory balanced slide valve.

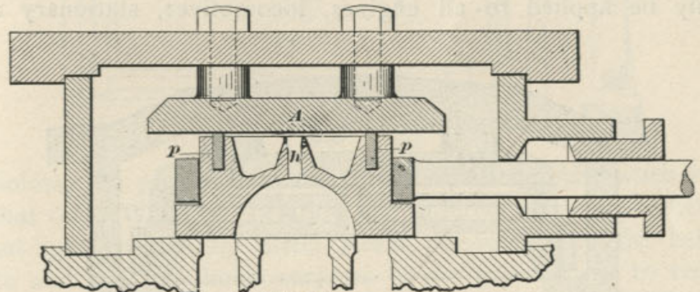


Fig.1

The reason for this is, certain essential elements that have caused others to fail have been sought out and the faults entirely overcome.

Its philosophy is readily stated and easily understood. Casual observation discovers that use wears the face of the ordinary slide valve in the form of a curve. Careful inspection further reveals that this curved surface is not uniform throughout. The ends of the valve face are found to be worn alike, in curves of the same radius; while the sides are found to be worn in curves similar to each other, but of a radius materially shorter than the curves at the end. Any device for removing pressure from the top of the valve which does not recognize these facts, must in use soon become worthless; for it will necessarily wear unequally in places, and will soon begin to leak steam, leaking worse as it wears more. These peculiar conditions which use develops in the face of the slide valve are the basis upon which the Richardson Balanced Slide

Valve is constructed. The packing in the top, which, by sliding against a balancing plate above, doing away with all undesirable pressure, is made in sections or separate bars so arranged that each bar in its travel does not cross the line of travel of any other bar, thus giving each bar an independent place for wear on the balancing plate and each bar corresponding to a portion of the valve face which wears in the same curve. These bars are at the same time so adjusted with respect to each other that they make and preserve steam-tight joints at their places of contact. Besides, as the valve wears, each packing bar bears uniformly throughout its entire section against the balancing plate above and preserves steam-tight joints with it. Under each packing bar is placed a semi-elliptic spring which holds the packing against the balancing plate whenever steam is shut off.

Besides being durable it is simple in construction and can readily be applied to all engines, locomotives, stationary and

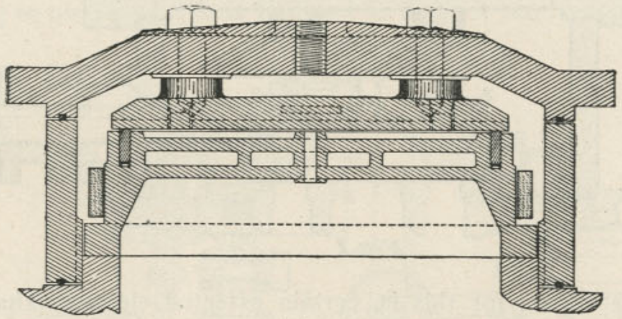


FIG. 2.

marine. It can, with little expense, be substituted for other valves on engines now in use.

THE RICHARDSON BALANCED SLIDE VALVE.

Referring to the illustrations herewith, Figs. 1 and 2 are transverse and longitudinal sections through the center of an ordinary locomotive steam chest fitted with this valve. Fig. 3 is a plan of the valve and Fig. 4 is an elevation of one of the end packing strips and spring. The only alteration made is the addition of the balance plate *A*, and the substitution of a valve suited to receive the packing strips *p p p p*.

In the present instance the balance plate is bolted to the steam-chest cover; but it is obvious that they may be cast in one piece if desired. As will be noticed, the four sections of packing enclose

a rectangular space, *s*, which is made equal in area to the amount of valve surface which it is desirable to relieve of pressure; the packing strips preventing steam from entering this space and its communication with the exhaust port in the valve, through the small hole, *h*, relieving it from any pressure that might otherwise accumulate. These packing strips, four in number, as previously noticed, are: the two longer ones, plain rectangular pieces of cast iron, while the shorter ones as shown in Fig. 4, are made with gib-shaped ends to retain them in place.

Under each packing strip is placed a light semi-elliptic spring —one of which is shown at *m*, Fig. 4—which serves the purpose

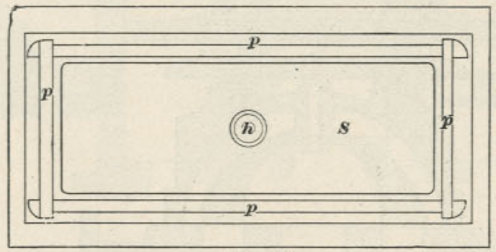


Fig.3

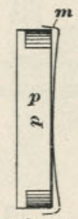


Fig.4

of holding the packing strips against the balance plate when steam is shut off. While in operation, the different sections are held in steam-tight contact, by direct steam pressure, with the balance plate and with the inner surfaces of the grooves cut to receive them, the joint being made complete by the abutting of the ends of the long sections against the inner surfaces of the gibbed sections at the four corners.

THE ALLEN-RICHARDSON BALANCED SLIDE VALVE.

The purpose of the Allen valve, Fig. 5, is to prevent in part, wire drawing of steam when running at high speed with the valve cutting off early in the stroke. The Allen ports furnish an additional passage for the admission of steam at such times; thus, when the steam port is open one-half in. in the ordinary manner, the port of the cored passage is also open to the same extent on the other side of the valve, and consequently the effective area of the steam port is doubled and becomes equal to a single port open 1 in.

The wire drawing which takes place when an engine is running at high speed with the valve cutting off early in the stroke, is thus much diminished and the consequent economy of steam and coal is obvious. The lessened wire drawing implies a higher average pressure on the piston when working at the same cut off, and, therefore, the usual average pressure can be obtained with a shorter cut off, thus effecting an appreciable economy. The unbalanced Allen valve effects therefore a better and more economical distribution of steam; but its use is attended with certain disadvantages. The bearing surface on the face of a slide valve is never sufficiently large to enable it to wear well under the heavy pressure of steam, and this wearing surface is still further reduced in the Allen valve, owing to the internal steam ports. The internal passage virtually divides the valve into two parts and the pressure of steam acting on the outer part springs and bends its working face below that of the internal or exhaust part of the valve. The useful

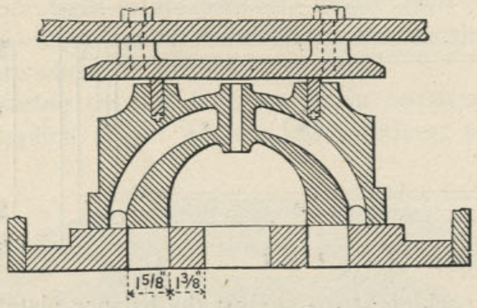


FIG. 5.

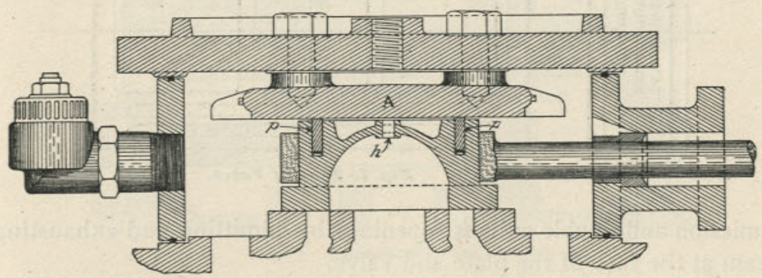
wearing face thus become reduced to a space about half as wide as the outside lap of the valve. It is, therefore, not surprising that the Allen valve when unbalanced wears very rapidly and the trouble and expense of constantly facing valves and seats and the loss of steam in blowing through leaky valves, counterbalances the advantages gained by the diminished amount of wire drawing. These disadvantages are entirely overcome by properly balancing the valve, and then are gained, not only all the advantages of the Richardson balancing device, but also the increased steam economy from using the Allen ports.

To be sure of getting the very best results from the use of the balanced Allen valve, the ports and bridges should exceed the full travel of the valve by at least $\frac{1}{8}$ of an inch. The radius of the link should always be as long as permissible, to avoid an excessive increase of lead when cutting off early in the stroke.

VACUUM RELIEF VALVE.

This valve, illustrated on page 281, is designed to be placed in the steam chest to automatically supply clean air to the cylinders through the air valve when engine is running shut off, and thus furnishes a free supply of air from the outside instead of its being sucked in from the smoke box laden with hot gases and cinders which lap all oil from the valves and seats.

The pressure relief valve performs a very valuable function in preventing the dangerous accumulation of pressure in the steam chest and dry pipe and ofttimes breaking of same when engine is suddenly reversed. The valve is set to open at a pressure slightly above the maximum boiler pressure, and will allow any excess of



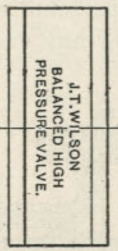
pressure to escape to the atmosphere, yet will maintain in the cylinders a uniform pressure of air within the limits of safety, when running forward after reversing, and thus supply resistance to the pistons and overcome the momentum of the train, and perform the functions of an automatic air brake in assisting to stop the train. By using this valve an engine may be suddenly reversed while running at high speed without strain or damage to any portion of the machinery or boiler.

This valve is well designed and made from the best steam metal.

THE WILSON HIGH-PRESSURE SLIDE VALVE.

This high-pressure slide valve consists of three principal parts, the valve itself, Fig. 1; the balance plate, Fig. 2, and the pressure plate, Fig. 3. Fig. 4 is a cross-sectional view of valve seat, steam chest and steam-chest cover with the valve, the balance plate, the pressure plate, the balancing rings, and the centering rings assembled therein. Fig. 5 is a longitudinal sectional view of same. The valve is similar to the "grid-iron" valve, it having two faces; one face operates on the valve seat proper, and the other face operates against the face of the balance plate. Both faces of the valve are the same, and it has no crown, but is open clear through. The face of the balance plate, against which the top or back face of the valve operates, is an exact duplicate of the cylinder valve seat.

The valve here illustrated is of the double-acting type. The balance plate contains the balancing cones marked M.C. and P.C. (main cone and port cone), and also supplies the means for double



End View of Valve.

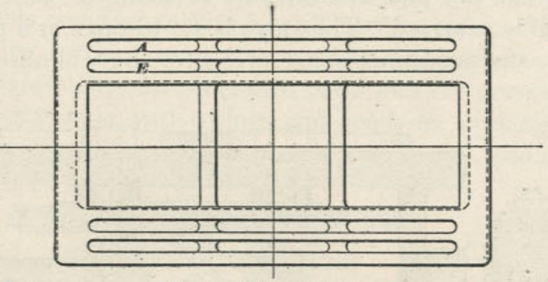


Fig. 1 - Plan of Valve.

admission and double exhaust openings by admitting and exhausting steam at the face of the plate and valve.

The face of the balance plate is an exact duplicate of the cylinder valve seat, and forms a second valve seat against which the valve

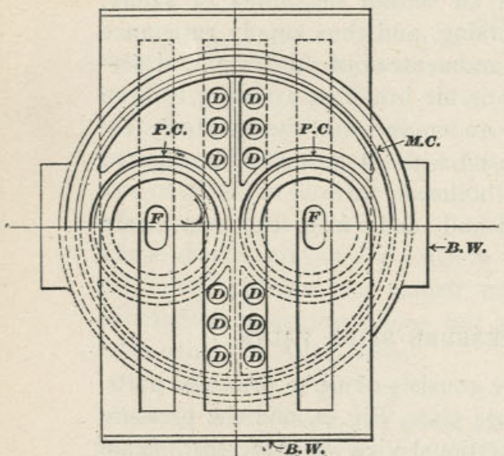


Fig. 2 - Plan of Balance Plate. Half Face. Half Back.

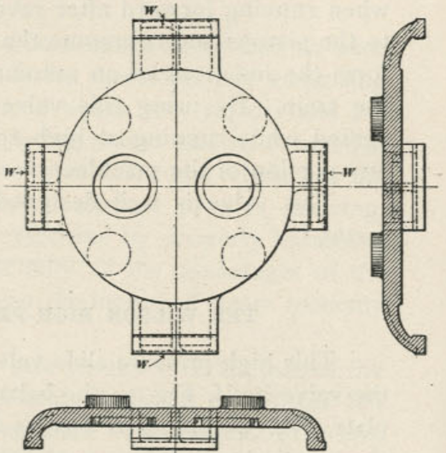


Fig. 3

operates in unison. The back or opposite side of the balance plate contains one large or main cone (M.C.) and two small, or port cones (P.C.), on the interior of the main cone, on which the packing rings are placed, which form the balancing feature to the valve. The upper face of the packing rings forms joints against the pressure

plate. The pressure plate is made either a part of or separate from the chest cover. With the type of valve here illustrated the pressure plate is made separate and provided with wings (W.) which fit snugly into the steam chest. The balance plate is also provided with wings (B.W.), which are machined to fit $\frac{1}{16}$ in. loose in the inside of the wings of the pressure plate. Into the face of the pressure plate

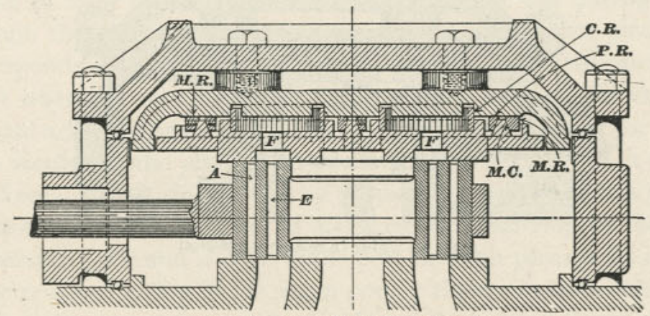


Fig. 4 - Assembled Cross Section.

two grooves are cut, which register correctly with the corresponding grooves in the balance plate. Into them two centering rings (C.R.), slightly under tension, are placed. Under normal conditions these steel rings hold the balance plate in alignment with the valve seat, but under abnormal conditions, such as dry valves, the strain will be

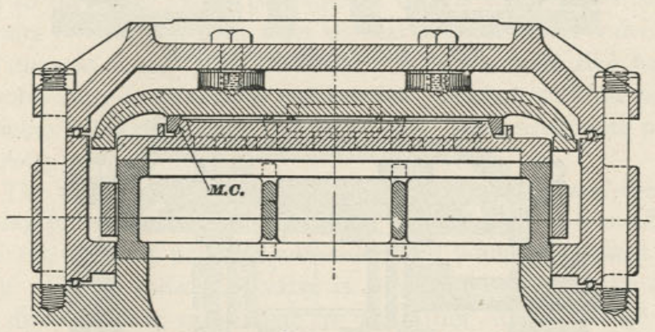


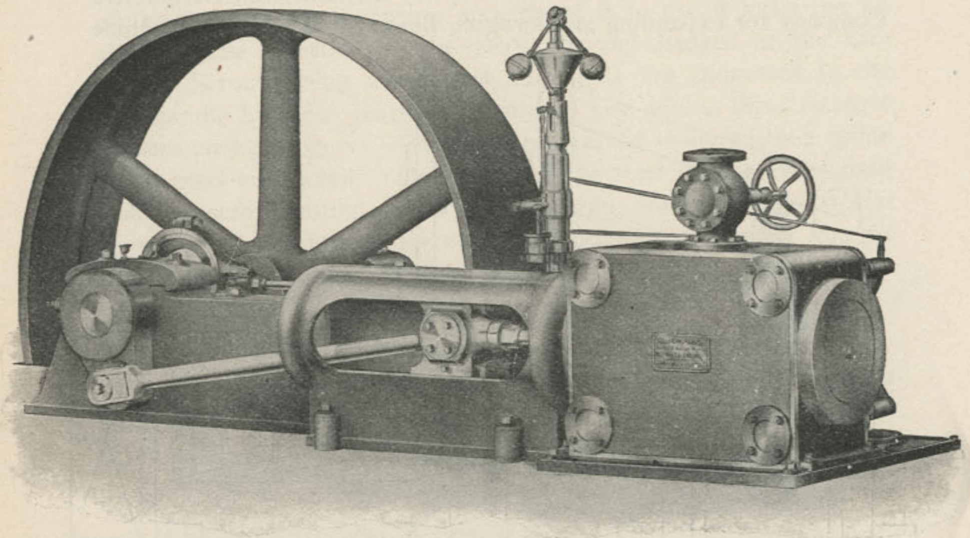
Fig. 5 - Assembled Longitudinal Section.

taken by the wing of the balance plate against the wing of the pressure plate, preventing excessive contraction of the centering rings. The balanced area of the valve is changeable automatically, so as to correspond with the changed condition of the valve on its seat at different points of its travel.

Fig. 4 shows the valve in central position. The finished wings machine does the work quickly and expeditiously. The whole arrangement is mounted on a long table for convenience in handling tubes. The machine was made at the works.

ALLIS-CHALMERS COMPANY'S NEW STANDARD REYNOLDS-CORLISS ENGINE.

We illustrate herewith a new Corliss engine which is being brought out by the Allis-Chalmers Company from the designs of Mr. Irving H. Reynolds. The present machine represents the experience of twenty-six years in building of Corliss engines, and combines all of the desirable elements of the best designs.



NEW STANDARD REYNOLDS-CORLISS ENGINE, ALLIS-CHALMERS CO.

Engines of the type illustrated are being built in seven sizes, ranging from 50 to 500 h.p., and are designed for steam pressures up to 150 lbs. They are built of somewhat shorter strokes than have heretofore been customary in Corliss engines, with the idea of economizing in space and making the construction more rigid. The speeds are also somewhat higher than usual, ranging from 110 to 150 revolutions per minute, although these speeds are not higher than those at which the Reynolds-Corliss engines of older design are frequently operated.

The frame is cast in one piece with the slide, the construction

being of the box type, resting on the foundation for its entire length. The main bearing shells are bored into the frame, thus insuring a solid bearing and also permitting the easy removal of the shells by rolling them out around the shaft.

The slide is of the barrel type with bored guides. The cross head is fitted with babbitt-faced shoes with wedge adjustment. The piston rod is screwed into the cross head and held firmly with a steel lock nut. The cylinder is of the round-cornered type, is fitted with double-ported steam and exhaust valves, lagged with planished steel. The cylinder is set on a cast-iron base plate, which extends under the valve gear, serving as a drip pan.

The valve gear is of the usual Reynolds-Corliss type, the wrist plate being of skeleton pattern and fitted with a new type of disconnecting device which, while clamping the hook rod firmly, is very easily detached by hand. The dash pots are of differential plunger type without leathers or packing of any kind. The regulator is of the high speed weighted type, designed to control the engine within narrow limits of speed variation. The crank is of plain type, polished on the face, and is protected by a planished steel oil guard. The engines are fitted either with belt flywheels, as shown, or with square rim wheels where used with direct-connected electric generators. The crank and cross-head pins and main journals are of a size ordinarily used with heavy-duty engines.

In brief, the engine is strong, simple and compact, and while nothing has been added for ornamentation, nothing contributing to economy or durability has been omitted, and the machine should find a large sale among power users who appreciate quality.

A HANDY SHOP TURNTABLE.

In the B. F. Sturtevant Company's shops, at Boston, one may see a very handy form of shop turntable for turning lorries, material carrying trucks, etc. The illustration is of a turntable tilted up so as to show the mechanism. The bottom frame is a casting and is fitted with four roller wheels which turn on composition axles. The wheels are made hollow and may be partly filled with oil so as to lubricate the bearings. The table itself is recessed out on the upper side for two tracks which cross it at right angles, and underneath it is substantially ribbed and altogether is made very heavy to prevent warping or breakage and it is thus able to stand lots of hard but fair usuage.

of the balance plate (B.W.) fit $\frac{1}{16}$ in. loose between inside faces of the wings of the pressure plate, but the balance plate is held perfectly central by two steel centering rings (C.R.). The tops of the cones on the balance plate are $\frac{1}{8}$ in. from the face of the pressure plate,

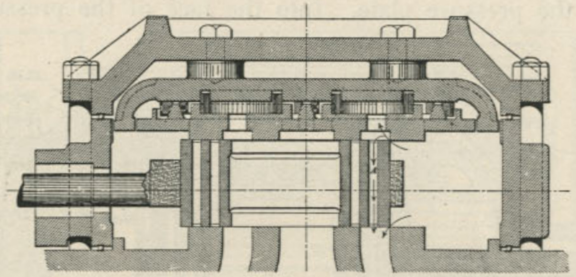


FIG. 6. Valve in opening position

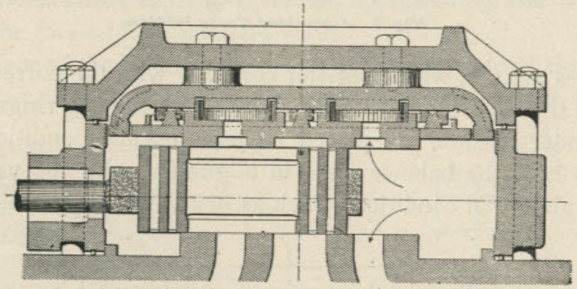


FIG. 7. Valve in wide open position.

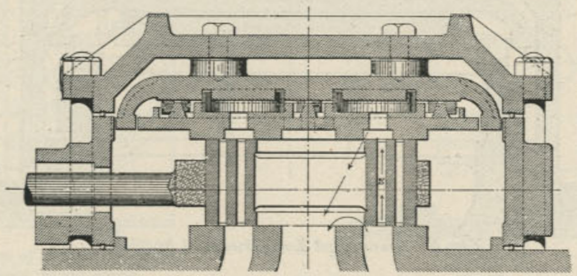


FIG. 8. Valve in exhaust opening position.

allowing the balance plate to lift $\frac{1}{8}$ in. off from the valve, which affords perfect relief to the cylinder while engine is drifting or for the relief of water from the cylinder from any cause. This $\frac{1}{8}$ in. clearance in height adjustment must be maintained. The main

balancing ring (M.R.) is made the proper diameter to balance the valve as much as possible while in its central and heaviest position. The interior of the main ring is open to the atmosphere through the holes D, which lead to the exhaust cavity of the valve. The valve conditions are changed by the opening of a steam port and at instant of cut off. See Fig. 6. In this valve the port pressure has free access to both sides of the valve by reason of the passages A.E. through the valve to the port in the face of the balance plate which corresponds with the cylinder port. The pressure in the port has no effect whatever upon the valve, being on both sides of the valve face in equal area and pressure, but the pressure in the port of the balance plate would lift the plate off from its seat on the valve if it was not equalized. A port ring (P.R.) of proper area to balance this pressure is placed over each port in the inside of the main ring on the top of the balance plate and is open to the port through passage F, so that a pressure equal to that in the steam port is always on both sides of the balance plate, as well as on both sides of the valve. Communication from the cylinder port, through the valve and through the balance plate to the interior of the port ring (P.R.) cannot be shut off at any time, but is maintained throughout the travel of the valve. There is a position of the valve during its stroke where the ordinary slide valve is subjected to an upward pressure, shown in Fig. 7, but in this valve the valve travels out from under the seat of the balance plate to the same extent that it over travels the cylinder seat, and pressure is equal on both sides of that portion of the valve that is over the seat at any point of travel. With the main ring balancing the valve fully in its central and heaviest position, with the port ring balancing the port pressure, the valve is fully balanced in all positions of stroke.

The double admission of steam to the cylinder and the double opening for exhaust of same are made clear in Figures 6 and 8, which show the valve at point of admission and point of exhaust respectively. Fig. 6 shows the valve is admitting steam to the cylinder port direct, and at same time is admitting steam to the pocket port in the balance plate and then by way of passage A, through the valve into the cylinder, thus securing double admission openings. Note direction of arrows. Referring to Fig. 8, the valve is opening for exhaust, and the steam leaves the cylinder at the face of the valve at cylinder seat and also by way of the passage E through the valve into the port in the balance plate and out at that face of the valve, thus securing the double opening for exhaust.

In applying this valve to the engine it is important that the face of the balance plate, or upper valve seat, shall be in alignment with the cylinder seat in order to secure simultaneous action of the valve at both faces, and accomplished by a very positive and easy method shown here. Direct communication from one cylinder port to the other is always maintained by reason of the ports A.E. through the valve.

A test measurement should be made before the balance plate is put into the steam chest by placing a square on the valve seat with its blade flush with one edge of the seat and then measure from the square to the finished strip at top of steam chest where the wings of the pressure plate are to fit, then reverse the square to other side of seat and measure to that side of chest, and these two measurements must be the same; the valve illustrated here is flangeless and will drop into the yoke after the chest is in position, but in case of a flanged valve where it is put in first, move the valve to edge of seat and measure from the valve or use a square on top face of valve.

This valve is manufactured by the American Balance Valve Company, of Jersey Shore, Pa., and San Francisco, Cal. In order to secure perfect service, the company does not allow the manufacture of any of the parts in any outside shops.

FORCES INVOLVED IN TRAIN MOVEMENTS.

ENERGY AND POWER.

Engineering writers are much given to using the terms energy and power as if the words conveyed the same meaning. We often wished to demonstrate the difference in the two terms, but the distinctions were difficult to define, and we never perceived them clearly until we saw them defined by Professor Reynolds, who says:

"Although the terms energy and power are in continual use, such use is seldom in strict accordance with their scientific meaning. In many ways the conception of energy has been rendered popular, but a clear idea of the relation of energy to power is difficult. This arises from the extreme generality of the terms; in any particular case the distinction is easy. It is easiest to express this distinction by an analogy; but as a matter of fact, everything that seems analogous is really an instance of energy. Power may be considered to be directed energy; and we may liken many forms of energy to an excited mob, while the directed forms are likened to a disciplined army.

"Energy in the form of heat is in the mob form; while energy in the form of a bent spring, or a raised weight, matter moving in one direction, or of electricity, is in the army form. In the one case we can bring the whole effect to bear in any direction, while in the other case we can only bring a certain portion to bear, depending on its concentration. Out of energy in the mob form we may extract a certain portion, depending on its intensity and surrounding circumstances, and it is only this portion which is available for mechanical operations.

"Now energy in what we may call its natural sources has both these forms. All heat is in the mob form, hence all the energy of chemical separation, which can only be developed by combustion, is in the mob form, and this includes the energy stored in the medium of coal. The combustion of one pound of coal yields from ten to twelve million foot pounds of energy in the mob form of heat; under no circumstances existing at present can all this be directed, nor have we a right, as is often done, to call this the power of coal. What the exact possible power is we do not know, but probably about four-fifths of this, that is to say, from eight to ten million foot pounds of energy per pound of coal is the extreme limit it can yield under the present conditions of temperature at the earth's surface. But before this energy becomes power, it must be directed. This direction is at present performed by the steam engine, which is the best instrument art has yet devised, but the efficiency of which is limited by the fact that before the very intense mob energy of the fire is at all directed, it has to be allowed to pass into the less intense mob energy of hot water or steam. The relative intensity of these energies are something like twenty-five to nine. The very first operation of the steam engine is to diminish the directable portion of the energy of the pound of coal from nine millions to three millions. In addition to this there are necessary wastes of directable energy, and a considerable expenditure of already directed energy in the necessary mechanical operations. The result is that, as the limit, in the very highest class engines the pound of coal yields about one and a half millions of foot pounds; in what are called "first-class engines," such as the compound engines on steamboats, the pound of coal yields one million, and in the majority of engines, about five or six hundred thousand foot pounds. These quantities have been largely increased during the last few years; as far as science can predict they are open to a further increase. In the steam engine art is limited to its three million foot pounds per pound of coal; but gas engines have already made a new departure, and there seems no reason why art should stop short of a large portion of the nine millions."

HOW TO CALCULATE THE POWER OF LOCOMOTIVES.

The practice of tonnage rating which has been steadily growing into favor for the last few years has set many officials outside of the mechanical departments to figuring upon the power of locomotives and on the trains which all kinds of engines ought to haul over certain divisions.

Rules for calculating tractive power have been known for many years, but the principles have been so much obscured by algebraic

formulas that they have not been comprehensible to the average railroad man. Although many people interested in train movements have tried to learn the rules for figuring tractive power, only a comparative few have succeeded. The rules we now give are so simple that any person familiar with the first four rules of arithmetic can work out the problems. While working out tractive-power problems, railroad men must remember that the rules are intended for a perfect track. Low joints and bad alignment increase the resistance.

HORSE POWER.

The power capacity of steam engines is generally expressed in horse power, which is a measurable quantity and is based on the arbitrary measure of one horse power being equal to the effort of raising 33,000 pounds one foot per minute. That is the unit used for measuring the power transmitted by nearly all kinds of prime motor and machines. It is sometimes applied to locomotives, but for a variety of reasons the horse-power capacity of a locomotive does not convey to the ordinary railroad mind its capacity for hauling different kinds of trains. The utility of a locomotive for train pulling has to be expressed in a different way.

When practical railroad men know the size of cylinders, the diameter of driving wheels, the weight resting upon them, and the boiler dimensions, they understand what kind of service the engine is adapted for, and in a general way what weight of train it will haul. A general idea of power is, however, a guess which may be considerably away from the truth. Guessing is not a good basis for designing or estimating the power of a locomotive, and so methods have been devised for figuring out the power and speed that certain dimensions will develop, which are as correct and reliable as any other engineering rules. It has become customary to reckon the power of a locomotive by the tractive force the driving wheels will exert upon the rail. That is the resisting weight which the engine will start from a state of rest.

TRACTIVE POWER.

The tractive force is the power which the pistons of a locomotive are capable of exerting through the driving wheels to move engine and train. The efficiency of the engine's tractive power is dependent upon the adhesion of the wheels to the rails. When adhesion is insufficient, the power transmitted through the pistons and rods will slip the wheels, and no useful effect will result. To prevent the slipping of locomotive driving wheels, it is necessary to put resting upon them at least four times in weight the force available for turning the driving wheels. If the weight is five or six times the piston power, the engine will do its work with less annoyance from slipping than would be the case with less weight. To prevent slipping on unwashed greasy rails more than double the adhesion would be necessary for that required on dry, clean rails. This cannot often be done, but the sand box provides the means for obtaining adhesion when the rails are in bad order.

Let us calculate the tractive power of the kind of engine most commonly used for hauling heavy passenger and fast freight trains, which has cylinders 19 x 26 inches, driving wheels 69 inches diameter, with a working pressure of 200 pounds to the square inch. The method by which the traction of a locomotive is calculated is, to square the diameter of the cylinders in inches, multiply that by the length of the stroke in inches, and divide by the diameter of the driving wheels in inches. The product of that sum will be the power exerted by the engine for every pound of pressure that reaches the cylinders from the boiler. A rule established by the Railway Master Mechanics' Association makes out that eighty-five per cent. of the boiler pressure is a fair average of what pressure will be useful in the cylinders at slow speed.

Follow that rule and the formula that we have described the method for finding out the tractive power of this particular locomotive would be:

$$\frac{d^2Lp}{D} = T$$

which means

d^2 = diameter in inches squared.
L = the length of stroke in inches.
p = the mean effective pressure on piston.
D = the diameter of the driving wheels in inches.
T = the equivalent tractive force at the rails in pounds.

To apply this rule in practice, we find that d^2 means multiply 19 by itself, or square, so we have $19 \times 19 = 361 \times 26$, the stroke in inches, $= 9.386 \times 170$, mean effective pressure, $= 1,595,620 \div 69$, the diameter in inches of driving wheels, $=23,125$. This gives 23,125 pounds as the power exerted at the circumference of the wheels, from which a deduction of about ten per cent. is usually made for internal friction. We have assumed the boiler pressure to be 200 pounds and have used eighty-five per cent. of it.

The formula described for finding the power of a locomotive seems at first sight theoretical, and not based on a good philosophical foundation; but it is merely a short way, and agrees in results with more detailed methods of calculation. It agrees with another plan which is more in favor with civil engineers. That is, to ascertain the foot pounds of work the engine is doing during each revolution of the driving wheels. By dividing the total thus found by the circumference of the drivers in feet, the force exerted through each foot which the engine moves is found.

Taking the same engine that we have figured on, with pistons 19 inches diameter, the area of one piston is 283.5294 square inches. This is multiplied by the mean average pressure of the steam, giving $283.5294 \times 170 = 48,199.9980$, which gives the aggregate pressure exerted by the steam on one piston. Multiplying that by 2 to take in both pistons, we have $96,399.9960 \times 4\frac{1}{3}$ feet, the stroke moved in a full revolution of the driving wheels, $= 417,733.3160 \div 18.0642$, the circumference of the driving wheels in feet, $= 23,125$ pounds tractive force, the same as by the other rule.

There are several other methods of calculating locomotive tractive power, but they need not be described, as they bring precisely the same figures as those found.

When people wish to find the horse power developed by a locomotive at various speeds, the steam engine indicator is usually employed to show the mean effective pressure inside of the cylinders. To explain the process to be followed, we will draw on our own experience with a representative locomotive pulling a fast passenger train.

WORK OF MOVING THE EMPIRE STATE EXPRESS.

The writer took indicator diagrams to find out the amount of work done by the locomotive in taking the Empire State Express over the New York Central Railroad. The details were published in LOCOMOTIVE ENGINEERING, June, 1892. A very common speed was 60 miles an hour. The engine had cylinders 19 x 24 inches, and driving wheels 78 inches diameter. The indicator diagram proved that the average cylinder pressure at 60 miles an hour was 53.7 pounds per square inch. The horse power is calculated in the following manner:

283.5294	square inches piston area.
53.7	pounds M. E. pressure.
15,225.5	pressure on one piston.
2	pistons.
30,451	pressure transmitted from both cylinders.
4	feet piston travel in each revolution.
121,804	
260	revolutions per minute.

$31,669,040 \div 33,000 = 959$ h.p.

That method of calculation of course applies to all locomotives, and can be used when the area of piston, revolutions per minute and mean effective cylinder pressure are known.

In the case recorded, the mean effective cylinder prsesure was little more than 33.5 per cent. of the boiler pressure. When the same engine was running at 37.1 miles an hour, making 160 revolutions per minute, the M. E. P. was 59.2 pounds, and 37 was the percentage of boiler pressure. At 20 revolutions per minute the mean effective pressure would be little short of the eighty-five per cent. of boiler pressure of the Master Mechanics' rule, but it would gradually decrease as the piston speed increased.

The work that a locomotive has to do in pulling a train is described under the heading of Train Resistances.

TO CALCULATE THE POWER OF COMPOUND LOCOMOTIVES.

To calculate the tractive power of compound locomotives, it is necessary first to know what the mean effective pressure on the pistons is in every case, and any attempt at a theoretical exposition of the methods for arriving at this information by calculation is very unsatisfactory and inaccurate, for this reason: In the case of the two-cylinder compound, there are too many unknown quantities, among which are the volume of receiver, pressure of live steam through reducing valve, and the amount of back pressure. In the case of the four-cylinder compound, there is no receiver, but the element of back pressure is present on the high-pressure piston. For these reasons calculated pressures are not reliable for finding the power of this type of engine. The indicator furnishes the means to arrive at the correct mean effective pressure, and the formula for a two-cylinder compound when the mean effective pressure is known is:

$$\frac{d^2 \times \text{M. E. P.} \times s}{2 \times D}$$

in which $d^2 =$ diameter of low pressure squared, M. E. P. = mean effective pressure, $s =$ stroke in inches, and $D =$ diameter of driving wheel. In the absence of indicator cards showing cylinder pressures for a given boiler pressure, approximate results may be had by taking the mean effective pressure in the high-pressure cylinder at seventy per cent. of boiler pressure, which for 200 pounds boiler pressure would be 140 pounds. If the reducing valve gives steam to the low-pressure cylinder so as to equalize the work on both the pistons, the low-pressure cylinder

will have a mean effective pressure of about 60 pounds for a ratio of cylinder of 2.3, which is the ratio between 23 and 35-inch cylinders. Referring the mean effective pressure to terms of the low-pressure cylinder, we have:

$$60 + \frac{140}{2.3} = 60 + 61 = 121 \text{ pounds.}$$

Placing the values in the formula, the tractive power equals:

$$\frac{35^2 \times 121 \times 32}{2 \times 55} = 43{,}120 \text{ pounds.}$$

If a deduction of seven per cent. for internal friction is made, the net tractive power is about 40,000 pounds. The tractive power of the four-cylinder compound is also found by taking mean effective pressures known to have been found in service. These may be taken at forty-four and forty-six per cent. of the boiler pressure for the high- and low-pressure cylinders, respectively, which for 200 pounds gauge pressure equals 88 and 92 pounds mean effective pressure. Taking, for an example, an engine with high-pressure cylinders, 18 inches diameter, low-pressure cylinders 30 inches diameter, stroke 30 inches, and diameter of drivers 55 inches, the ratio of cylinder areas is 2.77; and again referring the pressures to the low-pressure cylinder, we have

$$92 + \frac{88}{2.77} = 123 \text{ pounds mean effective pressure in the low-pressure cylinders.}$$

Placing these values in the formula, which in this case is somewhat different from the other, owing to the fact that there are now two cylinders to consider instead of one, we have:

$$\frac{30^2 \times 123 \times 30}{55} = 60{,}300 \text{ pounds.}$$

Taking out seven per cent. for friction, as before, the tractive power is about 56,000 pounds.

TRAIN RESISTANCES.

The practice of rating locomotives according to their theoretical power is becoming so common that a plain statement of the resistances which have to be overcome in hauling trains at various speeds will interest most of our readers, although the facts have been published before. In 1892 Angus Sinclair made a series of tests of locomotives pulling the Empire State Express to ascertain as accurately as possible the power required to pull the train at the different speeds. This was done to show that the Clark formula for calculating train resistances, which was generally used by railway officials, made the resistance too high. When Mr. Sinclair was a locomotive engineer he had often figured on the power of the engine he was running and on the resistance of the train based on its weight and Clark's rule, and found that his engine was often doing impossibilities. He had long desired to test the accuracy of the rule and his opportunity came when he was testing the engines hauling the Empire State Express.

According to Clark's formula there is a resistance to movement of eight pounds per ton, and the resistance increases with speed at the rate of the square of the velocity in miles per hour divided by 171. American engineers had modified this to read six pounds per ton for the constant resistance, and accepted the remainder of the rule, so that the common practice was to calculate the resistance to trains on a straight level track to be

$$\frac{V_2}{171}+6=R$$

That is V representing miles per hour and R resistance per ton. The rule stated in words is: Square the velocity in miles per hour, divide this by 171, add 6 to the quotient, the result being the resistance at the rails in pounds per ton. This is the rule found in nearly all engineering text books. And they are all wrong, a very common characteristic of text books.

In the run referred to, a speed of seventy miles an hour was maintained for some miles and several diagrams were taken when the locomotive was doing the work of maintaining the speed without loss or gain. The power developed showed that the entire resistance of the train and the locomotive at that speed was 17.6 pounds per ton. In the discussions that come up periodically about what the ultimate speed of railroad trains will be, arguments are advanced that after a speed of sixty miles an hour is passed a point is soon reached where the locomotive will absorb the whole power developed in moving itself. Figures to prove this are always given, based on the text-book rule. According to this rule the resistance per ton at 70 miles an hour is over 34 pounds. If this were true there is not a locomotive in the country that would keep three cars running at 70 miles an hour.

The fact is that the square of the velocity does not in any manner represent the increase of train resistance due to acceleration of speed. This rule is utterly worthless and has no right to be used to deceive people who are trying to find accurate basis to calculate from. Its existence was evidently due to the desire of mathematicians to establish formulæ for everything. In this case the formula was established without the necessary data upon which to build correctly.

A number of American railroad companies have used dynamometer cars for years in which excellent provision was made for keeping an accurate record of train resistances. Those go to prove, not only that the resistance does not increase in proportion to the square of the speed, but that the resistance varies greatly according to the load per axle. On a Western railroad a great many records were made some years ago on the resistance of different kinds of freight trains, with a view of finding out how many cars certain locomotives ought to haul. A train of loaded freight cars weighing 940 tons gave an average resistance of 5½ pounds per ton when running twenty miles an hour on the level. A train of empty freight cars weighing 340 tons showed a resistance of 12 pounds per ton when running twenty miles an hour on level track. A passenger train weighing 363 tons gave 7½ pounds per ton resistance at a speed of thirty miles an hour. The records respecting train resistance of the roads having dynamometer cars agree substantially with those concerning the Empire State Express.

When the record of the tests was published Arthur M. Wellington, a well known civil engineer, who had devoted much attention to train resistance, wrote:

"The observations are among the most important evidences on record of the actual resistance of trains at high speeds. Perhaps we might even go farther, and say that they are the most important, especially as they are reasonably consistent with the mean of the few other records which have been obtained for speeds of 50 to 75 miles per hour, while presumably far more trustworthy and decisive than any of these prior records. As such they are a real contribution to technical knowledge. We trust, though we hardly expect, that they will attract the attention they deserve, and we recommend electrical journals, especially, to reproduce them, as having an important bearing on pending efforts to obtain very high speeds by electric power, and going far to indicate that these efforts may be successful."

After giving the leading particulars about the route, the train, the speed and the resistance recorded, he made comparisons of the data with those of a famous run made by Mr. Wm. Stroudley on the London, Brighton and South Coast Railway, and published in the Transactions of the Institute of Civil Engineers, 1885, with the figures of train resistance found by Mr. P. H. Dudley in his tests with dynamometer car, and with the discoveries made on air resistance alone by Mr. O. T. Crosby in experiments with a high speed electrically driven car. It is demonstrated by figures that Mr. Sinclair's record agrees substantially with the most reliable data relating to train resistances, and the annexed diagram has been plotted to give a graphic illustration of the rate of train resistance in pounds per ton.

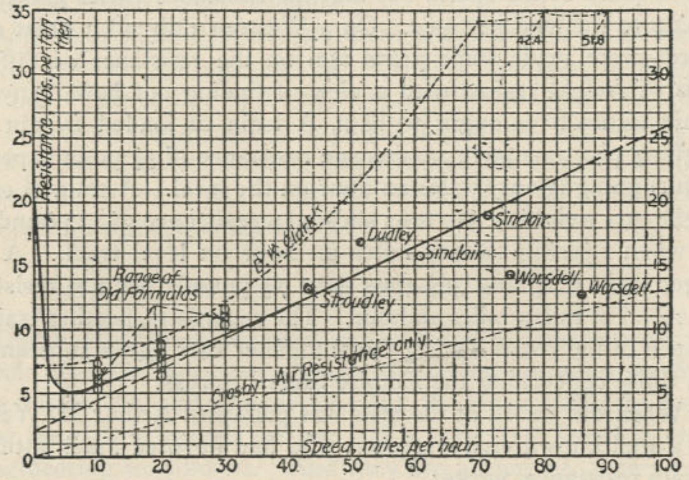


DIAGRAM OF TRAIN RESISTANCE.

On this subject Mr. Wellington said: "The element of axle friction only in train resistance is fairly determined at about 4 lbs. per ton for passenger and loaded freight cars, and 6 lbs. per ton empty freight cars at a speed of 10 to 30 miles per hour. The general law of friction is also well determined that at very high journal speeds the lubricants are so well carried around between the metallic surfaces that the friction is greatly reduced, and may almost become evanescent. Several engineers whose tests were of the most reliable character have directly observed this fact in railway service that at high speeds the journal friction proper may be less even than 2 lbs. per ton.

"It is now an admitted fact that the axle friction at the instant of starting is many times greater than after the vehicle is once under way, and that the drop from this high resistance, while very rapid, is by no means instantaneous, but requires a speed of from 5 to 10 miles per hour before the normal rate is attained. The starting resistance at times rises considerably above 20 lbs. per ton; i. e., a car on a 1 per cent. down grade, which gives an accelerating force of 20 lbs. per ton, will not always start of itself without aid. A force of 16 lbs. per ton will very rarely start a car in motion. A fair average is about 20 lbs.

"All these various data we have plotted on a little diagram reproduced herewith, to which we have added a solid black line to show what the evidence at hand appears to indicate as to the true rate of train resistance in pounds per ton. The six observations on high speed trains are shown by small circles with the name of each observer attached. Above and below these are shown by dotted lines (1) the old Clark formula as one extreme and (2) the Crosby formula for air resistance as the other. The range of the older formulas at 10, 20 and 30 miles per hour is shown at the left. There have been some showing still higher resistances than Clark's, but they have not met general acceptance. For the most part they fall below Clark's at low speeds.

"Considering that the Worsdell observations are known to need small correction at least, Mr. Sinclair's two records come extraordinarily near to giving the mean of the four others. If we add to the Worsdell observations 6 lbs. and 10 lbs. per ton respectively, which would be the effects of a 0.3 per cent. and a 0.5 per cent. grade (15 and 26 ft. per mile), they would fall exactly on the line which we have drawn as the 'weighted mean' of the six, allowing most weight to Mr. Sinclair's observations.

"Is it possible to find in this diagram any support for the theory that train resistance varies as the square of the velocity? We are unable to do so; especially as it is easy to see how the facts which we have narrated should make resistance observations within a narrow range of low speeds only appear to indicate that the velocity resistances vary as the square or even a higher power, when they really varied directly as the velocity. We by no means give our adhesion to the latter theory. We are merely weighing evidence. We do say that so far as the existing evidence as to high speeds goes, all of it supports the latter theory and none of it the older and heretofore accepted theory. If the solid line on the diagram gives a true mean of trustworthy experiments, then the resistance of passenger trains at speed is given by the equation

$$R=0.24V+2$$

or perhaps as accurately and more simply:

$$R=\frac{1}{4}V+2$$

"Both these forms are subject to a slight increment for difference in axle friction at speeds below 40 miles per hour, increasing as the speed falls, which is a more or less variable quantity and for practical purposes may be neglected."

The work which a locomotive performs in pulling a train is expended in overcoming the resistance due to wheel friction, gradients, curves and atmospheric or wind pressure. Ever since railroad trains began to be operated, engineers have been striving to devise formulæ for showing the train resistance at various speeds. From what we have found out in investigating this subject, we do not believe that it is possible to devise a formula that will show an approximation of the resistance due to different kinds of trains at different speeds when train tons are the basis of calculation.

The character and the load of the cars have a decided influence upon the resistance per ton of the train. Thus records made on the Chicago, Burlington & Quincy by the aid of the dynamometer car and indicator diagrams taken from the locomotive showed that with a train of loaded freight cars weighing 940 tons running at a speed of 20 miles an hour, the average resistance on a straight, level track was 5½ pounds to the ton. A train of empty freight cars weighing 340 tons run at the same speed showed an average resistance of about 12 pounds to the ton.

There is good reason for believing that the heavier the cars in a train are loaded, the smaller the ton resistance is, just as was cited in the case of the loaded and empty cars. A particularly heavy train of freight cars, weighing, with engine and tender, 3,428 tons, pulled over the New York Central, to test the power of a new type of locomotive, indicated that the resistance at 20 miles an hour was about four pounds per ton.

We have collected a great mass of information concerning the resistance of trains, and careful study of the facts convinces us that to show an approximation of the resistance of different kinds of trains, it is necessary to treat every one separately. The late A. M. Wellington, of the *Engineering News*, devoted a great deal of study to the subject of train resistances, and in his day

was probably the best living authority thereon. In 1892 Angus Sinclair took steam engine indicator diagrams from an engine pulling the Empire State Express, and in publishing them made some deductions about the resistance of the train. Mr. Wellington took the figures presented and compared them with records made by William Stroudley with express trains on the London, Brighton & South Coast Railway. From that and other data, he worked up a diagram of train resistances, particulars of which have been given on page 296.

While investigating the power of locomotives required to pull certain heavy fast express trains, Mr. S. A. Vauclain, of the Baldwin Locomotive Works, carried on a series of independent experiments, and he found the train resistances a little less than those formulated by Wellington; but he expressed the belief that Wellington's figures were near enough for all practical purposes.

From the facts which we have obtained from dynamometer car records and other sources, that may be relied on to be nearly correct, we have worked out the two lines added to the Wellington and Vauclain formalæ given in the subjoined table:

RESISTANCE PER TON OF 2,000 POUNDS.

Miles per hour,	10	20	30	40	50	60	70
Resistance in pounds per ton of heavy passenger train (Wellington).	4.5.	6	9.5	12	14	17	19
Vauclain	......	......	......	......	11	13	15
Loaded freight cars	4	5.8	9.2	11.3	12.5	......	......
Empty " "	6	7.5	11	14	17	.....	......

These figures apply to trains running on a straight, level track on a calm day. With a fresh side wind, a train of loaded cars of the same character as those which give a resistance of about 11 pounds per ton at 40 miles per hour, had the resistance increased to about 18 pounds per ton. The proportion of increase of resistance would be much greater with a train of empty cars.

RESISTANCE OF GRADES.

The factors of train resistance due to grades are exact. If the steepness of the grade in feet is multiplied by 0.38 the quotient will be the resistance in pounds per ton. Suppose the grade is one per cent. or 52.8 feet to the mile, we have the problem $52.8 \times 0.38 = 20$, the number of pounds per ton for that grade. If the train with engine and tender weighs 1,000 tons, 20,000 pounds of tractive power will be required to overcome the resistance due to gravity.

Curves increase the train resistance of trains to an extent that depends very much upon the physical condition of the curve and upon the length of train that is upon it in getting round it. The allowance generally made for the resistance of curves is $1\frac{1}{2}$ pounds per ton for each degree of curvature.

COMPUTING GRADES—THE DIFFERENT WAYS OF EXPRESSING.

Civil engineers, in computing grades, say, so much in 100, or, such a per cent. Thus, a grade of three inches in 100 feet would be stated as "$\frac{1}{4}$ in 100, or $\frac{1}{4}$ of one per cent." By the English method it would be called "one in four hundred." The American method always gives the grade per mile, which in this case would be "$13\frac{2}{10}$ ft. per mile."

Where the engineer said three per cent., or three in 100, the English would say, 1 in $33\frac{1}{3}$, which, by American practice, means $158\frac{4}{10}$ ft. per mile.

To reduce grades stated in per cents. or the rise in 100 ft., to feet of grade per mile, multiply by $52\frac{8}{10}$. Thus a three per cent. grade reduced to feet per mile is expressed $3 \times 52\frac{8}{10} = 158\frac{4}{10}$.

To reduce grades stated in the English method to feet per mile, divide 5,280, the feet in a mile, by the number stated; thus 1 in 25 would be expressed, $5{,}280 \div 25 = 211\frac{2}{10}$ ft. per mile.

LARGE CYLINDER CLEARANCE SPACES.

For the last few years our designers of locomotives have been imitating stationary-engine and marine-engine practice in the proportioning of steam ports and passages. Before cylinders came to be so large as they generally are in modern locomotives, there was a recognized rule among designers to make the steam ports 1 in. smaller than the diameter of the cylinder, and a fairly efficient and economical engine was produced under that practice. But with the latter-day idea of following the lead of our best automatic engine designers, the ports are made as long or longer than the diameter of the cylinder, with the result that the modern locomotive is far from being an economical steam engine.

It may be regarded as engineering heresy to say that the advance in forms and proportions that have admittedly improved stationary and marine engines to such an extent that it is by no means uncommon to obtain work at the rate of one horse power per hour for $1\frac{1}{2}$ lbs. of coal, is not the proper line of progress to pursue in locomotive engineering; but we venture to take that heretical position. Practice which is unquestionably good for stationary engines may be entirely wrong for locomotives because the conditions of operating are essentially different in many respects. Experience has demonstrated the truth of this at various times.

Builders of stationary engines design their steam ports and passages with the view of getting the steam into the cylinders as near to boiler pressure as possible; but they take good care to keep the piston clearances and spaces between the valve and piston as small as circumstances will admit of. With the short direct steam passages practicable in stationary and marine engines, the total clearance space between valve and piston can be made a very small percentage of the total piston displacement. In this respect builders of these engines have a great advantage over locomotive designers.

Those who do not make their clearance spaces very small for stationary engines have one important advantage which locomotive designers do not enjoy. The losses incident to large piston clearance can be to some extent regained by compressing the steam left in the cylinder, so that it shall reach initial steam pressure when the steam port begins to open for admission. According to Rankin, the whole of the losses due to piston clearance can be won back by compression, and his theory has done much to lead many engineers into the belief that large clearance was not a practice likely to cause waste of steam. While it is difficult to refute the theories of Rankin on this question, experience and experimental tests have not corroborated his teaching.

In stationary-engine operating, compression may be employed to the best advantage, because the exact degree of pressure may be regulated with considerable exactness since the size of outlet for the exhaust steam is always constant. This cannot be regulated closely with locomotives, because the size of the exhaust nozzle regulates, to a great extent, the amount of back pressure in the cylinders. If it were possible to keep the exhaust nozzle of uniform size, the variations in speed and work done would render it impracticable to regulate the back pressure so that there would be a constant volume of gas left in the cylinder when the valve closed for compression. But it is not possible to keep the exhaust nozzles of a locomotive of constant size.

Gumming of the inside surface is constantly varying the size of the nozzle, and bad coal often demands that smaller tips shall be employed. When these changes are made, the reduced opening increases the back cylinder pressure. Where attempts have been made to regulate compression in locomotives, so that it should rise to steam-chest pressure before port opening began, the causes referred to have forced the compression line so high that the valve got lifted off its seat, and the piston met with so much resistance before the stroke was completed that the engine worked against itself.

This experience has been gone through repeatedly and the practical effect of the lesson received is that designers keep the compression as low as possible consistent with the cranks passing the centers without pounding. This practice produces a smooth working engine, but with the large steam ports and passages in vogue the waste of steam must be very great.

SMALL STEAM PORTS GIVE BETTER RESULTS THAN LARGE ONES.

Experiments made by Mr. Robert Quayle, superintendent of motive power of the Chicago & Northwestern, on his experimental plant, and experience on the road, have demonstrated that engines with ports 16 ins. long did the work better than the same engines with the ports 20 ins. long. The ports were reduced only at the seat, leaving the piston clearance practically the same, so that it is reasonable to suppose that an engine having the clearance reduced in the same proportion as the port, would produce much better results in the way of steam economy.

The experiments were made with large eight-wheel passenger engines having steam ports 20 ins. long. They all have false seats, so there was no difficulty in substituting ports 16 ins. long, and valves to fit them. To the surprise of the investigators, it was found that the small valve gave a little better mean effective pressure than the large one, which would probably be due to the reduced spring of the valve gear. Several of the engines with the ports reduced to 16 ins. are now running the heavy express passenger trains between Chicago and Clinton, which frequently consist of twelve cars, and they are doing better work than they did when the ports were 20 ins. long.

This ought to be evidence sufficient to make the lovers of large steam ports pause and wait further developments. The probable saving in coal that would result ought to induce some enterprising railroad company to invest in a new pair of cylinders with reduced steam ports to run against an engine of the same class having long

ports. Expensive experiments have been made on investigations of much smaller importance.

The practice of making the steam ports very large is bowing the knee to theories which are all right when applied to certain engines, but probably all wrong for locomotives. This is not by any means the first time that locomotive designers have been allured into very expensive practices by adhering blindly to the gospel of the automatic engine designer.

It is a highly seasonable time at present to point out to locomotive designers the dangers besetting the road they are traveling, because at a Railway Master Mechanics' Convention a report was adopted which commits those following the recommendations of committees to an increase in the proportions of steam ports beyond anything yet known in locomotive practice. The report in question recommended that the ratio of steam-port length in inches to cylinder area in square inches, for passenger locomotives, should be preferably about 10 per cent. This would require the ports of the Chicago & Northwestern engines to be 28.3 ins. long, which is palpably absurd. The good sense of locomotive men prevents them from being carried away into excesses of this character, but they are liable to be influenced to some extent by the recommendations of men who have, presumably, given the subject careful consideration and exhaustive investigation. We have no doubt but the compilers of the report referred to were conscientious and painstaking in the work they did; but they worked on a false basis; they concluded that they must be safe in recommending for locomotives the proportions of ordinary steam engine practice.

There is another source of waste incident to the use of very large steam passages. Owing to the exposed position of the cylinders and steam passages of a locomotive, the engine necessarily suffers much from cylinder condensation. That is, the steam passes over cooling surfaces from the instant it emerges from the steam pipe and all those cool surfaces act as steam condensers. The huge passages in the saddle begin the condensing process and send damp steam to enter the cool cylinder. Only those who are familiar with Tyndall's experiments, showing the amazing heat devouring capacity of aqueous vapor, can realize the pernicious effect that results from condensing part of the steam before it reaches the cylinders.

That ordinary steam-engine practice was not always a safe guide for locomotive engineering has been demonstrated in regard to the throttling of steam. The theory has long been disseminated that steam should be passed from the boiler to the piston with the least possible restriction. This is undoubtedly a wise principle in the operating of ordinary engines, but its utility when applied to locomotives is very doubtful. With recent progress of steam engineering into railroad circles comes the demand that locomotives should be run at all times possible with the throttle wide open, the power to be regulated by the reverse lever. Intelligent engineers insisted that under certain circumstances the practice of running with the throttle wide open caused waste of steam, and made a hard-riding engine, but their views were treated as the expressions of prejudice and "keep the throttle wide open" became the watchword of progress. Motive power officers were rapidly making that a hard and fast rule when Chas. T. Porter, the celebrated mechanical engineer, read a paper before the American Society of Mechanical Engineers giving particulars of experiments which demonstrated that under certain circumstances throttling saved steam. Experiments made by Professor Goss on the locomotive Schenectady at Purdue University have sustained the position taken by Mr. Porter and the more intelligent locomotive engineers, and it now seems in order to modify the rules as to the use of wide open throttle.

When the theory that large ports and clearance spaces produce the best form of locomotive is reduced to the rigid test of accurate experiment, we are persuaded that our designers will learn that they have fallen into a fallacy which has been very costly to railroad companies.

THE DIFFERENCE BETWEEN COMPRESSION AND BACK PRESSURE.

It is perfectly plain from the arguments of a good many mechanical writers that compression and back pressure are too often confounded, and that compression is too often called back pressure.

Back pressure may be stated as pressure which opposes the movement of the piston by the live steam, therefore resulting in a loss of power that could, without this back pressure, be used in doing effective work.

Compression gives back to the piston as much power, on the return stroke, as was used in producing it. So long as the exhaust port is in communication with the cylinder in a working engine, there is back pressure on that side of the piston.

As soon as the port is closed, back pressure ceases and compression begins. Compression is simply the confinement of steam in the cylinder, and that steam compressed by the piston, driven by a greater steam pressure, on the other side, and by the momentum of the moving parts.

As all pressure on crank pins while piston is within tbout two inches of the end of the cylinder, only produces excessive friction and does no work, compression is used to help equalize this pressure in arresting the moving parts; it supplements the lead by filling the clearance with a pressure nearly as high as the steam chest pressure, and saves loss in cylinder condensation by keeping the walls of the cylinder heated.

As action and reaction are equal, the compressed steam will give out, in effective work, as much power as it took to produce it, less the friction, which is probably more than paid for by the saving in heat before mentioned.

Unless the compression causes a greater pressure than that in the chest, it is advantageous, and necessary, especially at high speeds. The great trouble, with those who have tried to improve the link motion for locomotive use, has been that they have confounded back pressure and compression, and have tried to produce a gear that would do away with both. The more back pressure is reduced, the better.

When compression is taken away (and you can get a card with a square heel on it) something must be introduced to do its work—in reducing the shock and friction at each end of the stroke—live steam will have to be used to reheat the walls of the cylinder, initial pressure will be reduced, larger water tanks be needed, and steam shovels on the tenders to do the firing.

INJECTORS.

HOW TO USE AN INJECTOR TO SAVE FUEL.

Owing to the simplicity of the modern injector it is possible for any one with ordinary common sense to prime it and to force water into a steam boiler, but to operate a locomotive injector according to the most approved methods for economy of fuel and efficient running of the engine requires a knowledge of underlying principles and judgment as to the operating conditions.

The importance of the judicious use of the injector is being realized strongly by railroad men. A report of the committee of the Traveling Engineers' Association states that "It would hardly cut any figure how careful an engineer might be in the handling of his train, with the skill he uses in regulating speed or in the adjustment of the throttle and the reverse lever, if the water was not put into the boiler at the right time and the right place. In our experience we have known almost remarkable results to be brought about in an engine's fuel performance by explaining this matter to engineers who perhaps had not given it the thought that the subject deserves." It was not possible for this committee to give detailed instructions, nor will this now be attempted, but it may be helpful to state the reasons why judgment is required and to outline some general suggestions.

When an injector is working the steam is taken directly from the boiler itself, causing a temporary fall of the steam gauge, which varies with the volume of the steam space in the boiler and other conditions. This is because each gallon of water fed takes out of the boiler about two cubic feet of steam, while, owing to condensation, only one-sixth of a cubic foot is returned. The heat of the steam is not lost; it is now stored in the feed water, but there has been taken away from it the power to exert pressure on the pistons for pulling the train. Therefore, in order to maintain the same quantity of steam in the boiler and at the same

pressure, it is necessary to strengthen the fire and burn enough coal to change sufficient water into steam to make about two cubic feet of steam for each gallon of water fed. This shows that to run the injector takes a large amount of available power away from the cylinders, and this loss is most severely felt when the boiler is pressed to its full capacity. A No. 9 injector delivers about 3,000 gallons per hour, and the steam required to run it may vary from 65 to 120 h.p., or from 8 to 15 per cent. of the power of the engine, depending upon the pattern of the injector in use; yet it must be clearly understood that although this steam goes back into the boiler as heat in the feed water, the effect produced is a temporary reduction of the pressure and of the pull on the draw bar, unless the cut off is lengthened; but this in turn takes more steam from the boiler and further lowers the gauge pressure. It therefore can be easily seen that when and how to use the injector has an important bearing upon both the fuel consumption and the time card.

As all the heat from the coal and stored in the steam is returned to the boiler, it becomes important to analyze the question a little further. The loss must be due to the varying demands for heat upon the fire; to the necessity for a heavy fire at one time, with the consequent heavy pall of smoke and the losses due to it, and the thin fire and light draft at other times. To save fuel the fire should be kept as even as possible and the drain upon the steam supply held as constant as changes of grade will allow, using the injector to check the tendency of the boiler at times to make steam too fast.

It is easy to keep the fire even when feeding with some styles of injectors, while others are noted for pulling down the pressure and making it hard for the fireman. If an injector has a wide range of capacities—that is, if the feed can be throttled very low without causing the jet to "fly off"—it can be used continuously, if the road is reasonably straight and level, with the feed regulated to suit the evaporation of the boiler. But when a hill is in sight shutting off the injector adds at least 10 per cent. to the power available for the pull up the grade. When the summit is reached starting the injector at full capacity prevents the pop valve rising on the down grade, because the boiler is filling with comparatively cold water, which temporarily checks the rapidity with which steam is made; the steam-making power of the boiler may then be used by the injector alone, and an opportunity is given to prepare for the next heavy pull without too strongly checking the fire. If a considerable amount of steam is still needed for the cylinders the injector may be used at half its capacity, when the temperature of the delivery will be nearer that of the steam and the steam-making power of the boiler will be less affected. At the minimum capacity the temperature of the feed should be anywhere from 250 to 280 degrees, filling the boiler with water much closer to the steam temperature, so that by careful handling at proper parts of the run and with judicious regulation of the amount of feed and the temperature of the delivery the injector can be utilized not only to keep the boiler full—which is the primary use of the injector—but to maintain the full gauge pressure and to keep the pop valve from blowing off, giving a constant temperature to the boiler sheets.

The old prejudice against feeding when the engine is not using steam is now almost entirely overcome, although still partially retained from the time when the cold delivery from the pumps was apt to chill the boiler, due to the water not circulating freely; with the hot feed from the injector there is no danger of this happening. When approaching a stop it is the practice of careful engineers to allow the water to run low, utilizing the heat stored in the water in the boiler to save fuel; when the station is reached both the water level and the fire will need replenishing, and the injector can be started either at full or half capacity, depending upon the length of time the train waits at the station. The train can then be drawn out of the station and full speed reached and the fire adjusted to the new conditions before water is needed, so that both steam and coal are saved.

The secret of economy in almost all operations consists in maintaining all conditions constant. With boiler firing it is the frequent change from light to heavy firing, caused by extreme variations in the amount of steam used, that is responsible for much of the fuel loss. To obtain the greatest economy and to give the least work to the fireman, keep the feed as cool and the fire as uniform as conditions will permit; when changes must be made make them as gradual as possible. Also, keep the steam pressure constant, as this reduces the wear and tear on the boiler and lessens the cost of repair.

The statement in a preceding paragraph that the loss of pressure due to working the injector is much more marked with some patterns than with others is corroborated by the experience of careful enginemen. The amount of steam that an injector requires depends not only upon its size and capacity, but also upon the proportion of its tubes. Just as a locomotive that is well designed is more economical than one whose valve ports and exhaust nozzles are not of proper size, so an injector whose tubes are carefully designed and manufactured will give the best results in service. The amount of steam that an injector uses depends upon the size of the steam nozzle. If this tube is larger than it should be both the efficiency of the injector as a machine and its range of capacities are reduced, and upon these two things depend, to a large extent, the opportunity for skill and economy in handling the boiler feed.

HOW AN INJECTOR WORKS.

"How can an injector lift and force large volumes of water into the boiler, against the same or even higher pressure than that of the steam?"

"An injector works because the steam imparts sufficient velocity to the water to overcome the pressure of the boiler."

This is a statement of fact; to explain the action, we will take up the important parts of the question separately.

Why should an injector work? Let us assume that the boiler pressure is 180 pounds—that is to say, every square inch of the sheets, top and bottom, receives an internal pressure of 180 pounds. If a thermometer is placed inside, it is found that both the water and the steam are at the same temperature, 379°. But the steam contains more heat than the water, because after water is heated, more coal must be burned to break up the drops of water to change them into steam; this heat is stored in the steam and represents work done by the burning of the coal. Steam not only exerts a pressure of 180 pounds per square inch, but also can expand eight to twenty-six times its original volume, depending upon whether it exhausts into the air or into a partial vacuum; water under the same pressure would be discharged in a solid jet and without expansion. Either steam or water can be used in the cylinder of an engine or to drive the vanes of a steam or water turbine, but one pound of steam is capable of much more work than one pound weight of water, on account of the heat which has been used to change it into steam. This is easily seen by comparing the velocities of discharge from a steam nozzle and a water nozzle under 180 pounds pressure; steam would expand while issuing, reaching at the end of the nozzle a velocity of about 3,600 feet per second, while the water, having no expansion, would have a velocity of only 164 feet per second, about $\frac{1}{22}$ of that of the steam. The same weight of steam discharging per second would therefore have vastly more power for doing work than the water jet.

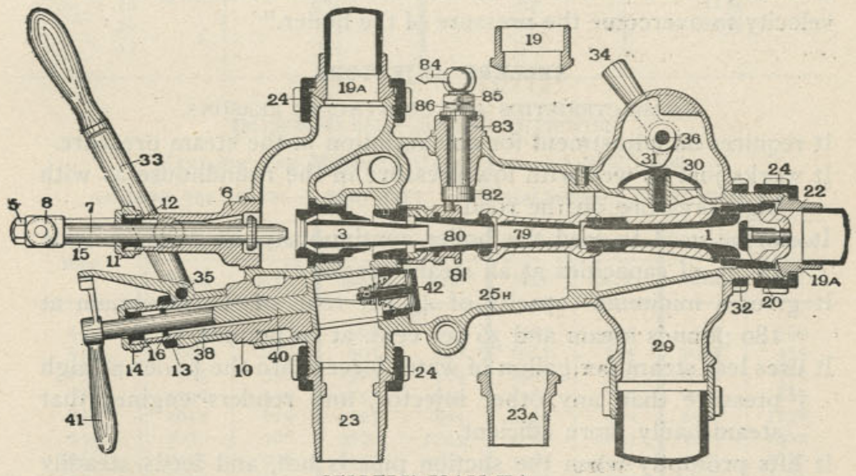
If a steam or water jet comes in contact with a body in front of it, the tendency is to drive the body forward. The force which tends to move the body is called "momentum," and is equal to the weight of water or steam discharged by the jet in one second, multiplied by its velocity per second. If one pound of both the water and the steam are discharged per second, the "momentum" of the steam jet is 3,600; because one multiplied by 3,600 = 3,600; the momentum of the water jet is 164. If the water jet discharged about twenty-two pounds per second, its momentum would be the same as that of the steam, because twenty-two multiplied by 164 is nearly 3,600. The two jets are discharged under the same pressure, but the steam has twenty-two times as much "momentum" or force as the water jet; it could, therefore, easily enter a boiler at 180 pounds pressure if we could reduce it to the size of the hole of the water nozzle.

How ought an injector to work? Here a practical difficulty is reached. A steam jet 6" from the nozzle is much larger than at the opening, and it would appear almost impossible to make it enter a smaller tube. Even at the narrowest part of the nozzle it is more than 16 times larger in diameter than a water jet discharging the same weight per second; therefore, if the steam is changed to water without reducing its velocity, it would pass through a hole $\frac{1}{16}$ the diameter of the "steam nozzle" at a velocity of 3,600 feet per second. The simplest and best way to reduce its size is to condense it, and to use water for this purpose, especially as water is needed in the boiler. To condense the steam and utilize its velocity, the water must be brought into close contact with it, without interfering with the direct line of discharge; a funnel or "combining tube" suitably placed will compel water to enter evenly all around the steam jet. The mouth of this funnel must not be too large, or too much water will enter and swamp the jet; if too small, insufficient water will enter to condense the steam. The effect of condensing the steam is to reduce the diameter of the jet; therefore the funnel or combining tube must be a smooth, converging taper, to lead the combined jet of water and condensed steam into the smaller hole of the delivery tube. The effect of the impact of the steam is to give to the water its momentum, so that a solid stream shall issue from the lower end of the tube. Each little drop of entering water is driven ahead faster and faster by the vast number of little atoms of steam moving hundreds

of times as rapidly, until the steam and water thoroughly combine into one swiftly moving jet of water and condensed steam, which contracts sufficiently in diameter to enter the smaller delivery tube.

Why does the jet enter the boiler? The combined jet now passes from the end of the combining tube into the delivery tube; why does it enter the boiler?

If a pipe shaped like a fire-hose nozzle or a "delivery tube" is connected to a tank or boiler carrying 180 pounds, the water will issue in a solid jet with a velocity of about 164 feet per second; or, if we could force water into the tube at a speed of 164 feet per second at the same part of the tube, this water would enter and fill up the boiler or tank against 180 pounds pressure. Therefore to enter the boiler the combined jet of water and steam



SELLERS' CLASS H.*

issuing from the combining tube must have a velocity of at least 164 feet per second.

Now what is the velocity of the combined jet at the lower end of the combining tube? If the steam nozzle discharges one pound per second at 3,600 feet velocity, the momentum of the steam is 1 multiplied by 3,600, or 3,600. If the vacuum caused by the condensation of the steam lifts and draws into the combining tube 10 pounds of water per second at a velocity of 40 feet, its momentum is 400; and that of the combined jet is 3,600 added to 400, or 4,000. The weight of the combined jet is 11 pounds, and at the time of entering the delivery tube its velocity ought to be

*This injector will operate with a feed-water temperature up to 154° Fahr.

equal to 4,000 divided by 11, or 366 feet per second; but as the water and the steam do not meet in precisely the line of discharge there is a loss of momentum, and the velocity in the delivery tube is only 198 feet per second. But the jet only needs a velocity of 164 feet to enter the boiler or tank carrying 180 pounds pressure, therefore the actual jet in the delivery tube is able to overcome a pressure of 206 pounds per square inch, or 26 pounds above that of the steam, because the velocity of a jet of water under a head or pressure of 206 pounds would be 198 feet per second. This excess is more than sufficient to overcome the friction of the delivery piping and the resistance of the main check valve. Therefore,

"The action of the injector is due to the high velocity with which a jet of steam strikes the water entering the combining tube, imparting to it its momentum and forming with it during condensation a continuous jet of smaller diameter, having sufficient velocity to overcome the pressure of the boiler."

SELLERS' INJECTORS.

CHARACTERISTICS AND CONVINCING REASONS.

It requires no adjustment for any variation in the steam pressure.

It works just as well with low pressure in the roundhouse as with high pressure on the road.

It can be used to feed the boiler continuously, as it has a wide range of capacities at all steam pressures.

It gives a minimum capacity of 43 per cent. of the maximum at 180 pounds steam and 36 per cent. at 60 pounds.

It uses less steam per gallon of water forced into the boiler at high pressure than any other injector, and renders engines that steam badly more efficient.

It lifts promptly when the suction pipe is hot, and feeds steadily with warm water in the tank.

It restarts instantly after a temporary interruption of the steam or water supply.

Its capacity increases with the steam pressure up to 225 pounds.

It is easy to take apart and economical to keep in repair.

It does not lime up quickly.

AND

It does not require careful adjustment to obtain the best results.

It does not waste water at the overflow in starting.

It does not put the feed water into the ash pan if the steam pressure falls.

It does not require any adjustment of the steam valve,

*SIZES OF INJECTORS FOR LOCOMOTIVES.

"In determining the size of injector required for locomotives, the size of the cylinder is usually taken as the standard, although the diameter of the boiler and the kind of service for which the locomotive is intended has a modifying influence."

TABLE.

Diam. of Cylinder Inches.	Size of Injector.	Diam. of Cylinder Inches.	Size of Injector.
9	$4\frac{3}{10}$	18	$8\frac{1}{2}$
10	$4\frac{3}{10}$	19	$8\frac{1}{2}$†
11	$5\frac{4}{10}$	20	$9\frac{1}{2}$
12	$5\frac{4}{10}$	21	$9\frac{1}{2}$†
13	$5\frac{4}{10}$	22	$10\frac{1}{2}$
14	$6\frac{1}{2}$	23	10
15	$6\frac{1}{2}$	24	$11\frac{1}{2}$
16	$7\frac{1}{2}$	26	$11\frac{1}{2}$
17	$7\frac{1}{2}$		

IMPROVED SELF-ACTING INJECTOR.

MAXIMUM AND MINIMUM CAPACITIES. ALL CLASSES.

GALLONS PER HOUR—5 FEET LIFT. ($7\frac{1}{2}$ GALLONS=1 CUBIC FOOT.)

Size.	60 Pounds Steam.		120 Pounds Steam.		180 Pounds Steam.		200 Pounds Steam.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
$4\frac{3}{10}$	427	158	562	208	517	345	500	350
$5\frac{4}{10}$	667	217	907	340	1027	395	1035	455
$6\frac{1}{2}$	967	358	1320	489	1492	568	1516	667
$7\frac{1}{2}$	1290	477	1755	650	1987	757	2010	885
$8\frac{1}{2}$	1657	613	2227	835	2550	970	2587	1138
$9\frac{1}{2}$	2070	766	2820	1044	3150	1197	3187	1402
$10\frac{1}{2}$	2535	938	3450	1280	3900	1482	3952	1740
$11\frac{1}{2}$	3037	1124	4132	1530	4672	1775	4725	2079

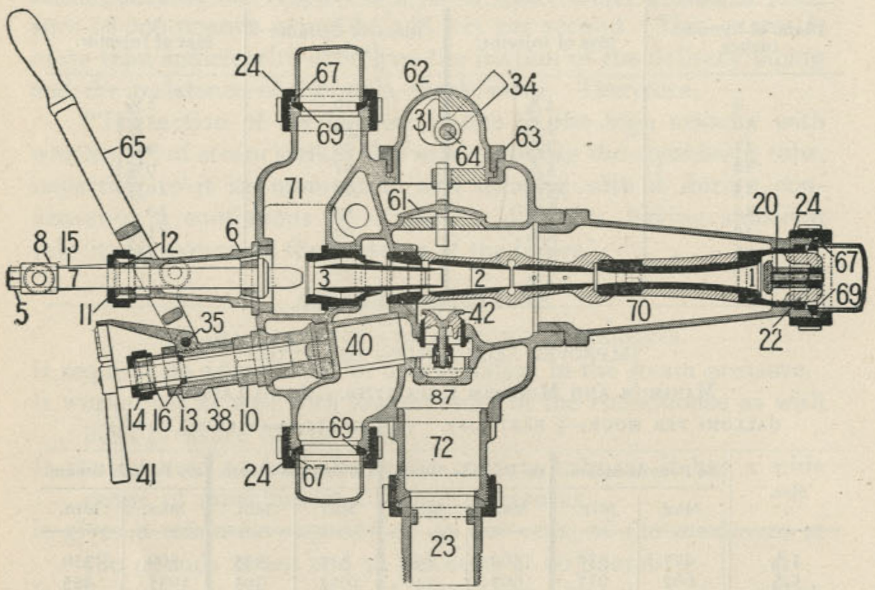
THE IMPROVED SELF-ACTING INJECTOR.

Description.—This injector is simply constructed and contains few operating parts. The lever is used for starting only, and the water valve for regulation of the delivery. It is self-adjusting, with fixed nozzle, and restarts automatically. All the valve seats that may need refacing can be removed, the body is not subject to wear and will last a lifetime.

The action is as follows: Steam from the boiler is admitted to the lifting nozzle by drawing the starting lever (33) about one

* From "Practice and Theory of the Injector," Wiley & Sons, New York.
† Use next size larger with specially large boiler.

inch, without withdrawing the plug on the end of the spindle (7) from the central part of the steam nozzle (3). Steam then passes through the small diagonal-drilled holes and discharges by the outside nozzle, through the upper part of the combining tube (2) and into the overflow chamber, lifts the overflow valve (30), and issues from the waste pipe (29). When water is lifted the start-



SELLERS' CLASS P.

ing lever (33) is drawn back, opening the forcing steam nozzle (3), and the full supply of steam discharges into the combining tube, forcing the water through the delivery tube into the boiler pipe.

At high steam pressure there is a tendency in all injectors having an overflow to produce a vacuum in the chamber (25). In the Improved Self-Acting Injector this is utilized to draw an additional supply of water into the combining tube by opening the inlet valve (42); the water is forced by the jet into the boiler, increasing the capacity about 20 per cent.

The water-regulating valve (40) is used only to adjust the capacity to suit the needs of the boiler. The range is unusually large.

The cam lever (34) is turned toward the steam pipe to prevent the opening of the overflow valve when it is desired to use the injector as a heater or to clean the strainer. The joint between the

body (25) and the waste pipe (29) is not subject to other pressure than that due to the discharging steam and water during starting; the metal faces should be kept clean and the retaining nut (32) screwed up tight.

To tighten up the gland of the steam spindle, push in the starting lever (33) to end of stroke, remove the little nut (5) and draw back the lever (33). This frees the cross head (8) and links (15), which can be swung out of the way, and the follower (12) tightened on the packing to make the gland steam tight.

The Improved Self-Acting Injector is specially adapted to railroad service, as its efficient, positive action and wide range of capacities at 200 pounds steam render its application to high-pressure locomotive boilers very advantageous. It will work from the highest steam pressures used on locomotives down to 35 pounds steam without adjustment and without wasting at the overflow, and by regulating the water supply valve on the injector it can be operated at 15 pounds As it restarts instantly under all conditions of service, it can always be depended upon to force all the water into the boiler, so that the engineer can give his whole attention to his other duties.

The injector is economical to repair. Comparative tests show the marked superiority of the improved form over all other styles of injectors, especially when the feed water is impregnated with lime. The tubes of all classes of the same size are interchangeable. All parts made to gauge and all openings of tubes guaranteed within $\frac{1}{10000}$ inch.

DIRECTIONS FOR OPERATING.

To Start.—Pull out the Lever.

To Stop.—Push in the Lever.

Regulate for quantity with the water-regulating valve.

HINTS TO BE READ BEFORE CONNECTING THE INJECTOR.

Blow out all pipes carefully with steam before attaching the injector, tapping the pipe with a hammer in order to loosen all the scale.

When drip pipe is attached close to overflow of injector, it must be same size or larger than feed-water pipe.

Always use a dry pipe attachment to insure perfectly dry steam.

The diameter of the strainer should be large enough to give an ample supply of water even when some of the holes are choked.

Keep all valves steam tight; all leaks tend to increase rapidity owing to the velocity with which steam passes through the smallest opening.

A leak at the overflow valve (30) diminishes the capacity of the injector and draws air into the boiler; this valve can be ground without removing the injector from the engine. In the case of the Class N types, unscrew the coupling nut (24) and the jam nut (32) at the delivery end; slide both parts over the boiler feed pipes and follow with the overflow sleeve (29); this uncovers the valve, which may then be ground to a bearing, using only fine sand or powdered quartz. In Class L and Class M this valve is even more accessible, and no special explanation is required.

EMERGENCY METHODS OF HANDLING THE IMPROVED SELF-ACTING INJECTOR.

The improved self-acting injector in good working order is the most satisfactory boiler feeder that can be used, and fully deserves the confidence placed in it by careful enginemen. But there are times when even the best injector refuses to work. It may not be the fault of the injector itself; in fact it seldom is to blame. Sometimes the trouble is due to careless handling, to the leaky condition of the steam valves, joints of the suction pipe and hose coupling; to cinders and dirt in the tank; and under such conditions many an injector is struggling, which not only reduce the efficiency and length of service, but finally prevent it from delivering water to the boiler.

It is, of course, difficult to do much in the way of repair to an injector when out on the road; even the pipe-coupling wrench is apt to be missing, and few tool boxes have wrenches for the removal of the tubes. A special feature of the self-acting injector is that the combining and delivery tubes can be removed with ordinary tools, but when it is necessary to take an injector apart the leakage from the steam and main check valves make the work very disagreeable; but when an injector does not work it is something more than aggravating, it is often serious, especially if the left-hand injector has not been used for some time and also refuses to start. Then is the time for quick thinking and quick acting.

Suppose That an Injector Suddenly Stops Working.—Probably the tubes, hose, suction pipe or strainer are stopped up. The last two can probably be cleared out by closing the cam over the overflow valve and drawing the starting lever quickly; if the hose lining has become loose it will let the steam flow back and close up again as soon as the injector is started, disabling this injector until a short nipple or coiled wire can be forced up the hose or a new hose obtained. If the next station cannot be reached before water is needed the left-hand injector must be made to work, unless the train is stopped and the injector and pipes thoroughly examined. Treat the left-hand injector exactly as the right. Open the tank valve and draw the injector starting lever; if the water is lifted, but will not enter the boiler, set the lazy cock at half capacity and tap the main check valve on cap with hammer to loosen it in its guide; at half capacity, because at that point the injector gives higher back pressure than with the lazy cock wide open. This will probably be effective.

To Remove Tubes.—The sectional views show very clearly how the tubes are held in the body. Uncouple the feed pipe from the injector and swing it out of the way; place a monkey wrench on the guide (22) for the lime check (20) and unscrew; in some of the older patterns of injector it may be necessary to insert an old file or flat piece of iron, or perhaps two pieces in opposite openings; at any rate, it can be removed quite easily unless the seats are heavily limed up. This draws out the combining (2) and delivery (3) tubes, which can be separated and carefully examined inside; here is where the trouble will usually be found, and the impediment must be taken out without bruising the surface or bending the tubes.

The cause of all this delay has been the absence of a strainer in the tank or suction pipe, or due to the fact that the holes in the straining plate are too large.

Suppose That Steam Nozzles (Pc. 3) Require Cleaning.—Stoppage of the lifting tube is usually gradual and is shown by a slow falling off in the working of the injector. These tubes are more difficult to remove unless a wrench to fit the hexagon is at hand. Sometimes a large iron chip or heavy piece of scale is carried into the nozzle (piece 3) by the steam, due to carelessness when cleaning the boiler, but this is of infrequent occurrence. If this happens it is better to make running repairs to the other injector and leave it for the men in special charge of injector repairs.

At times the main check valve does not seat and all efforts to close it prove unavailing; if the line check valve has been omitted during repair the water from the boiler rushes back into the injector. With injectors having no lazy cock, the only method of preventing the burning of the crown sheet is to draw the fires; but with the self-acting close the overflow valve by means of the cam, then quickly shut the lazy cock. The check pipe and injector body will then carry full boiler pressure until the roundhouse is reached, when the fire can be drawn and the pressure blown off.

Leakage of air into the suction pipe is usually the cause for unsatisfactory working of the injector. The Sellers' self-acting injector, on account of being restarting, will permit more air to enter than other patterns without causing the jet to break or "fly off," but yet it reduces the capacity and efficiency. Enginemen should be especially careful aabout this and always tighten the joints so that no air can enter; even a slight drip from any of the joints under the pressure of the water in the tank indicates a large enough opening to admit sufficient air to affect the working of the injector, especially when the water level in the tank is low. Another point is the tightness with which the cover of the manhole of the tank fits on its seat; if air does not enter freely upon the top of the water the capacity of the injector will be reduced, the effect being more marked at high steam pressures and long lift than under ordinary conditions.

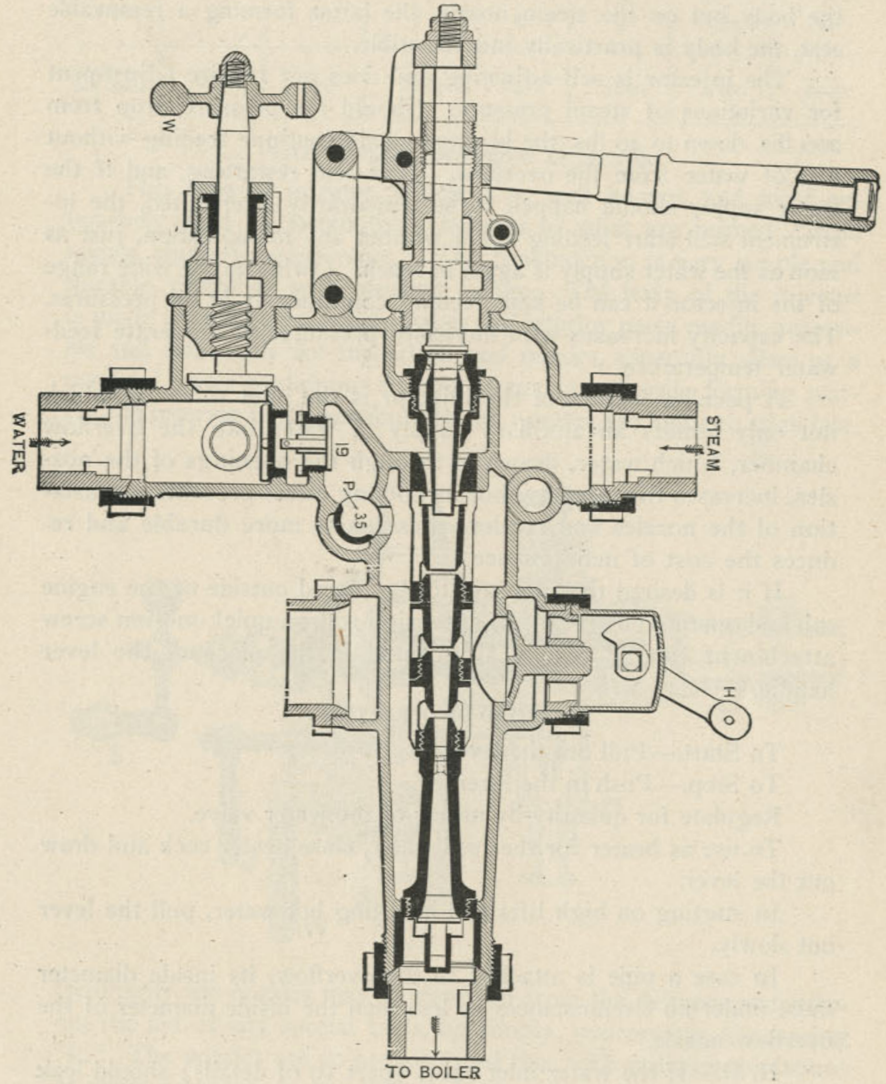
Lime and salts contained in the supply water coat the surfaces of the tubes; the accumulation occurs slowly, destroying the restarting feature, the promptness of lifting, and reduces the capacity; this should be at once reported to the proper authorities.

Inlet Valve (42).—When the improved injector is feeding the overflow chamber—the part of the body between the water branch and the waste pipe—is filled with cold water; if it does not feel cold to the hand the inlet valve (42) is not open and working properly. This method of surrounding the tubes with cold water tends to prevent the formation of scale, and this pattern of injector gives longer service in districts where the supply water contains lime than those that do not contain this feature. Crude oil introduced into the steam or water pipe softens the scale and is often helpful. Bosses on both the water and steam branches may be tapped for self-feeding oil cups, but all the joints should be tight.

Maintain the injector in good working order.

THE NATHAN SIMPLEX INJECTOR.

This injector is designed to meet the severest requirements of modern high-pressure locomotive service, especially where it is de-



SIMPLEX.

sired that the instrument be self-adjusting, and restarting. Its construction is such that the interior parts are readily accessible for inspection, repair and renewal, and as the steam valve does not seat on the body but on the steam nozzle, the latter forming a removable seat, the body is practically indestructible.

The injector is self-adjusting and does not require adjustment for variations of steam pressure. Should the pressure drop from 200 lbs. down to 40 lbs. the injector would continue feeding without loss of water from the overflow. It is also restarting, and if the water supply should happen to be temporarily interrupted, the instrument will start feeding again without any manipulation, just as soon as the water supply is again in reach. Owing to the wide range of the injector it can be kept feeding continuously at all pressures. The capacity increases with increased pressures at moderate feed-water temperature.

A peculiar feature of the injector is the inlet valve 19, which not only admits an auxiliary supply of water into the overflow chamber, which water, drawn in through the openings of the nozzles, increases the capacity, but its cooling effect prevents incrustation of the nozzles and renders these parts more durable and reduces the cost of maintenance.

If it is desired that the injector be placed outside of the engine cab and operated by means of extension rods, a quick-motion screw attachment can be readily substituted in the place of the lever handle.

METHOD OF OPERATION.

To Start.—Pull out the lever.

To Stop.—Push in the lever.

Regulate for quantity by means of the water valve.

To use as heater for the feed water, close heater cock and draw out the lever.

In starting on high lifts and in lifting hot water, pull the lever out slowly.

In case a pipe is attached to the overflow, its inside diameter must under no circumstances be less than the inside diameter of the overflow nozzle.

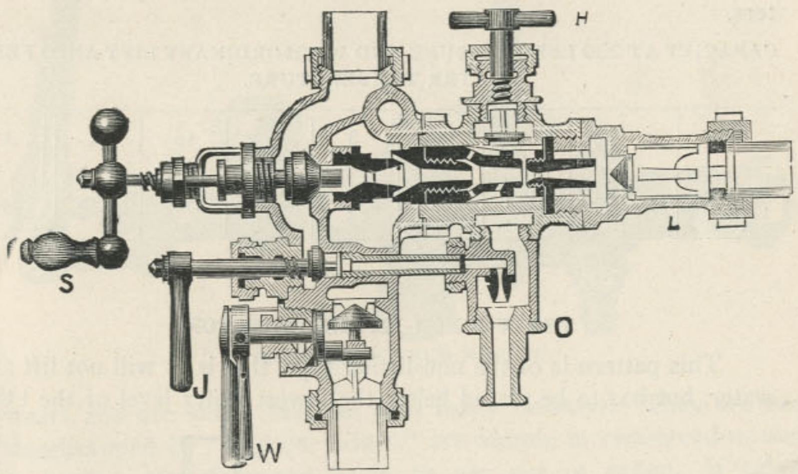
N. B.—If the water inlet valve (part 19 of details) should leak and prevent the prompt lifting of the feed water, it will only be necessary to turn around key 35, so that the letter "S" (not shown on cut) on the square spindle end will be "up." This will close passage "P," and permit the continued use of the instrument, until valve 19 can be repaired.

CAPACITY AT 200 LBS. PRESSURE AND WITH ORDINARY LIFT AND FEED-WATER TEMPERATURE.

Size.	5	6	7	8	9	10	11
Gallons per hour.	1140	1440	1950	2580	3240	3800	4560

THE NATHAN MONITOR INJECTOR.

This type of injector, which is so well known, and most extensively used on locomotives, belongs to what are termed "fixed nozzle, single-tube injectors." The construction is very simple and durable, combined with pleasing design. The body of the injector is made in two parts, which makes the interior parts readily accessible and removable for inspection and repairs, especially when as a result of water containing a large percentage of scale forming matter the interior parts, particularly the nozzles, are liable to stick fast.



Ordinarily the nozzles may be removed from the delivery end without the aid of any special tools, by simply unscrewing the casing "L." The nozzles are so proportioned that with ordinary variations of steam pressure, no regulation of either the steam or water supply is necessary. For varying requirements the water supply may be regulated by means of the water valve which also serves as a shut-off valve to prevent a back flow of the water into the tank in case the boiler check or line check valve should be out of order.

A peculiar feature of the Monitor injector is the independent lifting jet which enables the injector to start promptly at all times and under most adverse circumstances.

METHOD OF OPERATION.

To Start.—Open jet valve "J." This will lift the water. When the water appears at overflow, open valve "S," then close jet valve "J."

To Stop.—Close valve "S."

The steam valve need not be open more than necessary to stop the overflow.

To warm the water in the tank, close valve "H" and open valve "S" slightly; but valve "H" should never be closed except when the injector is to be used for warming the water.

Regulate for quantity of water needed by valve "W."

The letter "P" in the cut indicates a place for a small lubricator.

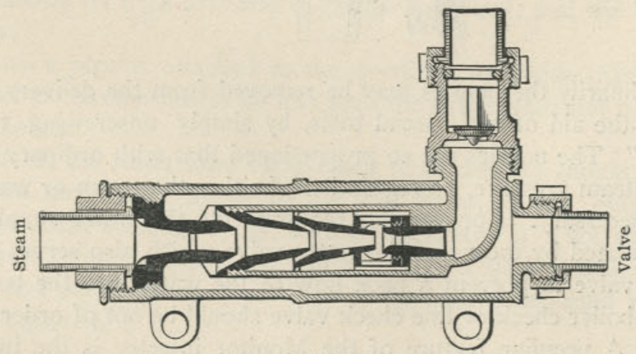
The occasional use of oil prevents, to a great extent, corrosion, particularly of the nozzles when water contains scale forming matters.

CAPACITY AT 200 LBS. PRESSURE AND WITH ORDINARY LIFT AND FEED-WATER TEMPERATURE.

Size.	4	5	6	7	8	9	10	11	12
Gallons per hour.	550	930	1230	1930	2340	2940	3750	4150	4450

THE W-F NON-LIFTING INJECTOR.

This pattern is of the non-lifting type, that is, it will not lift the water, but has to be placed below the lowest water level of the tank



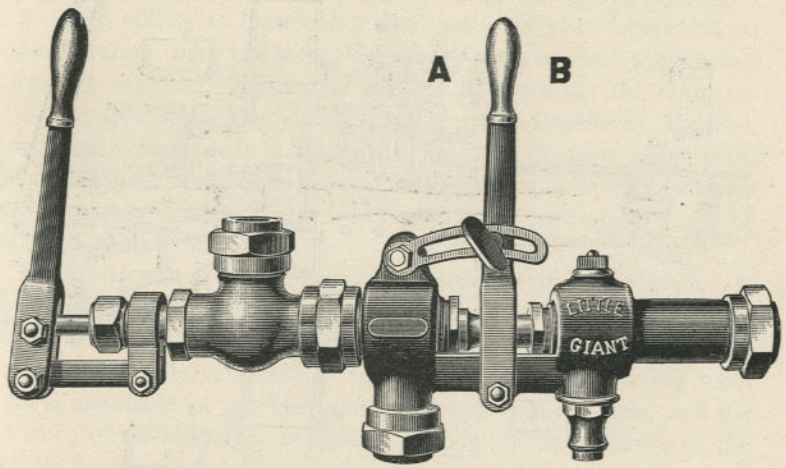
THE W-F NON-LIFTING INJECTOR.

so that the water will flow to it at all times by gravity. It does not contain any movable parts whatever, and has no water valve, but is supplied with water through a detached water valve or lazy cock placed in any convenient position in the water pipe. It is operated by simply opening or closing an ordinary globe steam valve in starting and stopping, and is virtually a one-motion injector of very effective kind. Usually a rod and handle extends from the overflow into the cab which is used only when the injector is required to do duty as a heater cock to warm the water in the tank. At all other times the overflow must be kept open.

Other characteristics of the injector, its capacities, range, etc., are the same as those of the Monitor injector.

LITTLE GIANT LOCOMOTIVE INJECTOR.

These injectors have been on the market for the past thirty



LITTLE GIANT, RUE MFG. CO.

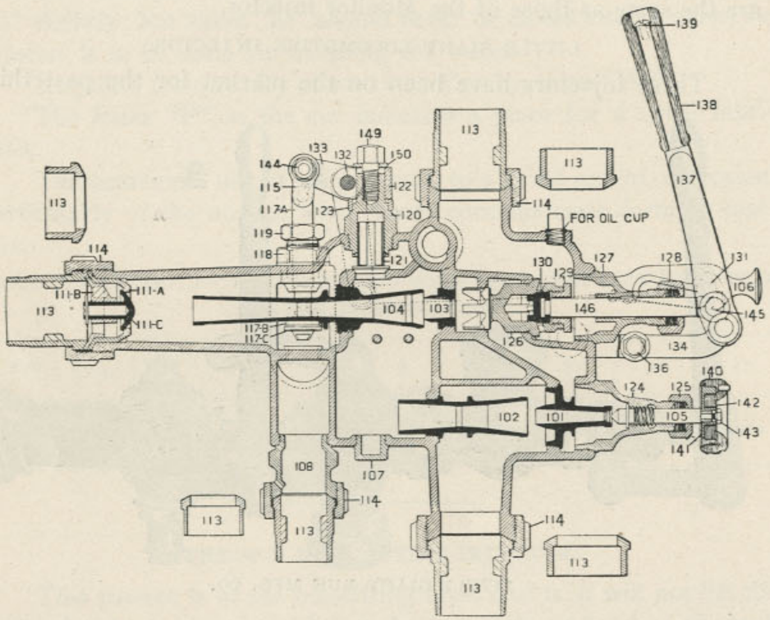
years and are still a favorite with many railways. They are not handicapped by "interior valves," are simple in construction and operation, therefore not liable to get out of order. If tubes corrode or wear from bad water they are easily replaced. They are fitted with a movable combining tube, operated by a lever which allows them to be adjusted to work correctly at different pressures of steam and conditions.

TO OPERATE.

Have the combining tube in position to allow sufficient quantity of water to condense the steam when the starting valve is full open, then open the starting valve slightly, when water shows at overflow, open full. Regulate the water by moving the combining tube. To use as a heater, close overflow by moving the combining tube up against the discharge, then open starting valve enough to admit the quantity of steam required.

THE HANCOCK INSPIRATOR.

The Hancock Locomotive Inspirator is composed of a lifting apparatus, which is the simplest form of ejector, and a forcing apparatus, which is the simplest form of injector, each being com-



ORDINARY HANCOCK INSPIRATOR—TYPES "A," "B" "D" AND COMPOSITE."

posed of a steam nozzle and a combining tube. The lifting apparatus acts as a governor, lifting and delivering to the forcing apparatus the proper amount of water for the varying steam pressures, thus enabling the instrument to work from 35 to 300 pounds steam pressure without any adjustment. Its operation under all conditions and with all steam pressures is the same, and it is impossible for the water to escape at the overflow when the inspirator is in operation, as the overflow valve is closed positively and is held to its seat by the pressure in the delivery chamber. That an in-

spirator or injector capable of filling the requirements of the modern locomotive should have this range of steam pressure is apparent.

1. The capacity should increase as the steam pressure increases up to the highest pressure carried, and to accomplish this the instrument must be capable of working at a steam pressure in excess of the maximum pressure carried. The capacity of the Hancock Inspirator increases constantly up to 230 pounds steam pressure.

2. The constant increase in capacity with increasing steam pressures, and the capability of working at steam pressures in excess of the maximum pressure carried, enables the supply of water to be easily regulated for light or heavy service. This regulation of capacity is not possible if the instrument is working at its limit. The minimum capacity of the Hancock Inspirator is less than 50 per cent. of the maximum at steam pressures from 100 to 230 pounds.

3. The ability to handle hot feed water is also dependent on the steam range. As the steam pressure increases and approaches the limit at which the injector is capable of working, the temperature of the feed water that can be used must be constantly lowered, and when the instrument is working at its limit, it must be supplied with cold feed water. The Hancock Inspirator will operate with feed water at a temperature of 125° Fahr., at steam pressures of from 60 to 230 pounds.

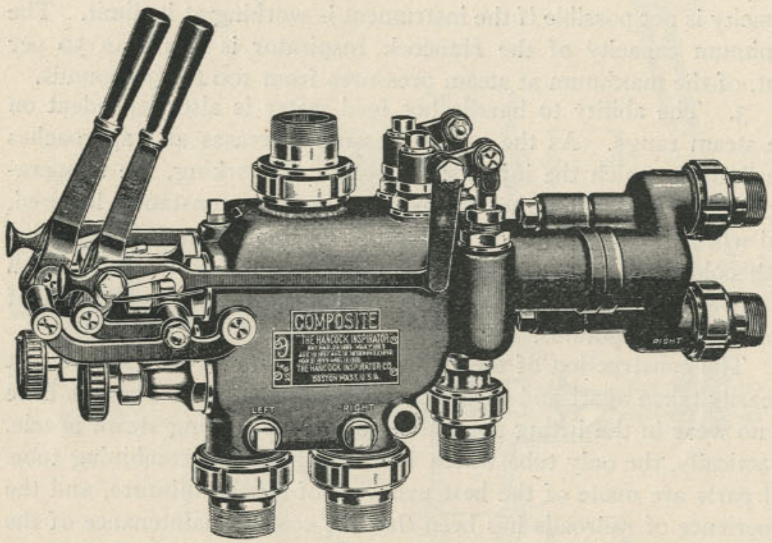
The construction of the Hancock Inspirator is very simple. It is easily taken apart and repaired at a small expense. There is little or no wear in the lifting apparatus and in the forcing steam nozzle. Practically, the only tube which wears is the forcer-combining tube. All parts are made of the best material, of special mixture, and the experience of railroads has been that the cost of maintenance of the Hancock Inspirator is less than that of any other instrument.

Types "A," "B" and "D" of the Hancock Inspirator differ only in size of connections, pitch of threads, location of holding bolt, and dimensions of body, to conform to the three recognized lifting injector connections known as the Monitor, Sellers and Mack. Each of these has been made to interchange with the others, and all the leading makes of locomotive injectors have been made to conform to the three above-named styles of connections, so there are at present but few lifting locomotive injectors in use that do not conform, in respect to connections, to those above enumerated.

"COMPOSITE."

The Hancock "Composite" Inspirator consists of two separate and individual inspirators within one body or casing, which can be operated separately or simultaneously, as desired.

Where it may be desired to locate both injectors on one side of the locomotive, convenient to either the engineer or fireman who has charge of pumping the engine, or on the boiler butt available to both, the advantages of the "Composite" are apparent. Owing to the limited room in the cab, it is generally difficult to locate both instruments so that they can both be operated by the engineer and be equally convenient. Appreciating these facts, the Hancock "Composite" Inspirator was designed to overcome these difficulties, and they have produced an instrument which has been recognized by prominent railroad men all over the country as a perfect boiler feeder.



COMPOSITE HANCOCK.

It occupies but little more space than a single inspirator or injector, and owing to its compactness it has been found that it can be located in positions where in the past it has not been possible to locate two separate instruments.

It places both instruments directly under control of the engineer, and both are equally convenient to operate, the result being that both instruments are operated and kept in good order.

Each instrument has an independent suction pipe, delivery pipe and line-check valve, thus enabling each to be operated independently of the other.

In attaching the "Composite" Inspirator (either to back head or side of boiler), one steam valve, one steam pipe, one overflow

pipe and one opening into the boiler are dispensed with, thus effecting a very considerable saving of material and labor which would be required with two separate instruments.

The operation of The Hancock "Composite" Inspirator is the same as The Hancock Inspirator, Types "A," "B" and "D." To operate either instrument, draw the lever back until the water is lifted, then draw it back as far as it will go. To put both instruments in operation, start one and then the other.

It is desirable to use a double-check valve in connection with the "Composite" Inspirator.

The following table gives the capacities of the various sizes of The Hancock Locomotive Inspirators, Types "A," B," "D" and "Composite," with various steam pressures:

Size	125 Pounds	140 Pounds	160 Pounds	180 Pounds	200 Pounds	210 Pounds
3	765 gals.	788 gals.	818 gals.	831 gals.	838 gals.	840 gals.
4	1012 "	1042 "	1082 "	1100 "	1109 "	1112 "
5	1102 "	1135 "	1180 "	1198 "	1208 "	1210 "
6	1500 "	1545 "	1605 "	1630 "	1643 "	1647 "
7	1958 "	2017 "	2095 "	2129 "	2146 "	2151 "
8	2479 "	2553 "	2651 "	2695 "	2716 "	2723 "
9	2762 "	2845 "	2954 "	3003 "	3027 "	3034 "
9½	3061 "	3153 "	3274 "	3327 "	3354 "	3362 "
10	3698 "	3814 "	3961 "	4026 "	4059 "	4068 "
11	4000 "	4100 "	4215 "	4345 "	4410 "	4450 "

These capacities are guaranteed as listed with feed water at 75° Fahr. on a 3-foot lift. As the lift is increased the capacity is decreased. The capacity is also decreased as the feed water is heated. With feed water at 80° Fahr. the capacities in the above table will be decreased about 3 per cent.; with feed water at 100° Fahr., about 10 per cent., and with feed water 125° Fahr., about 20 per cent. These facts should be considered when selecting the size of inspirator to be used.

DIRECTIONS FOR REPAIRING AND MAINTAINING THE TRAVEL OF VALVES.

Whenever it becomes necessary to reseat the forcer steam valve seat, the auxiliary valve seat, or the overflow valve seat before regrinding, proper tools should be used and care taken to remove as little metal as possible to secure a perfect seat.

In regard to the forcer steam valves, it will be apparent that the removal of any metal from their seats will allow the lever to go farther forward and the overflow valve will be raised higher above its seat, but, as the opening into which the piston of the forcer steam valve enters need not be disturbed, the proper relation between the opening of the piston and the closing of the overflow valve will be maintained as before, regardless of the increased movement of the lever forward. When, however, by reason of removing a considerable amount of metal from the forcer steam valve or its seat, the lever moves too far forward, a new valve should be substituted of increased thickness to bring the lever to its original position when the valve is closed. These valves are furnished with increased thickness for this purpose.

In regard to the auxiliary or lifting valves, it will be apparent that the removal of any metal from these or their seats will result in an increased movement of the valves, and to compensate for the metal removed, a washer can be placed on the stem between the valve and coupling nut, thus reducing the movement to the original amount, which should be $\frac{1}{16}$ of an inch. These washers are also furnished for repairs if required.

In the case of the overflow valves, when it becomes necessary to reseat them, an equal amount may be squared off from the adjusting ring, which is under the overflow crank holder, thus retaining the proper opening of the main steam valve.

DIRECTIONS FOR CONNECTING AND OPERATING—PIPE CONNECTIONS.

To obtain the best results, locate the inspirator with the "overflow nozzle" about four inches above the water in the tank.

Take the steam through a dry pipe from the dome.

All openings in the steam connections from the inspirator to the dome must not be smaller than the inside diameter of the size of copper pipe.

The openings in the suction or feed pipe connections from the inspirator to the tank must not be smaller than the inside diameter of the sizes of iron pipe.

OPERATION.

To start the inspirator, draw the lever (137) back to lift the water, then draw it back to the stop.

When the lever (137) is drawn back slightly, steam is admitted to the lifter steam valve (130) through the forcer steam valve (126) to the lifter steam nozzle (101). The flow of the steam into the lifter combining tube (102) creates a vacuum, and causes the water to flow through the lifter combining tube (102), condensing the steam, and out through the intermediate overflow valve (121) and through the final overflow valve (117) in the delivery chamber.

A further movement of the lever (137) opens the forcer steam valve (126), admitting steam to the forcer steam nozzle (103) and to the forcer combining tube (104), and creating a pressure in the delivery chamber sufficient to close the intermediate overflow valve (121) and open the intermediate or line check valve (111).

The final overflow valve (117) will be closed and the inspirator in full operation when the lever is drawn back to the stop.

When the pin in the wheel of the regulating valve is at the top, the inspirator will deliver its maximum quantity of water; to reduce the feed, turn the regulating wheel to the right.

To use the Patent Heater Attachment, lift the connecting rod until disengaged from the stud in the lever, then draw back the connecting rod to close the overflow valve. Regulate the quantity of steam by the lever without throttling the main steam valve on the boiler.

If the inspirator breaks or will not start promptly, see if there is a leak in the suction connections. If the openings into the tank are too small, or the hose strainer clogged, or the hose kinked or its lining collapsed, the inspirator will not get a sufficient supply of water.

If the inspirator will lift the water but will not deliver it into the boiler, see that the intermediate or line check valve and the main boiler check valve are in proper working order.

If the opening in the main steam valve or its connections is not of the required size, or if there is a leak in the dry pipe, the supply of steam will be insufficient.

If the overflow pipe is smaller than the overflow nozzle there will be back pressure, which will interfere with the starting of the inspirator. Overflow nozzle and overflow pipes should be kept free from lime or other incrustations; this is important.

WHY SOME INJECTORS OVERFLOW WHEN THE PRESSURE DROPS.

Because the tubes are designed for higher pressures, and too much water enters for the steam to force into the boiler.

WHY SOME INJECTORS DELIVER MORE WATER AT LOW STEAM PRESSURES.

The tubes are designed for the lower pressure and not enough water can enter the combining tube to condense the steam;

the vacuum inside this tube is less strong, and not as much water is lifted.

WHY SOME INJECTORS WILL NOT TAKE HOT WATER.

The opening of the combining tube is too small to permit sufficient water to enter to condense the steam.

WHY SOME INJECTORS BREAK IF THE VALVE IS THROTTLED.

The steam is not condensed and the overflow is too small to allow it to discharge freely, so that the steam is compelled to blow back into the suction pipe.

WHY SOME INJECTORS WORK BETTER IF THE STEAM VALVE IS THROTTLED.

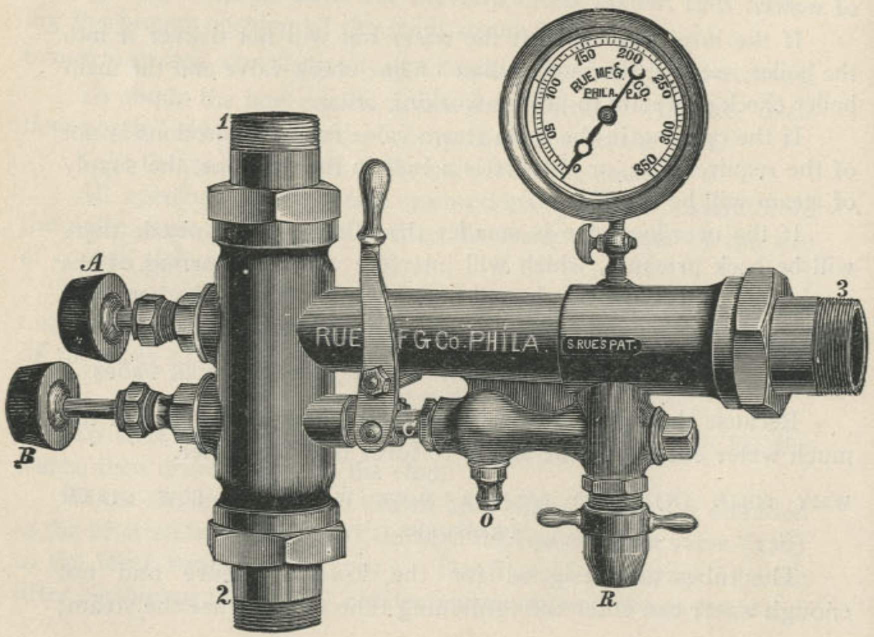
The steam nozzle is too large; throttling the steam reduces the amount to be condensed and strengthens the vacuum in the combining tube, increases the capacity and enables the engine to steam better.

WHY SOME INJECTORS GIVE A VERY HIGH BACK PRESSURE.

The steam nozzle is larger than necessary to do the work of forcing the water into the boiler, and live steam is taken away from the cylinder to heat the delivered water.

BOILER WASHING AND TESTING APPARATUS.

Your attention is called to the new Rue washing and testing



apparatus, which will wash out, fill, and apply pressure to a boiler, with hot water. It has a capacity of 5,000 gallons per hour.

When this apparatus is used, the boilers are washed much more effectually than can be done with cold water, and their temperature is not materially reduced.

It enables one to blow out, wash and fill with hot water and have engine ready for service within one hour, without injury to the boiler.

When applying pressure this apparatus will produce and maintain from three to five times the amount of steam pressure used in operating it.

DIRECTIONS FOR ATTACHING.

Connect steam pipe to swivel No. 1; water supply to No. 2; and discharge to No. 3.

TO WASH OUT BOILER.

Close overflow *O* by moving tube *C* over to the discharge. Open water supply, then steam valve *A*, until the required force is obtained.

TO APPLY PRESSURE.

When boiler is filled with hot water, the same as when washing, shut steam valve *A*; open overflow *O* by moving combining tube *C* to about midway of its travel; when water shows at overflow *O*, open steam valve *B* slowly until full open; then adjust combining tube so as to allow the least quantity of water possible to show at *O*. Relief valve *R* can be adjusted as desired.

(By keeping cock to the pressure gauge partly closed will prevent the hand from unduly vibrating.)

ONE OF THE MANY WAYS IT MAY BE LOCATED.

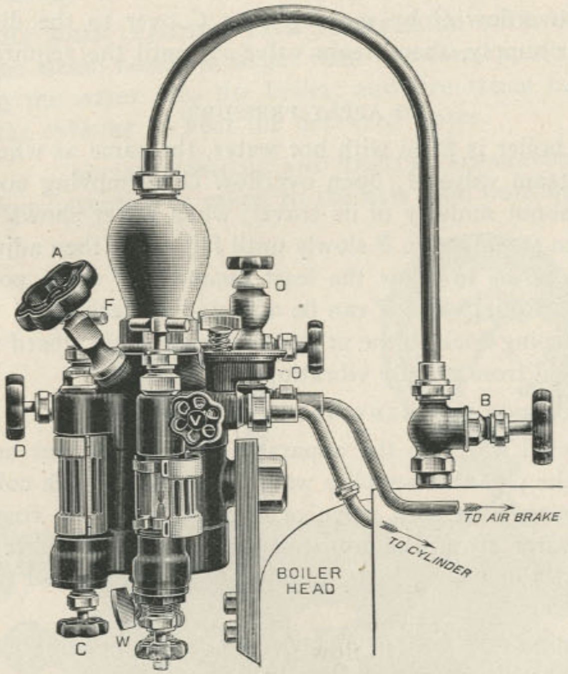
Take cold water to the apparatus out of, and put hot water back into, the pipe that supplies water for washing with cold water, always putting in a stop valve or cock between the connections. The hot water from the apparatus will pass with great force through the same pipe, hose, nozzles, etc., as are used with cold water.

This apparatus has connection for 2-in. pipes, and must be located where the water will flow to it.

SIGHT-FEED LUBRICATORS.

THE NATHAN SIGHT-FEED LUBRICATOR, CLASS 1899.

This lubricator is an improvement of the well-known Nathan lubricator, consisting largely in casting the glass holders, or brackets, in one with the body of the lubricator, thereby preventing



NATHAN, CLASS 1899.

the possibility of leaky brackets or of the brackets getting out of line, causing the glasses to break. The lubricator is of heavy pattern and of compact and pleasing appearance. It is provided with the usual steam admission, equalizing pipes, and choke plug, the relative

proportions of which are such that the lubricator will feed the oil into the steam chest regularly and continuously without any specific attachment either at the lubricator or at the steam chest. It is only necessary that the steam chest oil plug, which may be of any of the usual standards, be provided at the outlet end with a bore of not less than $\frac{3}{32}$ in. or more than $\frac{1}{8}$ in. The steam pipe of the lubricator must not have less than $\frac{3}{4}$ in. inside diameter when iron pipe is used or not less than $\frac{5}{8}$ in. inside diameter when copper pipe is used. Steam valves and their shanks must have openings fully in accordance with these dimensions. The oil pipes must have a continuous fall toward the steam chest and should have no "pockets" in them which are liable to retard the flow of oil.

The lubricator is provided with safety valves to shut off the steam from the glasses if the latter should break, and with hand oilers, by means of which the cylinders can be oiled on down grades, if, for some reason, the sight feeds become inoperative.

The lubricator is made in capacities of from one and a half pint to one-half gallon, and with two to four feeds.

METHOD OF OPERATION.

The lubricator is to be filled with clean, strained oil from filling plug "A," and immediately after filling, the water valve "D" is to be opened. After opening the steam valve "B" and after the sight-feed glasses have filled with water, the feed should be started and regulated by opening the regulating valves "C," more or less, according to the feed desired.

To Stop Either of the Feeds.—Close the respective regulating valve "C."

To Renew the Supply of Oil.—Close valves marked "C" and "D," draw off water at waste cock "W," then fill the cup as above and open water valve "D" immediately after filling, whether the feed is started again or not. A strict compliance with these directions will prevent the bulging of the cup by expansion when the oil becomes heated, before the lubricator is put into operation.

The outlet valves "V" must be kept open at all times, excepting when using the hand oiler.

To Oil By Hand.—Close the outlet valves. Fill the hand oilers with oil, open the hand-oiler valves, and when all the oil has entered the tallow pipe close the hand-oiler valve and open the outlet valve wide.

The safety valves "F" must be always kept open, excepting when one of the glasses breaks. In such case, valves "C" and "F" belonging to the broken class, should be closed and the hand oiler of the glass used on down grades in accordance with the above directions. The breaking of one glass does not interfere with the proper function of the others.

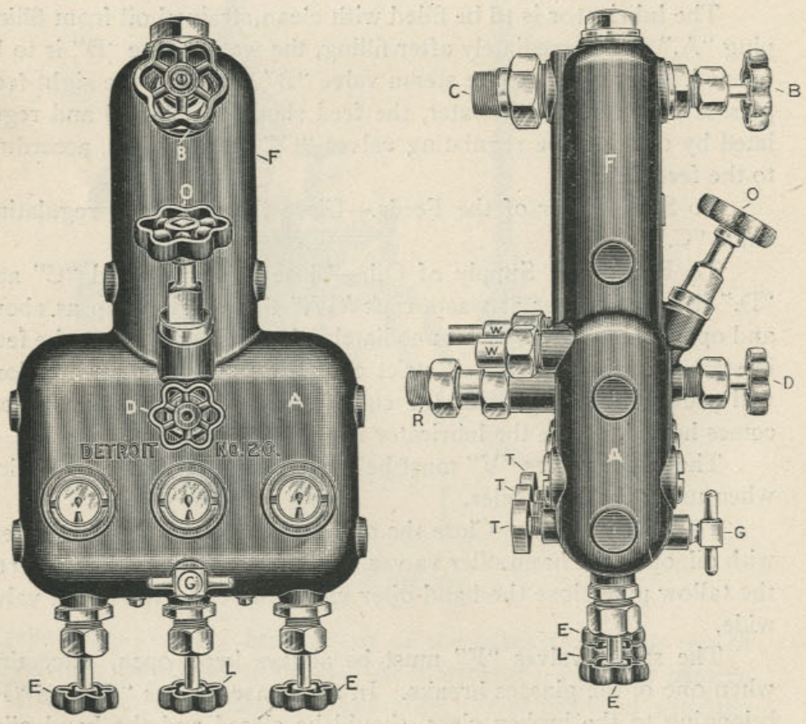
The steam valve of the lubricator should always be opened before the engine begins to do any work whatever, whether the feed is started right away or not, and should be kept open as long as the engine is doing service of any kind.

The water valve should always be kept open, except during the period of filling the cup as per directions.

Once in two weeks, at least, the lubricator should be blown out with steam with all valves wide open, with the exception of the filling plug, which should remain closed.

DETROIT No. 20 TRIPLE-FEED LOCOMOTIVE LUBRICATOR.

The illustrations accompanying this article give a good idea of the latest type of locomotive lubricator put into service by the Detroit



Front. DETROIT. Side.

Lubricator Company, and the points of superiority over the old style made by them.

The principal points of difference between it and the former type are:

It has forty per cent. less parts.

Thirty-five per cent. less variety of parts.

Eighty-five per cent. less metal joints.

No arms to shake loose, causing leakage.

No valves either inside or outside not necessary in a perfect lubricator.

No tubular glasses, but a glass which will not break under any conditions of service.

A glass and its packing so designed that the conditions are ideal and the greater the pressure, the tighter the joint.

A packing which will neither burn nor blow out.

The amount of metal formerly used in arms, hand oilers, by-pass valves, etc., is now in the metal line of the oil reservoir, giving additional strength and durability.

It will not chill.

The feed is absolutely regular.

Occupies 25 per cent. less space in cab.

Simple in construction and simple in operation.

The valve at top which controls the supply of steam from the boiler, thus brings all valves used in operating the lubricator within easy reach of the operator.

The cost of maintenance is practically eliminated.

All feeds are visible from two sides.

It saves oil.

F—Condenser. A—Oil reservoir. O—Filler plug. G—Drain valve. TTT—Sight-feed drain stems. D—Water-feed valve. B—Steam valve. EE—Feed regulating valves to right and left-hand cylinders. L—Feed regulating valve to air pump. WW—Coupling to right and left-hand cylinders. R—Coupling to air pump. M—Automatic steam chest plug.

DIRECTIONS FOR OPERATING.

When the lubricator is first applied, blow out thoroughly, then close all the valves.

To Fill.—Remove filler plug O and fill the reservoir with clean strained oil.

Note.—If there is not sufficient oil to do so, always use water to make up the required quantity. This will enable the feeds to start promptly.

Steam Valve.—The regular boiler valve should be left wide open, and the steam valve B at top of condenser should be opened and closed as occasion requires. This will be found a great convenience over old methods.

To Start Lubricator.—1st: Be sure that the regular boiler valve is wide open. Then open steam valve B at top of condenser gradually until wide open and keep wide open while lubricator is in operation. Allow sufficient time for condenser and sight-feed glasses to fill with water.

2d.—Open water valve D.

3d.—Regulate the flow of oil to right and left cylinders by valves EE, and to air pump by valve L.

To Refill.—Always close valves EE and L in advance of valve D. Open drain plug G, then filler plug O. Refill and proceed as before.

Blowing Out.—Blow out lubricator at least once a week.

In getting a new or rebuilt locomotive ready for service, disconnect oil pipes at steam chest, and blow out thoroughly both oil pipes and automatic steam-chest valves; also disconnect coupling to air pump and see that choke is free.

Note.—In shutting off the pressure to the lubricator to refill or for other reason, either at terminal point or while the engine is drifting or at rest, the water of condensation in the sight-feed glasses will sometimes disappear. In such cases the boiler pressure is suddenly removed from the water in the sight-feed glasses and a partial vacuum is created in the tallow pipes, causing the water in the sight-feed glasses to flash into steam.

How to Prevent.—Leave a slight steam pressure turned on the condenser. It will pass down into the tallow pipes and prevent the formation of a vacuum. It will also prevent too rapid contraction and expension of the lubricator.

Care of Lubricator.—With a high steam pressure there is a tendency even with good valve oil, to deposit a gummy substance resembling vaseline around the feed steams and cones. This substance can be removed and the glasses cleaned and filled by the following method: After the oil is all fed from the lubricator, leave the pressure turned on and close all feeds but one; open vent stem to this one which will allow the condensation to circulate and thoroughly cleanse the feed stem, cone and glass. Close vent stem. The glass immediately fills with condensation from lubricator. Close feed stem. Repeat same operation with other feeds. Close the water feed valve, blow out body and fill with oil in the usual manner.

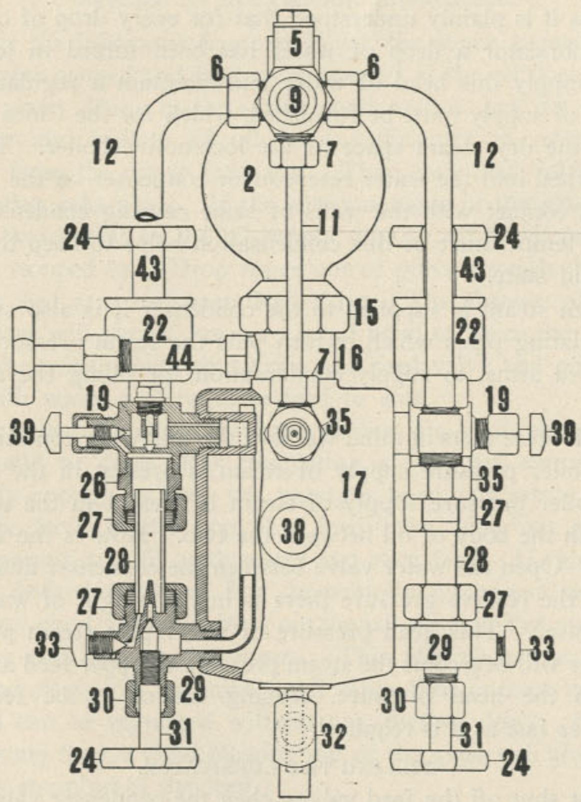
Never pound a lubricator. Such actions on the part of enginemen indicate unfamiliarity with the principles, construction and care of a lubricator.

If the rules require lubricator to be filled on completion of trip, don't fail to open both water feed valve and steam valve slightly in order to prevent any excessive pressure due to expansion.

Steam for lubricator should be taken from turret if large enough, or from dome through an independent dry pipe of one inch inside diameter.

THE CHICAGO LOCOMOTIVE LUBRICATOR.

The important features of this lubricator that commend it to railways is the regularity of feed under all conditions of service or steam pressures, with wide open throttle, and the positive delivery of oil to the steam chests and cylinders.



CHICAGO—FRONT.

It is simple in construction and operation, and the choke is transferred from the upper feed arm to the steam chest end of the tallow or oil delivery pipes.

The choke valve is made so that it adapts itself to the varied pressures in the steam chest, and is designed so that it makes a perfect balance on the lubricator.

The oil cannot be siphoned out of the condenser steam pipe connection (a very desirable feature).

The Chicago Lubricator is designed on the hydrostatic and displacement principle, and depends on a body of water elevated above the oil bowl which gives it head pressure to force a drop of water into the bottom of the oil bowl, and force a drop of oil out of the oil bowl into the sight feed glasses. When the drop of oil leaves the feed nipple this head pressure ceases, and the oil is carried to the upper feed arm through the water by the difference between the specific gravity of the oil and water.

Thus it is plainly understood that for every drop of oil fed out of the lubricator a drop of water has been forced in to displace it. To supply this head of water and maintain a regular pressure a source of supply must be furnished, which for the Chicago Lubricator is the dry steam space of the locomotive boiler. The steam being turned into the water reservoir or condenser on the lubricator comes in contact with the walls of same causing condensation and the high temperature of this condensation helps to keep the oil in a free liquid state.

When steam is supplied to the condenser it is also supplied to the circulating pipes which in turn puts the steam pressure into the upper feed arms, to supply condensation for filling the sight feed glasses.

With these facts in mind we have the following conditions:

A boiler pressure supply of steam is present in the condenser and a boiler pressure supply of steam is present in the upper feed arms with the body of oil between the two. How is the feed of oil started? Open the water valve between the condenser and oil bowl, utilizing the reserve pressure there is in the weight of water stored in condenser. This head pressure of water plus steam pressure in condenser will overcome the steam pressure in upper feed arm, which is minus the head pressure, causing the oil to be fed out of oil bowl as fast as it is required.

FILLING THE LUBRICATOR.

First shut off the feed valves, then the condenser valve and the boiler steam supply valve last. Great care should be exercised when

filling the lubricator to see that no foreign substance is allowed to enter into it. This is important, as any dirt or foreign substance is liable to so clog the openings that serious results would follow.

After the lubricator is filled if the engine is going into the house do not open the water valve, and see that all other valves are closed. If, however, the engine is on or going on to the road, first open the steam-supply valve at boiler, then the condenser valve, and regulate the feed valves for the amount of oil required. In no case should the lubricator be filled with cold oil.

The Chicago Lubricator has a perfect feed free from variations. If the requirement is known it can be set for same when engine is standing or ready to start, and it will supply that feed regardless of pressure, speed or train.

LUBRICATOR AILMENTS AND REMEDIES FOR SAME, THAT CAN BE APPLIED TO THE CHICAGO LUBRICATOR.

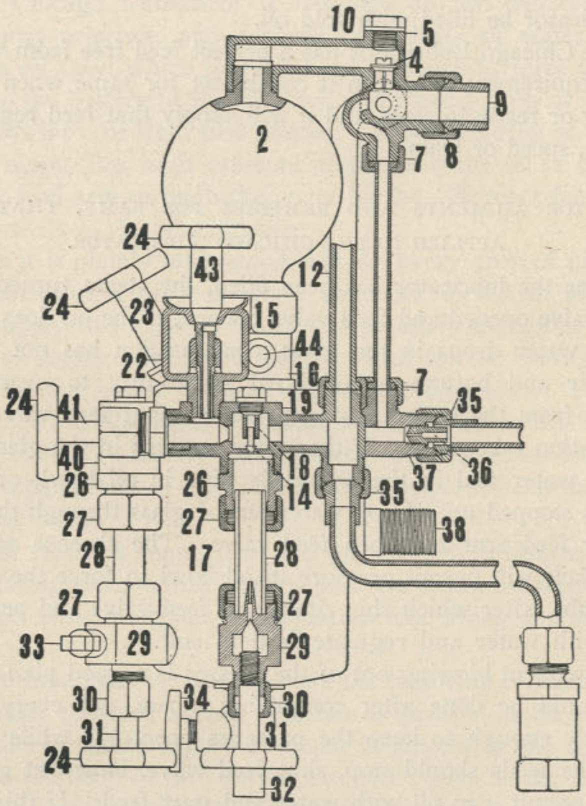
After the lubricator has been filled, the steam turned on, condenser valve opened and feed valve opened, if the oil does not start, and the water drops in the glass, condensation has not filled into condenser and bottom of oil bowl sufficiently to overcome the pressure from the upper feed arm. Then shut feed valves and let condensation take place. If the water remains in the glass there is either a water seal in the oil-supply pipe in oil bowl, or the feed nipple is stopped up. Drop water out of glass through drain valve in lower feed arm and open feed valve. The absence of pressure in the glass will permit pressure in oil bowl to force the water out of the tube, after which shut drain and feed valve and permit glass to fill with water and regulate feed to suit.

A frequent blowing out of the glasses is a good plan to follow. This should be done after completing a run, not every run, but frequently enough to keep the passages open. If while on a run one of the feeds should stop, shut feed valve, blow out glass thoroughly, permit it to fill with water and start feed. If this does not give the desired result, at first opportunity disconnect tallow pipe from steam-chest valve and blow out the tallow pipe. Put reverse lever on center and give engine steam. This will clean out the chest valves and oil plug. Examine small valve, then connect up oil pipe, and feed can be regulated without any further delay. In case of the air-pump feed, a good blowing out of the glass will always overcome any stopping of the feed.

Should there be any unusual variation in the level of the oil and water in index glass it indicates that there is dirt in the guide-ways of the automatic valves. To overcome this the oil bowl should be blown out when empty.

HOW TO OPERATE THE CHICAGO LUBRICATOR.

1. To start the lubricator to feed first open steam-supply valve at boiler; this admits steam into the connection at No. 9; next open pressure valve 39, one-eighth turn on all upper feed arms. Note



CHICAGO—SIDE.

glasses 28 to see if they are filled with water; if glasses 28 are filled open water valve 44, and regulate feed with valve 31.

2. Valve 41 and plug 43 of auxiliary oil cup must be kept closed when engine is supplied through feed glasses 28.

3. To use auxiliary cup 22, close valve 41, open plug 43, fill cup, close 43, and open 41, one turn to allow oil to feed out.

4. To drain glasses 28 close valve 39, and open 33.

5. To blow glasses 28 out with steam after it had been drained break joint on 39 and open 33.

6. To put condensed steam into glasses 28 after they are drained, close 33 and open 39.

7. If lubricator should stop or feed irregularly, open 39 wide to permit feed to regain its regularity, then set to one-eighth turn.

8. If glasses 28 should fill with oil when engine is running, reduce feed with 31 and open 39 wide. After glass is clear, reduce 39 and regulate feed with 31.

9. To renew glasses loosen packing nuts 27, then detach glass sleeve 26, after which place new gaskets in the packing nuts. Put them on the glass with sleeve 26 on top. Put these in place and screw down bottom nut first to hold glass in position. Then screw sleeve 26 up tight, and set packing nuts to hold the pressure.

BROWNING GUN BARRELS.

Mix 16 parts sweet spirits niter, 12 parts saturated solution of sulphate of iron, 12 parts chloride of antimony. Bottle and cork the mixture for a day, then add 500 parts of water and thoroughly mix. Clean the barrel to a uniform grain free from grease and finger stains. Wipe with a staining mixture on a wad of cotton. Let it stand for twenty-four hours, scratch brush the surface and repeat twice. Rub off the last time with leather moistened with olive oil. Let dry a day, and rub down with a cloth moistened with oil to polish.

Turpentine and black varnish, put with any good stove polish, is the blackening used by hardware dealers for polishing heating stoves. If properly put on, it will last throughout the season. It makes a good polish for boiler head and smoke box.

An "inch of rain" means a gallon of water spread over a surface of nearly two square feet, or a fall of about 100 tons on an acre of ground.

THE ELECTRIC HEADLIGHT.

EDWARDS ELECTRIC HEADLIGHT.

Among the new devices for safety and convenience with which a locomotive is equipped nowadays, one of the newest and one which is steadily and, it seems, deservedly growing in favor is the electric headlight. Indeed, its claim to rank next in importance among these devices to the air brake itself appears to be well grounded. Of course the air brake comes first, from the standpoint of both safety and convenience, for the reason, if none other, that it is serviceable at all times, while the electric headlight comes into play only during the hours of darkness. But one of the most convincing and no doubt one of the soundest ways of presenting the merits of the electric headlight is by calling attention to the fact that it is the only thing which renders available during half, on an average, of every 24 hours the safety element of the air brake. To the man at the throttle a good electric headlight makes visible practically as great a stretch of his track as daylight does, and this is of course the one necessary condition of his being able to apply his "air" in time to avoid an impending disaster.

Following is a brief description, with some illustrations, of the Edwards Railroad Electric Light Company, of Cincinnati.

The apparatus is complete in itself, comprising the generating part, the focusing arc lamp, and the specially designed headlight case and reflector.

The generating set consists of a small dynamo, about one kilowatt capacity, driven by a direct connected steam turbine.

THE STEAM TURBINE.

The motive power for the Edwards electric headlight equipment is produced by a steam turbine. The steam passes through the governor balanced piston valve; after passing through this valve the steam enters the nozzle; passing through the nozzle it enters the wheel buckets, and is discharged on the opposite side of

the wheel, passing through the exhaust port, then through the balancing ports to the exhaust opening, and from there discharging into the smoke arch. For boiler pressures varying from 150 pounds to 200 pounds use No. 1 nozzle. For boiler pressures varying from 100 pounds to 150 pounds use No. 2 nozzle. The turbine wheel is keyed to its shaft and locked thereon by a left-hand nut, the shaft operating in hardened steel ball bearings. These bearings are adjustable for wear, and it is very important that these adjustments be kept up. When a slight looseness is shown by undue vibration at once set up the adjusting nuts, but not so closely as to bind; simply take up the lost motion. The cones of these bearings are keyed to the shaft. The cups are threaded against shoulders in the engine housings, the one on the governor end having a right-hand thread, and the one on the dynamo end having a left-hand thread.

Two stuffing boxes are provided for the engine shaft; the one on the governor end having a left-hand thread, and the one on the dynamo end having a right-hand thread. Quarter-inch square steam packing should be used and the glands adjusted only tight enough to prevent leakage. The exhaust steam pressure in this chamber is very low, being only two or three pounds, so that it is not necessary, nor advisable, to adjust these glands very tight. A special spanner wrench is furnished, fitting both the ball-bearing cups and the stuffing-box caps.

The bearings are oiled by means of rings and suspended from grooves and in the ball-bearing cones, the bottom of the rings dipping into oil in the reservoirs; these rings must always hang in the grooves. If they become displaced and hang on the shaft the bearings will not receive any oil. The oil wells should occasionally be cleaned of sediment by removing plugs and washing out with kerosene. The turbine shaft should have not less than $\frac{1}{64}$ of an inch lateral motion, and it should not exceed $\frac{1}{32}$ of an inch when the turbine is cold. This is to prevent binding by expansion, when the turbine is in operation.

The speed of the turbine and dynamo is kept constant by a special governing device which automatically regulates the flow of steam. Lubrication is effected by loose rings hanging from, and revolving with, the shaft, which dip into oil wells cored in the housing.

THE DYNAMO.

The dynamo is of the multipolar type, the armature being chordal wound. The field and armature connections may be traced from the diagram furnished by makers, the direction of the flow of the current in the several circuits being indicated by arrows, the heavy wire coils in the main or working circuit being the differential, and the finer coils of wire being the shunt. It will be noticed that around any one field core the current in these two circuits circulates in opposite directions. The purpose of this combination of circuits is to provide automatic regulation, maintaining the amperage and voltage practically constant, which it will always do providing the lamp adjustments are right. This winding also has the great advantage of neutralizing all current should a short circuit occur anywhere in the working circuit, thus preventing the machine from being burned out. Should a short circuit occur the machine will operate properly as soon as it is removed. Should these several field coil connections be opened, great care must be exercised to restore them precisely as per diagram. A very good plan to follow when opening these connections is to attach tags to the ends of the wires, marking them "1" "1," "2" "2," etc. After connecting carefully bind tape around the joints.

TO REMOVE THE ARMATURE.

To remove the armature, first take out the brushes from their holders, back of the set screw on the brush holder yoke; then remove the four nuts and two cap screws. The end plate may then be taken off, after which the armature may be withdrawn. The field coils are held in place by ¼-inch square keys. The coils may be removed by driving out the keys and removing the pole pieces. In reassembling the dynamo, be sure the oil rings are raised to permit the shaft to pass through the bearings; then replace the end plate. The field coils and armature are protected by a circular sheet steel casing fitting into grooves in the end plates. The armature is mounted in self-adjusting bronze bearings. These bearings are lubricated by means of rings, the shaft having spiral grooves to carry the oil throughout the bearings. Overflow oil holes are drilled in both oil wells to prevent too much oil being placed in the bearings. These overflow holes must be kept open, and the oil wells occasionally cleaned of sediment by removing the plugs, and cleaning the reservoirs with kerosene. Care must be taken to have the oil rings in the slots in the bronze bearings.

THE COMMUTATOR.

The copper bars of the commutator are separated by mica insulation.

The copper will wear more than the mica, and if the mica is allowed to project above the surface of the copper, even slightly, it will prevent perfect contact between the copper bars and brushes, which must, at all times, be maintained. To prevent the mica from thus interfering with perfect contact between the brushes and the copper bars, the mica should always be a little below the surface of the copper bars. This is accomplished by filing out the mica to a depth of about $\frac{1}{64}$ of an inch by the use of a small file. This process will raise a slight burr on the edges of the copper bars which must be removed by using a strip of No. 0 sandpaper (never use emery), as shown by accompanying illustration. In this operation run the machine slowly, meantime working the sandpaper back and forth lengthwise of the communtator so as to cover the whole surface, until it is perfectly smooth, then wipe the commutator clean, working a clean cloth, or waste lengthwise to clean out the shallow grooves between the copper bars.

Use sandpaper as above described whenever the commutator becomes slightly rough. Should the commutator become too rough, or out of round, the armature should be removed, and the commutator dressed off in a lathe, using a diamond-point tool, and removing only enough metal to make a perfectly true and clean surface. After turning, polish with sandpaper (never use emery), then file out the mica as above directed.

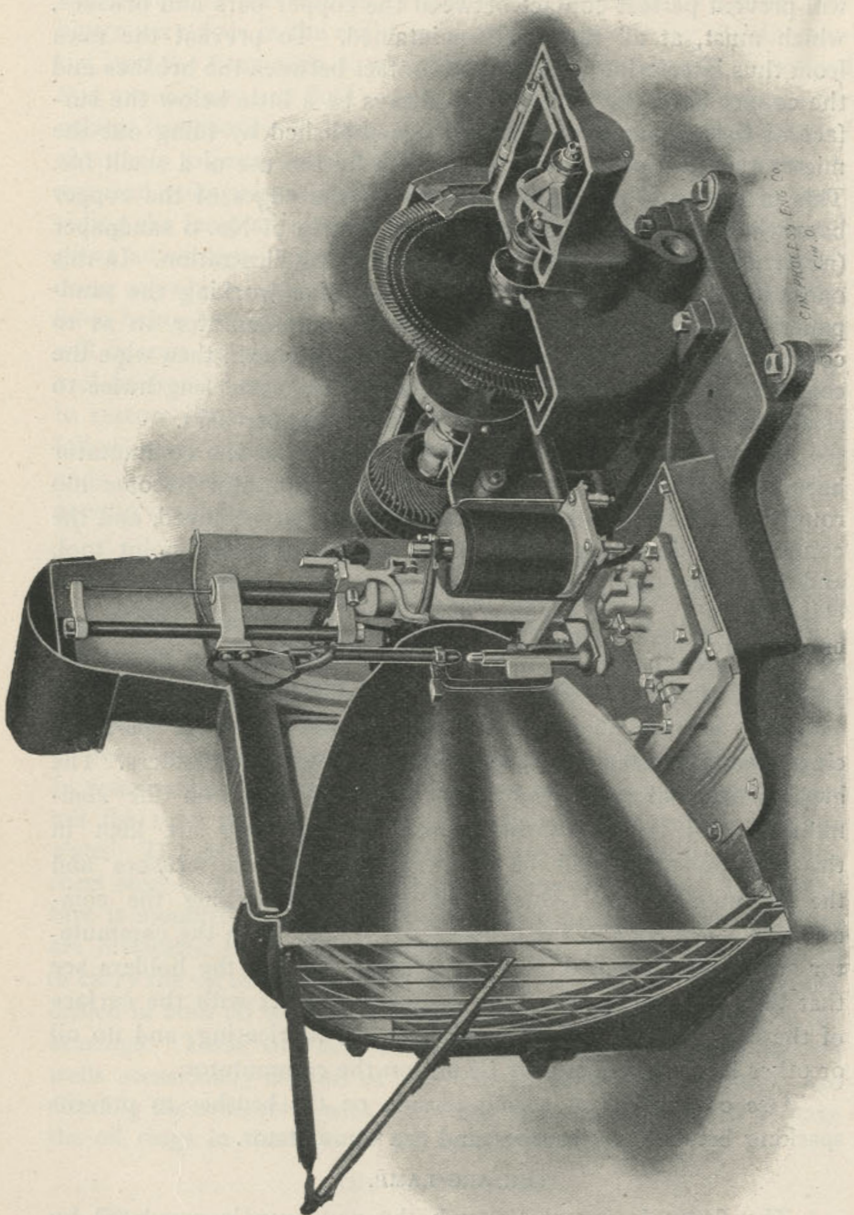
THE BRUSHES AND BRUSH HOLDERS.

The brushes and brush holders must be kept perfectly clean, and the brushes must always slide freely in the holders. The brushes must always occupy the proper position on the commutator, and the screw firmly set. Unless they are kept in this position there will be sparking between the brushes and the commutator, thus reducing the light and burning the commutator. The ends of the brushes which bear upon the commutator are slightly beveled, and in replacing them in the holders see that their full end surface have complete contact with the surface of the commutator. The brushes are self-lubricating, and no oil or other lubricant must ever be put on the commutator.

Use only sufficient spring tension on the brushes to prevent sparking between the brushes and the commutator.

THE ARC LAMP.

The flow of current through the arc lamp is regulated by shunt coil and series coil, as can be seen from the diagram supplied by makers. The shunt coil is always in circuit with the



SECTIONAL VIEW OF EDWARDS HEADLIGHT.

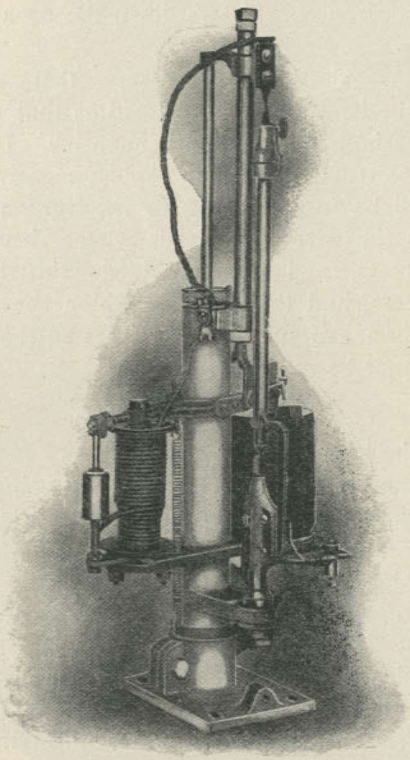
armature and field shunt of the dynamo. The circuit through the lamp series coil, and field differential coils, is held open at the carbon point by spring, when the dynamo is not in operation. When the dynamo is started, the current flows through the shunt coil, and draws down the soft iron core suspended on the equalizer; this releases and breaks the engagement between the pawl and escapement wheel, thus permitting the brass column, or oil cylinder, to fall until the carbon point comes into contact with the copper negative. The instant this occurs a circuit is established through the series coil, and its iron core draws down the equalizer, thus establishing the arc.

It is always absolutely necessary that the leads from the dynamo to the lamp be so connected as that the current shall flow from the carbon to the copper negative. If the current be reversed, or so as to flow from the copper negative to the carbon, the negative will be fused, giving to the light a greenish color. To prevent this the wire cable leads where they connect to the lamp binding posts, and are provided with brass plugs of different diameters, and the holes in which they are inserted in the binding posts are of suitable diameters so that the connection at this point cannot be reversed.

TO ADJUST THE LAMP.

To adjust the lamp, first have the correct speed on the dynamo, and the commutator and brushes working properly, then set the adjusting screw on the shunt side of the lamp, so that the pawl will clear the escapement wheel about $\frac{1}{100}$ of an inch; then raise the brass tube, or oil cylinder, which carries the carbon by means of the carbon holder support, and permit it to fall; then adjust the limit screw so that when the arc is established it will hold over without breaking the circuit. If the arc breaks when the light is started, or if, while the light is in operation, the equalizer sets up a pumping action, giving a vibrating or flickering light, the limit screw is set too high. On the other hand, if this limit screw is set too low, there will not be sufficient separation, when the light is started, and there will be only a small red light. This also may occur when the light is in operation and the locomotive in motion, which defect may be easily and quickly corrected by slightly raising this limit screw. When the arc is properly established the spring should be adjusted by means of the nuts so that the carbon will feed as it burns away without breaking the arc. If "tack head" deposits form on the top of the negative, and, breaking off, interrupts the light occasionally it is evidence that the spring is too weak, thus not allowing the arc to be drawn out long enough. A slight increase of the spring tension by adjusting the nuts will correct this fault.

It is necessary that the brass tube, or oil cylinder, guide rod, and valve rod should be kept perfectly clean. For this purpose a soft felt cloth should be used, never using sand-paper or emery paper or waste, as the sand and emery will roughen these surfaces, and the lint from the waste may clog the rack,



EDWARDS ARC LAMP.

thus preventing the carbon from feeding properly. The engagement between the rack and pinion should be as close as possible to prevent any lost motion, and yet permit the brass tube, or oil cylinder to fall freely; this adjustment is effected by means of screws, the flat spring having oblong holes through which these screws pass.

The descent of the brass tube, which carries the carbon holder, should be occasionally tested to see if it is feeding at

its proper speed. To do this, remove the carbon and raise the brass tube, or oil cylinder, to its upper limit, then press down the equalizer and permit the column to fall. It should fall its full distance in not less than $1\frac{3}{4}$ minutes, and not more than $2\frac{1}{4}$ minutes. The time of falling is governed by the flow of kerosene through the valve, and if the time is longer or shorter than above mentioned, it is due to dirt in the hole or under the valve seat. It is therefore essential that the valve should always be perfectly clean. The oil cylinder is filled with kerosene oil, and there may be slight evaporation which may reduce the quantity below the proper amount. This may not occur for six months or a year, but when it does occur it is shown by the oil cylinder suddenly dropping a fraction of an inch when at the bottom of its stroke, and when the carbon is nearly consumed. Should this happen, remove the lamp from the case and fill the oil cylinder with the best, clean kerosene oil.

THE LAMP NEGATIVE.

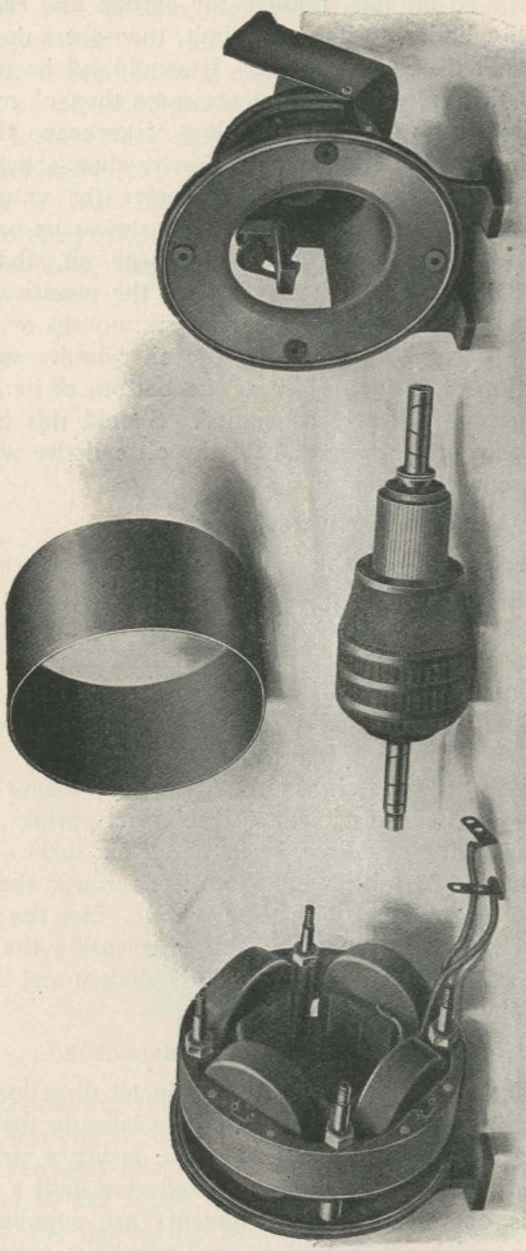
The negative is made of the best rolled copper rod, and the position of its point determines the focal point of the arc in the reflector, hence it always is necessary to set the negative with the aid of the gauge, which is chained to the lamp.

When the point of the negative becomes flattened, concave or rough, it should be removed and dressed to a point. In replacing the negative be sure to clamp it firmly.

To adjust the equalizer weight remove the lamp from the case so as to be able to shake it violently; disconnect spring so that it has no tension on the equalizer, insert about six inches of carbon in the holder, and permit its end to project through the guide, but not to come into contact with the negative. Set the weight so that the pawl will be just on the point of releasing the wheel, but will not do so when the lamp is violently shaken and roughly jarred in every direction.

THE ADJUSTMENT OF LAMP AND REFLECTOR.

The lamp and reflector are adjustable in all directions with relation to each other. To properly focus the lamp in the reflector, place the locomotive on a straight track, facing a stretch at least a mile long, and shift the lamp and reflector until a perfect parallel beam is obtained. The equipments are supplied with special reflectors which are formed to true parabolic curves, and a perfect parallel beam can be drawn without any crossing of the rays which produce dark spots. When the focus is properly lo-



PARTS OF EDWARDS GENERATOR AND ARMATURE.

cated on the track, the engineer should be able to see at least a mile ahead of his engine.

One feature which distinguishes the Edwards system of headlighting is the vertical beam of light, which is produced by arranging a plane reflector (mirror) outside the goggle in such a position and at such an angle as to intercept about one-third of the whole volume of light and throw it skyward in a perpendicular shaft. Aside from its undoubted spectacular quality, this vertical beam appears to have a real value of considerable importance, especially on steep grades or in a hilly country where the track is winding. Under such circumstances, where conditions are at all favorable, this aerial shaft of light serves as a signal which can be seen for a considerable distance, for many miles even when the atmosphere is unfavorable.

The prime requisites in an apparatus of this kind are simplicity and stability, implying ease of operation and low cost of maintenance.

A FEW WORDS OF CAUTION.

Keep all nuts, bolts and screws drawn tight.
Keep the light in proper focus.
See that brushes always slide freely in their holders.
Always keep the mica filed below commutator surface.
Keep the commutator smooth and clean.
Preserve all adjustments as directed.

WATCHES NOT MAGNETIZED.

The dynamo is of the enclosed type and is designed with magnetic circuits of generous proportions, in which there are no stray lines of magnetism. It is therefore impossible to magnetize watches from the dynamo, and engineers need have no anxiety upon that point when using the apparatus.

ELECTRIC SHOCK NOT POSSIBLE.

The electro-motive force generated by the dynamo does not exceed 35 volts when the light is in operation. This low voltage cannot be perceived through the hands. Operators handling the light need have no fear of shock, as it is not possible to receive a dangerous shock from the apparatus.

THE PYLE NATIONAL HEADLIGHT.

INSTRUCTIONS FOR APPLYING THE EQUIPMENT.

If equipment is to be located on front end forward of stack, measure the depth of the headlight case you intend to use, add 18 inches to this measurement, and have a baseboard made, using these measurements for the length of board, and make the breadth your standard width for oil headlights. Bend a piece of $\frac{3}{4}$ by 3 in. iron flat ways, "U" shaped, making center of iron come over the center of your brackets on your engine and make the length about two inches shorter than your baseboard. Place this iron "U" on the brackets within about two inches from the stack and mark for bolts through brackets.

Put baseboard on the iron "U" so the back edge will just clear stack, and bolt to brace. Place the equipment on the board, with dynamo on the left side of locomotive and as near the back edge of board as possible, and bolt to board. Then bolt headlight case to board in front of equipment. Put a $\frac{3}{4}$-in. angle valve in the highest part of the boiler in the cab with dry pipe, and run a $\frac{3}{4}$-in. pipe from this valve under the jacket on right side of boiler to the equipment. Use $1\frac{1}{2}$-in. pipe for the exhaust, running it through the arch and end of pipe about flush with the top of the nozzle tips of the locomotive. We recommend the use of 2-in. pipe inside the arch, as it reduces noise and does not act on the fire.

If equipment is to be located on boiler just in front of cab, take up back sheet of jacket and fasten two brackets to boiler suitable for holding our equipment crosswise of boiler. Have a baseboard (iron or wood) made and bolt to braces, then place equipment with dynamo on left side of locomotive and bolt to base.

If steel or iron baseboard is used, equipment should be insulated from base by wood or asbestos sheet. Place a $\frac{3}{4}$-in. angle valve in the highest part of boiler in the cab (with dry pipe) and run a $\frac{3}{4}$-in. iron pipe to the equipment. You can run the $1\frac{1}{2}$-in. exhaust pipe up above cab or down to running board and into arch. Run the lead wires through an independent pipe if possible or through the hand railing, being sure to insulate them carefully to prevent chafing, etc.

To apply the lamp to the reflector and case, remove oil tank and all supports and guides from the reflector. Cover the board holding the reflector with tin, having the edges turned up about one-half inch. This prevents sparks from the lamp from setting fire to the oil-saturated board. Secure the support for the back of the reflector to the lamp board on right-hand side, and adjust the screw until the reflector stands level. Remove both carbon holders from the lamp and set the lamp on the board, on side nearest door of case, then put bottom holder in lamp and place lamp on board with copper electrode in center of hole in reflector,

being sure to have base of lamp square with reflector slide. Mark for holes in center of large square holes in base of lamp and bore for $\frac{3}{8}$-in. bolts.

Secure the small wires for the incandescent lamps by the small screws at the right of brush holders. Run the incandescent wires through the hand railing to the cab, in wood strips. Run wires for cab in wood strips. Wind all the joints with tape.

THE ELECTRIC HEADLIGHT EQUIPMENT COMPLETE CONSISTS OF ENGINE, DYNAMO AND LAMP, AND MATERIAL FOR THREE INCANDESCENT LIGHTS IN CAB.

The Engine.—Their engine is known as the Pyle compound steam turbine. There are no wearing surfaces inside the engine requiring lubrication, hence they do not use any sight feed lubricator in the cab. Before starting engine be sure the casing is thoroughly drained, and do not turn on steam too suddenly in starting light, thus allowing time for the condensation to get out of the engine. It must have dry steam.

Remove plug in top of engine once each week and pour in a little black oil. This will prevent corrosion of parts. The inside bearing only needs enough oil in the well for the loose ring to touch the oil and carry up on top of the shaft. If you have too much oil, it will be thrown out of the ends of the cellar by the motion of the locomotive, which may ruin the armature. Oil well for the outside bearing should be filled each trip. Use valve or cylinder oil in these bearings.

The Dynamo.—The dynamo is constructed on the latest scientific principles, and the electrical balance is so perfect that no sparks should be seen at the brushes. The armature is held in place on the engine shaft by one screw which can be easily taken out if occasion demands. The brush holders are fixed, and the brushes can be taken out and replaced without changing the tension of the springs. They use a graphite brush for the top and a carbon brush for the bottom, and if you will give them only a few moments' care each trip, you will have no trouble at all when on the road.

The mica between the copper strips of the commutator should always be a trifle below the surface. If it gets too high, file it down with a small file. Do not get it too low, as it will collect dirt, etc., and cause a short circuit. The commutator should be cleaned each trip with a damp piece of waste (not wet), rubbing endwise so as to keep the creases clean where mica is filed out.

Be sure and have your brushes fit perfectly on the commutator. If you have poor contact your brushes will spark. If you find your commutator is running out or has the appearance of getting rough, clean it up. To do this nicely, remove your brushes and hold a strip of No. 0 sandpaper (not emery paper) about the width of the brushes by the ends of the sandpaper on the commutator while running. Don't press the sandpaper on with your fingers, for if there are any low spots, they will increase in size.

If the brush tension spring is too tight, it creates friction, heat and unnecessary wear, both to the commutator and the brushes. If too loose it will spark and commutator will not run clean. Have it just tight enough to prevent sparking. In this case a little judgment must be used, for if your brushes are not in the proper condition, or your commutator smooth and true, you will have sparking at the brushes, no matter how much pressure is used. Do not forget that the commutator is the vital part of all dynamos, and none will run successfully without regular care and attention. The voltage of the dynamo is entirely too low to force a current through any portion of your body, so you can handle it freely and without any possible fear of being injured by it. It only requires a few moments' attention each day to keep the plant in perfect condition. If you fail to follow the instructions, your light may fail.

If the commutator becomes rough or out of round, it should be trued up in a lathe. The tool used must be very sharp and light cuts must be taken, then polish it with fine sandpaper. It must be carefully examined to see that no two sections touch, as the copper is liable to lag or burr from one section to the other, and before putting it back, it would be better if you cut or file the mica (between each section) a little below the surface, for it does not wear away as fast as the copper, and if the mica is not cut away, it may lead to sparking. After doing this, be sure no ragged edges of copper stick up, for this will cut away the brushes rapidly. The speed of the armature should be as near 1,800 revolutions per minute as possible, unless the copper electrode burns off, when it should be reduced until the copper electrode does not burn.

The Lamp.—Is simple, durable and reliable, and after a few trials you will find it an easy matter to trim your lamp in the dark, should occasion demand. In putting in the top carbon, you will find it much better to remove the carbon holder from the slide. After securing the carbon in the holder, take it between your

thumb and forefinger and with your remaining fingers resting on the guide you can easily put it in place. If you desire to clean the reflector, remove only the top guide by loosening thumb nut at the end of the upper arm, then you can easily remove guide, carbon and carbon holder.

The tension spring in the lamp is for two purposes. It brings together the points of the carbons, so as to establish the arc when the dynamo is set in motion, for we must have a complete circuit before we have any current. If the carbons are separated only a small fraction of an inch, the lamp will refuse to work, because the current will not jump across the separation. Sometimes there will be a deposit of scale on the point of the lower copper electrode which prevents the top carbon touching the copper, and as the current will not go through this scale you will get no light until this is removed. We suggest that engineers see that the point of copper is clean before each trip. Suppose all wires are connected and the lamp properly trimmed, we turn on steam and set the armature in motion. The current enters the lamp and passing through or around solenoid magnet draws down the iron armature. This in turn separates the carbons, thus forming the arc or light. You will notice the spring is secured to the end of lever toward the carbons, or on the opposite end from the magnet and pulls against it. This prevents solenoid from pulling the carbons too far apart. The volume of light will depend largely on the way you regulate this tension spring. You may have it so tight that the magnet will be unable to separate the carbons, consequently you will have no light. If you run your dynamo too long with your lamp in this condition, you will burn out the armature or the fields for the current become very heavy.

If the tension spring is very loose, the lamp will flash and go out, for the magnet will be drawn down too far. When the light goes out the current is broken, and there being no strength in the magnet, the spring will again bring the carbons together, then the current is instantly re-established. You want to adjust the spring so the lamp will flicker just a little, when locomotive is at rest, for then you are getting all the light possible at a given speed of the armature, and your light will burn steady when locomotive is running.

The wires leading back to the incandescent lamps may come together, causing a short circuit. This will put your light out. You can tell when this occurs, for the dynamo will be generating a heavy current, the speed will be quite low, and there will be a small light in the lamp. In this case just disconnect one of the small wires from connecting screw, then when you have time you can look for the cause of the trouble.

Most of the troubles are traceable to the adjustment of the lamp.

Magnet yoke may travel too far sometimes and strike small lug on frame of lamp before carbons are separated sufficiently to make proper arc. In this case wire should be shortened so that magnet yoke is about half way down before clutch grips carbon.

If the wire is too short the lamp will jump or carbon will stick in clutch.

If the carbon feeds too fast top clutch spring is too weak and should be given more tension. To do this remove cotter pin from No. 100 A and you can get top-clutch spring out of casing. Then pull it out a little, thereby giving it more "set."

If your light burns green your dynamo is running too fast and the speed should be reduced.

This can be stopped on the road at once by throttling steam in the cab. There is another reason for light burning green. The main wires from the dynamo to lamp may be connected wrong; therefore one wire should have a sleeve on each end large enough to prevent its going into the binding post with a small hole. The other wire should have plain ends.

The lamp can be moved in all directions for focusing. To get the proper vertical focus on the track, either to have the light close to you or to strike the track far ahead, loosen the set screw on the side, and by turning the adjusting screw the lamp can be raised or lowered as desired. To move it sideways, backward or forward, loosen the hand nuts and the lamp is free to move.

When once in focus, there is no need of changing it again. Tighten all screws.

The back of the reflector is supported by an adjustable step, with screw to raise or lower it, so the volume of the light will come out in parallel lines.

TO FOCUS LAMP.

1. Adjust back of reflector so front edge will be parallel with front edge of case.

2. Adjust lamp to have point of copper as near center of reflector as possible.

3. Have carbon as near center of chimney hole in reflector as possible.

4. Have locomotive on straight track and move lamp until you get best results on track. The light should be reflected in parallel rays and in as small a space as possible.

To lower light on track, raise lamp. To raise light on track, lower lamp.

If your light throws any shadows it is not focused properly.

If light is focused properly and does not then strike center of track do not change focus, but shift entire case on base board.

Point of copper should be about one inch above top of holder. If it is higher than this there will be too much heat on clutch.

TO ROUNDHOUSE MEN.

A centrifugal brake is placed on back side of spoke of wheel No. 2½ and should be set so as to act at about 100 revolutions per minute more than where the governor acts, so that, if for any reason, the governor fails to act, this brake will check the speed and hold it at any speed at which the brake is set. The application of this brake commences with equipment No. 2,600, but cannot be applied to equipments with serial number lower than that.

To adjust centrifugal brake, remove armature and cap to engine, pull out wheel and shaft when you can have free access to brake. If you wish to adjust brake so it will act at a higher speed, turn nuts to right, being sure to adjust both brakes the same, then tighten up jam nuts. One-half turn of the nut will change the speed at which brake will act about 150 revolutions.

The governor should be examined once each month, and if plungers are found cut they should be ground in or faced off as the case requires. If plungers are cut, engine may run away and be broken by centrifugal force. If plungers are faced off, the ends of governor yoke should be bent further out from face of wheel, thereby allowing plungers to again seat firmly before governor weights are thrown out further than at right angles to face of wheel. If the speed is too high, adjusting screws should be turned back half a turn each, being careful to adjust all the screws the same. Half a turn of these screws should change speed about 100 revolutions per minute. If by turning back governor spring adjusting screw the speed is not reduced, your plungers do not seat, and you should then proceed as above.

SUGGESTIONS.

Have a few strips of No. 0 sandpaper about 1½ in. wide to clean up the commutator. The Pyle Co. are having a special and superior carbon made expressly for the apparatus, which will be furnished by them at a very reasonable price.

If your light fails to burn when turning on steam, see that all screws are tight, and that point of copper electrode is clean. Push down on lever and see if carbon lifts up and falls freely. Put a carbon across both binding posts, and if there is a flash when it is removed, your dynamo is all right and the trouble is in your lamp. If you do not see a flash when carbon is removed, take out brushes and clean commutator with sandpaper (not emery paper), put the brushes back and try the carbon again. If you do not then get a flash, you have a "short." This is probably caused by wires touching each other and you must not run the dynamo until this is remedied.

Keep all screws tight.

After putting in a new carbon, always push down on lever, and notice if carbon lifts and falls freely. If it does not lift, it is not in the clutch. If it does not fall down freely, turn it partly around and find the freest place.

The carbon should burn from eight to nine hours.

Engineers should be held responsible for the proper care of the equipment unless some one is appointed to examine and care for them at roundhouses.

Before leaving on your trips the equipments should be started and brushes examined, as to tension of springs, and adjusted if necessary before getting out on the road.

Their equipments are not automatic, and as we have quite a number of enemies to electricity on the locomotive, such as grease, dirt, jar, heat, etc., it is necessary to give it a few minutes' attention every day. If you do this you will never have a failure on the road.

Don't attempt to remove reflector from the case until you have removed top carbon holder by loosening thumb nut.

If the copper electrode burns off, your equipment is running too fast, and the speed should be reduced by turning governor spring screws to the left until the trouble is stopped. Be careful and adjust all screws the same as nearly as possible. One-half turn of screws will change speed about 100 revolutions per minute.

Be sure and adjust tension spring as loose as possible and not have your light go out while locomotive is standing still.

If your light dies down when locomotive is running fast, the tension spring may be too tight, which prevents solenoid from separating carbons sufficiently to form proper arc, or top-clutch spring may be too loose, allowing back edge of clutch to be jarred up and release carbon.

If light goes out when locomotive is standing still, tension spring may be too loose or carbon may not feed freely.

If your light burns green on the road, throttle steam at once.

If your electrode does not come in line with the carbon, the holder should be bent until electrode comes in line with top carbon.

Both ends of one lead wire should be doubled about one inch so it cannot go into binding post with the small hole, and thereby prevent crossing of wires.

Special motor brushes should be used with the improved brush holders, top and bottom brush being the same quality. The graphite and carbon brushes used with the old-style brush holders should not be used with the improved brush holders nor special motor brushes in the old-style holder.

TABLE OF PRINCIPAL ALLOYS.

A combination of zinc and copper makes bell metal.

A combination of copper and tin makes bronze metal.

A combination of antimony, tin, copper and bismuth makes britannia metal.

A combination of copper and tin makes cannon metal.

A combination of copper and zinc makes Dutch gold.

A combination of copper, nickel and zinc, with sometimes a little iron and tin, makes German silver.

A combination of gold and copper makes standard gold.

A combination of gold, copper and silver makes old standard gold.

A combination of tin and copper makes gun metal.

A combination of copper and zinc makes mosaic gold.

A combination of tin and lead makes pewter.

A combination of lead and a little arsenic makes sheet metal.

A combination of silver and copper makes standard silver.

A combination of tin and lead makes solder.

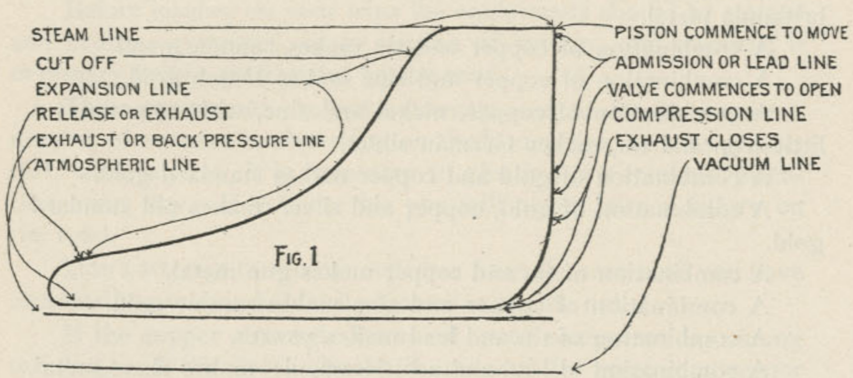
A combination of lead and antimony makes type metal.

A combination of copper and arsenic makes white copper.

THE STEAM ENGINE INDICATOR.

PURPOSE OF THE INDICATOR.

As its name implies, the office of the steam engine indicator is to determine the action of steam, doing work in the cylinder of a steam engine, or, in other words, to outline on a piece of paper, called the "card" or "diagram," a map of the various pressures exerted against the piston throughout the entire revolution. An indicator card may be compared to the surveyors' profile or map



INDICATOR DIAGRAM.

of a railroad in its manner of conveying information; each has its base line from which calculations are made, and in each case the base line may be called zero. On the surveyors' profile, the zero or base line is a line representing sea level, or no altitude, and from this line all grades and elevations are estimated. This map is drawn to a reduced scale, whereon an inch represents a much greater distance, perhaps miles, which is marked on the drawing so that one can take an ordinary rule and by measuring from the base line to

the grade or elevation, readily find the exact height of any point on the road.

VACUUM LINE.

The base line on an indicator card is called the vacuum line, or line of no pressure, which, at sea level, is 14.7 below the average pressure or weight of the atmosphere. At greater elevations the air is lighter, and consequently the vacuum line is a trifle higher, but 14.7 lbs. is ordinarily used. In analyzing an indicator card, this line must be considered, especially in dealing with a card from a non-condensing engine, where the pressure of the air is largely reduced by the condenser.

ATMOSPHERIC LINE.

There is still another line on the indicator card which may also be considered as a base line, and which is quite as important as the vacuum line. This is called the air or atmospheric line, and represents no effective pressure on a card from a non-condensing engine. This line on the card is traced by the indicator pencil, when air is on both sides of the indicator piston, and the spring in the indicator is under no tension.

SPRINGS GRADUATED TO SCALE.

All the indicator springs are made to a known scale, that is, they are made so as to allow the pencil of the indicator to represent a given number of pounds of steam pressure for each inch of vertical movement, and, as in the case of the surveyors' map, one may put a scale on the card and accurately measure the pressure on the engine piston at any point in the stroke. He may also measure the back pressure or resistance due to the atmosphere. The air and vacuum lines are independent of any lines made by the indicator, and the condition of the engine or steam pressure has no influence on them.

LINES OF THE DIAGRAM.

The lines on the diagram which are made by the steam are:

First: The admission line (sometimes called the lead line, because it is the steam which passes through valve lead which makes it) which is made by the upward movement of the pencil when steam is admitted to the cylinder through the opening of the main valve at the beginning of the stroke. When the valve has so much lead that it opens the part before the piston has reached the end of its stroke, the admission line will not be vertical, but will incline slightly outward. If the valve has lap, or negative lead when the piston is on the center or at the end of its stroke, the admission line will incline inward, but if the main valve opens just as the piston begins its movement, the admission line will be vertical.

Second: The steam line is that line marked by the pencil after the piston has commenced its stroke, and the steam is passing through the port. This line leaves at nearly a right angle from the admission line, and continues along the card until the cut-off takes place; that is, when the main valve has moved across the port and back again, shutting off the steam from the cylinder during the remainder of the piston's stroke. This line is influenced largely by port opening, steam-pipe connections, and the velocity of the piston. When the port and pipes are ample, and the piston velocity not too great, the steam line is parallel to the air line; but in the majority of cases these conditions do not exist, and this line falls off perceptibly; so much in some cases that the point of cut-off is hardly discernible on the card.

CURVE OF EXPANDING STEAM.

Third: The expansion line is what its name would suggest, viz.: that line which is made by the indicator, after the cut-off has taken place, and the steam is doing work by its expansive power. This line takes the form of a hyperbolic curve, and falls to a lower pressure, just in the ratio that the steam is expanded. There is no line on the indicator card that possesses the interest and importance of the expansion curve. It is the index of steam economy, and represents work done by the piston after the steam has been shut off. When compared with an engine that takes steam throughout its entire stroke, it means work done without cost. It should be well studied, for it indicates good or bad performance in a steam engine.

Fourth: The release or exhaust line (often called the back pressure line) follows the expansion line; in fact, the expansion line runs into it the same as the steam line runs into the expansion line. It is formed by the opening of the exhaust port and the flow of steam to the atmosphere in a non-condensing engine, and to the condenser in a condensing engine. It takes a rounded form while the engine is passing the center, then makes a line nearly straight and nearly parallel to the air line, until it is lost in the compression line or curve. Its proximity to the air line depends upon pipe and port openings and piston velocity. This is also an important line showing loss of power. It is always well to have this line approach the air line as nearly as possible, as the greater the distance between the two makes the loss greater.

Fifth: When the exhaust valve is closed on the return stroke, the steam remaining in the cylinder cannot escape, and the movement of the piston forces it into a smaller space, compressing it to a higher pressure; in some cases, where an engine is linked up, or the clearance is very small, even higher than the pressure in the boiler. This line runs into the admission line, and it is sometimes difficult to tell where the compression line ends and the admission begins.

Fig. 1 is an indicator card showing very clearly all the lines on the diagram. In considering this it must be kept in mind that the air and vacuum lines are not a part of the diagram made by the steam pressure.

To obtain well-defined diagrams with instruments of this description, it has been found desirable to employ a spring of high tension, so as to permit but a small movement of the piston. That a suitable height of the diagram may be obtained, this plan requires the multiplication of the movement of the piston. In the means that are employed for accomplishing this result, still preserving a straight line movement, the various forms of indicators that have been extensively used find their essential differences.

For an exhaustive and easily understood treatise on the "Steam Engine Indicator," we refer our readers to Hemenway's "Indicator Practice and Steam Engine Economy."

THE IMPROVED TABOR.

The special feature of this instrument consists in removing the spring from within the steam cylinder of the Indicator and connecting it on top of the cylinder, outside. This arrangement overcomes the detrimental influences on the spring from direct contact with the steam, and subjects the spring to the temperature of the atmosphere only.

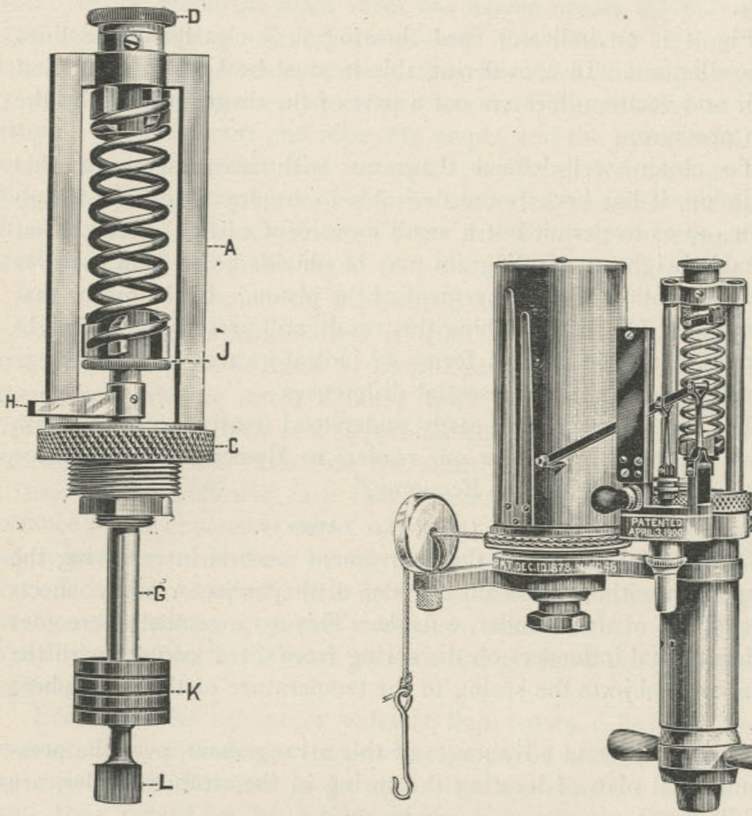
Other important advantages of this arrangement, over the present universal plan of locating the spring in the steam cylinder, are the following:

1. The spring is at all times in plain view of the operator, and its momentary action can be observed at a glance.

2. The spring is accessible, and can be readily removed from the Indicator without disconnecting any other part of the instrument, eliminating the disagreeable necessity of handling highly heated parts, such as cylinder cap, piston rod, piston, etc., in connecting or disconnecting a spring, as is required in all Indicators where the spring is located in the steam cylinder, and attached to the pencil mechanism.

3. The deterioriating influences of the steam are entirely eliminated where the spring is located outside of the steam cylinder, and as a result the life and accuracy of the spring is prolonged indefinitely.

4. With the spring located outside of the steam cylinder and not subjected to the heat of the steam, no allowance for expansion is required in its manufacture; and in consequence the spring can



TABOR.

be made exactly correct for any given pressure, and can be employed for indicating either steam, water, air or gas pressure.

In the improved construction the spring is rigidly held at one end by the knurled thumbscrew D in yoke A. This yoke A swivels in cylinder cap "C" which covers the top of the cylinder. The body thumbscrew D contains a circular groove which receives the end of a small set screw, as shown in the cut, for holding it in position, and prevents it becoming detached when spring is disconnected. To

disconnect the spring it is only necessary to loosen the thumbscrew D, and unscrew the spring from the mounting on top of the piston rod.

The piston rod is simply a straight rod with a threaded mounting secured to its top end, outside of the cylinder, to which one end of the spring is secured. The horizontal arm is used to connect the piston rod to the pencil movement. This connection between the piston rod and pencil movement can be instantly made or broken by simply moving arm to or from the grooved collar, allowing the operator, at all times, to test the freedom of vertical travel of the pencil movement, by moving the piston rod arm out of contact.

In the construction of a Steam Engine Indicator, the pencil movement and the spring are of foremost importance. Any defects or inaccuracies in either of these essential features will be so multiplied on the diagrams taken as to make the records unreliable and therefore comparatively worthless.

The desired results are obtained in the pencil movement of the Tabor Indicator, by guiding the pencil bar in a steel plate. This plate contains a slot of such shape as to entirely counteract the tendency to a radial movement. The slot in the plate is carefully ground to an irregular curve, deviating slightly from a true circle, its irregularity just compensating for the error that would arise by use of such radial links as are common to other indicators.

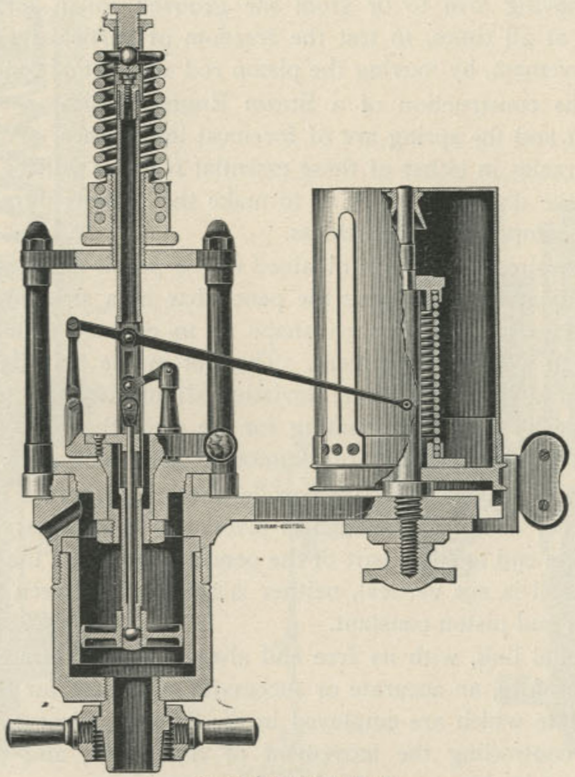
In the so-called Indicator parallel motions, where a radial link is employed, one end of which is pivoted to a stationary point on the opposite end to some part of the pencil mechanism, the line made by the pencil is not vertical, neither is the ratio between the pencil movement and piston constant.

A radial link, with its free end always moving in a true circle is not, therefore, an accurate or successful substitute for the irregular slot plate which are employed in the Tabor Indicator, for guiding and controlling the movement of the pencil, and permitting accurate results from every position it may assume.

All Tabor Indicator springs are composed of two separate wires, and so arranged in their mountings as to prevent their distortion or buckling when being compressed.

As the accuracy of the Indicator diagrams also depends upon the Indicator springs, as well as on the movement of the pencil, the springs must be accurate for all conditions of use. A spring, when confined within the cylinder of an Indicator, is necessarily influenced by the change in the temperature therein, to counteract which each spring must be made and calibrated for the temperature under which it is to be used.

For steam pressures, in order to provide for the expansive action of the heat imparted to the coils, springs must be made somewhat heavier than for water or air pressures; but as all springs have a range considerably above the exact pressure for which they were made, it must follow that any increase in temperature, due to a higher steam pressure, must affect the accuracy of the spring.



CROSBY INDICATOR.

By removing the spring from contact with the steam, the spring remains accurate for all pressures throughout its entire range.

THE CROSBY NEW INDICATOR.

This instrument is a departure from the ordinary steam engine indicator. One difference is in the location of the spring. This has been removed from the cylindrical case near the piston to the outside, and is affixed above the moving parts, where it will re-

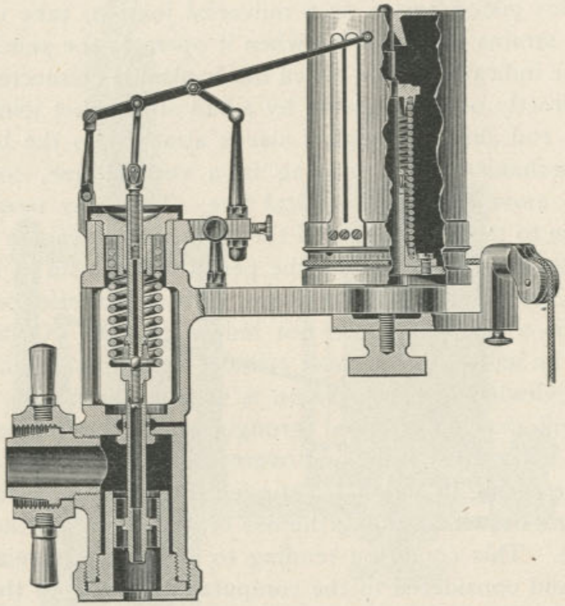
main cool under all conditions of use. Whatever error arises from heat, therefore, as affecting the spring in the ordinary indicator, is not present in this instrument. The other and more important difference lies in the size and shape of the piston. This piston is one square inch in area, and is in form the central zone of a sphere, thus affording great active force with a very light pencil mechanism. It is attached by a rod directly to the upper part of the spring, and moves freely and without restraint notwithstanding there may be eccentricity in the action of the spring. In other words, this piston serves as a universal joint to take care of the torsional strains of the spring when it operates the pencil mechanism of the indicator. The pencil mechanism is connected by a rod to and directly over the piston by a ball and socket joint.

This rod slides through a sleeve attached to the base of the pencil mechanism, and, moving in a vertical line, compels the pencil to move also in a vertical line. Thus any motion of the piston due to the movements of the spring which causes the spring rod to deviate, will not affect the pencil mechanism in its vertical course. The contact of the piston with the interior side of the cylinder is a line, and does not induce friction. Ordinarily the piston of an indicator is a short cylinder fitted to slide easily within another cylinder. Such a piston is usually about ½ in. long, and in use will develop friction throughout its circumference. The piston so made must resist and overcome if possible the eccentricities of the spring in action. Yet even then there is always a want of freedom, notwithstanding the use of devices to aid the piston in such case. This condition tending to error is recognized by engineers, and considered in the computations made of the diagram taken by the indicator. The freedom of the piston movement in this indicator dispenses with the necessity of this correction.

A novel feature is the adjustment of the pencil to any desired position on the drum by loosening the binding nut below the spring and screwing the spring upward or downward, carrying with it the entire pencil mechanism. So located, with the binding nut again screwed firmly into place, the pencil is held in position. It is simple, convenient, and free from heat.

STAR IMPROVED INDICATOR.

The Star Brass Manufacturing Company, of Boston, Mass., have got out an improved form of indicator, in which the spring is placed outside of the little steam cylinder, the drum and pencil motion remaining the same as in the former types made by this concern. The area of the piston has been reduced to equal one-quarter of a square inch, for the purpose of allowing much smaller wire to be used in the spring, and this gives greater elasticity and freedom in operation.



THE STAR IMPROVED INDICATOR.

Another feature is that the pressure of the steam pulls the spring apart, and this, it is claimed, tends to move everything in a straight line. This makes the atmospheric line come at the top of the card when it is on the drum. The cylinder can readily be removed for examination by unscrewing the cap at the bottom. The steam cylinder is always surrounded by live steam when in use. The connection to this indicator is made at the side and the steam pressure is, therefore, exerted on the top side of the indicator piston.

MACHINE TOOLS AND SHOP APPLIANCES.

MACHINE TOOLS.

By Angus Sinclair and James K. Cullen.

"Man is weak of himself and of small stature," says Carlyle; "he stands on a basis, at most for the flattest soled of half a square foot insecurely enough; nevertheless, he can use tools, can devise tools. With these the granite mountain melts into light dust before him; he kneads glowing iron as if it were soft paste; seas are his smooth highway; winds and fire his unvarying steeds. Nowhere do you find him without tools; without tools he is nothing; with tools he is all." When we look at a massive machine of wondrous power, we seldom reflect that it is a triumph of the toolmaker's art, and that the capacity to create massive engines has kept steady pace with the improvements in machine tools. The tendency of many people to forget their benefactors is well illustrated in the works of many writers on engineering subjects. They will fatigue language in descriptions of the products of tools and never say a word about the tools themselves.

Tools have grown from humble beginnings and civilization has grown with their growth. Take, for example, the hammer, which was doubtless the first of tools. A history of this implement would embrace the origin and progress of all the useful arts. In tracing the various purposes to which it was applied we should become acquainted with all the important transactions the world has ever seen. How infinitely various we should find the materials, sizes forms and uses of the hammer. At first a club, then a rude mallet of wood; next the head formed of stone and bound to the handle by sinews of animals; afterwards the head formed of metal—copper and even gold, then steel or iron. It is a pity that ancient historians had so little to say about the growth of the hammer and of other tools of which it was the parent. Their discourses would make much more interesting and edifying reading than the records of human butcheries which form the mass of ancient history.

The hammer produced modifications of the wedge, the knife, chisel, shears and the axe, and with them the awl or gimlet. The saw and the file represented ages of progress, and probably were contemporaries of the first potters wheel, which was the forerunner of the modern lathe. Applying power to the operation of those tools is of modern enterprise scarcely older than the steam engine. A student of the growth of the mechanic arts is surprised at the small progress which tools had made at the beginning of the eighteenth century. The blacksmiths' art had been developed in fabricating armor for war, and a crude boring mill had been invented and improved for boring cannon, but the germs of modern machine tools had not advanced perceptibly since the ancient civilizations had been blotted out by the warfare which they fostered. When James Watt began engine building a few ill-constructed hand lathes with some drills and crude boring mills constituted the principal furniture of his shop, and we find him writing to a friend that workmanship was improving, for an eighteen-inch cylinder recently finished was only three-eighth inch out of round.

The successful construction of all machinery depends on the perfection of the tools employed; and whoever is a master in the art of toolmaking possesses the key to the construction of all machines. "The contrivance and construction of tools must therefore ever stand at the head of the industrial arts," said Babbage, of calculating machine fame, at the opening of the 1851 Exhibition. Accepting those ideas as true, we must accord high praise to the men whose ingenious labors brought forth modern machine tools.

For years after the steam engine had been applied to driving machinery, the principal machine tool in use was the lathe manipulated by hand. Its successful operation called for exertion of great physical endurance and accurate skill by which the heaviest work had to be finished. The slide rest introduced a revolution in this tool.

There is great conflict of opinion as to who invented the slide rest. In 1648 Maignan published at Rome engravings of two curious lathes for turning the surfaces of metallic mirrors for optical purposes, in which the tool is clamped to frames so arranged that when put in motion it is compelled to move so as to form true hyperbolical, spherical, or plane surfaces, according to the adjustment. So also in the screw-cutting lathes, fusee-engine

and other machines introduced by clockmakers. In plates of the French Encyclopédie published in 1772 there are complete drawings and details of an excellent slide rest, and lathes for amateurs were made, according to these designs, more than a century ago by Holtzapffel, a German toolmaker. English-speaking people, however, attribute the invention of the slide rest to Henry Maudsley, an English engineer. Whether he was an original inventor or not cannot now be proved; but it is certain that Maudsley constructed slide rests that rapidly gained popularity in British workshops, where such an attachment had never before been used.

The work of machine toolmaking was greatly stimulated in Great Britain during the first three decades of last century, through the great increase of manufacturers, and by the middle of the century the germs of nearly all modern machine tools had been brought into use. Clockmakers had long employed a crude sort of milling machine for cutting the teeth of clocks. This machine was so much improved by Joseph Brahma, the inventor of the hydraulic press, that it gradually came into use in general machine shops. The planing machine came gradually into favor, and no one seems to know who was its inventor any more than they know who first began cutting screw threads by stocks and dies, which was a modern invention. Roberts of London made a big planing machine early last century which is now in the South Kensington Museum, but it was by no means the first of its kind.

The building of railway machinery gave the first great impetus to machine toolmaking in the United States. British tools were at first imported and became the patterns from which our machine tools were made; but, like the builders of locomotives, American machine toolmakers soon displayed original ideas, and they have so perfected their products that they are now regarded as the best machine toolmakers in the world, and other countries honor them by imitation.

The existing trend of machine toolmaking for railroad work is very well described in a paper presented to the Western Railway Club by Mr. James K. Cullen, president of the Niles Tool Works, from which we give the following extracts:

As the efficiency of any machine is determined by the quality and quantity of its output, modified to an extent by the skill of the workman, and the cost of operation, the designer must be familiar with the details of the various lines of manufacture in which it may be employed. He must also possess a theoretical knowledge of the properties of all materials, under all conditions, coupled with a very broad practical experience, before he can expect to solve the innumerable problems which will be presented. When the vast field to be covered is considered, it must be admitted that no ordinary task is imposed upon him, and that his mental equipment must be very complete. His labor is somewhat lightened on account of the comparatively limited number of methods employed in removing surplus from, or changing the form of, materials of different kinds. Rolling, forging, pressing, planing, turning, milling, grinding, drilling, tapping, punching, shearing and sawing cover the most important, and all machines for effecting these operations can virtually be classified under one or the other heading.

The existing designs are the result of a gradual evolution, the changes developed being the outcome of the market's demand, combined with the intelligence and versatility of the designer and manufacturer. It is needless to attempt to trace the stages of progression from the ornate productions of twenty-five years ago to the severely plain constructions of to-day.

The most noticeable feature in recent years in machine design is the immense increase in strength and power, and the introduction of cutting steels, having lasting properties under excessive speeds and feeds that appear phenomenal, will make it still more pronounced. Radical innovations are now being made in the most progressive concerns to meet the latest requirements. Fifty to one hundred per cent. increase in power with proportionate additional strength being not unusual to provide for cutting speeds of from forty to seventy-five feet—and the limit not yet in sight.

The very first tool specially designed and built to meet the new conditions was a driving-wheel lathe furnished the Altoona shops of the Pennsylvania Railroad Company. Its swing was sufficient to turn tire from 52-inch to 68-inch on the tread at speeds ranging from 10 feet to 30 feet per minute. It is driven by a 25 h.p., variable speed motor, connected to gear train by magnetic clutch. The clutch is so constructed that the current can be passed from the end giving the speeds mentioned to the opposite end where a reduction to 4 inches is obtained, this being used to cut out hard spots. The changes are instantaneous and made by the operator simply throwing a switch. A small 3 h.p. motor is attached to the end of the bed for adjusting the right-hand headstock. The gearings are all cut and of gun iron and steel. The main spindle bearings, 13 inches diameter, 16 inches long, are of

high grade bronze, and the internal sliding spindles, of steel forgings, 45 carbon, 7 inches in diameter. The power and strength is sufficient to give a pressure of 18,000 pounds at each tool, which is as much as the steel will stand. Carriages and tool rests are of the most substantial construction and capable of resisting the enormous strains that are imposed upon them. The weight, 80,000 pounds—about double that of the ordinary lathe of the same swing—indicates its massiveness and rigidity. I regret that I have no record of its output, but as each rest is carrying two cutting tools, it may reasonably be presumed that the time of turning is materially reduced. Other machines of a similar character might be described, but this example of what will be needed under the conditions found in the latest practice will serve our present purpose. Designing this class of machinery demands the highest order of engineering ability, as the revolution is complete and knowledge based on existing designs of little or no avail.

Another, perhaps equally important change manifesting itself within the last year or two, is the adoption of motor drive. This was received at first with some degree of doubt, but it has come to stay, and the value of this method is no longer questioned. While there are instances in which the application of motors has been carried to extremes, their use in connection with the larger and most of the medium size tools has proven eminently satisfactory. The extremes referred to are found where the attachment has been made to very small tools, the cost, size and weight of the motors offsetting the economy in their use. The experience of those who have most carefully investigated the subject has demonstrated that direct connection is only serviceable on the larger machines, and that the smallest should be grouped and operated by short lengths of line shaft with motor attached.

For convenience we may divide all machines into two classes, general and special. The former contains those employed in doing the work on a great variety of pieces, and the latter for some specific duty only, or, at the most, for a very limited number of parts.

The trend has been lately toward the specials. This is particularly noticeable in railway machinery; the axle lathe, car-wheel borer, cylinder borer, frog and switch planer, the rod borer, the car-wheel lathe, the frame planer, the frame slotter, and numerous others, having superseded ordinary tools, or very imperfect specials, for the work indicated by their names.

Sharp competition making minimum cost with maximum output of product a necessity, created the call for such tools, and their use has fully demonstrated their efficiency.

One great advantage they possess lies in the requirement of unskilled labor in their operation. Any man entirely lacking in mechanical experience can soon be taught to manipulate them so skilfully as to obtain the best results.

The most tangible economy, however, is in the shortening of the period in which locomotives and cars are out of service. It requires no detailed statement to impress you with the value of this, long contact with the traffic department having made most of you keenly aware of its importance.

The ancient practice of boring cylinders in lathes, with boring heads filled with wooden blocks, days being consumed in the work, has given way to simpler methods in cylinder borers, the main opening and the end facing being accomplished simultaneously, with a saving of time of nearly fifty per cent.

The latest double axle lathes have increased the output from four to five axles per day to from fifteen to twenty.

Driving wheels are now finished at the rate of two pair per day, instead of one pair in two days.

Car wheels, in modern wheel borers, are bored in from seven to ten minutes, two cuts being taken, and steel-tired wheels are turned in car-wheel lathes in two hours per pair.

Frames, in frame slotters, planers and drills, are completed in twenty per cent. of the time formerly required, and in arch bars, tie bars, side sheets, crown sheets, flue sheets, and a large variety of boiler and car work, eight to ten holes can now be drilled in the time heretofore needed for one, with arch bar and multiple drills.

Power presses, with pressure gauge and safety attachments, turn out four to five times the work the older machines could, and do it so well that trouble from broken and loose wheels is now rarely encountered.

Bending rolls shape up boiler shells of the heaviest material, at one pass, at a speed of from 10 to 12 feet per minute.

Hydraulic riveters and flangers, punches with spacing tables, shearing and plate planing tools, have worked a miracle in boiler work.

Three-spindle bolt cutters and seven-spindle tappers have supplanted the single- and double-spindle tools, and automatic screw machines now turn out more bolts in an hour than a lathe could in a day.

In tools and appliances more especially adapted for repair work, portable cylinder borers, valve-seat planers, crank-pin turners, flue welders and cleaners, stay-bolt cutters, portable crank-pin presses, and numerous devices of similar character, great ingenuity combined with almost perfect adaptability is displayed. The work done by them has effected a saving that in proportion to their cost is far in excess of machines of more pretentious appearance.

Air compressors, making the service of pneumatic hoists, chisels, drills, flue expanders, cushion cleaners and paint sprayers possible, are now very generally installed with excellent results, and bulldozers, upsetting machines and steam hammers are indispensable adjuncts of the modern smith shop.

While so much thought was being expended on the special, the general class has not been neglected, and nothing has been overlooked that would assist in broadening their efficiency along the lines described.

Boring, planing, shaping, slotting, turning, drilling, and other machines, have been virtually redesigned, supplied with automatic stops, wherever possible, and quick adjustments, by hand and power, have replaced older and slower movements.

The range of feeds and speeds has been enlarged until, with the additional power supplied, the only limit is the durability and strength of the cutter.

Convenience in manipulation and minimizing cost of repairs are points that have obtained more than casual investigation. The reduction of frictional losses, a subject overlooked by the copyist, has been diligently studied by the expert designer with the most gratifying returns for his efforts. Correct shape of gear teeth, momentum of pieces running at high velocities, torsional, longitudinal and transverse strains have each been investigated by careful and extended experiment and the information received used to the betterment of previous designs.

Wood-working machinery has kept pace with the iron-working, and this line embraces machines much different from those of even ten years ago. Old patterns have been greatly improved and new ones added. By keeping the automatic feature constantly in mind, mistakes due to carelessness can scarcely occur, the acts of cutting, handling, starting, spacing and aligning being performed almost independently of the operator.

The time has arrived when railroad managers must consider the mechanical department from the same viewpoint as the manufacturer, and treat it accordingly. Heretofore, interest on bonds, roadway and rolling stock improvements took precedence of everything else, and shop equipment was sadly neglected. Requisition after requisition was pigeon-holed, but master mechanics were nevertheless held strictly to account for expense and disastrous delays. A broader and more liberal policy on some of the more progressive lines demonstrated conclusively the advantages accruing from the "weeding" out process, and the others being quick to perceive the valuable results have followed the example set, until all are now imbued with the spirit due to modern methods and ideas.

Before closing, it is proper to pay a just tribute to those who have devoted the best years of their lives to the advancement of mechanical productions. Master mechanics, not in name only, but by reason of their keen conception of the possibilities and their devotion to the processes needed for the proper development of mechanical questions, have contributed more to the success of the manufacturer, and have done more for the cause of humanity and civilization, than many to whom the meed of praise has been more generously accorded. Too much credit cannot be given them for thorough investigations made, the kindly criticism and valuable suggestions offered, making the American machine tool the model for the world.

The early American toolmakers displayed much ingenuity in designing special tools, such as the lathe, invented by Ely Whitney, for turning gun stocks and other irregular forms, but most of them imitated the tools brought out in England by Maudsley, Whitworth and others. The home-made tools were very crude, stone and wooden beds taking the place of cast iron.

New England shops were better provided with machine tools than any others, yet as late as 1850 crank axles for locomotives were turned on a lathe that had a wooden bed. The driving wheels were bored on another lathe of similar construction, being fastened to the face plate by means of a wooden chuck with straps and bolts. Before being removed from the place where they were bored, the key ways were spliced with a tool fixed in a bar attached to the foot-stock spindle forced forward by a screw.

The hydrostatic wheel press had not come into use, and the wheels were forced on the axle by long bolts and nuts passing through heavy straps outside the wheels. If the force applied was not quite sufficient, a few blows from a 50-pound sledge hammer

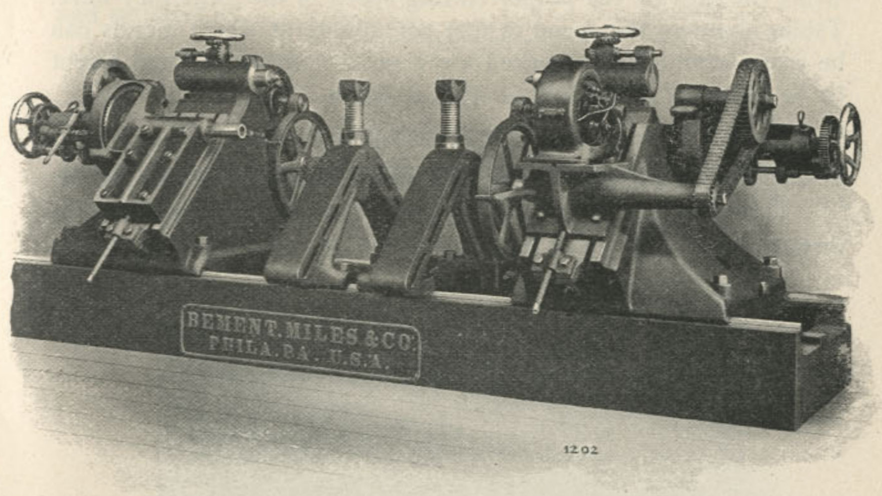
helped to finish the job. The crank pins were forced into the wheels in a similar manner.

All other mechanical operations were performed with tools that were merely an aid to skilful handicraft.

As the business of toolmaking became specialized all sorts of elaboration and ornamentation in design were indulged in. It was a curious circumstance that while the early architecture of the United States was severely plain, the designers of such machinery as machine tools and locomotives imitated the worst forms of ancient art for elaborate ornament.

NILES-BEMENT-POND QUARTERING MACHINE.

The illustration shown is an 85-in. quartering machine, driven by direct-connected motor, and made by the Niles-Bement-Pond Company. It is arranged for quartering and boring crank-pin holes in locomotive-driving wheels having either right-hand or left-hand



QUARTERING MACHINE, NILES-BEMENT-POND CO.

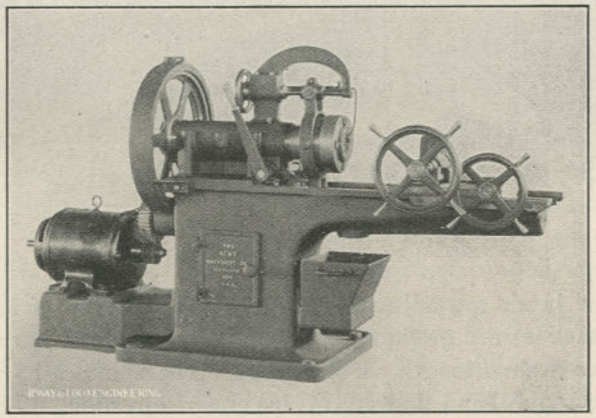
lead. The heads are adjustable for different lengths of axles and the saddle slides are graduated for easy adjustment of boring spindles to the desired length of the stroke. The spindles have power feed and rapid hand movement in either direction. The axles are held on centers and have adjustable V bearings to which the wheels are securely clamped. The motors are geared to the spindles through Renold silent chains. For changing from right to left hand quartering, the heads are flopped over to the other side of the machine, and the motor base is also turned over and put on the other side of the machine. This affords an exceedingly simple and efficient method of driving.

GETTING WORK OUT OF MACHINE TOOLS.

There is considerable agitation going on in some machine shops, about how to get full work out of high-speed steel. We think it would be more practical and profitable to agitate in favor of getting maximum work out of ordinary tool steel, for then the tools on hand could be used without change except that of speeding up when necessary. In the ordinary shop old tools and the steel suitable for them have never been properly operated. Instead of complaining that their tools are too weak for high-speed tools, the foremen ought to exert themselves a little more to instruct the men on the proper cutting speed of the tools they have. Tables showing the speed in feet per minute at which metals can be most economically worked are a great convenience and ought to be more in evidence.

ACME TWO-INCH BOLT CUTTER DRIVEN BY VARIABLE SPEED MOTOR.

This 2-in. bolt cutter is one of the most popular sizes made; it threads both solid stock and tubing up to and including 2 ins.



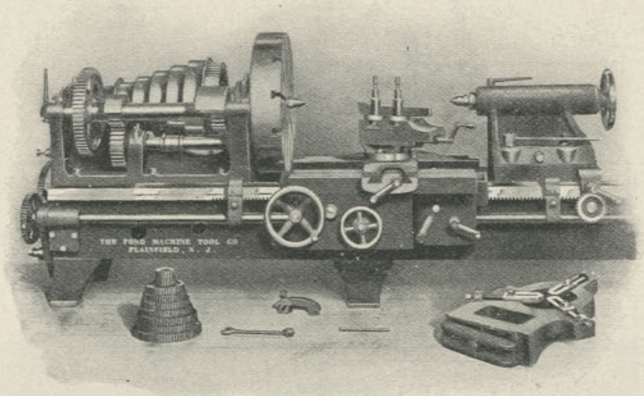
ACME 2-INCH BOLT CUTTER.

diameter. The machine requires a range of speeds from about 18 to 75 per minute. This is easily secured by the use of this variable speed motor of a horse power of 2.25, minimum speed of the motor 225, maximum 900. The connection between the motor and the machine is by a compressed raw-hide gear, so that the machine is comparatively noiseless. By placing the motor on a detachable base, it may be taken off in shipping; it also does not interfere in any way with the machine; that is, it is not placed in such a way as to hinder free access to all parts of the machine.

Really there is not very much to be said on this subject because the half-tone makes it quite clear how the motor is applied. There seems to have been a good deal of humbug put out on this subject; we have had illustrations of machines that are driven by motors with a chain gearing, belting and all sorts of contrivances. We presume they are all satisfactory enough, but none of them, we think, are ingenious enough to call for any great amount of credit. We are quite sure that the above-mentioned arrangement does not indicate any great mechanical genius; it is the most obvious method of applying the motor, and it has been found to be effective, durable and satisfactory.

POND 36-INCH LATHE.

Annexed engraving illustrates the 36-inch lathe, made in the Pond Shops of the Niles-Bement-Pond Company. It swings 37 ins. over the bed and $30\frac{1}{2}$ ins. over the carriage. With 12 ft. bed,

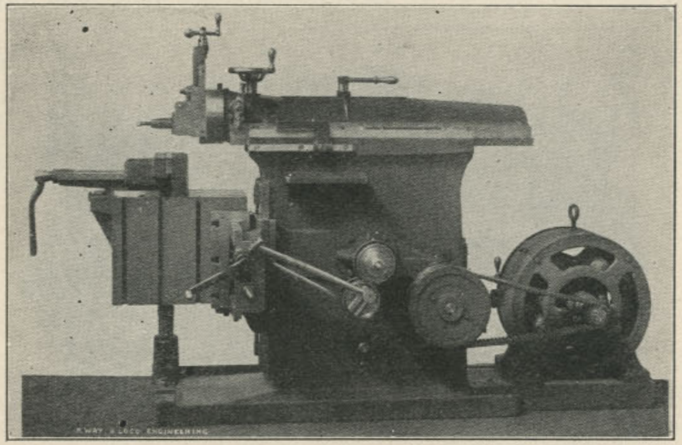


36-IN LATHE, NILES-BEMENT-POND CO.

will turn 5 ft. between centers. The spindles are of hammered steel. The live spindle is mounted in bronze bearings. The cone has five wide belt steps of large diameter. It is mounted on the face-plate spindle, is back geared and geared into an internal gear on the face plate, giving fifteen changes of speed. The sliding head has a set over for taper turning and is easily moved by gearing engaging the steel feed rack. The bed is sufficiently wide to support the tool slide without the latter overhanging its front when turning the largest diameters. The carriage has long bearings upon wide tracks, is gibbed to outside edges of the bed, and can be clamped when cross feeding. It is provided with a tool slide having compound and swiveling movements; also with screw-cutting attachment and automatic friction, longitudinal and cross feeds. If either of the feeds or screw-cutting attachment is in use it locks out all others. The direction of the feeds can be changed at the carriage. Screw-cutting attachment and feeds are connected to the live spindle by three gears and a sliding key, giving three changes without changing gears. The carriage gearing is driven by a spline in the steel lead screw. The thread of the steel lead screw is used only for screw cutting. The gear engaging feed rack can be disengaged when cutting screws, thus preventing uneven motion caused by revolution of the feed gearing.

CINCINNATI SHAPER COMPANY'S CRANK SHAPER.

Our engraving shows one of the Cincinnati Shaper Company's 24-in. B. G. Crank Shapers, driven by a Westinghouse type S

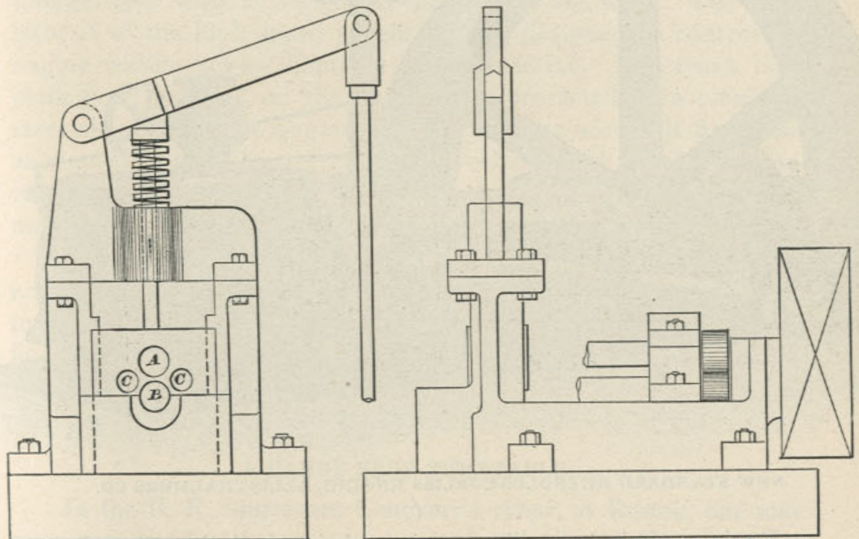


CRANK SHAPER, CINCINNATI SHAPER CO.

variable speed motor. This is also for two-voltage, three-wire system, and the motor develops 2 and 4 h.p. at 115 and 230 volts respectively. The connection of the motor to the shaper is through the Reynolds silent chain, and is clearly shown in the photograph. On this machine the 4-step cone is left off, and the sprocket wheel for the silent chain attached to the cone shaft. The machine is their regular 24-in. B. G. Shaper, with automatic power down feed and with table support attached.

MACHINE FOR EXPANDING AND SWAGING FLUES.

The accompanying engraving shows a very satisfactory tool which is in use in the Pittsburgh shops of the American Locomotive Company for expanding and swaging flues. It is a simple machine

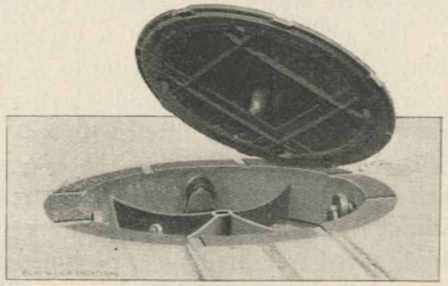


Railway & Locomotive Engineering

FLUE EXPANDING AND SWAGING MACHINE.

operated by belt power, and consists of four rolls, one of which, marked B, is used at all times; the others, carried in a guide, are raised and lowered by a treadle. When it is desired to expand a flue it is put on roller B, and roller A is brought down upon it and a few turns of the tube complete the operation. For swaging, rollers C C are brought in contact with B, which has a shoulder at the portion with which rollers C C come in contact. A few turns of the

On the under side, the circular path, which moves over the four rollers when the table is turned, is chilled so as to reduce wear to a minimum while it gives a hard, smooth surface. In this chilled pathway for the wheels are four notches or depressions. These are so spaced that when the table is in position the small roller which can be seen in the engraving as standing by the near margin of the frame close to the left hand rail, engages with one of the depressions, thus making an effective lock which holds



SHOP TURNTABLE, B. F. STURTEVANT CO.

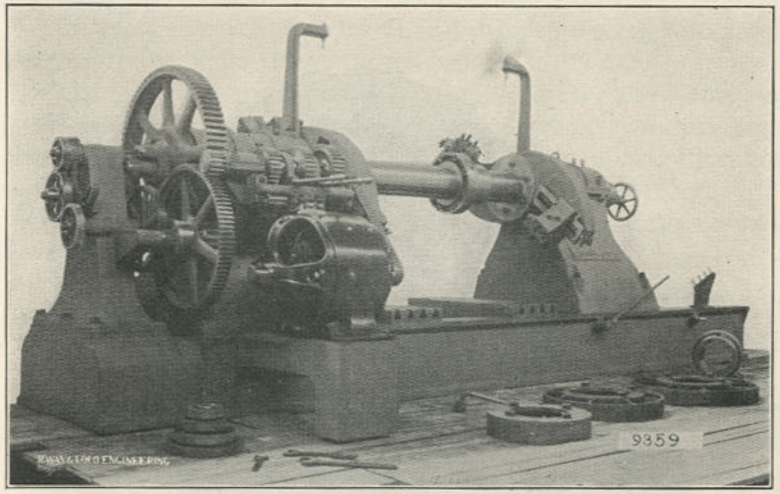
the tracks in register. The small roller or lock wheel is held up by a spring which acts automatically and stops the table at each quarter. Exact centering is secured by a chilled conical bearing at the center, upon which the table turns. The bottom frame is let into the floor so that the top flange is flush. The whole is substantially made and well braced. The table is a good example of a well designed and serviceable piece of shop furniture.

WHEN AN ELECTRIC SHOCK HAS BEEN RECEIVED.

The means for resuscitation in electric shock accidents are the same as those for apparent death by drowning. That is a most important fact. Accidental shocks seldom result in absolute death unless the victim is left too long unaided, or efforts at resuscitation are stopped too early. It is well also to remember that the victim seldom receives the full force of the current in the circuit, but usually only a shunt current which may represent a very insignificant part of the whole. Well directed effort, persevered in faithfully, will in the great majority of cases restore those who have been "struck by lightning" in any form. As so many of our railroad companies have electric adjuncts to both shop and road, the diffusion of this kind of knowledge is most important.

NILES CYLINDER BORING MACHINE.

Annexed engraving shows a Cylinder Boring Machine, made by the Niles Tool Works, Hamilton, O. It is driven by direct-connected motor through Renold silent chains. The machine will take cylinders up to 37 ins. in diameter and 60 ins. long. The boring bar which is 10 ins. in diameter is provided with various sizes of interchangeable cutter heads traveling on the bar by hand and var-



NILES CYLINDER BORING MACHINE.

iable power feeds. The bar may be traversed out of the work by moving the tailstock by ratchet. Speed-change clutch levers are conveniently located for the operator, and with a range of speeds in the motor enables a very quick and close adjustment to the desired speed. It is driven by a Bullock electric motor. The machine is provided with double-facing heads.

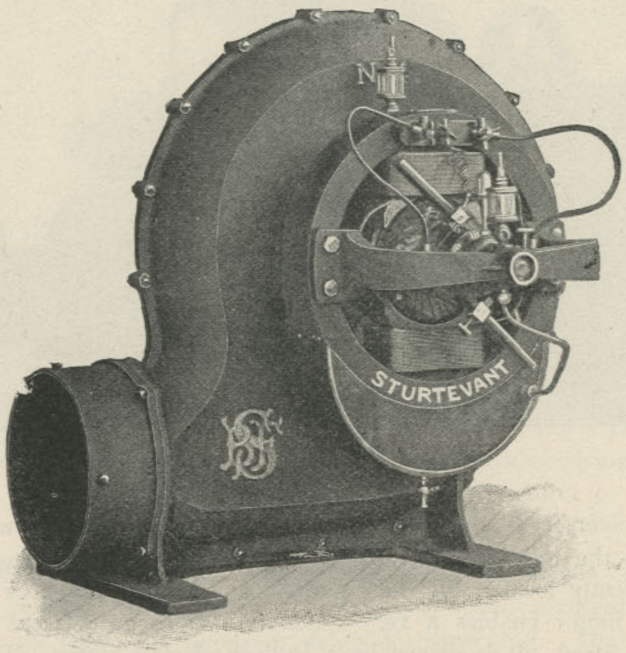
AN ENCLOSED ELECTRIC FAN.

The demands of manufacturing frequently make it necessary that motors attached to fans should be thoroughly enclosed and protected from dust or moisture. This is particularly true in the case of the iron industries and in foundry practice.

To meet this demand there has been designed, and is now being built by the B. F. Sturtevant Co., of Boston, Mass., a line of enclosed electric motors with encased blowers as shown in the accompanying illustration.

The field ring of the motor forms a part of the enclosing shell, which is complete by the attachment to the hemispherical ends as clearly indicated. The ring is attached to and centered by three lugs projecting from the fan side. As both ends of the motor are enclosed, there is no opportunity for the drawing of dust across its moving parts.

The door in the outer end renders the interior perfectly accessible.



In small sizes such a fan is readily portable and of great utility under many conditions, for it is particularly true in foundry practice that a fan might be placed much nearer the cupola if it were not for the inconvenience in transmitting power, but with such an arrangement it is perfectly feasible to place it in close proximity.

In the accompanying illustration is presented one of the Sturtevant Monogram Type Electric Fans. The shell of the fan is of cast iron, exactly similar in proportion and form to that used in the regular Monogram blowers and exhausters. This fan is arranged as an exhauster, having the side to which the motor is attached entirely closed, so that air and dust will not be drawn across the motor.

The field ring of the motor is of wrought iron, and is bolted directly against lugs which projects from the side of the fan.

The poles are two in number, also of wrought iron, and carry the field windings as shown.

The armature is of the drum-wound type, and the shaft carrying the same is supported in ring oiler bearings suspended in yokes projecting from either side of the field ring.

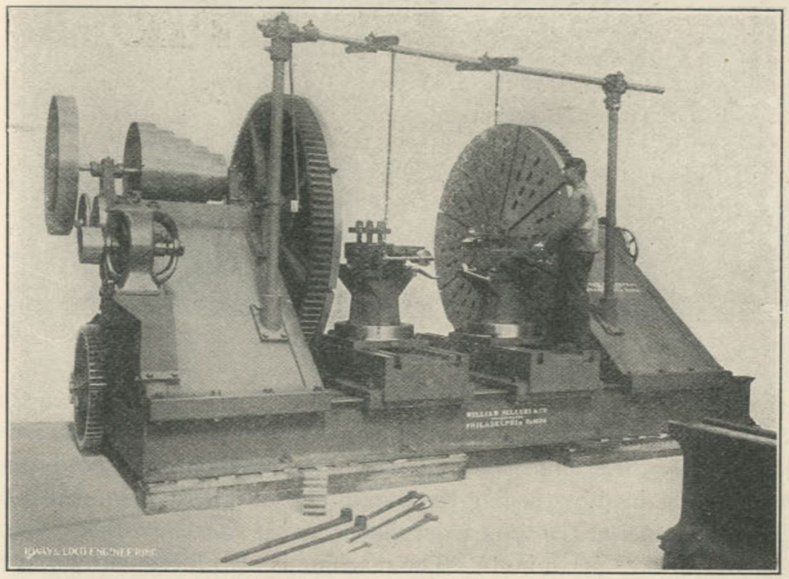
To avoid any trouble from oil, it is dripped directly into a tank attached to the under side of the field ring.

The entire arrangement is extremely compact and stable, and is susceptible or support in any desired position. In very small sizes it is sufficiently portable to be used for temporary location, as for instance, in different parts of the hold of a ship.

Plants of this type are usually built to operate at pressures of from 1 oz. to 5 oz. per sq. in.

SELLERS' HUNDRED-INCH LATHE.

The driving-wheel turning lathe here shown, made by William Sellers & Co., Philadelphia, is a tool which has great capacity

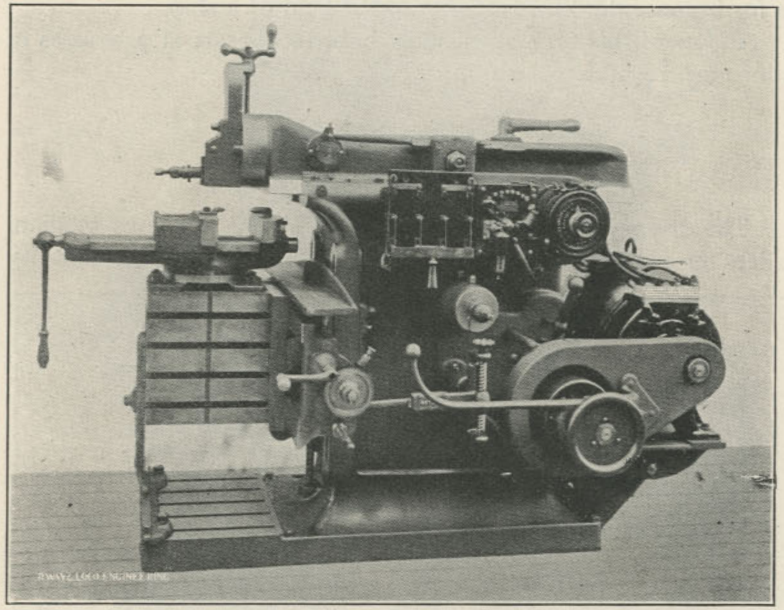


SELLERS' WHEEL LATHE.

for doing work expeditiously. It has two powerfully geared heads and two extra heavy compound rests, operated by electric motor attached to the machine. Both heads have very large steel sliding spindles, with steel extension bearings and clamps. All gears are cut from solids. When operated by counter shaft, fast and loose pulleys are 36 ins. diameter by $7\frac{1}{2}$ ins. face, to make 120 revolutions per minute. A quartering attachment is supplied when required.

EBERHARDT'S EXTENSION BASE SHAPER.

The annexed engraving illustrates the 24x26-inch extension base shaper fitted with direct connected variable speed electric motor



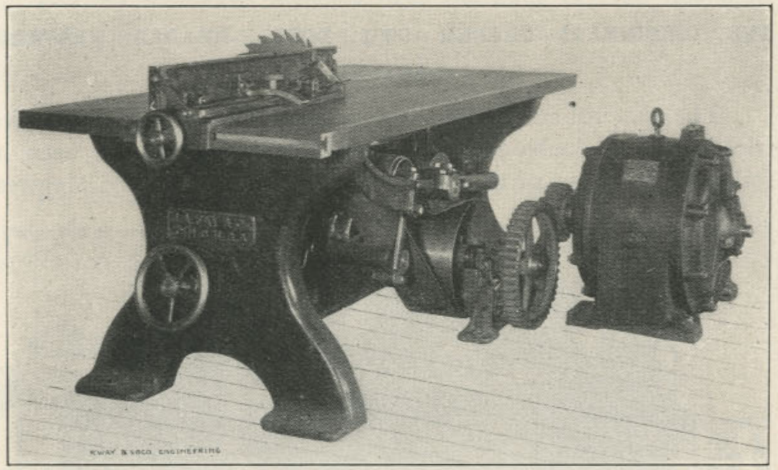
GOULD & EBERHARDT SHAPER.

drive, recently put on the market by Gould & Eberhardt, of Newark, N. J. This tool is one of the most complete equipments of the kind that has ever been put on the market. The variations in speed are instantly obtained by turning the round rheostat knob shown mounted on the panel at the top of the shaper and it can be worked from 5 to 100 strokes per minute. The machine is also fitted with a particularly efficient clutch and brake arrangement controlled by a long

lever which enables the operator to instantly stop the shaper at any point of the stroke without stopping the motor and waiting for it to run down. It also saves time in starting up, in not having to wait for the motor to get up speed again. All controlling handles operate while standing in the working position at the front of the machine. The shaper itself is of a re-designed pattern, which has been strengthened and made more powerful, so as to obtain the fullest benefits from the new "high-duty" cutting steels. The Pennsylvania Railroad Company ordered fourteen of these machines for use in their new shops and subsequently increased the order to eighteen. This shaper is very popular in locomotive-building shops and quite a number of them have been purchased for the various works.

LARGE SIZE CAR RIPPING SAW TABLE.

The machine we illustrate here is made by the J. A. Fay & Egan Company, of Cincinnati. It possesses great strength and durability and is designed for the heaviest class of work in car



LARGE SIZE CAR RIPPING SAW, MOTOR DRIVEN.

shops, shipyards, etc. The frame which supports the saw and table consists of two solid ends bolted to a heavy ribbed plate connection upon which the saw frame is gibbed, giving it great solidity while leaving all parts easy of access.

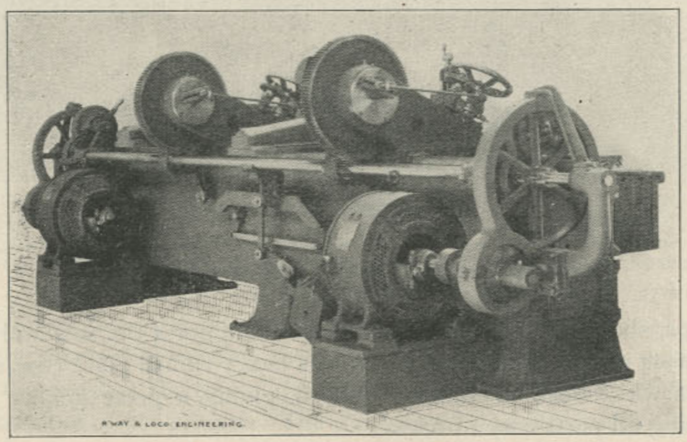
The top may be either iron or wood 72x40 ins., planed true and low, to allow all heavy lumber worked upon it to be handled easily. The arbor is 1⅜ ins. diameter where the saw is placed, with heavy journals designed to carry saws 36 ins. diameter. It has a patent-expanding device which allows saws with different-sized holes to be used without bushing.

The arbor runs in self-oiling boxes, attached to arms pivoted to the frame and raised or lowered by means of a hand wheel at the end of the machine. The saw can be quickly adjusted to different thicknesses of lumber, while the table remains at the same height. A belt tightener pulley maintains a uniform tension on the belt no matter at what height the saw may be working.

The machine is provided with a patent adjustable saw gauge, the side of which is graduated. It moves in a slot in the end of the table, leaving the face of the table without bolt holes. The saw gauge can be adjusted for sawing beveled work, and can be set at a right angle without squaring. The tight and loose pulleys are 14 ins. diameter with 8-in. face, and should be run at a speed of 550 revolutions per minute. A neat electric motor, geared to the pulley shaft, drives the machine

THE CINCINNATI SHAPER CO.'S DOUBLE-HEADED TRAVERSE SHAPER.

The annexed cut shows the Cincinnati Shaper Company's electrically driven double-head Traverse Shaper, which has been installed in the shops of the Locomotive & Machine Co., of Montreal,



DOUBLE-HEADED SHAPER

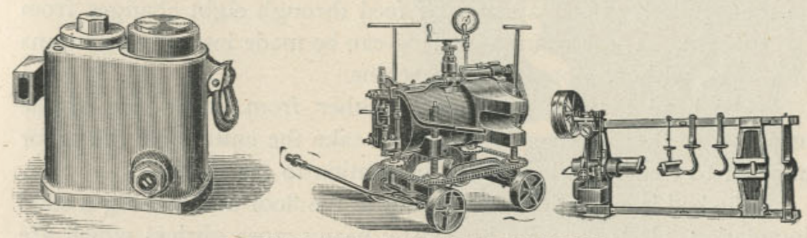
Can., being one of two machines thus equipped, the other being a 24-in. double-head machine, and one of four placed there, the other two being belt-driven shapers.

This machine is operated by two Westinghouse motors, arranged for a two-voltage, three-wire system, rating at 3 and 6 h.p. at 115 and 230 volts respectively. The variation in speed of machine is obtained through variations in the motor and also by back gear on the machine, which may be seen through the large gear wheel on one of the two splined shafts at back of the machine, this large gear wheel being driven by pinion mounted on the motor shaft.

The two heads on the Traverse Shapers are driven independently, one from each end of the machine, and as they are arranged to work at any point along the bed, it is necessary that they travel past the center; but owing to the length of the splined driving shaft, by which the heads are driven in a machine of this length, the makers have provided a support at the center of the bed for the splined shaft, which is clearly shown and have made this support to be depressed automatically when either head is passing the center of the bed. The arrangement is very clearly shown in the cut. In the machine in question, the travel of each saddle is 118 ins., and the maximum distance from the tools 144 ins., the minimum distance 26 ins. The weight of the machine is about 14,000 lbs.

MACHINE TOOLS.

We illustrate here three very useful and necessary tools for the repair shop. The double pump, portable crank-pin press, made by the Watson, Stillman Company, is a most powerful tool adapted to a



WATSON, STILLMAN COMPANY TOOLS.

variety of service and capable of exerting a power of 250 tons. The hydraulic journal box jack is an absolute necessity since the advent of the large capacity cars. The belt power wheel press, made in various sizes to accommodate wheels from 38 ins. to 78 ins. and exerting from 60 to 300 tons pressure, has all the latest improved attachments.

NEW PLANER TYPE MILLING MACHINE.

This machine, illustrated on page 393, is built from new designs and new patterns and is of very heavy construction. It is designed for strength, rigidity and power, with special provisions for ease of operation and the demands of modern milling machine practice. It is built by the Becker-Brainard Milling Machine Company, of Hyde Park, Mass. The machine is 32x26 ins. by 10 ft., and is of the planer type of milling machine.

The spindle is made of hammered crucible steel, 5 ins. in diameter, has a threaded nose and runs in self-centering bronze boxes with a nut and check nut to compensate for wear. The spindle carrier is heavy and is held firmly to the upright by long gibs. It is elevated by a screw with adjustable dials graduated to thousandths of an inch and has a counterbalance for ease of operation. There are 20 changes of speed for the cutter spindle obtained by gearing in the main driving cone, operated by clutch and lever, so that all changes can be made instantly.

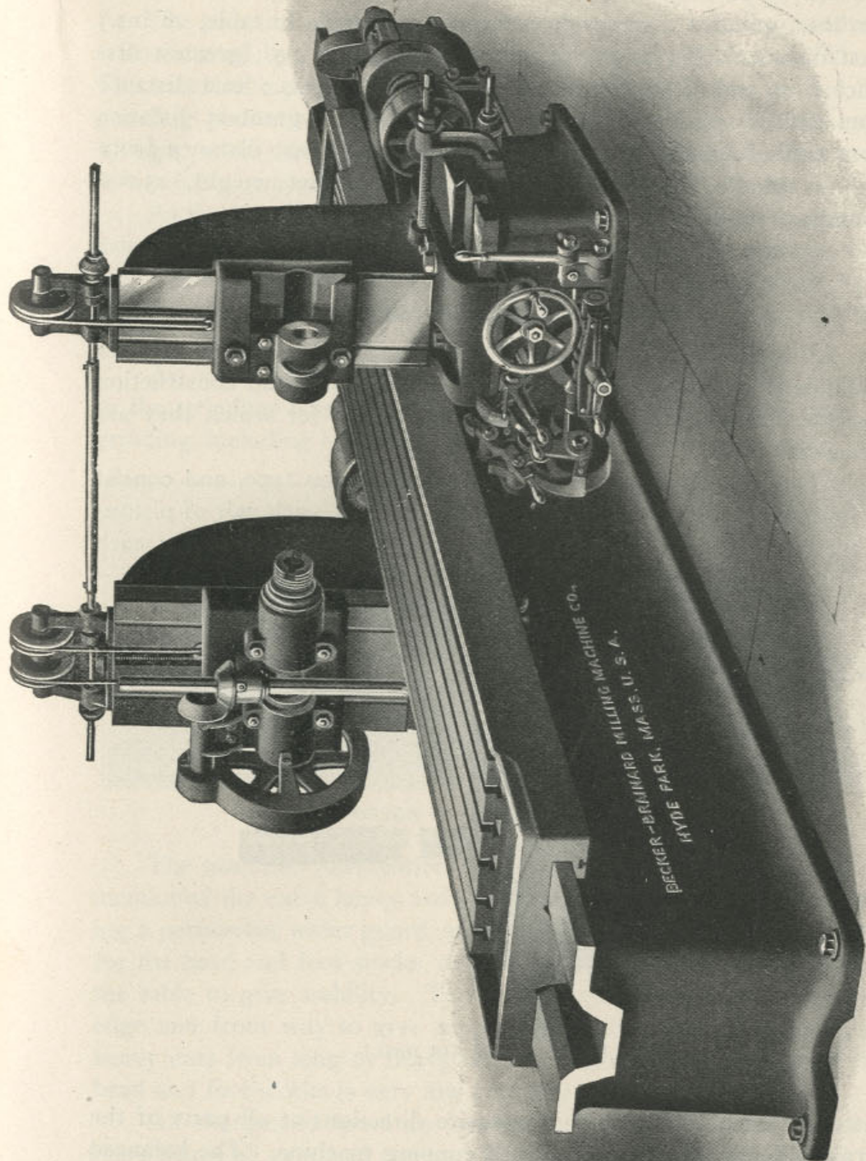
The table is very heavy and is regularly built with five T slots lengthwise, and an oil channel the full length and at each end. It travels on flat ways securely gibbed and has a quick return operated by power from a separate countershaft. It can also be moved by the usual hand wheel.

The feed of the table is directly operated through gearing from the spindle at ratios of $13\frac{1}{2}$ and 27 to 1 by 5 in. belt on a 5-step cone, the diameter of which is 23 ins. on the largest step and 13 ins. on the smallest, giving a range of feed through eight changes from $\frac{3}{64}$ to $\frac{3}{8}$ in. These changes of feed can be made instantly by means of a lever, without stopping the machine.

The head may be adjusted in either from either side of the machine, so that it is not necessary to take the cutters off the arbor in order to change their position in relation to the work.

The bed is extra deep, extending to the floor and making a solid foundation. It is securely braced by heavy cross girders which are evenly spaced throughout the entire length. The bed can be made any length desired.

The specifications are as follows: Working surface of platen, 120 ins. by 26 ins.; length of bed size of platen inside oil pockets,



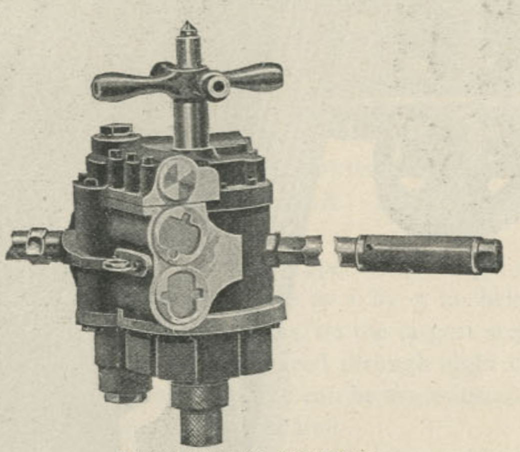
BECKER-BRAINARD PLANER TYPE MILLING MACHINE.

120 ins. by 26 ins.; longitudinal feed, automatic in both directions, 120 ins.; greatest distance from center of spindle to table, 28 ins.; least distance from center of spindle to table, 2 ins.; greatest distance from end of spindle to center of table, $16\frac{3}{8}$ ins.; least distance from end of spindle to center of table, $6\frac{3}{4}$ ins.; greatest distance from end of spindle to tail stock pin, 37 ins.; least distance from end of spindle to tail of stock pin, 17 ins.; net weight, 25,000 pounds.

LITTLE GIANT PISTON AIR DRILLS.

All Little Giant Drills and Reversible Machines are made after a standard design or pattern, varying only in size and construction necessary to adapt them to the particular uses for which they are intended.

These machines are of the "balanced" piston type, and consist of four single-acting cylinders, arranged in pairs, each pair of pistons being connected to opposite wrists of a double crank shaft; each



LITTLE GIANT AIR DRILL.

piston of each pair travels in opposite directions at all parts of the stroke, thereby insuring a smooth running machine. The balanced piston valves are set to cut at $\frac{5}{8}$ of the full stroke, thus insuring great economy in the use of air without sacrificing speed or power.

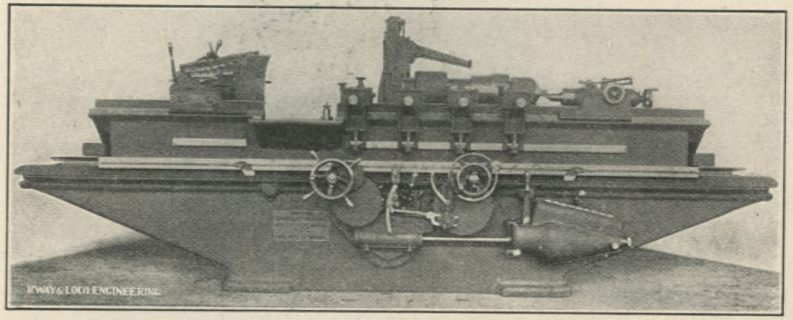
This useful little tool, the invention of the Chicago Pneumatic Tool Co., can be put to a great many uses, among which with the proper attachments are the flue cutter and steam-ring grinder.

NORTON GRINDING MACHINE.

The annexed engraving shows the 18x96 plain grinding machine manufactured by the Norton Grinding Company, Worcester, Mass. This machine is particularly useful for railroad shops and is used for grinding piston rods, valve stems, crank pins, axle journals, etc. The gap in the table allows the regrinding or repairing of piston rods in use without entailing the necessity of removing the head.

As the increased efficiency over the old method of ground cylindrical surfaces is becoming manifest to many railroad officials, this tool deserves special attention. The machines do the work very rapidly, but there is sufficient rigidity to prevent spring, and the driving power is ample.

As an example: Piston rods sent for repair are taken directly to the grinding machine without any lathe work, and the time of grinding, including handling, is on the average 15 minutes each.



NORTON GRINDING MACHINE.

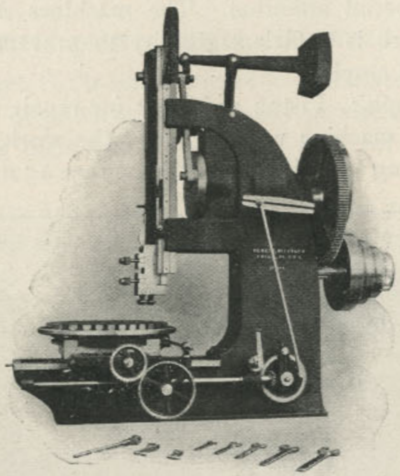
The machines have entirely new features, among which may be mentioned the extra heavy swivel tables of triangular section, forming a permanent water guard, and a two-way front and back support for the head and foot stocks, one of these ways being at the base of the table to give stability. The table is very rigid along its upper edge and front way to give support to steady rests when grinding heavy cuts from long or heavy work. The center of gravity of the head and foot stocks is very low and they rest on a wide base.

All changes of speed are conveniently effected at the machine, there being no overhead cones. This feature will be appreciated by all, and especially by those who have high ceilings.

There are sixteen changes of table speed, six changes of wheel speed, and eight changes of work speed. All changes can be made without stopping either the table, work or wheel. These machines are arranged for electric drive when so ordered.

22-INCH CRANK SLOTTING MACHINE.

The very powerful crank slotting machine here shown is made by the Bement & Niles shops, belonging to the Niles-Bement-Pond Company. The cutter bar is counterbalanced and has Whitworth drive, with quick return and adjustment for any length or position of stroke. It is provided with spring relief tool apron; having both vertical and horizontal clamping surfaces. Directly behind the cutter bar is a reinforcing slide which is adjustable vertically by hand.



22 IN. CRANK SLOTTING MACHINE, NILES-BEMENT-POND CO.

Maximum stroke, 22 ins. The table is circular, 40 inches diameter, with pan on circumference for collecting lubricant. It is provided with hand or power longitudinal feed of 48 ins., cross feed of 41½ ins.; also circular feed; all variable and operated by a cam at the upper end of the stroke and controlled from one convenient position. Height of frame above surface of table, 24 ins. Distance from front of tool apron to frame, 36 ins.

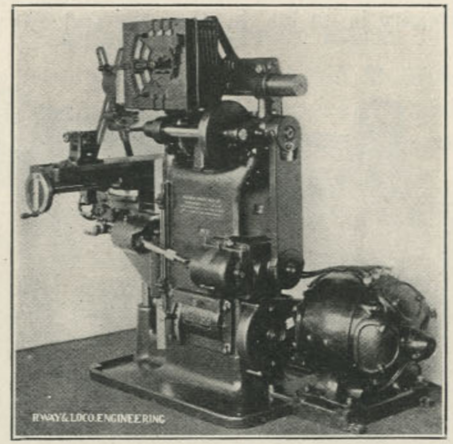
BROWN & SHARPE'S NO. 3 UNIVERSAL MILLING MACHINE.

Annexed illustration shows a motor-driven No. 3 Universal Milling Machine, made by the Brown & Sharpe Manufacturing Co., Providence, R. I.

The drive is by a constant-speed motor connected to the spindle-driving mechanism by a chain and sprocket wheels; the chain

is of the Hans Renold silent type. The advantages of the constant-speed motor are apparent, for the reason that the full efficiency of the same is at all times available.

The gearing for obtaining the various spindle-speed changes is attached to the apron shown at the bottom of the stand. The plate on the front of this apron gives the various speeds that can be obtained with the back gears in or out of position. The gearing consists of a cone of gears similar in construction to that shown



UNIVERSAL MILLING MACHINE, BROWN & SHARPE.

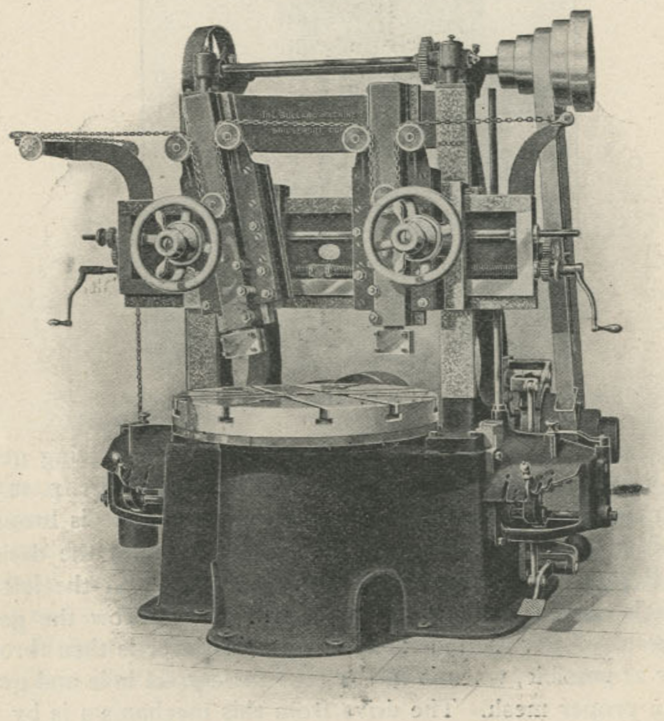
by the company's circular marked A. The spindle-driving gears provide for 10 different speeds, varying from 17 to 416 r. p. m.

To change the feed, the index slide over the plate is brought to a position over the column on the plate containing the desired speed. Before this index slide is moved, the lever at the left of the plate is moved down as far as it will go to throw the gears out of mesh. After the index slide is set, this lever is then thrown up as far as possible, when it will engage the correct hole and gears will be in proper mesh. The drive from this mechanism is by the Hans Renold chain directly to the spindle sleeve, which, in this case, replaces the usual cone and head. This chain is also of the Hans Renold silent type.

The variable feeding mechanism is new in design, and embodies many features not heretofore incorporated in mechanism employed for this purpose. The gearing of the mechanism itself being spur gears, all with properly arranged bearings, and the drive through a telescopic shaft to the feed-clutch gears in the knee being also by spur gears, the loss of power by friction is slight and the efficiency unusually great. It gives a wide range of feeds, varying in geometrical progression, that fully covers all the requirements of modern milling practice.

37-INCH BORING AND TURNING MILL.

The annexed engraving shows the 37-in. boring and turning mill made by The Bullard Machine Tool Company, Bridgeport, Conn. The capacity is 42 ins. in diameter and $32\frac{1}{2}$ ins. in height.

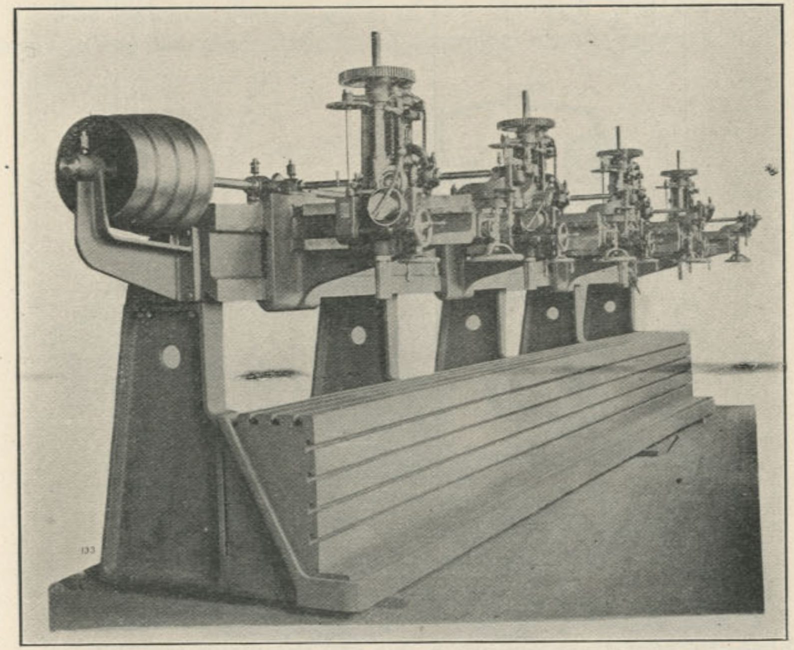


BULLARD BORING AND TURNING MILL.

The table is $37\frac{1}{2}$ ins. in diameter, is powerfully geared, and has ten changes of speed. The teeth on both table and pinion are accurately planed. The heads are entirely independent in their movements, both as to direction and amount of feed. They can be set at any angle and carry the tool bars, which have a movement of 19 ins. Either head can be brought to the center for boring. The feeds are positive, have ten changes, and range from $\frac{1}{37}$ to $\frac{3}{4}$ of an inch horizontally, and from $\frac{1}{50}$ to $\frac{1}{2}$ an inch in angular and vertical directions. The cross rail is raised and lowered by power. The cone has five sections for $2\frac{1}{2}$-in. belt, the largest being 18 ins, in diameter. A brake and belt shifter are both provided as shown. The countershaft has two pulleys 14 ins. in diameter, for $4\frac{1}{2}$-in. belt, and should run 400 revolutions per minute, forward.

BICKFORD MULTIPLE DRILL.

Our illustration here shows a Bickford Multiple Drill for locomotive frame work built for the Locomotive & Machine Co. of Montreal. It is one of the most advanced tools made and has many ex-



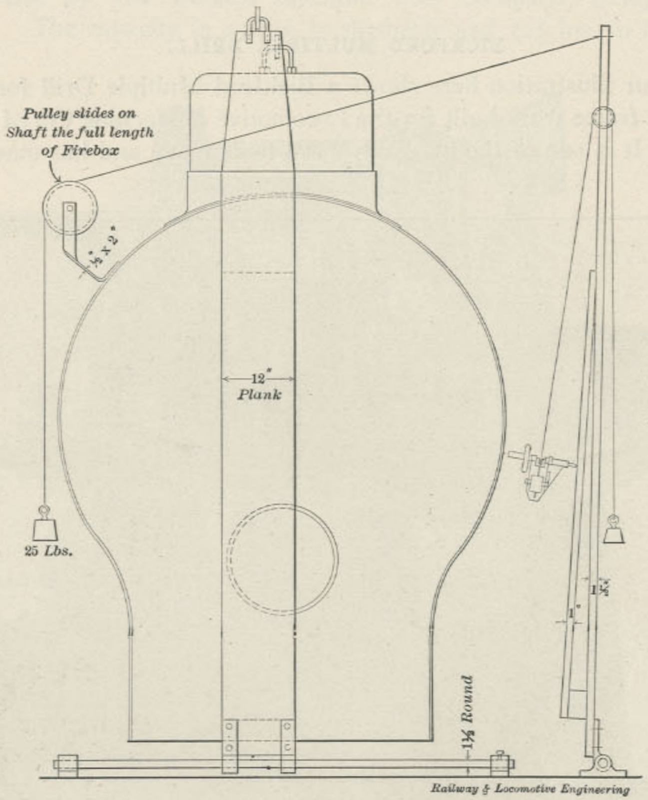
BICKFORD MULTIPLE DRILL

cellent features. The back gears are so arranged that they may be instantly engaged, disengaged, or the spindles stopped altogether, by one stroke of the lever. It is of much value for other purposes and readily adaptable to a wide field of usefulness.

APPARATUS FOR DRILLING STAY BOLTS.

The accompanying illustration shows a handy apparatus for drilling the small tell-tale holes in the ends of stay bolts, which many railroads require to be done when buying new equipment. It is used in the Pittsburgh shops of the American Locomotive Company.

The apparatus consists of an upright plank $1\frac{1}{2}$ ins. thick, hinged at the bottom upon a $1\frac{1}{2}$ in. round iron rod which lies just



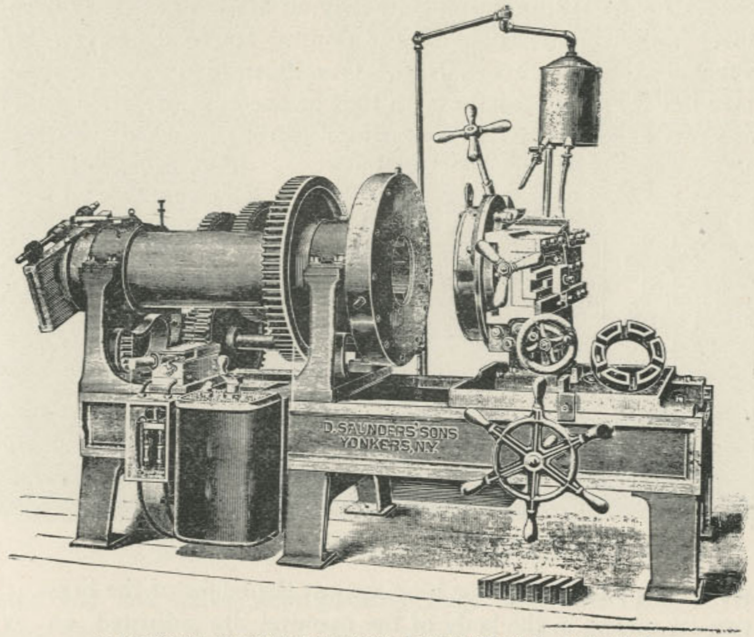
APPARATUS FOR DRILLING STAY BOLTS.

above the floor level, and upon this rod the plank can slide so as to stand opposite any portion of the fire box sides or end. The long upright plank is held at the top by a cord leading to a small weight. The cord passes over a pulley which revolves upon a shaft held at each end by temporary brackets. The pulley also slides along this shaft as the board is moved along the side of the fire box. The board for drilling stays in the end of the fire box has a

counter-weight pulley which can swing on a pin that fits the socket of a dome stud. The plank also carries a smaller one, made out of 1 in. stuff and perforated so as to hold the end of a small drill. The drill is also similarly counterbalanced with cord and pulley so that the workman is not fatigued by constantly supporting the weight of his machine, and is thus enabled to devote his entire attention to the accurate performance of the work in hand. The plank can be drawn back, or pushed toward the fire box at the top so that the required angle for the drill is easily got, and as the weight of the board is practically balanced, very little exertion on the part of the workman is required to hold it as he may require it. The whole rig is very simple and very ingenious, and is a time and labor saver in the shop.

SAUNDERS' PIPE THREADING MACHINE.

The annexed illustration is of the Standard Pipe Threading and Cutting Machine, made by D. Saunders' Sons, Yonkers, N. Y.,

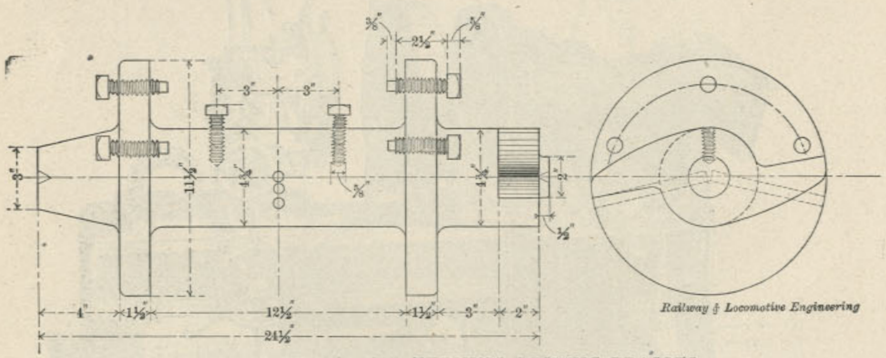


SAUNDERS' PIPE THREADING AND CUTTING MACHINE.

and very favorably known in railway shops. The engraving represents Nos. 5 and 6 machines, with direct connected electric motor. The electrical equipment consists of a Standard round type Lundell motor, Standard rotary controller for forward and reverse speeds, armature and field resistance, circuit breaker and main line switch. Motor is compound wound operating at standard rate of speeds. It is entirely enclosed, having suitable trap doors at commutator end, to enable access to brushes and commutator. Upon the motor shaft is mounted a suitable steel pinion which meshes into a cast-iron cut gear wheel located upon driving shaft of machine. The motor is substantially mounted upon cast-iron brackets, which are bolted fast to the bed of machine. Beneath the brackets is fastened the necessary armature and shunt field resistance, which is used in connection with the controller for operating the motor at its various speeds. This resistance is self-contained, and is so constructed that it is practically indestructible, the resistance wires being entirely enclosed in special iron box castings, making same both oil and fire proof.

HANDY MANDREL FOR TURNING DRIVING BRASSES.

A handy rig for turning up driving brasses has lately been put in operation in the shops of the Central Railroad of New Jersey, situated at Elizabethport, N. J. Our illustration shows a cast-iron mandrel for use in a lathe with lugs at one end for driving. There are two flanges cast on this mandrel, through each of which three



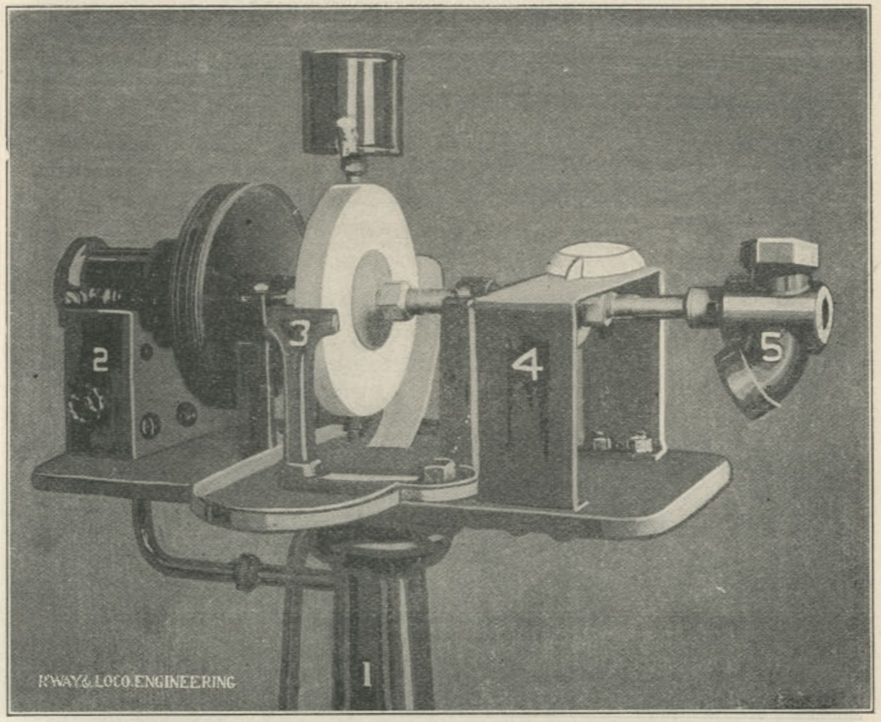
HANDY MANDREL FOR TURNING DRIVING BRASSES.

set screws pass, and these bear against the edges of the brass. The two set screws in the body of the mandrel are adjusted so as to hold up the crown of the brass inside, and the two dowels are for the purpose of having the brass rest on them during the process of adjustment. A brass held in place on this mandrel can be quickly turned off and removed by the slackening of three set screws at one

end. If the lathe hand has a number of the same kind of brasses to do, it is readily seen that time occupied in "setting" his work has been reduced considerably. The officials at Elizabethport speak very highly of the handiness of this appliance, and claim it to be a very good cost-reducing device.

A NEAT AIR-DRIVEN MACHINE.

The accompanying cut shows a neat stand (1) supporting a small air motor (2) which drives a shaft on which is arranged a cast-iron balance wheel, a small grindstone (3), a metal circular saw (4) ($\frac{1}{32}$ in. by 3 ins.) which is used principally to split metallic

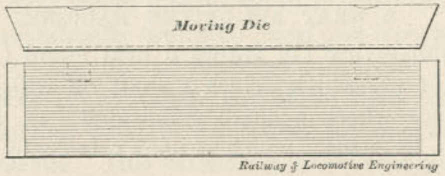


A VERY NEAT AIR MOTOR AND MACHINE.

piston rod and valve stem packing rings as shown, and on the end of the shaft is a small chuck which is used to grind valves in angle cocks as shown at 5; also air valves, etc. This is a machine in the shops of the New York, Susquehanna & Western Ry. at Stroudsburg, Pa., to whose officials we are indebted for this illustration.

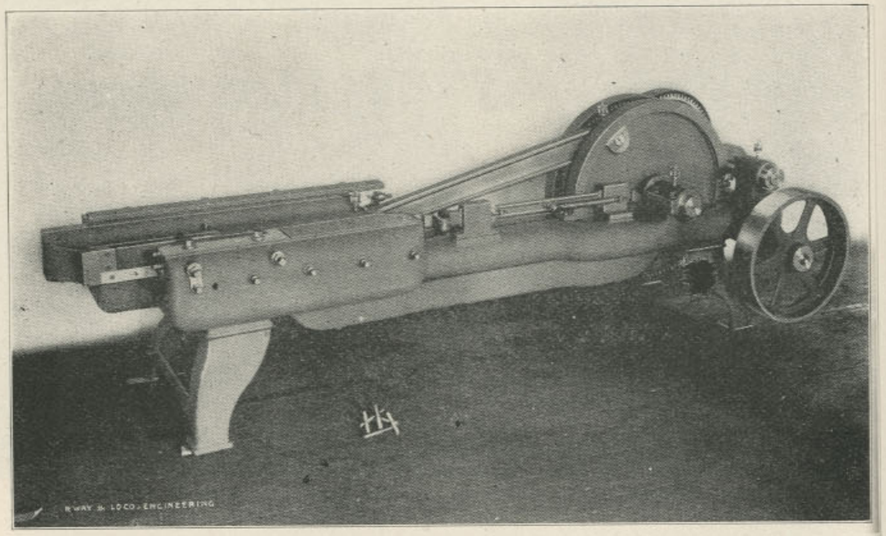
A SCREW THREAD ROLLING MACHINE.

A very ingeniously made machine for rolling the screw threads on bolts is on the market. The operation which makes the thread consists essentially of moving one thick, flat plate past another similar stationary plate, but without either of them coming in con-



MOVING DIE FOR ROLLING THREADS.

tact. Both these plates or dies are made of ground tool steel and have a series of grooves cut in them the exact shape of the screw thread which it is desired to cut. These dies are placed horizontally while the grooves which are quite straight are inclined and fall slightly, but regularly, from one end to the other.



SCREW THREAD ROLLING MACHINE, BLAKE & JOHNSON.

The screw thread on a bolt always descends or ascends exactly half the pitch in the distance of half the circumference; therefore, the lowest point of a groove on one die is placed exactly opposite the high point between grooves on the other die, and the dies are

spaced apart just the diameter of the bolt, measured across the base of the threads.

The stationary die is cut away the depth of the threads at the entering end for about one inch, so that the machine may get a grip on the bolt at the start and so force it to go in. When it is desired to roll a thread on, for example, a 1-in. bolt, the dies are set the proper distance apart and the operator takes the threadless bolt and places it the proper depth, determined by a stop, in the machine waiting for the moving die to draw back to the end of its return stroke. When the moving die begins its working stroke the bolt is caught between the dies and is rolled between them, the operator keeping his hand loosely on the revolving head. Just before the end of the stroke the bolt is rolled out and the operator removing it at once prevents the possibility of the return stroke drawing the bolt back into the machine.

The thread is, in this way, not cut on the bolt in the sense that it is cut by a tool in a lathe or by the dies of a bolt threading machine. The thread is formed by the upsetting of the metal and as no stock is cut away the burr, so often left by a cutting tool, is not formed. There is, however, a certain amount of scale from rough stock, and the fuzz from the finished stock which drops between the dies, as this would in time injure the lower slide, a slot is made in the bed plate, with a stripper attached to the slide, so that at each revolution the scale or fuzz drops into the slot and is thrown out by the scraper, thus insuring a clean working surface of the slide, which is not cut or scored in any way.

The largest size of thread rolling machine shown in our illustration is adapted to the rolling of threads on railway track bolts and all the heavier kinds of bolts and screws. The dies can be made equally well for rolling the U. S. standard, the Whitworth standard, Harvey grip, straight "V" and any other threads which may be desired.

The machines are made by Messrs. Blake and Johnson, of Waterbury, Conn., and are designed for all classes of machine screws up to $1\frac{1}{8}$ ins. diameter by $3\frac{1}{2}$ ins. long.

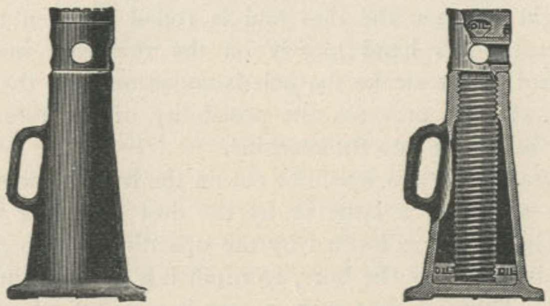
TO CLEAN RUSTY STEEL.

Mix ten parts of tin putty, eight parts of prepared buck's horn, and twenty-five parts of spirits of wine to a paste. Cleanse the steel with this preparation and finally rub off with soft blotting paper.

THE CHAPMAN JACK.

The base of the jack being closed and filled with oil the screw is always lubricated and protected from rust and dirt, consequently the jack is always ready for instant service. In common jacks with the open base, dirt and sand collect upon the screw, which soon start it cutting, increasing the friction and rapidly destroying the jack.

When common jacks have not been used for some time, the screws become set with rust and are frequently destroyed in efforts



to make them work quickly. This consideration alone makes the Chapman jack the most economical one to purchase. The cap of the jack has an oil chamber, and the top of the screw being cup-shaped the oil is retained and not forced out as soon as the load is applied, as in common jacks. This feature greatly adds to the life and easy working of the jack, as it entirely prevents the cutting between the surfaces of the cap and the screw, which is one of the greatest faults of common jacks.

The screws of these jacks are made from a special quality of machine steel, and are fitted up in the best manner, insuring good service and years of usefulness.

CAMEL'S-HAIR BELTING.

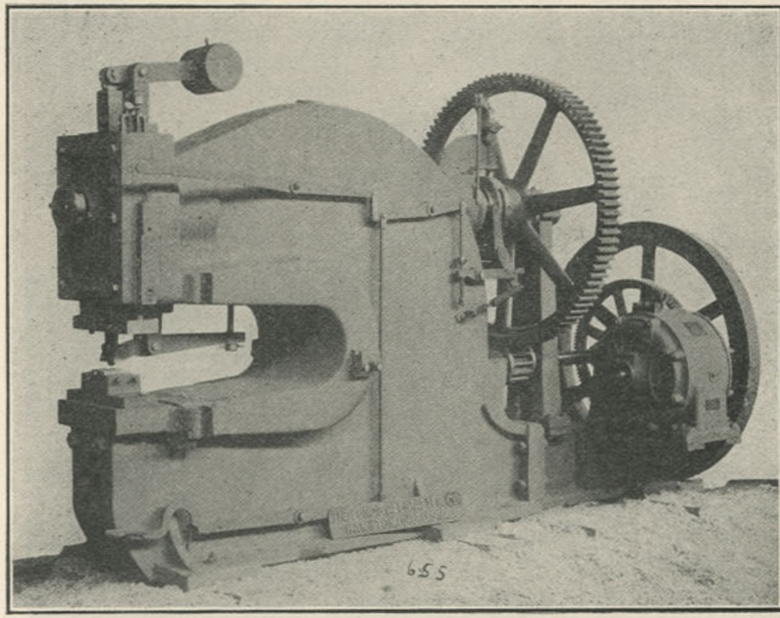
Camel's-hair belting has been the subject of experiments at the Polytechnic school, at Munich, from which it appears that the strength of camel's-hair belting reaches 6,315 pounds per square inch, whilst that of ordinary belting ranges between 2,230 pounds and 5,260 pounds per square inch. A contemporary says the camel's-hair belt is said to work smoothly and well, and it is unaffected by acids.

PUNCHING AND SHEARING MACHINE.

Annexed engraving illustrates a single punching and shearing machine with 36-in. throat, driven by a $7\frac{1}{2}$ h.p. induction motor.

The lower jaw is made with a removable block, increasing the scope of the machine's work so as to punch the flanges and webs of I-beams, channels, angles, etc. When this removable block is out the die block overhangs, providing room for the lower flange, while the upper flange rests on the die. The web can be punched with the same tools.

When the removable block is in place all other tools for plates and bars—for splitting, cross cutting and punching—can be used the same as on a regular machine.



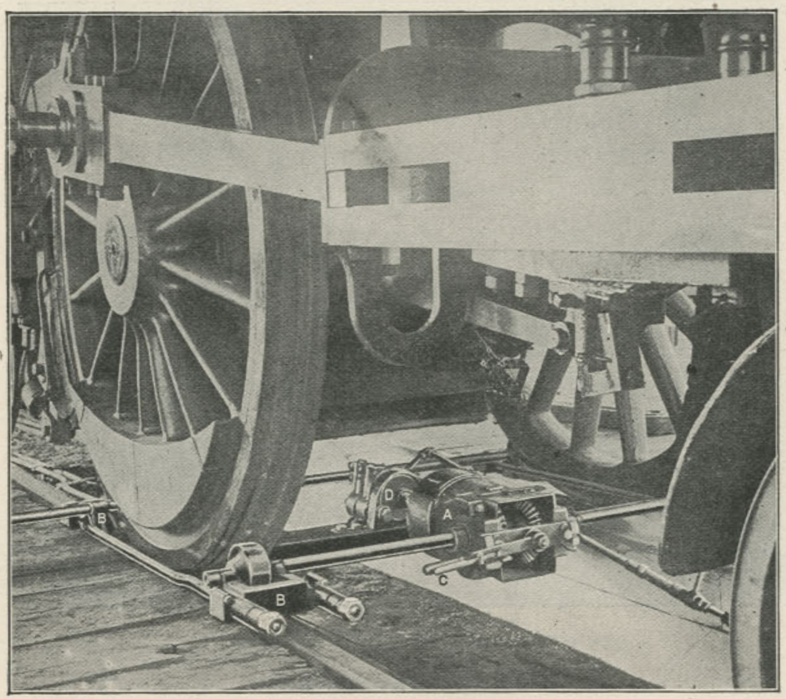
PUNCHING AND SHEARING MACHINE.

This machine has a steel-forged cam shaft—steel-faced clutch jaws—and steel-forged stripper, foot and hand levels. The slide is spring-weight balanced. An adjustable automatic stop brings the slide to rest at any point of the stroke. A safety lever prevents the clutch being thrown in gear except through the use of the foot or hand lever, thereby preventing accident through premature starting of the cam shaft. Provision is made for taking up wear in slide through tapering gibs and the face plate. An open-front punch holder provides for removal of the punch stock or adjustment of same.

The machine is made by the Long & Allstatter Company, Hamilton, Ohio.

WHEEL-ROTATING APPARATUS.

Those who have had to wrestle with the various old-fashioned methods of revolving driving wheels when the operation of valve setting is going on, will appreciate the arrangement shown in the annexed engraving in which the power from a pneumatic drill is

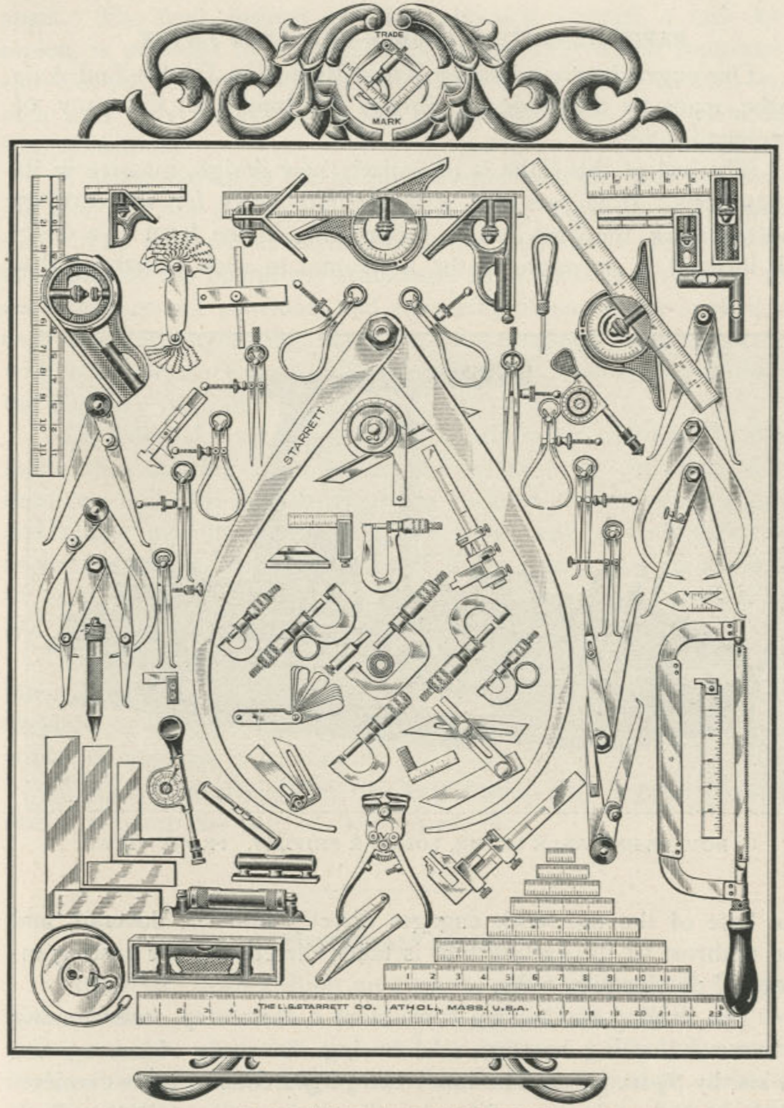


WHEEL-ROTATING APPARATUS.

used to operate the well-known Sherburne rotating mechanism. To a shopman who is interested in valve setting the picture needs no description. The apparatus is sold by Sherbourne & Co., Boston, Mass.

MACHINISTS' TOOLS.

The annexed engraving gives but a meager idea of the many and thoroughly up-to-date tools manufactured by the L. S. Starrett



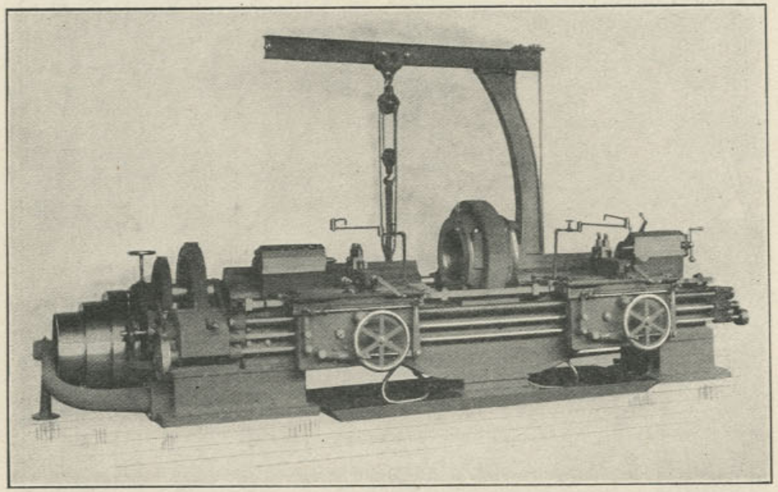
STARRETT MACHINISTS' TOOLS.

Co., of Athol, Mass. Made from the best material obtainable and by specialists in this kind of work, superior to anything of their kind on the market; accurate in every particular, they naturally appeal to any mechanic, where accuracy is the first and only consideration.

RAPID REDUCTION DOUBLE-END AXLE LATHE.

Our engraving represents a Rapid Reduction Double-End Axle Lathe, made by the Lodge & Shipley Machine Tool Company, of Cincinnati, Ohio.

The bed of this lathe is of entirely new design, massive in its proportions. It is provided with separate ways for the carriage and tail stock, the ways for the latter being in the form of a dovetail inclined at an angle to the horizontal in such a manner that



DOUBLE-END AXLE LATHE, LODGE & SHIPLEY. FRONT VIEW.

the base of the tail stock engages directly into the dovetail, and the upthrust of the cutting tool is taken directly by the casting instead of on clamping bolts.

The driving mechanism consists of a three-step cone running between self-oiling bearings and having diameters of 20, 25 and 30 ins. by 6½-in. face. The inner end of the cone shaft is connected through two changes of gearing directly to a short driving shaft at the back of the lathe. This driving shaft is geared into a central driving gear 30 ins. in diameter by 4-in. face, mounted between bearings at the center of the bed. An equalizing driving plate

transfers the power to the axle, and a 15-in. opening through the center greatly facilitates the insertion and removal of axles.

The carriages are arranged to take one or more tools, which can be placed anywhere along their length and varying distances apart. The feed, instead of being obtained through a rack and pinion, is provided by a bronze nut 14 ins. long which completely encircles the stationary lead screw, which is cut double thread, one-inch lead. By revolving the nut on this screw a more powerful feed is obtained.

A safety device in the apron prevents both the feed for turning and that for the quick movement being engaged at the same time. The hand-wheel movement to the carriage is always at the command of the operator. Automatic stops in both directions for each carriage are provided, and calipering stops can be applied to each tool for duplicating diameters; the combination doing away with considerable measuring and calipering. Shear wipers keep the way free from dirt and grit.

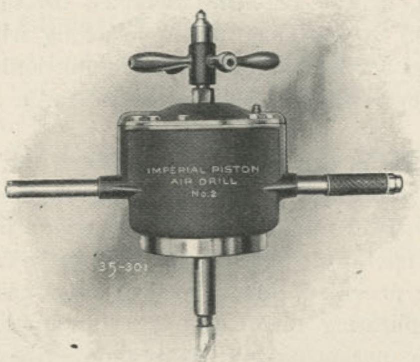
The tailstocks are shaped so as to allow the carriages to pass them when starting a cut at the end of the axle. In using more than one tool, this feature is of the greatest importance. A rack and pinion movement facilitates the movement of both tailstocks to accommodate different lengths of axles, and a pawl in the rear of each engaging in this rack forms a positive lock against the end movement.

The feeds obtainable on this lathe are six in number, as follows: 3, 5, 8, 11, 16 and 32 to one inch, any one of which can be obtained by a simple movement of a lever at the head of the lathe while the machine is running.

The complete weight of the Axle Lathe, with regular countershaft, oil pump and pan, is about 19,000 lbs.

"IMPERIAL" DRILLS.

"Imperial" drills exhibit an advance over conventional designs. The cylinders revolve on a fixed crank pin in which there are two ports, one for admission and one for exhaust. Thus, the crank itself, which is a steel forging case hardened and ground, serves as a valve and there are no eccentrics. The motor consists of three cylinders which are cast of steel in a single piece. The cylinders are 120° apart and radiate from a central hub. The cylinders, however, are not truly radial, but are set off ¼ in. to ½ in., according to the size of the drill. As a result of this set off the connecting rods are practically perpendicular to the piston head throughout the out-



"IMPERIAL" DRILLS. FIG. 1.

ward or working stroke, thus minimizing the wear of the cylinders and pistons.

"IMPERIAL" DRILLS. FIG. 2.

The cylinders are hung between triangular-shaped frames which revolve with them, the connecting rods of the pistons working on

the pins which rigidly connect the upper and lower frames. These frames are mounted on stationary disks upon which they revolve on ball bearings. The stationary crank pin, referred to above, is forged in a single piece with the upper disk, the center of the crank pin being set off from the center of the disk by a distance equal to one-half of the piston stroke. The cylinder hub through which the crank pin passes is bored with a taper hole and has a bronze bushing with corresponding taper, thus permitting of adjustment to take up wear. This tapered bushing has three parts, registering with ports at the end of each cylinder, and air is admitted to and exhausted from the cylinders successively through the ports in the crank pin as the cylinders revolve, the crank pin thus forming a Corliss valve.

All parts are perfectly balanced and all rotation takes place about fixed centers, resulting in absolute freedom from vibration and consequent long life for the tool. It will therefore be seen that, as admission and exhaust takes place only at this central crank pin, there is no necessity for having the casing air tight. This point is evidenced by Fig. 2, which shows the "Imperial" motor without casing working at 3,000 revolutions per minute. This is an advantage over designs where the casing must be kept air tight by packing.

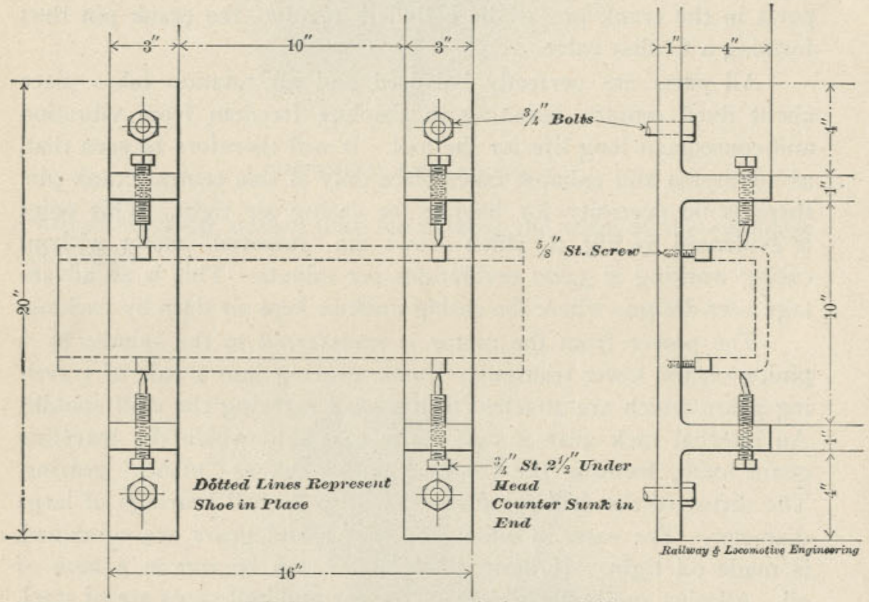
The power from the motor is transferred to the spindle by a pinion on the lower triangular frame, gearing into a pair of traveling gears which are attached to the head carrying the drill spindle. An internal rack gear is cut in the case into which the traveling gears mesh, forming the combination known as "planet" gearing. The thrust of the drill spindle is taken up by ball bearings of large diameter. The case, in which the motor and gears are contained, is made oil tight. If desired the motor can be run in a bath of oil. All pins and bolts subjected to wear and ball races are of steel, case hardened and ground, and all working parts are of phosphor bronze. This machine is built by the Rand Drill Co. of New York.

FLEXIBLE GLASS.

An article called flexible glass is now made by soaking paper of proper thickness in copal varnish, thus making it transparent, polishing it when dry, and rubbing it with pumice stone. A layer of soluble glass is then applied and rubbed with salt. The surface thus produced is said to be as perfect as ordinary glass.

PERCY'S WEDGE AND SHOE HOLDER.

The shoe and wedge holder shown requires little description, as any machinist will readily appreciate its use. John W. Percy, of the South Tacoma shops of the Northern Pacific, its inventor, says: I have used various kinds of shoe and wedge holders, but this one meets more of the requirements of a holder than any other I have seen or used, inasmuch as it does away with the small wedges used to raise and lower the corners. Then, beside, when the wedges are in use a heavy cut will disturb them and a second setting is necessary before taking finishing cut, but when shoe



PERCY'S SHOE AND WEDGE HOLDER.

or wedge is set up and fastened in place in this holder there is no resetting, as the set screws under the corners hold it up in place and the four spurs hold it down on the set screws.

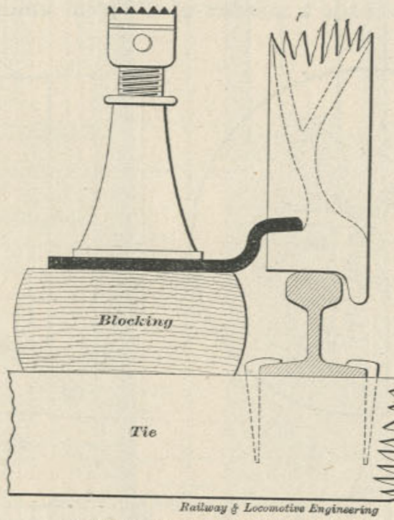
Then again, if a shoe or wedge has to be skimmed off again on account of engine not tramming, the operator places two parallels between or outside of each holder, then turns shoe or wedge up-side-down on parallels and skims flanges, then turns over and takes off the required amount. This last operation with the parallels saves the time of setting again to pop marks.

This holder can also be used to hold guides while being planed.

The two pieces of holder are separated to any required distance and by placing parallels under guide (as in skimming off shoe) we then hold the guide in place with the four spurs.

A HANDY RIG.

A handy rig for assisting the busy car repairer or roundhouse man when jacking up an axle box to take out a brass is here described. It consists of nothing more than a piece of heavy flat iron, say $\frac{3}{4}$x4 in., cut to a convenient length and lipped up at one end so as to rest on the rim of a wheel as shown in the illustra-



HANDY SHOP APPLIANCE.

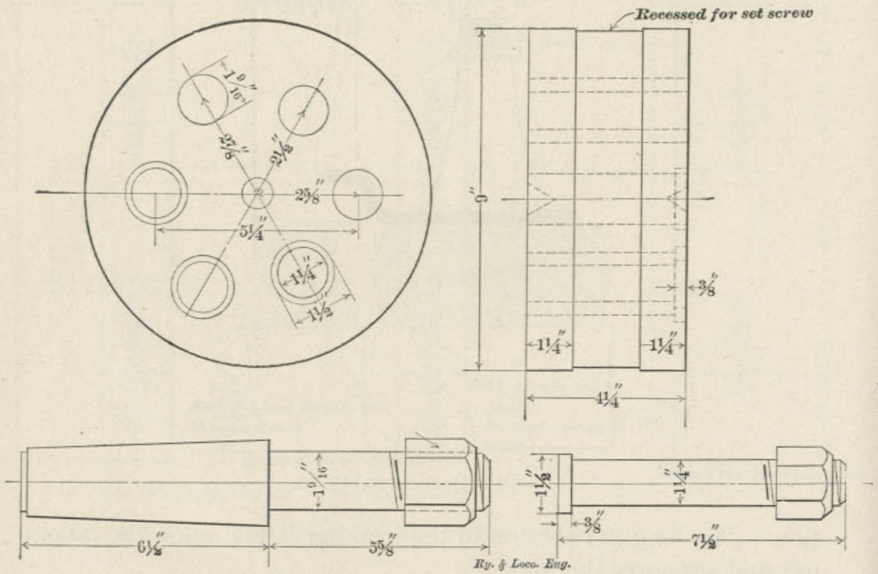
tion. The long flat portion of the iron bar is laid upon the blocking and supports the jack.

When pressure is applied to the underside of the axle box by working the jack the wheel is practically clamped down by the jack and the flat iron and the box has only to be raised far enough to free the wedge, and the brass may be easily removed.

In every-day life, where some such appliance is not used, when the weight is taken from the journal, the wheel rises up off the rail owing to the weight of the car resting on the journal at the other end of the axle and usually the wheel has to be held down by a helper who often does a sort of fantastic teeter-tauter act at the end of a long wooden lever or a pit plank before the wedge drops below the lugs in the box roof. Time and labor may be saved by the use of this handy little jack attachment, and the helper can be otherwise employed or at least can preserve his personal dignity during the operation, and that may be worth something at a crowded passenger station when working against time with a hot box, amid highly interested onlookers.

HANDY SHOP APPLIANCES.

The sketch of a slotter bar shown here has proved to be the best of any ever used in the Santa Fe shops at San Bernardino, Cal. They have made a number of different kinds of bars, but they

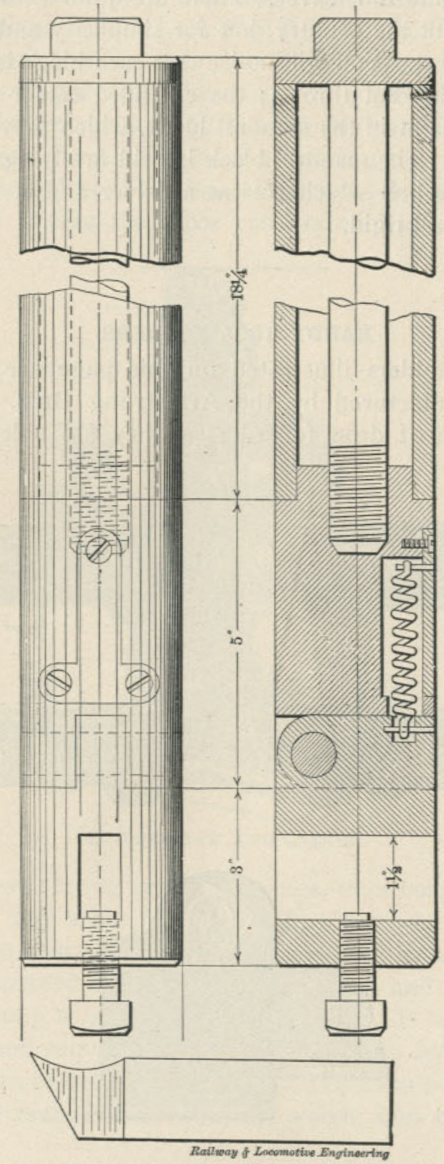


Extended center *Faceplate bolt*

MANDREL FOR TURNING LOCOMOTIVE ECCENTRICS.

have all been sidetracked for this one. You will notice that the position of the tool may be changed without stopping the machine, and if you wish to change tools, it is not necessary, as in the case of a solid tool, to stop the machine and loosen up four large clamp nuts. The small tools in this bar do not require dressing, owing to the fact that they are small enough to be easily ground to shape. This of itself is quite a saving both at the tool fire and at the steel rack. Instead of having three or four hundred pounds of steel in

the form of solid tools piled up by the slotter, which pile represents expensive blacksmith work, they use an easily made, neat little tool



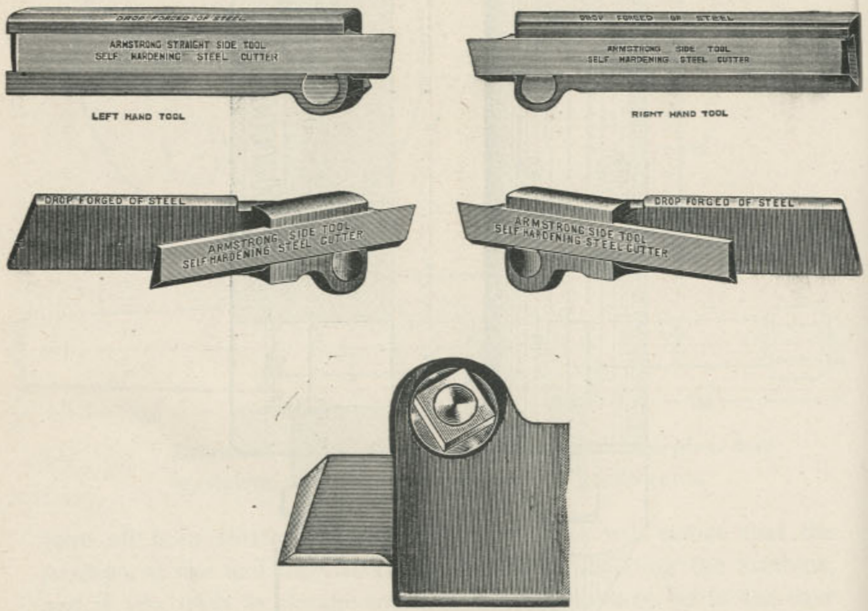
SLOTTER BAR, SANTA FE SHOPS.

which gives every satisfaction. This bar is not patented, and those who wish to prove its merits may do so by giving it a trial.

The sketch of the mandrel for turning up locomotive eccentrics used in the San Bernardino shops shows a tool worthy of note as a labor and time saver. There are quite a number of styles in use throughout the country, but for simplicity and accuracy this one is hard to beat. You will notice that each block is large enough to give three different throws; the extended center in head stock of lathe is a neat fit in the mandrel block, which prevents any variations in throw. The mandrel block is held firmly against spider of lathe by suitable bolt which acts as a driver and at the same time makes the mandrel rigid.

HANDY TOOL HOLDERS.

The tool holders illustrated on this page are some of the specialties manufactured by the Armstrong Bros. Tool Co., of Chicago. Made of drop forged steel they are able to withstand

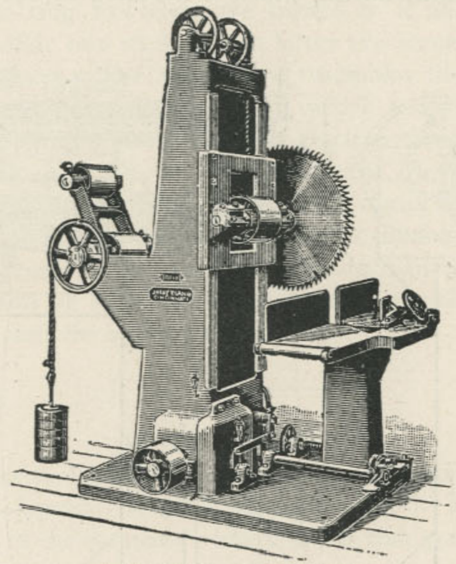


the very severe strains to which tools of the present time are subjected to and make it possible to get longer and better service at a minimum cost where time and cost of material is to be considered.

NEW CUT-OFF SAW AND GAINER.

This cut represents a new and improved machine especially built for car shops by the J. A. Fay & Egan Co. Special attention is invited to some of its features. It will carry a saw 40 ins. in diameter, cut-off material 13 ins. square, or 26 ins. wide by 1 in. thick, and when proper gaining head is used, will cut a gain 6 ins. wide and 1½ ins. deep. The head expands from 3 to 6 ins. The column is securely bolted and has a large base, decreasing vibration.

The feed raising the arbor consists of frictions operating on



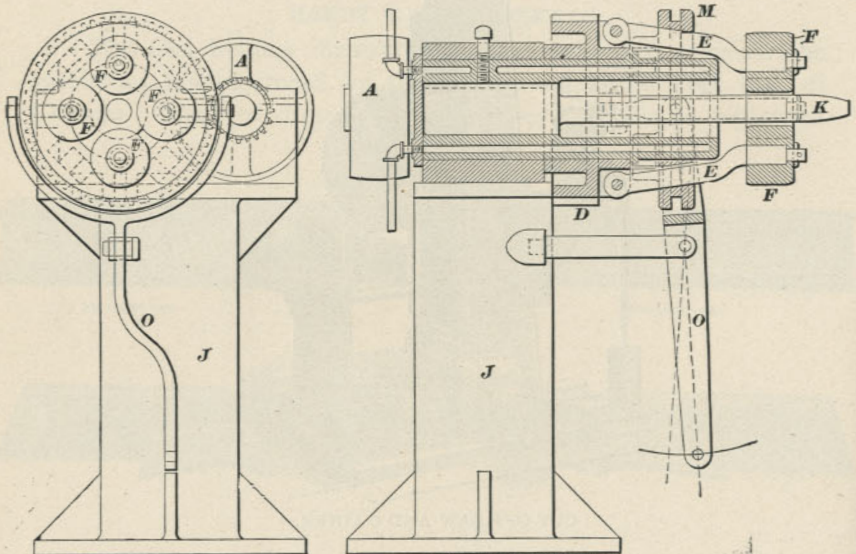
CUT-OFF SAW AND GAINER.

two large screws resting on ball bearings, nuts being fitted to take up all wear. The arbor is easily adjusted, controlled by treadle convenient to operator, and the travel regulated by adjustable stops. The table is mounted on a stand, adjustable to and from the arbor, and can be swung to an angle of 30 degrees. It has friction rolls on each side, and provision is made for securely holding the work. The machine can be belted either overhead or from below, the swinging idler being reversible to bring the weight into action for either position.

BYRD'S FLUE WELDER.

There is a very efficient tube welder to be seen in the Winnipeg shops of the Canadian Pacific Railway, illustrated herewith.

It was invented and patented by Mr. Walter Byrd, the general foreman. In doing work with this tool, the scarfing machine has been dispensed with, the tube and the safe end are taken just as they come from the cutter, and the safe end is expanded in an air machine so that it goes $\frac{3}{16}$ of an inch on the end of the tube and is ready to weld. When at a welding heat the tube is pushed on to the stationary mandrel of the machine and the rollers are brought down. The pressure which the rollers put upon the hot tube is supplied by compressed air, which is admitted to a cylinder by a very ingenious device, which is actuated by the foot of the



Railway & Locomotive Engineering

Fig. 1 *Fig. 2*

BYRD'S FLUE WELDER.

operator. Pressure is applied until the tube and safe end are brought down to the required thickness. The work is done so neatly that it is necessary to scrape off the scale in order to discover the weld. Any size of tube may be welded by simply changing the mandrel and rollers. For cutting tubes the rollers are taken off and disk cutters put on instead.

The machine as shown in our illustration, consists of an upright stand, J, carrying a pulley, A, and gear necessary to revolve the four rollers, F, F, around the mandrel, K. The shafts, E, E, carrying the rollers, F, are pivoted to a head, D, which revolves

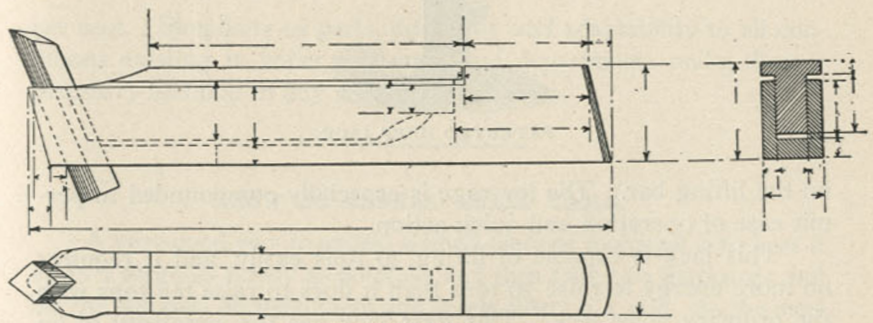
upon a hollow water-cooled center. These shafts pass at a slight angle through openings in the ring, M, which latter can be moved in or out parallel to the axis of the mandrel by the action of a lever which is operated by air. The ring, M, revolves with the rollers, and turns upon the water-cooled center of the machine. On account of the angle at which the roller shafts, E, E, lie, a movement of the ring, M, away from the rollers, causes them to come down on the mandrel, K, while an opposite motion of the ring forces the rollers away from the mandrel. The mandrel is pinned in place and can be easily removed when required.

The method of attaching the lever to the ring, M, is very simple. The ring has a groove turned in it all around, and in this groove slide two studs, which latter are secured to the forked ends of the lever. The attachment resembles the gimbles, which support the familiar kerosene lamp, which is such a conspicuous feature in torchlight processions at election times.

A treadle is arranged near where the operator stands, and the pressure of the foot upon this treadle opens an air valve which admits air behind the piston of a small cylinder, and this moves the lever, O. Springs are arranged to produce an opposite motion in the mechanism as soon as the pressure to the little cylinder has been cut off and the air exhausted.

UNIQUE TOOL HOLDER.

A unique tool holder is in use in the Missouri Pacific Railway shops at St. Louis. It was invented by Mr. F. W. Roebbel, who is in charge of the company's tool room at that point.

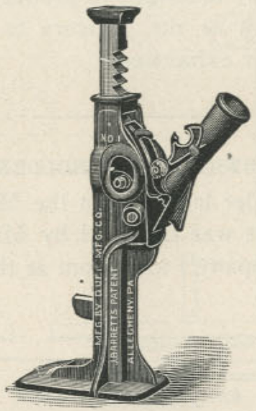


ROEBBEL'S TOOL HOLDER.

The device which we here illustrate has given every satisfaction in service. The body of the holder is made of soft steel, while the clamp, which fits into the body and secures the tool in position, is made of tool steel. There are no set screws used to hold the actual cutting tool; the whole device is held securely by the set screw in the ordinary tool post. The tool holder resting on a parallel washer the tool can be raised and lowered for the required height, and thus retain the proper clearance and the proper rake. The tool itself needs grinding only on the top. The holder has been used in the Missouri Pacific shop on all kinds of work, including heavy cutting, such as tire turning, and a saving in tool steel has been effected. Mr. Roebbel has made application for a patent on the device.

THE BARRETT PATENT COMPOUND LEVER JACK.

This jack has just been put on the market by the Duff Manufacturing Co., of Allegheny, Pa., and is an improved quick-acting jack for the rapid handling of loaded freight cars, Pullman cars and all heavy loads. It has patented features, and in its operation two pawls operate on a gear, the gear on a pinion and the pinion



PATENTED DUFF JACK.

on the lifting bar. The leverage is especially compounded to permit ease of operation and quick action.

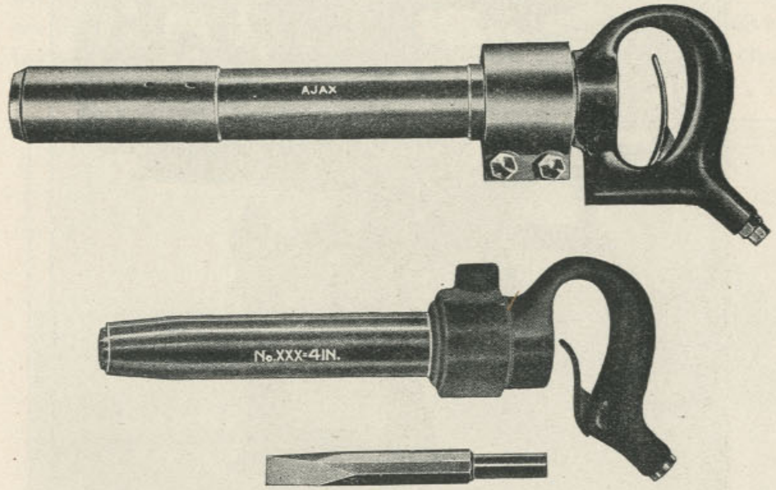
This jack is capable of lifting 30 tons easily, and it requires no more energy to raise 30 tons than it does to raise ten tons with the ordinary lever jack. This gear jack has the simplicity of an ordinary lever jack having no complicated features, and cannot get out of order like a hydraulic jack or a slow-working screw jack. It is operated in the same manner as the regular Barrett

lever jacks. The load is lowered in the same manner as it is raised, by simply turning the eccentric at the side of the jack.

The jack is particularly adapted to railway car shops, and would be an indispensable part of the equipment of a wrecking car.

PNEUMATIC RIVETER AND CHIPPER.

The accompanying engravings show a pneumatic riveter and chipper made by the Cleveland Pneumatic Tool Co. They are labor-saving devices, reducing in some instances the cost of labor over 50



RIVETER AND CHIPPER.

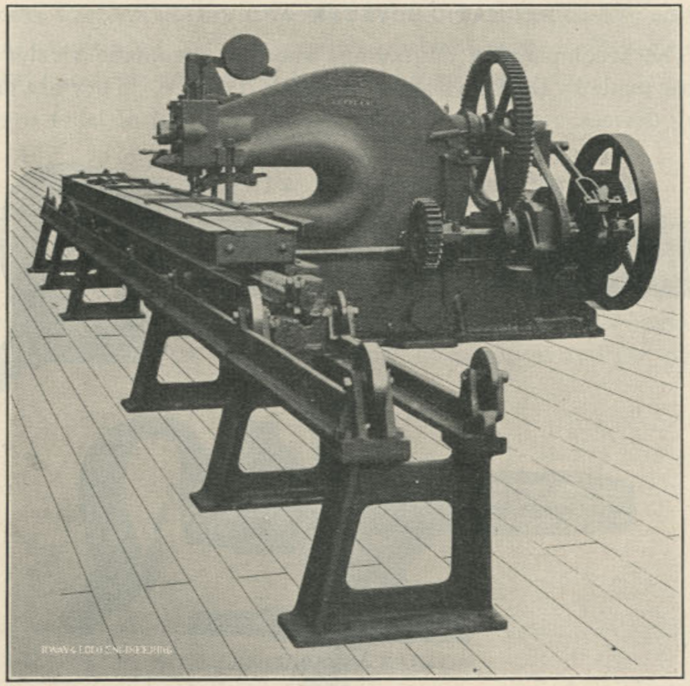
per cent. Simplicity of parts, durability and adaptability to all conditions existing in boiler and structural departments make them a necessary addition to any well-regulated shop.

HOW TO ANNEAL SMALL TOOLS.

A very good way to anneal a small piece of tool steel is to heat it up in a forge as slowly as possible, and then take two fireboards and lay the hot steel between them and screw them in a vise. As the steel is hot, it sinks into the pieces of wood, and is firmly imbedded in an almost air-tight charcoal bed, and when taken out cold will be found to be nice and soft. To repeat this will make it as soft as could be wished.

PUNCH FOR SMALL ANGLES AND TENDER PLATES.

Annexed engraving shows a 30-in. throat style "C" punch with automatic spacing table made by the Cleveland Punch & Shear Works Co., and recently installed in the new shops of the Lake Shore Railroad at Collinwood, Ohio. This machine is designed to punch small angles and tender plates. Table is operated by means



PUNCH FOR SMALL ANGLES, CLEVELAND PUNCH & SHEAR CO.

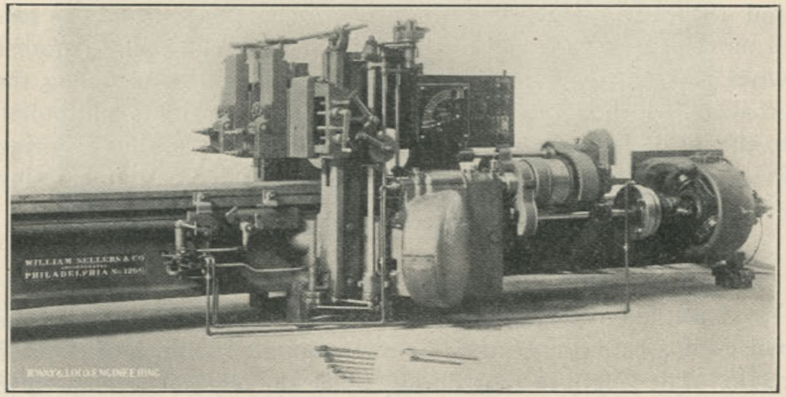
of a screw through bronze nut. Any spacing from $\frac{1}{8}$ in. to 4 ins. by eighths can be obtained by adjusting the crank at the rear end of the machine. The adjustment is by means of screw. Machine carries two punches and dies of different sizes, operated by gags, so that holes of different sizes can be punched without removing the work from the table. This is a quick-acting machine, intended only for light work.

SELLERS PLANER.

There are few machinists in railroad shops who are not acquainted with the Sellers planer, which is a permanent favorite

and the most popular tool made by William Sellers & Co., Philadelphia.

The most interesting feature about these planers is the drive, which is accomplished through friction clutches actuated by compressed air. The motor runs constantly in one direction, and the reverse movement of the table is made through gearing, with a possibility of changing the rate of cutting speed for a given speed of return by changing the ratio of the reducing gears. Compressed air is admitted to either end of the clutch shaft as may be desired, and the admission is controlled by a valve on the side of the planer bed, which is operated by table stops. It is also controlable by the hand lever shown. The action of the dogs on the table at the end of the stroke, is as follows: The valve is brought into the central position so as to exhaust the clutch



cylinder. It then admits air to the opposite clutch at the same time tripping the escapement, which allows the feed motion to act. The Westinghouse Electric Co. motors are 20 h. p. nominal size, 600 revs. per minute, coupled directly to the driving mechanism. The pinion shaft which drives the table carries a spur wheel, operated by a spiral pinion, which is mounted on the clutch shaft. The clutch cylinder has on its faces cone clutches, which engage alternately with the wheels. Keyed fast to the shaft is a disk, which is a piston in the clutch cylinder. As air is admitted through one end or the other of the shaft, the clutch cylinder moves in a corresponding direction, engaging either the cutting or the return clutch as the case may be, and the power of the clutch is transmitted to the piston, and thence to the shaft through projections or lugs; that is, when the cylinder turns around in either direction it causes the piston to rotate in the same direction, the wheel running continuously in one direction and receiving power either by belt as in the diagram, or by gearing. The pinion shaft when the clutch is engaged, rotates at the speed of the wheel to return the table, but the cutting clutches are driven at a reduced speed through the gears and may be made changeable when it is desired to employ a variety of cutting speeds. By rotating the hand lever 90° the feed can be cut out so that the table may be reversed by hand without feeding the tool, and it may be controlled in this way from either side of the machine.

These planers cut at 13 ft. a minute, and the table returns at 90 ft. a minute. The action of the table is extremely uniform—that is, it will always reverse at the same point, and they can be worked on a very short stroke. The loss of movement at each end of the work being very small. Another novel point in these machines, is in the method of clamping the crossrail, which is extended back between the uprights and bolted to the inside faces, as well as to the outside flanges, thus securing the crossrail in an extremely rigid manner and greatly increasing its torsional strength.

HOW TO REMOVE RUST FROM IRON.

A method of removing rust from iron consists in immersing the articles in a bath consisting of a nearly saturated solution of chloride of tin. The length of time during which the objects are allowed to remain in the bath depends on the thickness of the coating of rust; but in ordinary cases twelve to twenty-four hours is sufficient. The solution ought not to contain a great excess of acid if the iron itself is not to be attacked. On taking them from the bath, the articles are rinsed in water and afterward in ammonia. The iron, when thus treated, has the appearance of dull silver; but a simple polishing will give it its normal appearance.

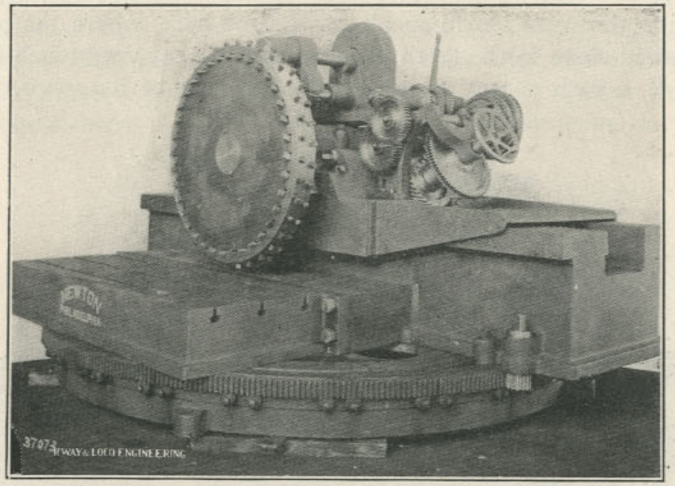
TO PERFORATE GLASS.

In drilling glass, stick a piece of stiff clay or putty on the part where you wish to make the hole. Make a hole in the putty the size you want the hole, reaching to the glass, of course. Into this hole pour a little molten lead, when, unless it is very thick glass, the piece will immediately drop out.

NEWTON MACHINE TOOL CO.

ROTARY PLANER.

This machine is of the rotary type and has a cutter head 48 ins. in diameter, which is internally geared, driven by a 15-h.p. motor. The feed motion to carriage, which is 7 ft., is by means of a spiral rack and pinion. The machine has four changes of positive gear feed and quick traverse in either direction. Mounted on opposite

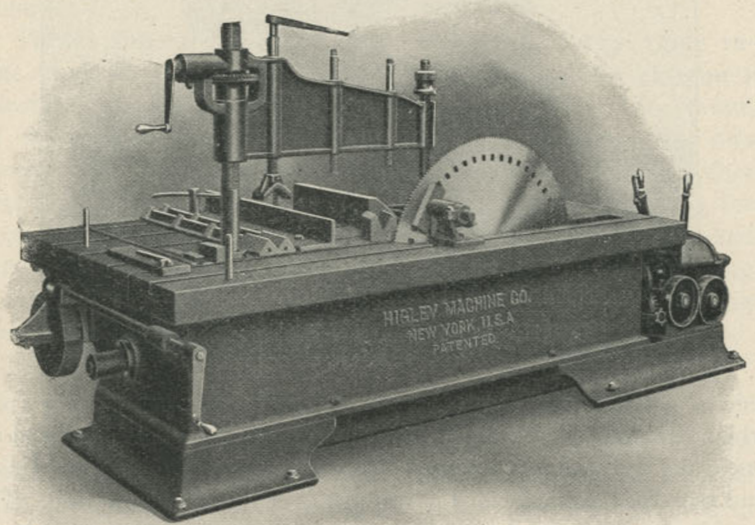


side of carriage and not shown in the illustration is a motor from which the power is obtained. All the operating levers are placed on one side and can be operated from platform. The spiral pinion and rack feed are a decided advantage over the old screw feed. The machines, which are intended to take the heaviest cuts with high-speed steel, are made in three styles, round base, portable and fixed base.

THE HIGLEY COLD METAL SAW.

The principal thing which strikes an observer as he looks at a Higley Cold Saw at work is the way it is driven. You have seen a man take hold of the spokes of a cart wheel when his vehicle is well nigh stuck fast, and help the tugging team. He catches the spokes near the rim and pushes on them with might and main. Well, that is pretty much the way a Higley Saw is driven. Motion is given to the saw blade by a sheer steel sprocket wheel meshing in radial slots placed as near the periphery as possible. The slots, however, leave sufficient depth beyond to permit of the frequent regrinding of the saw.

On machine Size No. 21, which you can see in the P. & R. shops at Reading and in other railroad repair plants, the saw blade is carried in a carriage having a horizontal travel of 45 ins. This makes it possible to make very long straight or angle cuts. The blade is held firmly in place by four adjustable wearing plates, which keep it rigidly in line. The sprocket method of driving has stood the test of time, as it has been in satisfactory use for ten or twelve years on Higley saws. By drawing the saw through the work, so to speak, as is done here, where the power is applied close to the teeth, it is possible to cut very much faster than it is with a saw driven by the rotation of its arbor. The



HIGLEY COLD METAL SAW.

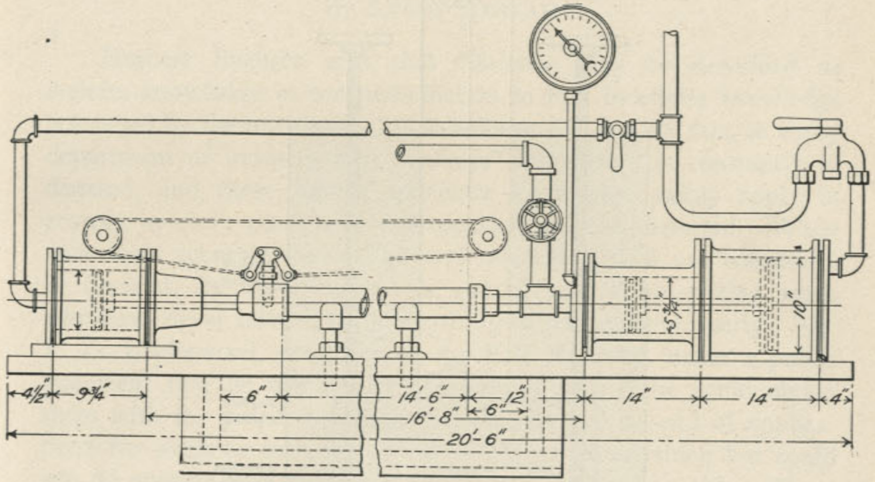
sprocket-driven blade is not liable to buckle when the machine is forced.

This cold metal saw has proved to be a very popular tool in railroad shops, not only on account of its ability to do lots of hard work and stay at it, and on account of its strong, positive drive, but because of the conveniences provided. Work can, if desired, be clamped on both sides of the blade. The Higley saw takes hold of all sorts of operations where the dividing of metal is the work in hand, and it does it quickly and well. In the matter of economy it makes a good showing in running some more pretentious machine tools hard for first place. There are a good many more things that can be done with a good cold saw than a casual observer

would imagine. To get a good idea of the whole thing you ought to see the saw. The J. R. Vandyck Company, 8 Dey street, New York City, handle the machine.

HANDY FLUE TESTER.

This machine is mounted on a trough to carry away the waste water and at each end of it, firmly secured, are cylinders of various dimensions. The cylinder to the left, whose diameter is 6 ins., has a piston with detachable rods of various lengths to accommodate tubes of various lengths and the caps on these

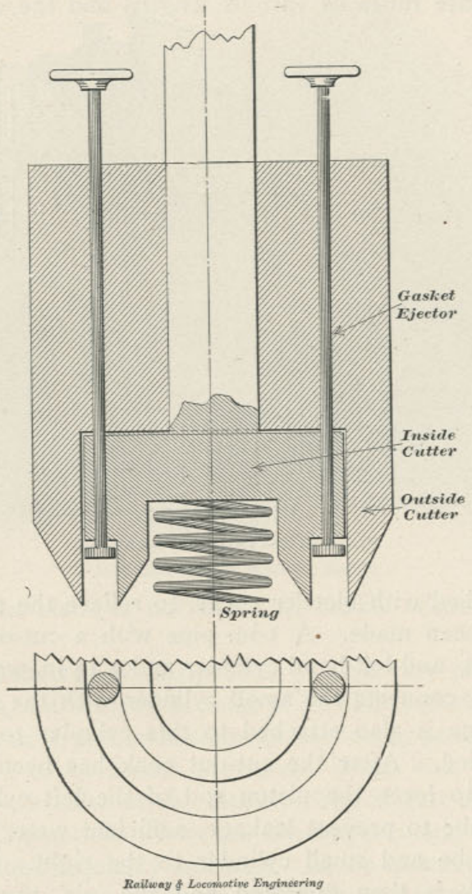


FLUE TESTING APPARATUS.

rods are supplied with bleeder cocks, to relieve the pressure after the test has been made. A 1-in. pipe with a cut-out cock connects the right- and left-hand cylinder and a 1½-in. water pipe with a globe valve, connects the small cylinder with the water-service line. A gauge is also attached to this cylinder to indicate the pressure applied. After the cut-out cock has been opened and air admitted to force the piston rod of the left cylinder snugly against the tube to prevent leakage, sufficient water is turned on to fill both tube and small cylinder to the right. An old style threeway cock is then operated and the air pressure forced against the piston of greater area. This then moves the smaller one, as both are connected by a rod. The smaller one moves against the imprisoned water and forces up the pressure in the tube. The sizes of the various cylinders which should be used to get the best results are respectively: Left-hand cylinder, 6 ins.; small right, $5\frac{3}{4}$ ins., and large right, 10 ins. This device, which is not patented, has saved many an engine failure by revealing defective or poorly welded tubes before application to the boiler.

FOR CUTTING RUBBER GASKETS.

A handy cutter for various sizes of gaskets, invented by Mr. E. L. Miller, M.M. of the Nickel Plate at Conneaut, O., is shown here. The device is secured to an air cylinder in his machine room



and all the condemned air hose are cut up into different sizes of gaskets. It has proved to be a money saver to the Nickel Plate. This device is not patented. Mr. Miller will gladly give further information.

EDUCATIONAL.

DEFINITE AND INDEFINITE KNOWLEDGE.

By Angus Sinclair.

Herbert Spencer says that "Science may be described as definite knowledge in contradistinction to that indefinite knowledge possessed by the uncultured." In railway life and, in fact, in every department of industry that "definite" knowledge is constantly in demand, and those having indefinite knowledge vainly apply in crowds in every place where occupation may be expected. While men with accurate knowledge and developed skill are constantly in demand, the labor market is glutted with men seeking work who have never learned to do anything in particular properly. Mr. F. D. Underwood, president of the Erie Railroad, made a public statement that he would hire a thousand men if he could obtain them with the proper training, and that he had no end of applications for work by men who were willing to do anything but could not do anything in particular. This is a national trouble. There is a multitude of people who think they ought to be able to earn a living without acquiring accurate knowledge about any occupation. They are a mob as compared with an army. They may have acquired a mass of general information, which is a good thing in its way, but it is like the water running in a stream that might be made to drive power wheels or turbines if the proper appliances were put in its way and its movement was properly regulated. General information is useless when it is not applied to a specific purpose. When a person learns to do any useful work well, he is likely to obtain employment doing it; then he may have the means of applying general information to expand processes connected with his work.

A good hand at any occupation, no matter how humble it may be, recommends himself for advancement. The good mechanic, the good car repairer, the skillful fireman, the first-class engineer, the quick, accurate telegraph operator, the pushing, clear-headed track workman, the flagman who protects his train, and the machinist who does his work well, are the men who will be officials a generation hence. We hear a great deal about what education is going to do for the people who have to earn their living, but education is useless unless its possessor can apply it to a specific purpose and pushes with all his might the work he is engaged on.

LOOKING FOR EASY JOBS.

The men who start out in life looking for easy jobs are never likely to have heavy responsibilities placed upon their shoulders. Since the United States became rich, the proportion of its population who are willing to earn their living by the sweat of their brows appears to have steadily decreased. The Chicago & Alton Railroad Company have in operation an employment bureau which receives applications from people desiring to enter the service of the company. During one year there were applications from 495 persons wishing to secure positions as clerks and telegraph operators, while there were only 103 applications for the position of fireman and 140 from men who wanted work as brakemen. The genteel job is the popular one, and it opens the door to a life of semi-penury.

INDUSTRIAL HEROES.

America is naturally proud of her many sons who have distinguished themselves in every department of industry, the men who made themselves leaders in the great achievements for which the country has been celebrated. Most of these men have sprung from the lowly ranks of life; but it may be accepted as a certainty that those who became distinguished leaders did not begin their working life by looking for the softest jobs they could command. There is a book called the Biographical Dictionary of Railway Officials which is used mostly as a work of reference; but it contains hidden within its prosaic notices the germs of more romances of real life than any other book of its size within our ken. It is the most eloquent record of self-help that ever has been collected. It briefly outlines the careers of thousands of railway officials most of whom have forced their way upwards through sheer force of merit and devoted attention to their business. Opening the book at random, we find a railroad president whose career condensed is: "Entered service of ——— R.R. as office boy; apprentice machinist; worked in drawing office; chief draftsman; mechanical engineer; shop foreman; master mechanic; division superintendent; general superintendent; general manager; president." Imagination can readily fill up the hiatuses between these positions with personal efforts and steady endeavor kept active by aspiring ambition.

Another representative notice which we expand a little is to this effect: "Returned from the war in 1865 and began work as night watchman (on a Western railroad); truckman; baggagemaster; bill clerk; cashier; claim clerk; chief clerk; general freight agent; superintendent freight traffic; general freight agent; freight traffic manager; general traffic manager;" and his last move is to the position of general traffic manager of one of the greatest railway systems on this continent. This success was achieved without any outside influence whatever. The influence for steady advancement was all in the man's determination to learn everything relating to his work and to do it with all his might.

Still another is: Entered ——— railway as clerk; brakeman, foreman of elevators; conductor of working train; freight and passenger trains; yardmaster; assistant division superintendent and superintendent; general superintendent; general manager; vice-president; president. This was a case where the genteel occupation of clerk was given up for the strenuous position of brakeman on a Northwestern railway. But it was a good illustration of "he stoops to conquer."

The great majority of the mighty men of the earth never have their names printed among the list of heroes or stand out conspicuously above the heads of the madding crowd. They do their work quietly with pride's humility and permit their achievements to bear testimony after they have gone hence. The sublime lives leave their footprints, but no tumult or noise is heard while they pursue their path through life.

VICTORIES OF DEFINITE KNOWLEDGE.

Among the multitude of men whose heads and hands have directed the building and operating of our vast system of railroads, it is safe to say that few of them were uncultured, possessing only indefinite knowledge. Every man in his place, from the track foreman to the general manager, earned his pay by putting into practice operations regulated by definite knowledge. This definite knowledge is nearly all begotten of experience. Education may shorten the road to the acquirement of definite knowledge concerning railroad business, but it must always be an aid rather than a substitute. The old royal road to learning which has always been diligently sought after, is still pursued by many people, and would-be railway officials are numerous among the seekers for the easy way, which when found proves a delusion and a snare.

The work of railroad building and operating has been managed by men who acquired the necessary skill and knowledge by performing the operations they were afterwards required to direct. Those men were perfectly efficient, as their performances testified, but a sentiment has arisen among owners of railroads and their representatives, that college training would be a great aid to railway officials, and that the knowledge acquired in a college course would greatly enhance their efficiency. This has proved true when the college-bred man was willing to begin at the bottom of the railroad ladder and work through the different grades, acquiring skill and familiarity of details by experience; but if he is floated upwards by the influence backing his college training, without learning the things which are the strength of the purely practical man, he will always be weak in lines where strength is of much importance to his employers. He will always be weak on details which make him depend on subordinates for information he ought himself to possess.

PRACTICAL AND COLLEGE EDUCATION.

The working of this is particularly conspicuous in the mechanical department of railroads. The railroad world employs two classes of mechanical engineers as heads of the mechanical department. One, the oldest and most numerous class, is composed of men who, with an apprenticeship training and common-school education as a foundation, have acquired by personal effort the scientific knowledge that entitles them to rank as mechanical engineers and to perform satisfactorily the duties of superintendent of motive power and machinery. The other is the technical college graduate who has acquired sufficient mechanical knowledge and has obtained sufficient experience of workshop operations to enable him to manage satisfactorily as head of the mechanical department. When the question arises, which of these two classes of engineers is likely to perform his duties most satisfactorily and prove the most useful official to a railroad company, we incline to the side of the self-educated, practical man. The habits and characteristics which move a young mechanic to acquire scientific knowledge by burning the midnight oil, are likely to promote his usefulness and advance his efficiency as a railroad official.

EXECUTIVE ABILITY.

Probably the most valuable characteristic of a successful railway manager to-day is that subtile personal quality known as executive ability. Some people think that a college training cultivates executive ability better than practical work, but observation and results contradict this. Our experience is that executive ability is a natural product that is very little strengthened by cultivation, and that the hard knocks of practical work prove the better fertilizer.

MANAGING MEN.

That part of executive ability relating to the handling of men must be possessed by every man in charge of railway departments and manufacturing establishments or his management will be a failure. Personal skill of manufacturing or business operations is not essential to this qualification; but he must have been sufficiently in touch with the men under his charge to understand their good and bad qualities, their virtues and their vices, their enthusiasms and their prejudices. The man who has gone through the workshop, the office or train service from the bottom up, understands the strength and weakness of the toilers therein. Their inner lives are to him as an open book which enables him to guide them to promote their own and their employers' interests. The man who comes in from the top mixes with an uncongenial element outside of his sympathies, which is never properly understood. This want of fellow feeling is a source of weakness in the management of men, and is equally hurtful to success in business as want of human sympathy. It does not pay, apart from higher considerations, to have a man in charge who regards workmen as mere machines, and the man who has shared their difficulties, enjoyed their triumphs and pleasures, is likely to manage them better than the man who has never been in real touch with their lives. When complaints and grievances threaten trouble in the shop or on the road, he can discriminate readily on what action will most easily produce harmony and keep the working force satisfied and in good humor. That capability has a high money value in these days when the relations between capital and labor are almost constantly in tension.

We consider that the present is a good time to discuss the relative value of the purely practical mechanic and the scientifically trained engineer, because there is a tendency in some quarters to undervalue the former and magnify the latter. Both of the classes have their good characteristics, and the personal equation exercises a powerful influence on the success or failure of each. College education has become in some quarters a shibboleth which will pass a man to a higher position over those having greater fitness, a condition of affairs which is not conducive to the welfare of railroad companies. Before being influenced by such a consideration, it is well for railroad managers about to appoint a new head to their mechanical department, to find out which of the two men possesses in the higher degree the "definite knowledge" which must be applied to the business he will be engaged upon.

TRAINING AN ARTIST IN THE FORCES OF NATURE.*

By E. H. Mullin.

If we go back in the history of our language to the first-known use of the word "education," we find that in 1540 it had as its meaning "the process of nourishing or rearing a child or young person." It will be noticed that in this case, as in so many others, a term which may now be regarded as meaning something abstract and psychological is derived by metaphorical extension from an earlier concrete and physical concept. Yet if the word "education" has gained in breadth since its first use four and a half centuries ago, it has also lost much in depth—at least as commonly used. The essence of the word "nourishing" is assimilation; it conveys the idea of the food which is most easily converted into life-giving blood, and thence, with hardly a pause, into nerves, bones and muscles, to become an inseparable part of our bodies. For one reason or another, we seem to have passed beyond the stage of a simple educational diet which can be thoroughly assimilated; we present either the jaded palates of a worn-out race, or the capricious appetites of spoiled children. Instead of the educational roast and boiled joints of our forefathers, we toy with highly seasoned *entrées* which blunt our appetites for the time being, but do not give us the strength for long fasts, the energy for great work, or the physical repose necessary for deep thought.

We shall find, if we keep the idea of assimilation as the primary attribute of all education, that the physical and mental analogies are reasonably close and hardly, if at all, misleading. Mental indigestion from overstuffing, no less than physical indigestion, produces cloudiness of the brain. Mental dyspepsia may follow a diet of too large a variety of elective courses, just as physical dyspepsia may follow over indulgence in highly spiced but non-assimilative foods. In both cases time is an indispensable factor to assimilation; plain food will be most enduring in results; maximum efficiency will be found in maximum assimilation and minimum waste.

*Read at a meeting of the Institute of Electrical Engineers.

Fixed habits are perhaps the most valuable gift we can receive, whether from home rearing, from college training, or from that first part of our lives passed in the world of men. Yet granted that we have taken a firm hold of essentials, we may pursue cognate non-essentials as an enlightening means of recreation. Every author has his historical background; every science has its borderland; every art has its path of development. Knowledge is the result of profound study; culture is the reward of diligent exploration. With knowledge alone we are as flatlanders, realizing our neighbors only when we touch them; by the aid of culture we can rise above our surroundings, and, by viewing the relation of our neighbors to each other, form a juster estimate of our relation to them.

For in our realization of our true relationship to the whole of the outer world lies the benefit of our education. The pure specialist, without sympathy and without comprehension, is simply a machine tool in the hands of a higher order of intelligence. When Mr. Carnegie claimed for himself only the power of acting as a magnet for much abler men, he either meant much more than he said, or said much more than he meant. To utilize ability, to turn it into its proper channels, to mark the time and place when and where one kind of specialized mind should begin and where it should stop to allow the next specialized mind to take up the running, is the function of true greatness. The general in command of armies, the statesman responsible for a party, the captain of industry with success or failure hanging upon his decision, asks no more than that the subordinate whom he chooses can convert his ideas into action. "Be bold, be bold, be not too bold," said the ancient sage. "Specialize, specialize, but don't specialize too much," says his modern analogue.

Capital, modern economists are agreed, is the crystallized savings which can be lent out to reproduce itself in useful work. It is, in fact, stored energy. In its baldest form, capital represents the wheat saved from last year's crop to enable the laborer to garner next year's crop without dying of starvation while next year's crop is growing. In its broadest sense, education is not capital, but tools. It is not the knowledge of facts which makes a man educated, but the possession of method. To teach a man to learn how to learn is the true function of education, and to stuff his mind with facts beyond this point is merely to encumber him in pursuing his means of livelihood. It is true that the method of education adopted may, and perhaps should, bear some relation to ultimate ends. The future classical scholar will save himself much annoyance by a diligent study of Greek irregular verbs. The future mechanical or electrical engineer will enjoy an ease, not otherwise procurable, by a thorough mastery of elementary mathematics. But, still, education is not so much intended for the elucidation of old problems as for the tackling of those that are new. And, as a knowledge of facts without the power of ratiocination is worthless for new ventures, and as every problem which meets us in life is a new venture, therefore, method by itself is everything, and facts by themselves are nothing.

The faults of technical education of the present day are that they tend to reproduce a microcosm of real life. Every one has heard of, or has seen, a typical specimen of the "tank drama," in which there is real water, real horses, a real fire engine, or what not, to heighten the verisimilitude. The technical colleges which attempt to make a blacksmith or a mechanic out of a student, fail, just as the "tank dramas" do, by endeavoring to make their courses a miniature copy of future work instead of making them typical of crises and illustrative of principles. Let us glance for a moment at the two great professions where education, as commonly understood, utterly fails to supply a man with the power of commanding success. It will be acknowledged that painting is an art which requires initiation and instruction. Yet, without genius, without inspiration, even the most skilful painters have been unable to rise above the ranks of mediocrity. The Italians call Andrea del Sarto "the faultless painter." But, as Symonds says, he lacked inspiration, depth of emotion, energy of thought, and cannot therefore take rank among the great Renaissance painters. Or take again the two typical cases of the Archduke Charles and Major-General Halleck, for both of whom it may be claimed they were bright and shining examples of profound technical education in the military art. The genius of Napoleon, not a particularly distinguished student, overthrew with ease the strategy of the Archduke Charles, while all that Halleck's technical knowledge seemed to be able to do for him was to point out every possibility of defeat without inspiring him to a single means of victory. More recently we have seen Sir John French, the only really successful cavalry general of the South African war, overthrow in the field the reputation which the pedants of Aldershot gave him of not being able to handle a cavalry brigade.

We may gather from these examples, and from others which will occur to the minds of every one, that all that technical education can do is to give each man his chance of success or failure. Genius may be able to dispense altogether with technical education; inherent

stupidity will ultimately sink to its true level, in spite of the most careful collegiate training. In considering educational matters, therefore, we are concerned not with geniuses or with muddle heads, but with average men. How the average man may be trained for a profession for which he feels within himself some aptitude is the question which it behooves us to answer. And the answer which we should give is to teach methods, to instil principles, to lay deep and sure the foundation of elementary knowledge, and trust the future to take care of itself. We have, therefore, two co-related branches of education to consider—education as an art and education as a science.

Education as an art involves perfect familiarity with a larger or smaller number of facts, according to the purpose to which these are to be devoted. In this age of universal reading and writing we are apt somewhat too hastily to assume that a categorical knowledge of the alphabet and the arithmetical tables is necessary to success in life. Those who have lived in countries where a considerable portion of the population is wholly illiterate must have often been struck by hearing men who could not read use language all but grammatically correct, or by observing intricate accounts made up by mental arithmetic without the aid of either multiplication or division. It must also be remembered that in the Dark Ages kings and bards were usually illiterate, though they were none the less the rulers and inspirers of their times. Education as an art, therefore, must be separated from personality on the one hand and from mere pedantry on the other. We may compare education as an art to a knowledge of the names and functions of the pieces on a chessboard divorced from any knowledge of the game of chess itself. If we can then imagine a series of chessboards, each having more pieces than the one preceding it, and each set of pieces having more complex moves than the set preceding it, we shall have a fair analogy of the gamut of education as an art, from simple elementary education to the highest classical or mathematical standard. Throughout this series there are things to be known by name—what may be called primary concepts—and these mere names have to be clothed with ideas or attributes or functions, by means of which we may see how far we can utilize them. In other words, in education as an art we have to exercise the faculty of memory, and this memory must be clear and accurate if our minds are always to have their tools at hand ready for instant use. But this in turn implies familiarity, and familiarity implies constant practice for a longer or shorter time. Here again our average education for the average man comes in. If we have in mind only the first 25 per cent. of our pupils—the geniuses and the hard-reading men—we shall pass along to the next stage before our 50 per cent. of average men have had time to become perfectly familiar with the facts and their connotations which are being studied. If, on the other hand, we attempt to wait until the last 25 per cent. of our pupils—the incorrigibly idle and muddle heads—we shall waste the time of our 50 per cent. of average men. In every stage of education as an art we have therefore two things to consider, namely, the accumulation of a sufficient number of names and their connotations to give us an ample nomenclature or set of tools, and also enough familiarity with this nomenclature or set of tools to enable us instinctively to select the right tool and to use it efficiently.

Let us now pass to education as a science. A man might know the dictionary from end to end and yet not be able to use more than one thousand words of it for any particular purpose. Having obtained our tools through education as an art, the problem in education as a science is not to use them as we have been taught, but to apply them to new problems. To go back to our former illustration, we must be able to play the game of chess after having learned the names of the pieces and their functions. It took the world 2,000 years to find out that deductive logic could state nothing new beyond what was contained in the premises. Science, we are told, is organized and classified knowledge, and the first thing a truly educated man will do with a new fact is to place it under its proper classification—that is, he will refer it to the principle which governs facts of a similar kind. Not only, therefore, is memory needed here, but imagination. A man's whole education goes for nothing if in dealing with a new fact he cannot see resemblances in it to other facts where none outwardly exist, or cannot see profound differences between a new fact and an old one where the outward resemblance is strong. And the highest function of education as a science is to make a man of average ability see resemblances and differences in cases where he would otherwise be blind. Indeed, genius itself, as we see it in the great inventors, is usually nothing more than the power of classifying a fact under its proper generalization and then restating it in terms of some other fact classed under the same head.

Rising stage by stage, therefore, according to the future for which our educational requirements are to fit us is our elementary knowledge plus perfect familiarity in dealing with and handling it. Better, far better, that we should know little but be on terms of perfect familiarity with that little, than we should know much and

have to grope for what should spring to our minds as quick as thought itself. The time spent, the labor involved, in obtaining an absolute mastery over our primary concepts or elementary knowledge marks the difference in our future work between having strange tools to handle and having tools which so fit into our hands as to become an inseparable part of ourselves.

Let us turn now to the education of an engineer. The definition of an engineer, according to Telford, is one who applies the forces of nature to the service of man. Mr. Mansergh, recently president of the Institution of Civil Engineers, quoted with approval an American definition of an engineer as "a man who could do for one dollar what any fool could do for two dollars." Perhaps the best definition will lie somewhere between these extremes. If a man does not know how to apply at least one form of the forces of nature to the service of man he is not an engineer; and if he cannot do this more economically than an outsider, no capitalist with common sense will employ him. An engineer differs from a physician or a lawyer in that patients die and cases are lost without damaging the reputation of a member of either of these professions, while, on the other hand, an engineer's work must speak for itself. The motto over Sir Christopher Wren's tomb in St. Paul's might be adopted as that of the engineering profession as a whole, "*Si monumentum requiris circumspice.*" Posterity camps on the trail of the engineer, and its conclusions, like the judgments of the Lord, are true and righteous altogether. Whether it be the aqueduct of Rome or the Brooklyn Bridge, whether it be a generator at Niagara Falls or the switchboard of a New York power station, it will either form a model from which other generations of engineers will expand into new conceptions to meet new needs, or it will become a beacon post to point out the way which is to be avoided. Verily, it is no light thing to train up an artist in the forces of Nature!

Let us begin with the prime essential. Without reverence for great works and for the great men by whose agency they were brought forth, there will be no great engineers. Granted that, a sound knowledge of one's native tongue is the best substructure. The great engineers who have been deprived of this aid have borne eloquent testimony by their efforts at self-improvement in later life to what they considered would have been its usefulness at an earlier period of their careers. An elementary knowledge of Latin is most indispensable to the clarification and consolidation of the knowledge of nearly every European tongue. Next to these my vote would go to a good working knowledge of French because, besides its obvious advantage as a language to be spoken, it imparts lucidity and precision to writing—a thing, by the way, which mathematics often fails to do. Early practice in mechanical drawing should also be given to every boy who feels within himself the stirrings to become an engineer, because familiarity with the pencil is easily acquired early in life, but is often one of the greatest stumbling blocks when taken up too late.

Then as to mathematics. As the profession of an engineer always involves constant dealing with quantities and values, he ought to know mathematics as he knows the currency of his native country. In other words, he ought to be able to make change with ease, quickness and accuracy—not as if one were in a foreign country in a constant state of painful reckoning. A thorough knowledge of ordinary mathematics is here prescribed, not any vain ascents with crippled wings into the empyrean. What is meant by "ordinary mathematics" may perhaps be more clearly indicated by a remark and an anecdote. One may make accurate change without any knowledge of the science of numbers. Lord Salisbury, when president of the British Association, told the story of the old Oxford professor who said to him, fiercely, "What I like about quaternions, sir, is that they cannot be used for any base utilitarian purpose."

This makes our substructure complete. The first part of our superstructure should consist in learning the principles of the applied sciences. These should be studied in books, assisted by oral teaching, and enforced and re-enforced by the practice of dozens or hundreds of examples. If one wants to know how each principle should be learned, he should watch a great singing teacher train a pupil. A false note in a scale demands a hundred perfect repetitions. A false note in an *aria* means back to the scale for a hundred more repetitions before attacking the *aria* a second time. Why should the future artist in Nature be less carefully prepared for his work? Is that work likely to be less important? Or is it merely because his future audience is less likely to detect a false note?

With this, the education of our engineer ends or rather begins. He may be fifteen, sixteen or any age. He may have studied in school, or in college, or at home. He is, however, a trained engineering soul, according to the measure of his talents. He is able to learn the art of engineering, or any other art, for which he has an aptitude, in months, where another man of equal ability might take years and not know it half so thoroughly. All he needs to ensure his success in life is to find a master who can utilize his powers.

PROGRESS.

By B. D. Caldwell.

It has been well said that progress is based upon principle, not policy; it moves forward, never backward, always toward the right and against the wrong; it does not necessarily mean peace, but will involve conflict when only that will answer. It is the survival of the fittest, not so much in man's power over nature, but through the power of principle in his control of self and his influence over his fellows. Ignorance or selfishness will antagonize and may temporarily impede the triumph of this fundamental truth, but ultimately it must be recognized that true progress means a broad unity of all great interests and activities and that purely individual or selfish aggrandizement has no part in the plan of human progress.

A proper recognition of this, in identification with and in judging as to the merits of all great activities, makes their real interest, as well as that of society at large, the same, simply because principle must ever be the underlying foundation of all real advancement, and therefore, no activity, individual or collective, can ever attain distinction in the world's progress unless in harmony with this law.

Progress means quicker movement. Great undertakings require great preparation and equipment, not only in ability, knowledge and experience, but in confidence and courage to promptly apply them. Large equipment and great opportunity bring increased responsibility. Where one life was touched a century ago, a thousand, yes, many thousands, are affected to-day. Never truer were the words of Carlyle: "The race of life has become intense. The runners are treading upon each other's heels. Woe be to him who stops to tie his shoe-strings." As Wendell Phillips put it: "To be as good as our fathers we must be better." And there is no escape from individual responsibility, which necessarily increases in proportion to that of the whole. As Disraeli said: "We put too much faith in systems and look too little to men." Individual responsibility cannot be hidden behind machinery, toward which there is some tendency in our times. Machinery is essential. Its use has revolutionized the world's methods, but when it gets so ponderous as to cover up individuality and become an end, instead of a means, it is an obstacle rather than a help. There is an old Italian proverb which says: "The work proves the workman." This principle has been true in all the ages of the world and is true to-day as a standard by which all work, collective and individual, must be judged.

VALUE OF KNOWING COMMON THINGS.

Many people nowadays turn up their noses on hearing the homely saying, "Where there's a will there's a way," because so many of them are waiting to be coddled into the way, without displaying the least trace of a will for well doing, or for self help.

So much has been preached of what a college education will do for people, that crowds of youths drag through a college course and then expect that their fortune is made; whereas they are at the real commencement, as the graduating proceedings are rightly called. The man or woman who has the energy to make a way will always leave behind all others devoid of active ambition, no matter how well favored their start has been by circumstances.

The ordinary graduate depends too much upon the knowledge acquired in a college course, whose real value is in training the mind how to acquire and digest useful knowledge. There is too much generalizing and too little digesting of details. It is not easy descending from the genteel speculative to the prosaic working out of details. Observation of common things is good training to help in collecting professional knowledge. City life and training have a tendency to develop a certain species of sharpness, but for most people it blunts the observing faculties.

The writer was riding through the parks of a great city with a town-bred lawyer, who acknowledged that he did not know one tree from another. That man knows something of books, horses and law, but he is an ignorant creature, nevertheless. But his ignorance is only equal to that of many others whose daily labors are made less profitable for want of knowledge of common things. How many of our engineering graduates know how a steel tire is made and how it is held on a wheel center? How many of them can tell the proper cutting speed of machine tools for various metals? How many of them can tell when a machinist at the vise is doing a fair day's work? Very few, which is a weakness begotten of beginning business at the wrong end.

Civil engineers succeed in life by utilizing and controlling natural forces, and by making the best possible use of material that can be obtained convenient to their operations; yet many men who try the business are constantly handicapped through ignorance of common things. How many of them know what procurable timber will stand the heaviest strains, or why white oak is proper for one purpose and not for another, and what timber will last best under water and what out of the water? How many know sandstone from limestone, or trap from granite?

How many know that a horse gets up before and a cow gets up behind and the cow eats grass from her and the horse eats to him? How many know that a surveyor's mark upon a tree never gets any higher from the ground, or what tree bears fruit without bloom? There is power of comfort in knowledge, but a boy is not going to get it unless he wants it and wants it badly, and that is the trouble with most college boys, they don't want it. They are too busy enjoying themselves and haven't got time. There is more hope of a dull boy who wants knowledge, than of a genius, for a genius generally knows it all without study. The close observers are the world's benefactors.

UNTIDINESS AND WASTE.

Whether it is that untidiness leads to ruin, or that a manufacturer who is losing money has not the moral stamina to keep things in trim, thrifty shape, is a hard matter to determine, but true it is that untidiness in the shop and office and ruin are such close friends that they are ordinarily seen together, and the sight of one suggests the other.

We have often seen men of rare industry, judged by their bustling manner, who would spend much time each day looking for tools; forgetting where they had left them last; stumbling over piles of stray castings under the lathe or piled under the bench, or pawing those castings over for a piece somewhere in this pile or that, when it ought to be in a place by itself; going from tool to tool, bench to bench, to find or borrow a drill, or wrench, or hammer, or block, when there should be just one place to find the desired article. When the articles are found the man never thinks of returning them to their proper place. In fact, there will be no "proper place" for tools in such a shop, and the next man who wants them will go on the same hunting expedition about the shop.

Such a shop will always have black and dirty walls and ceiling, with windows spattered with dirt and decorated with cobwebs, notwithstanding that the light is so bad that careful work is rendered impossible or tedious of accomplishment, when a few cents' worth of lime and a brush would whiten the walls and the ceiling and greatly improve the light and so expedite and improve the work. Money and time are lost and ruin invited by a neglect of these things. We have all found railroad shops that this description applies to.

But the greatest loss experienced by this deplorable and needless state of things is in the morals of the shop. Workmen compelled to work in a dingy, ill-kept and ill-lighted shop will suffer loss of self-respect and of respect to their employer and his interests. If they are forced to work at disadvantage, the stimulus to activity and ingenuity suffers a gradual decay and no one will pretend to deny that this decadence on the part of the workman is a direct money loss to the proprietor. Tidy workshops stimulate manliness and ingenuity on the part of workmen, and right there may be found the profit on the year's business, or, if neglected, on the year's losses. There are plenty of establishments in which by a careful attention to these matters—too often regarded as non-essential—the efficiency of their workmen could easily be increased 10 per cent., and that per cent. would determine the difference between a profit and a loss.

COMBINING THEORY WITH PRACTICE.

The practical man must know by experience how a thing is, rather than by theory how it should be; but the nearer any machine approaches in practice to what it would be in theory the nearer perfect it will be; hence the necessity for the practical man to understand enough of theory to make the necessary comparisons. The theory, no matter how simple it may appear, is not so easily kept in the mind. Like geometry, it is easily understood because it is true and simple; but it is quite as easily forgotten, unless it is fixed in the mind by some illustration.

The moving of one pound one foot high in one minute is called a foot pound. The pound itself, in this case, is nothing; but when lifted one foot high it is a unit of work. The pound and the foot must be combined when they represent work. The pound is called force when driving, and weight when driven. Many pounds acting together will do more work than a few pounds thus acting, and a few pounds moving many feet will do as much work as many pounds moving a few feet. Thus, 50 pounds moving 200 feet in one minute is exactly the same as 200 pounds moving 50 feet in the same time; that is, $50 \times 200 = 200 \times 50$. If 250 pounds move the distance of 500 feet in five minutes of time, we have $500 \div 5 = 100$ feet in one minute, and $250 \times 100 = 25{,}000$ foot pounds in one minute, which would be five times as much in five minutes.

The trouble is, in such calculations, the *duration*, which must be taken into consideration in the work done by animals, and in the strength of material doing work. For instance: A horse pulling over a roller and hoisting 550 pounds 60 feet high in one minute, exerts $550 \times 60 = 33{,}000$ foot pounds, or 33,000 pounds one foot high in one minute of time; but this does not demonstrate that the horse can raise 33,000 pounds instantly. It does demonstrate that he can do it in a definite time; that is, as in the example, raising 550 pounds 60 feet in one minute, which is *equal* to raising 33,000 pounds one foot high in one minute. Thus, doing work which is *equivalent* to raising 33,000 pounds one foot high in one minute, is termed a horse power.

Take the example of a hoisting engine—all dimensions given. In what time will it hoist a given weight? Let the dimensions be: Bore of cylinder, 6 ins.; stroke 8 ins.: steam pressure, 80 lbs.; revolutions, 240 per minute. Let it be geared 6 to 1, and let the hoisting drum be 18 ins. in diameter. Then $6 \times 6 \times 0.7854 \times 80 = 2.262$ pounds, which is the total pressure on the piston, and

$$\frac{240 \text{ x } (8 \text{ x } 2)}{12} = 320,$$

which is the number of feet the piston travels in one minute. Then $2{,}262 \times 320 = 723{,}840$ foot pounds, or pounds moved one foot in one minute of time; $240 \div 6 = 40$, the number of revolutions made by the drums in one minute, and $3.14 \times 1.5 = 4.71$, the circumference of drum; $4.71 \times 40 = 188.40$ the number of feet the circumference of the drum travels per minute; $320 \div 188.40 = 1.6985$, the number of times the speed of the piston exceeds that of the drum, hence $2{,}262 \times 1.6985 = 3{,}842.23$ pounds, which is what would be sustained by the drum when the pressure against the piston is as stated. The engine then can, theoretically, hoist $3{,}842\frac{1}{4}$ pounds $188\frac{1}{2}$ feet high in one minute of time.

To change the conditions: Let it be required to raise a weight 80 feet high in one minute; how much more can be elevated by the same engine, and what must be the diameter of drum? $188.40 \div 80 = 2.36$ times *less* distance for the weight to travel, therefore 2.36 *more* weight can be raised; hence $3{,}842.23 \times 2.36 = 9{,}067$ pounds that can be hoisted 80 feet per minute. To find the diameter of the drum, divide the diameter of drum, as in the previous example, by the number of times less distance the weight has to travel, $18 \div 2.36 = 7.62$ ins., or the diameter of drum. The correctness of this can be proved as follows: 7.62 ins. $\times 3.14 = 2$ ft., the number of feet in circumference of the drum, and $2 \times 40 = 80$, the number of feet hoist in one minute.

As a further example, take the hoisting with a belt: as, 2,000 pounds hoisted 100 feet high in one minute. What should be the dimensions of gears and drums? Assume a driving pulley, 30 ins. in diameter, making 100 revolutions per minute, and on the same shaft with this pulley let there be a pinion of 5 ins. diameter, which drives a gear 6 times its own diameter, or $5 \times 6 =$ 30 ins., the diameter of the gear. This gear will make $100 \div 6 =$ 16.60 revolutions per minute. Let the drum be on the same shaft as this gear, when it will also make 16.60 revolutions per minute. Assume the diameter of drum to be 10 ins. and the circumference will be $10 \times 3.14 = 31.40$ ins., and $\frac{16.60 \times 31.40}{12} = 43.43$ ft. of rope per minute, which will be wound on the drum. We want to wind 100 feet per minute, so the drum is $100 \div 43.43 = 2.30$ times too small; or it should be 10 ins. $\times$ $2.30 = 23$ ins. in diameter, as $\frac{23 \times 3.14 \times 16.60}{12} = 100$ ft. per minute.

Now we have all the diameters, but how about the power to drive it? The weight to be hoisted is 2,000 pounds, and the velocity is 100 feet per minute; so we have $2{,}000 \times 100 = 200{,}000$ foot pounds, or $200{,}000 \div 33{,}000 = 6$ h.p. If we have 2,000 pounds to lift 100 feet high in one minute of time, we must apply a power or force equal to this to lift it.

The driving pinion is $5 \times 3.14 = 15.70$ ins. in circumference, and running at 100 revolutions has a velocity of $\frac{15.70 \times 100}{12} = 131$ ft. per minute at the pitch line, and a strain due to 200,000 foot pounds resistance. The strain on the teeth will be $200{,}000 \div 131 =$ 1,534 pounds. Allowing 1,000 pounds per square inch of section for the strain on the teeth, we shall require to stand thus: $1{,}534 \div 1{,}000 = 1.53$ square inches. If the tooth is $\frac{1}{2}$ in. in depth and $\frac{1}{2}$ in. wide, there being two teeth in contact, we shall have $0.5 \times 1.5 \times 2 = 1.50$ square inches of section, which is very near what we require.

The foregoing dimensions are for a good, tight belt, and are calculated from practical experience, but may be more or less according to circumstances. It has been my practice to subject a belt $\frac{3}{16}$ in. thick to a strain of no more than 25 pounds per inch of width.

In practice, the dimensions will not often come as given in these examples, for various reasons, such as lack of room, different velocities, etc., etc., and the apprentice who would make himself proficient in these calculations should vary the proportions and work up the results.

Of course, these calculations are theoretical, but theoretical calculations do not, as some assert, give results so altogether different from practice. It is the duty of the practical engineer to learn from observation what the difference will be, and modify his calculations thereby. For instance, in the last example, if we allow 25 per cent. of the effect to be absorbed by friction, we must either get 25 per cent. greater adhesion of belt, or lift 25 per cent. less weight. This and other contingencies must be provided for by the individual judgment of the engineer.

USEFUL PHASES OF SELF HELP.

The time was when the majority of railway enginemen and trainmen despised information concerning their business, which was taken from books. The book-studying engineer was looked upon with pitying contempt by those who boasted they knew nothing, and did not wish to know anything, which was not acquired by observation and practical experience. This class of men never learned more than the simplest and most rudimentary knowledge of their business, but their views or prejudices were popular, and for long obstructed the growth of sentiment in favor of enlightenment. A locomotive engineer who is now a prominent road foreman of engines, and a strong advocate of book instruction, recently told the writer an incident of his early ambition to learn all he could about the locomotive. He bought a well-known instruction book on the locomotive, and he was so much pleased with it that he told an engineer he was firing for about it. The engineer asked him to bring it along next trip and he would look at it. This was done, and when the engineer looked it over he pitched the book into the fire box, at the same time using some profane language about books and people who read them. When the period came round that required engineers to pass an examination concerning air brakes, this engineer was taken off passenger service, owing to his ignorance of air-brake mechanism and for the notoriously rough way in which he braked trains. This is only one of the numerous cases where the cultivation of ignorance proved an expensive practice.

The sentiment in regard to acquiring knowledge is very much changed to-day, especially among younger men. The prevailing feeling is not against book-learning, but thousands of men are striving against great obstacles to acquire knowledge about their business from books, from periodicals of an educational character like *Railway and Locomotive Engineering* and from technical-school instruction papers. The desire for education is very active; but a large proportion of those who are willing to purchase educational facilities find that they are unable to make use of what they have purchased for want of training in study. However ambitious a person may be to acquire knowledge, he will find it difficult to learn things by private effort unless influences are around him which tend to stimulate him to persevere in study. We have often heard it asserted that the most valuable influence of a college course is that it trains a person to study. This training is remarkably hard to acquire by one who has been in active work for eight or ten years since leaving school and has given no thought to learning things. This is why so many persons fail to persevere in the study of subjects relating to their business, after they have purchased papers, books, or a school course with the intention of acquiring knowledge.

People who have been for years engaged on active physical work nearly always become mentally indolent, and it takes a wonderful amount of self-denying perseverance to overcome this indolence. Unless this indolence is conquered a person will make very unsatisfactory progress in studying any subject. A common spectacle is to see a man go home after the day's work is over with his mind made up to begin studying, say, his air-brake catechism. After supper he goes out to take part in some active amusement, or perhaps he devotes himself to working in the garden or doing some household work which is cheerfully undertaken, and bedtime comes without the catechism being reached. And so the distasteful studies are put off from day to day, and good intentions bring forth nothing but procrastination, that thief of time.

The writer in his youth belonged for years to mutual improvement societies, and he has the best of reasons for believing that their influence kept alive a love of study, and did much to direct his studies in useful channels. Every town where ten locomotives lie up over night has now enough railway men interested in learning their business to make the material for forming a mutual improvement society or a class for study. We advise the men in such places, who are anxious to study the science of their business, to associate themselves together and form a class of the kind mentioned. The saying that "in union there is strength," applies very forcibly to the influence which union exerts in stimulating men to study, or to any other self-denying labor. A solitary student early in his search after knowledge, encounters something that he does not understand, becomes discouraged and very often throws up the work as being beyond his capacity. When two or three work together the difficulty which

floors one person is likely to be solved by one of the others, and this process goes on with every hour of study. Helping each other over difficulties is a very valuable feature of mutual help; but even of greater value is the influence it has in keeping up the interest in study.

The cheapening of literature, which has progressed so rapidly in the last quarter of a century, and has brought the best of books and the most valuable periodicals within the reach of wage-earners, has done much to spread the taste for reading. The person who cannot spend an evening pleasantly reading a book is now an exception. The majority of books read by young people are neither of an instructive nor an edifying character; but it often happens that by reading trashy sensational stories, a person acquires a taste for reading of a more valuable character. The writer is a case in point. He was reared in a reading household and acquired a passion for reading stories before he was two years in his teens. For five years he devoured every novel or book of travel he could beg or borrow, and often walked ten miles to a library to obtain a book after a hard day's work. One day a school fellow asked him if he had read "Dick's Christian Philosopher," a book then having a popular run. He had not, but no time was lost in borrowing it. Its contents turned his mind to more useful reading, and he did not read another novel for years.

Reading books or periodicals that treat of the science of a man's business is a useful and instructive pastime and brings much incidental information; but careful study is required to master principles and details. Reading engineering literature gives a person good general ideas about the subjects treated, but reading will not impress the exact knowledge necessary to pass an examination. An intelligent reader learns that steam is made by the boiling of water and that the steam is employed to drive pistons which transmit power to turn the driving wheels, but study is required to find out how the different operations are performed. It is the same throughout all lines of knowledge. Reading will impart information about outlines, but study must be exerted to master particulars.

A common and popular medium for imparting exact information concerning railway mechanism and engineering principles or particulars, is catechisms of various kinds. It is not enough that a student should read those to acquire the information imparted. If he merely reads them they will pass away from his memory within a few weeks. If he wishes to acquire the knowledge embraced in the answers he ought to have someone to catechise him periodically. It is not necessary that he should answer in the exact words given in the paper. It is sufficient if he gives the correct answer in his own language. Trying to learn the exact words of answers is not a good practice. Any mutual union of persons to help each other in this sort of study will bring excellent results.

POWER OF HABIT.

We are acquainted with a gentlemen who carries an umbrella until it is worn out. His explanation for doing so is, that he never ventures out without it, rain or shine. Sheer force of habit prevents him from leaving it where he stops, a common fate of most umbrellas. If the apprentice who is learning a trade or a fireman engaged to keep up steam on a locomotive would adopt a similar plan at the beginning of his career of doing his work in first-class shape he will form a habit that will stick to him like the gentleman's umbrella and which in later years will bring him large returns. Few people realize the enormous power of habit. The young man engaged in mechanical pursuits who is going to do the next job right never amounts to anything. The young man who is determined to do this job right cannot be kept down.

TO SOLDER SMALL CASTINGS.

Clean the surfaces of the fracture with a file, then take a piece of wrought iron and clean it also by filing. Place the wrought iron in the fracture, wire the parts together and braze with spelter solder, using borax as a flux in the usual way. This process, if properly carried out, will secure a joint which will not rust, and will be so strong that the casting will be likely to break at some other place rather than at the former fracture.

MISCELLANEOUS.

TO DETECT CRACKS IN AXLES.

The Canadian Pecific Railway people in Montreal have a good way of finding flaws in iron or steel. It is simply this: Whenever a pair of wheels is sent to the lathe for tire turning, the axle is first carefully cleaned with naphtha; this removes all the grease; then a thin coat of white paint, in which only turpentine is used, is applied, and the mixture allowed to dry. As soon as the wheels are put into the lathe, the stress in the axle, due to the process of turning, develops any flaw or crack if there is one, and it shows at once, as the grease in the crack comes to the surface. Piston rods and side rods undergo similar treatment, and the result has been that many dangerous defects have been found that would have escaped even a careful examination by the eye alone. When the wheels are in, is a good time to watch for cracks in the axle, as there is good reason for believing that many axles are cracked through the excessive strains put upon them in the wheel lathe.

In 1890 the railroads in the United States carried 80,000,000 tons of freight one mile and were paid a fraction over nine-tenths of a cent for carrying each ton one mile; in 1900 they carried 140,-000,000 tons of freight one mile at a rate of seven and a half tenths of one cent per mile. That rate is pretty near cost.

ASKS FAIR PLAY FOR THE COMPOUND.

I do not think the compound should be blamed for the ignorance of the men who is placed there to run her. Ignorance is a very poor excuse, owing to the means that every one has to get a knowledge of the work he has to perform nowadays.

There is a good old saying, "Where there's a will there's a way," and I think that if our brother is very anxious to learn anything about the compound he has got as good an opportunity as firemen or engineers.

How many traveling engineers or others know anything about the simple engine by a knowledge gained by running one; show me a first-class engineer and I will show you a man that has taken advantage of it by study and in this way has gained the point desired.

Let us take, for example, the doctor coming into the sick room; he goes to the patient's side and by feeling the pulse gains a knowledge of the organs inside. He knows what is going on and what is being done by them. The time that that man or doctor has spent in study has given him an insight into the whole subject.

The engineer, if he is a good one, listens to the exhaust of his engine; he can, by running the engine slowly, tell what is going on inside and on which side the trouble is; he then goes on and makes his tests and reports the same.

Why cannot this be done with the compound? It requires study with her as well as with the simple engine. But remember, when you are running a compound she is not a simple engine.

THE BALDWIN LOCOMOTIVE WORKS' UNIT SYSTEM OF PRODUCTION.

The Baldwin Locomotive Works people have an excellent way of getting the actual cost of each engine they build, which they speak of as "unit system of production." Two sets of books are kept—a financial and a manufacturing. In the financial department accounts of sales, purchases and expenditures appear. In the manufacturing books a separate account is opened for each locomotive, and material and labor are charged against the engine they belong to. At the end of the year these two sets of books must balance each other. It is upon this unit system, which preserves the identity of each engine, that the organization of the labor and the management of the work is based.

In the Baldwin Works wages are reckoned by the hour. Piecework wages for convenience of accounting are equated to a per-hour rate. A pieceworker can earn the equivalent of from 18 to 50 cents an hour, the average being 30 cents. The unskilled worker averages 16 cents per hour, and all hands are paid every Friday. Payment is made in coin so as to insure accuracy. The shops run continuously

23 hours a day, with a day and a night force. Rigid inspection of work is maintained, and damage for spoiled work is charged to the workman unless occurring from a reasonable cause. A man accepting a piece of work from a fellow employee in order to finish it, is held responsible for any errors in the work of his predecessor. A workman whose machine breaks down through no fault of his own receives a per-hour rate proportionate to his piecework rate, at the discretion of the foreman.

In the Baldwin Works there is piecework proper, where the workman is paid according to the quantity produced, and there is also the contract system, where sub-foremen, called contractors, execute a portion of the work on a locomotive. The contractor is paid for the job, but the firm pays directly each workman for his labor on the job. The contractor cannot, therefore, get more than the amount due him on any one job by curtailing the wages of his labor. Being paid by the job, he has an incentive to see that his men do their best.

The accurate knowledge which this firm obtains of the actual cost of every piece of work done by the unit system enables those in authority to make stable piecework prices.

LINING OF SHOES AND WEDGES.

By W. D. Chamberlin.

The following method of lining up shoes and wedges is, I think, safe and practical if properly carried out. It has been used for years in one of our railroad repair shops, and gives satisfaction, having been much used on repair work where the old center lines and marks are worn off or cannot be depended upon, so that new and reliable lines have to be laid out.

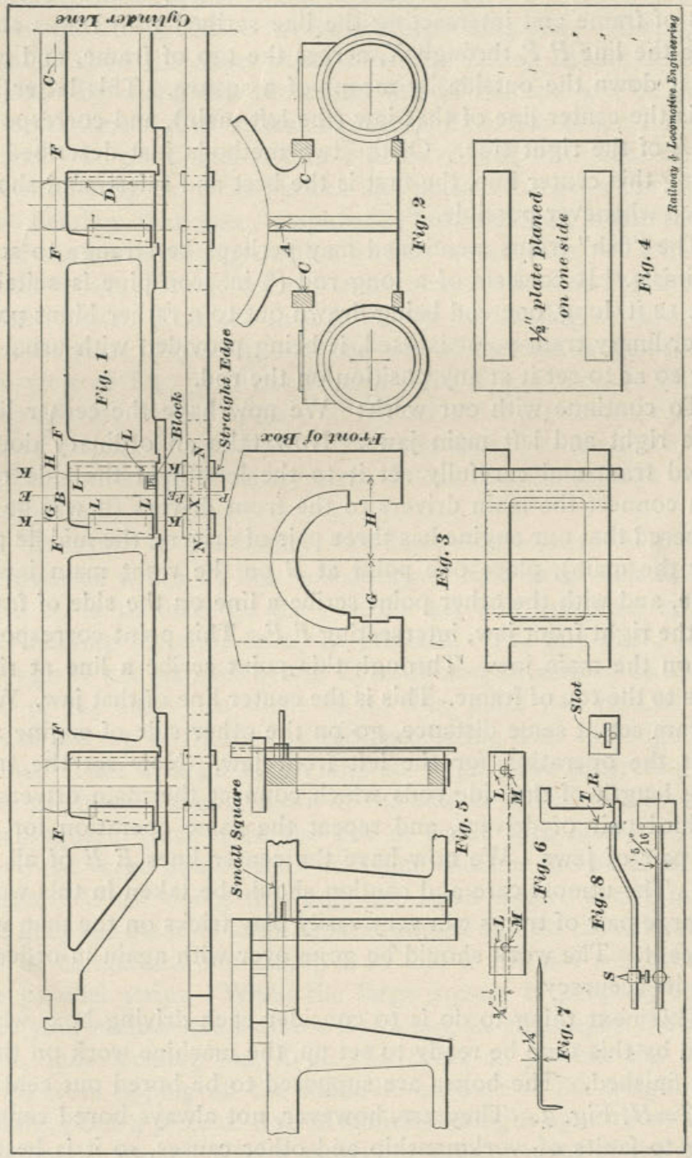
In lining up shoes and wedges the utmost care should be observed when laying off distances or taking measurements, as the accuracy of the finished work depends, of course, upon the care which has been taken in doing it. This is true of most machine shop work, but particularly so with shoes and wedges, the work being simply a matter of taking and laying off certain measurements. The main object in view is to place the axis of the driving wheels and axles at right angles to the frames and parallel to each other, the distance from the axis of one pair of wheels to the axis of the next pair being the same as the length of the rod which connects them. There are other points which must be taken into consideration, but this is the principal one. In the first place, the frames, cylinders, boiler, etc., are supposed to be set up and firmly bolted into place. The pedestal braces should also be bolted into place. We will suppose the engine to have six drivers, the shoes and wedges being ready to set up, having been planed and fitted to the pedestal jaws, all planer work on them being finished except the face or surface, which bears against the driving box. This is left rough until properly laid out.

On the side of the frames over each jaw lay off short lines *F F*, Fig. 1, parallel to and equally distant from the top of frames. When this is done, a point *A*, Fig. 2, on back of cylinder saddle equally distant from each frame and down a convenient distance from the boiler, must be located as follows: Lay off a point *C*, Fig. 1, on the inside of each frame near the cylinder, the distance from the finished surface *D* of the front jaw being the same on both frames, and the distance down from the top of frame also being the same on both frames. Mark this point lightly with a prick punch. Now get a piece of $\frac{1}{4}$ in. wire and bend it as shown in Fig. 7, the end bent being about 1 in. long, Cut the wire off long enough so that it will reach from the point *C* to where point *A* will come, then sharpen both ends. Place the point of straight end at *C* and with bent end scribe a line on cylinder saddle about where *A* will come, then do the same on the other frame. Where the two lines cross will be the point *A*, midway between the frames. Before locating *A* it is best to chip off the rough casting at that point and make a smooth surface to work on. Mark the point *A* with a prick punch. Now go to the right main jaw and lay off its center line *E E*, intersecting *F F* at *B*, Fig. 1.

It is best to use the main jaws to work from, but if they are unhandy to get at, use the front jaws. Take a long "fish" tram with one movable point; place the pointed end at the point *A* on cylinder saddle and set the movable point at *B* on the frame (right main jaw), the intersection of *E E* and *F F*. Take the trams to the left side of the engine, leaving it set at this distance, place the pointed end at *A* as before, and with the movable point scribe a line on side of frame over left main jaw, intersecting *F F*, thus locating at this point of intersection a point corresponding to *B* of the right side. Through this point scribe a line at right angles to the top of frame. This line is the center line of that jaw and corresponds to *E E* of right side.

In some cases the guide yoke or other parts interfere so that the movable point of the trams cannot be set at *B*. In such cases

continue the center line *E E* across top of frame by means of a square set to *E E*, the blade extending across top of frame. On



LINING UP SHOES AND WEDGES, LINES AND POINTS REQUIRED.

this line locate a point a certain distance from edge of frame, say midway between edges, and set the tram point to this point. Take the trams to the left side of the engine, place the point at *A* as before, and with movable point scribe a line on top of frame. Now lay off the line *N N*, shown on plan view of Fig. 1, midway between edges of frame and intersecting the line scribed with trams at *X*. Scribe the line *P P* through *X*, across the top of frame, and continue it down the outside by means of a square. This latter line then is the center line of that jaw (the left main), and corresponds to *E E* of the right side. Of the two methods just described for locating this center line, the first is the best and safest, and should be used whenever possible.

The "fish" trams mentioned may perhaps be strange to some machinists. It consists of a long rod ($\frac{3}{8}$ in. iron pipe is suitable) about 12 ft. long, one end being drawn out to a rather blunt point. One ordinary tram point is used, it being provided with usual set screw so as to set it at any position on the rod.

To continue with our work: We now have the center lines of the right and left main jaws. Now take an ordinary double pointed tram and carefully set it to the length of the side rods which connect the main drivers to the front drivers (it will be remembered that our engine has three pair of drivers, the middle pair being the main), place one point at *B* on the right main jaw of engine, and with the other point scribe a line on the side of frame over the right front jaw, intersecting *F F*. This point corresponds to *B* on the main jaw. Through this point scribe a line at right angles to the top of frame. This is the center line of that jaw. With the tram set at same distance, go on the other side of engine and repeat the operation for the left front jaw. Now set the tram to the length of the side rods which connect the main drivers to the third pair of drivers, and repeat the same operation for the third pair of jaws. We now have the center lines *E E* of all the jaws. The utmost care and caution should be taken in this work, as a large pair of trams can very easily play tricks on the man who handles it. The work should be gone over with again in order to prove its accuracy.

This next thing to do is to consider each driving box, which should by this time be ready to set up, the machine work on them being finished. The boxes are supposed to be bored out central; *i. e.*, $G=H$, Fig. 3. They are, however, not always bored central, owing to faults of workmanship and other causes, so it is best to take this into consideration.

Take a box, say the right main one, get the distance *H* from the center of the brass to the front bearing surface, and lay it off on *F F* of the right main jaw, measuring to the front from the center line *E E*, thus locating point H^1. Do the same with *G*, measuring back from *E E* and locating G^1 on *F F*. Take each box and repeat the operation for its corresponding jaw. These points *H* and *G* show the exact position which the box should occupy in its jaw. By doing this the center line of the box will be kept at the center line *E E* of its jaw, no matter if the box is not bored out central. To get *G* and *H* take a piece of lead or a piece of wood with a tin strip set in its surface and place it between the sides of brass bearing, then take "maphrodite" calipers and locate the center of the brass bearing on this lead or wood piece. A $\frac{1}{2}$-in. plate planed on one side and cut out to the shape shown at Fig. 4 should now be made. This can then be set on the bearing surface of the box, the plate projecting over the side of the box as shown in the plan view of Fig. 3. The distance *H* or *G* can then be obtained by measuring from this plate to the center of the brass previously located on the strip of lead. The plate should be made so that it can be used on any ordinary box. It can then be used on any job of shoes and wedges.

To return to the frame: We have now located on each jaw the position which its box will occupy. Now take each shoe and set it up in its place on the jaw, the set bolt being set up tight, thus holding the shoe firmly in position. The line *K K*, passing through *H* and parallel with *E E*, must now be scribed on the outside of the shoe. In order to do this, place two parallel strips across the top of frame, the ends projecting over the edge of the frame. Take a large square and set it on these projecting ends, with the blade hanging down at the side of the shoe; then take a small square, place it on the side of frame with blade at *H*, and move the large square until its blade touches the blade of small square. While doing this hold the small square firmly in place and keep the blade of large square pressed against the side of shoe, but be careful and not cramp it so that it will not rest evenly on the parallel strips. When the large square is properly located, take your scriber and scribe a line along its edge upon the side of shoe, thus locating line *K K*. In order to prevent the parallel strips from tipping off the frame on account of the weight of the square, place a piece of iron of sufficient weight upon them as they rest on the frame. Fig. 5 shows the arrangement of the squares and shoe. This operation should be repeated on all the shoes.

The next thing to do is to locate on the inside of the shoe a line corresponding to *K K* and at the same distance from *E E*.

Take a long straight edge and pass it between the jaws and across the engine from frame to frame. Select two points *L L* on *K K*, near the top and bottom of the shoe. Cut two small wooden blocks long enough so that when placed on the pedestal brace (one on each brace), with the straight edge resting on them, it will come opposite the lower point *L*. Two blocks should also be cut so as to reach the upper point *L* in the same manner. With the straight edge resting on these smaller blocks, place it so that it is the same distance from *L* on each shoe. The plan of Fig. 1 shows one block and the end of the straight edge as it rests against the shoe.

Now take your "maphrodites" and set them to this distance, *i. e.*, from the straight edge to *L*, which is equal on both sides of engine, then lay that distance off on the side of the shoe with the leg of the "maphrodites" placed against the straight edge. Do this on the other shoe on the other side of the engine, then place the straight edge on the long blocks in the same manner and repeat the operation for the upper point *L*. Scribe a line through these two points just located on the inside of shoes. This line then corresponds to *K K* on the outside of shoe. Repeat this operation on all the shoes.

If the distance *H* is not the same on the opposite jaws it will be seen that the above operation is not theoretically correct, but unless the distance *H* varies greatly it is considered close enough for practice the error being very small..

After all the shoes are thus laid out, they are taken down and planed to these lines. Before taking them to the planer locate with your dividers a point *M*, Fig. 6, a certain distance from *L* on the side of shoe—$\frac{3}{4}$ in. is a convenient distance. It should be laid off from each point *L*, and a small circle described about it so as to make its position plain. After the shoe is planed, by measuring the distance from the planed surface to this point, it can be seen whether the shoe was planed to the lines laid out. This is called a "proof" mark, because it is a means of proving whether the shoe was planed as laid out. If this mark is left off the planer hand can swear that he planed to the lines, and his word will have to be taken.

After the shoes are all planed, set them up in place again; also set the wedges in place on their respective jaws, the wedges being set at their lowest position. Now take a large pair of calipers and caliper the distance between the bearing surfaces of the right main driving box, *i. e.*, $H+G$, Fig. 3. A line *K K* parallel to the planed surface of the shoe must now be scribed on the wedge, both

inside and outside. The handiest and most accurate way to do this is by means of the tool shown at Fig. 8. This consists of a piece *R*, shaped as shown, the inside surfaces *T* and *R* being at right angles to each other. In this piece is screwed a $\frac{5}{16}$-in. steel rod, with an offset and a movable point *S*. The side *T* has a slot cut in it for convenience in setting the point *S* to its proper position. Set the point *S* a distance from the surface *T* equal to the distance obtained by calipering the box.

Place the squared surfaces *R* and *T* against the corner of shoe, the surface *T* bearing against the bearing surface of the shoe, and the surface *R* bearing against the outside of shoe as shown. Now slide the tool down the shoe, holding it firmly with the point *S* against the side of the wedge. This scribes a line *K K* on the side of the wedge parallel to the planed surface of the shoe and at a distance from it equal to the distance between the bearing surface of the box. Do this on all wedges both inside and outside, being careful to set the point *S* for each box, then take the wedges down, put on the proof marks and get them planed.

After the wedges are planed set them up in place again, then place the long straight edge across from frame to frame as before, first rubbing its edge with damp lampblack. Place this edge against opposite shoes or wedges and rub it back and forth a few times, then notice how it bears on the surfaces. By this means it can be seen whether the bearing surfaces of opposite shoes or wedges are parallel to each other or not. To test the work in another way, caliper the boxes again and set the inside calipers and caliper the corresponding shoes and wedges. As a final test after the wheels are placed under the engine and wedges set up in place, the side rods not being up, go to each wheel and plug up the center holes made at the lathe, by hammering lead into them, then with dividers carefully locate the center of wheel, a circle for this purpose being usually cut in the hub of wheel when it is in the lathe; then lightly prick the center. Do this on all the wheels. Now set the large trams to the length of the side rod as before, place one point in center of main driving wheel, and try the center of the next pair of drivers with the other point.

It can then be seen whether the work is right or wrong. Try all the wheels this way with the trams set to the proper length. If the work has been carefully done, the wheels will undoubtedly come all right.

It will be noticed that the point *G*, Fig. 1 was not used in locating *K K* on the wedge. It is not necessary to lay in *G*, but it will do no harm to do so, as the position of *K K* on the wedge may be compared to it as a proof.

This method of lining up shoes and wedges, of course, cannot be used in all details on some makes of locomotives, owing to their peculiar construction, but it will be found that it can be used on ordinary engines. For instance, in getting the line *K K* on the shoes by means of the squares and parallel strips, as described, it will be found that this cannot be done on the rear pair of jaws with those locomotives where the fire box sits on top of the frame. Instead of getting *K K* in the manner described, it may be located by setting the large trams to the length of side rods, as before, and tramming from *K K* of the main shoe, then *K K* of the wedge can be obtained as usual.

CALCULATING TRAIN SPEED.

Sherlock Holmes was, on one occasion, able to astonish Dr. Watson with a remarkably close estimate of the speed of a railway train in which both were traveling. Holmes and his friend were journeying from London to Tavistock, the famous English detective having been engaged on the "Silver Blaze" case, which involved the mysterious disappearance of the favorite for the Wessex Cup and the death of the trainer. Dr. Watson, in describing the trip, says: "We had left Reading far behind when Holmes thrust the last of the daily papers under the seat and offered me his cigar case. 'We are going well,' he said looking out of the window and glancing at his watch, 'our present rate is 53½ miles an hour.' 'I have not observed the quarter-mile posts,' I said. 'Nor have I, but the telegraph poles on this line are sixty yards apart, and the calculation is a simple one.' "

In the United States and Canada the telegraph poles are usually spaced 55 yards apart, and on the average the number of rail lengths passed over in 20 seconds gives very nearly the train speed in miles per hour. The mental calculation made by Holmes would have been unnecessary if he had carried one of *Railway and Locomotive Engineering* speed cards.

INTERNAL COMBUSTION MOTOR FOR RAILWAYS.

In a small way the oil motor is invading the domain of steam, a car for track inspection purposes having been constructed by Mr. F. R. Simms, principal of the Simms Manufacturing Co., Ltd., London. The motor is of 7 h.p. and is capable of propelling the car at a speed up to 30 miles an hour, its stock of fuel, which may be either gasoline or kerosene, being sufficient for 200 miles. The motor is fitted with the Simms-Bosch magneto electric ignition gear by means of which, and constant level fuel feed, the action is entirely automatic. The transmission is by gear of Panhard type, giving three speeds up to the maximum, either backward or forward. This form of vehicle will probably find a sphere of usefulness soon.

A smaller vehicle for the same purpose is doing good service in South Africa on the Sir Lawry's Pass and Caledon line. It was built by De Dion-Bouton, Ltd., of London, and is fitted with one of their 3½ h.p. water cooled motors, which is capable of maintaining a speed of 20 miles an hour.

The makers of American hand cars might find a useful suggestion in this one.

FITTING UP DRIVING ROD BRASSES.

IRA A. MOORE.

The first step after receiving the brasses from the foundry is to plane the flanges *a a*, Fig. 1, of each half brass, taking off only enough to clean them up, when the opposite face *b*, Fig. 2, is flat down on the planer bed or table of the shaper, as the case may be. The flanges *a a*, Fig. 1, should now be put on the planer bed and a cut taken off the face *b*, Fig. 2. The two planed parts of the brass are now perfectly parallel, which will be of assistance later.

When all the half brasses have been subjected to the operation described, they are ready for the tinner to "sweat" the faces *b*, Fig. 2, together. From the tinshop they should go back to the planer and be placed on the bed with the side *c*, Fig. 2 (no difference which side), down. Take just enough off the other side to clean it up.

In Figs. 3 and 4 is shown a special chuck for holding the brasses while planing them to fit the straps.

In Fig. 3, *a a*, is a stud with a collar *b*, forged on it, near the outer edge of which are four ⅝ in. holes, shown also at *a* in Fig. 4. These holes are exactly 90 degrees apart.

On one end of this stud are two steel collars *c c'*, Fig. 3, which are a sliding fit on the stud. The other end of the stud fits the hole in the bracket *b*, Fig. 4, just loose enough to turn without the aid of a wrench.

Holes are provided for holding the bracket to the planer bed, or to the table of a shaper, and it should be bolted on with the stud at right angles to the direction of the cutting tool, and also parallel with the bed or table.

Having fastened the chuck to the machine properly, remove the nut *f*, and collar *c*, and put the brass on the stud with the faced side next to the collar *c* and the flanges *a a*, Fig. 1, perpendicular to the planer bed.

Now plane half enough off the top to fit it to the strap, and enough off the insides of the flanges to make it fit the strap, taking an equal amount off each flange.

Having finished this part of the work, loosen the nut *e* and remove the open washer *d*, which will permit the stud *a* to move endwise far enough to let the collar *b* clear the stud *g*, when the brass can be turned bottom side up without disturbing the nut *f*, which will bring the hole *h* opposite the stud *g*. Replace the washer and tighten the nut *e*. Proceed with this side of the brass the same as before, and if the holes in collar *b* are exactly 90 degrees apart, the two sides of the brass now planed will be parallel, as they should be. Loosen the nut *e* again and turn the stud *a* one-quarter turn either way, and plane one end of the brass, then turn the stud one-half revolution and plane the other end.

Thus the brass is planed on all four sides without loosening the nut *f*. After the brasses have been planed to fit the strap and the oil holes drilled, heat them enough to melt the solder that holds the halves together, to separate them. Remove what solder adheres to them, then put them in the strap, and put the straps in place on the rods. Put a center in each brass to be used in laying out the brasses for boring. Set a tram to the length of the rod, then with one point in the center of, say the back brass, draw a line across the center in the other brass. Suppose this line to be $\frac{1}{8}$ in. back of the center of the brass, then move the back center $\frac{1}{16}$ in. ahead and draw another line with the tram across the center in the front brass. This line will now be $\frac{1}{16}$ in. instead of $\frac{1}{8}$ in. back of the center of the front brass, but the difference between the right length of the rod and the distance between the centers of the brasses has been divided between both ends of the rod.

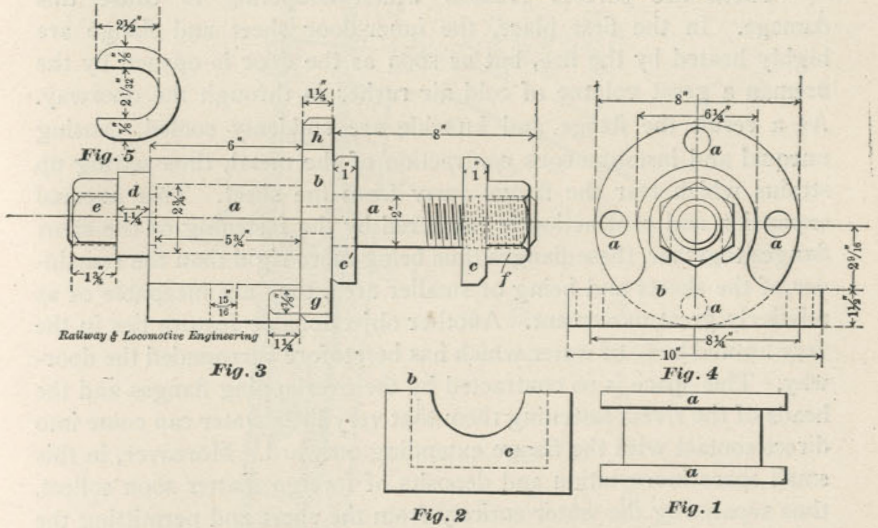
With a pair of dividers scribe a circle somewhat larger than the pin around the centers, for use when setting the brasses up in the lathe or boring mill.

Main-rod brasses should be bored $\frac{1}{64}$ in. larger than the pin and given $\frac{1}{64}$ in. lateral or side motion, being careful to have the flanges the same thickness on each side of the strap. To prevent the brasses wearing themselves loose in the strap, they should fit

it tight enough to require three or four blows of a hand hammer to drive it to its place in the strap, using a block of hard wood between hammer and brass. But the ends of the strap should not be sprung open more than $\frac{1}{32}$ in. when the brass is home.

When strap rods are used for side rods, the brasses should be $\frac{1}{32}$ in. larger than the pins, and have $\frac{1}{64}$ in. side motion. After boring out and facing the sides, take the brasses out of the straps and fit them to the pins, being careful to have no bearing on the fillets.

Solid side-rod brasses should be turned enough larger than the hole in the rod to require $1\frac{1}{2}$ tons per inch of the outside diameter of the brass to press it into the rod. When the brasses are bored



FITTING UP DRIVING ROD BRASSES.

out before putting them in the rod, allowance should be made for the compression due to forcing the brass into the rod.

When the engine frames are in a position to become heated from the boiler or ash pan, the side rods should be $\frac{1}{64}$ or $\frac{1}{32}$ in. longer (according to the temperature of the frame) between centers than the distance between centers of axles, when the frame and rod have the same temperature. All strap rod brasses should be brass to brass, and the keys driven down enough to hold them that way, but not enough to spring the brass out of shape.

To find the length between centers of brasses, of the main rod, place the cross head midway between striking points. Then the distance between the center of cross-head pin and center of main axle is the length of main rod.

AN IMPROVED LOCOMOTIVE FIRE-BOX DOOR FLANGE.

By M. O'Connor.

Foreman Boilermaker, Chicago & Northwestern Railway Shops, Missouri Valley, Iowa

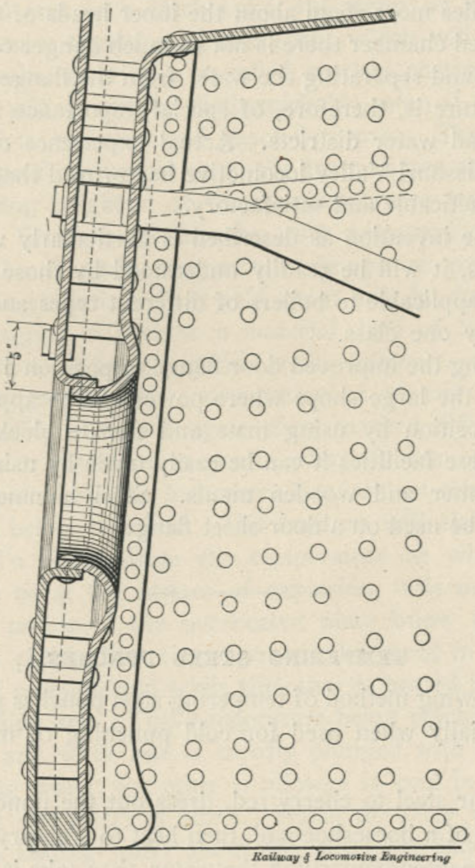
In the construction of steam boilers, and particularly those employed in locomotives, difficulty has often been experienced in preventing cracking and leakage about the door of the fire box. The outstanding flange carried by the inner sheet is disposed substantially at right angles thereto, and the connection of the flange with the sheet is in the form of a sharp bend in the metal. It is with this portion of the structure that the difficulty is experienced, as the cracks occur along the inner bend or knuckle.

There are several reasons which coöperate to cause this damage. In the first place, the inner-door sheet and flange are highly heated by the fire, but as soon as the door is opened by the fireman a great volume of cold air rushes in through the doorway. As a result the flange and knuckle are suddenly cooled, causing unequal and instantaneous contraction of the metal, thus setting up strains which tear the flange away from the sheet. This unequal expansion and contraction is furthered by the fastening of the short flanges together, these flanges thus being more rigid than the remainder of the sheets and being of smaller area, they are incapable of as relatively great movement. Another objectionable feature lies in the very limited body of water which has heretofore surrounded the doorway. This space is so contracted by the overlapping flanges and the heads of the rivets fastening them that very little water can come into direct contact with the flange extending outward. Moreover, in this small space incrustation and deposits of foreign matter soon collect, thus separating the water entirely from the sheet and permitting the metal to become overheated, thereby assisting in doing the injury above described.

Information that I lately received from foreman boiler makers who have charge of boiler shops in the western and northwestern portions of the country indicates that they are having a great deal of trouble with the door flanges by cracking, and they describe it as "the meanest leak and the hardest to keep tight of any leak about a fire box."

It is the object of my improvement to entirely eliminate this objectionable feature by providing an improved structure which will freely expand and contract without causing undue strain, and at the same time obtaining a sufficiently enlarged water chamber about the doorway to prevent to a very great degree accumulations therein.

The structure by which these objects are obtained is simple and is not more expensive than that heretofore employed. Instead of the usual sharp bend or knuckle between the flange and the inner sheet, the portion of the metal connecting the flange and sheet is inwardly swelled, thus forming a circular and inwardly convexed boss about the door opening. As a result, an enlarged water chamber is provided which entirely surrounds the opening.



EXPANSION FIRE-BOX DOOR.

While it will be apparent that this change does not involve any radical departure from the usual construction and that it can be easily made without additional expense, the advantages which are obtained are very important. In the first place, there is no comparatively sharp bend in the metal, while additional area is obtained. As a result, when the flange is cooled during the inrush of cold air in the manner above described, the swelled portion can freely contract without any danger of cracking, as the pronounced curve in the inner sheet gives freely to the strain. A number of benefits are derived from the enlarged water space. The comparatively large body of heated water tends to maintain a more even temperature of the metal, preventing to a great extent its being overheated and also tending to preclude the too rapid cooling of the flanges. Furthermore it provides more room about the inner heads of the rivets, and in this enlarged chamber there is not so much danger of the sediment accumulating and separating the water from the flanges.

This feature is, therefore, of special importance in locomotives running in bad water districts. Actual experience on a Fremont, Elkhorn & Missouri Valley locomotive has proved that the structure is entirely practicable and satisfactory.

While the invention as described is particularly useful in locomotive boilers, it will be readily understood by those skilled in the art that it is applicable to boilers of different types and hence is not limited to any one class.

In forming the improved door flange to position I would recommend that in the large shops where power can be applied that it be pressed to position by using male and female blocks, but in the absence of these facilities it can be easily made by using the swelled cast iron former and wooden mauls. Steel hammers or sledges should never be used on a door-sheet flange.

TEMPERING STEEL PUNCHES.

The following method of tempering steel punches gives excellent results, especially when used for cold punching of machine horseshoes.

Heat your steel to cherry red, dress out the punch, cut off the point the size of a horseshoe nail, then heat to a cherry red, immerse it a half inch perpendicularly in the water, then take it out and stand it up perpendicular, clean the end with a piece of grinding stone. When you see the first blue pass over the point, dip it in the water the same depth as before. Clean it again with the stone, and on the appearance of the blue again, cool it off. The second blue is to make the punch tough. The reason for keeping the punch perpendicular is to allow the atmosphere and the water to cool all sides equally, and to have it cool straight and true.

HOW TO TELL IF A CROWN SHEET HAS BEEN HOT.

"Low water, however caused, always produces excessive heating; and if the temperature rises sufficiently to weaken the material, failure may occur by stripping of the stay bolts or rupture of the sheets by bulging between them, or otherwise. If the temperature has raised the material to a low or bright-red color, this can be readily determined by superficial inspection. While the fire side will show red rust or a black color, the water or steam side will invariably show a typical steel-blue scale, which will not disappear even after years, as it is a so-called rustless coating. If this be once oiled it will always be distinguishable, even if the plates had been exposed to moisture and gases for years. The color of this scale will depend somewhat upon the temperature at which it was produced, being brightest at those points where temperature was the highest. Carefully made tests, with autographic diagrams, of such material will again demonstrate changes of properties which are very characteristic. The yield point will be found very low, while the diagram will show a material drop of curve just after the yield point. The elongation will, however, as a rule, be materially increased, with a diminution of tenacity. Nicked and quenched bending tests will again show marked difference between strips cut from the sheet at points which in one case were overheated or were above the low-water line, and in others were taken from a part below this line. The fracture will also be materially different. To demonstrate the temperature at which the plates happened to be at the instant of explosion, it is necessary to cut strips from points of the overheated plate below the water line. These strips polished on the edges are then held in a clear fire so that one end remains cold while the other is heated to a dull yellow or a very bright red. This temperature being reached, the bars are withdrawn, and while one is rapidly plunged with one end into a pot of boiling water, the other is allowed to cool in air, but not in contact with wet metal or stone. When the piece which had been immersed in boiling water about one inch deep has become nearly cold, below blue heat, it is plunged into cold water.

"On the polished edges of both bars will be found scale and heat colors, the temperatures producing them being well established. These bars are then carefully nicked at points opposite every change of color and then broken off at these nicks. By comparing these fractures and their scale and color with those obtained from pieces cut from the overheated plates, the temperature at which they were at the instant of explosion can be determined with great accuracy.

Having thus determined the temperature at which the sheets were during operation, it is also known whether the metal was sufficiently soft to bulge off or strip from the stay bolts; examination of plates and bolts will verify the conclusion."

KEEPING TOOLS.

Keep your tools handy and in good condition. This applies everywhere and in every place, from the smallest shop to the greatest mechanical establishment in the world. Every tool should have its exact place, and should always be kept there when not in use.

Having a chest or any receptacle with a lot of tools thrown into it promiscuously, is just as bad as putting the notes into an organ without regard to their proper place. If a man wants a wrench, chisel or hammer, it's somewhere in the box or chest, or somewhere else, and the search begins. Sometimes is found—perhaps sharp, perhaps dull, maybe broken; and by the time it is found he has spent time enough to pay for several tools of the kind wanted.

The habit of throwing every tool down, anyhow, and in any way, or any place, is one of the most detestable habits a man can possibly get into. It is only a matter of habit to correct this. Make an inflexible rule of your life to "have a place for everything and everything in its place."

TO MAKE A WIPED JOINT.

Melt the solder in a ladle and pour it on the joint quite plentifully, so as to heat it. As the solder accumulates, wipe it into shape with a piece of cloth (bed ticking is good for the purpose), folded several times and greased with tallow. The cloth is also used to hold the solder as it is poured on the pipe.

TO PUT COPPER COATING ON STEEL.

Dissolve bluestone in water and apply it to the steel, or take a piece of the bluestone (which can be obtained at any drug store), wet it in water, and rub it over the steel.

WORKSHOP RECIPES.

TO TIN BRASSES.

To tin railroad-car brasses so that they can take the lead lining, the bearings are first bored; they are then placed on a coke fire and allowed to become well heated; then they are cleaned with muriatic acid and tinned. They must be warmed again, so that the tin will be in a condition for the lead to adhere to it. They are then placed on a mandrel to receive the lining of lead. The device for holding the bearing during the lining can be of very simple construction. It should be so designed that the bearing can be clamped only central with the mandrel, which will make the lining of uniform thickness over the bearing. The radius of the mandrel should be $\frac{1}{32}$ to $\frac{1}{16}$ of an inch greater than the radius of the journal which the bearing is to fit. The lead lining should not be more than $\frac{1}{16}$ of an inch thick.

TO MAKE BRAZING SOLDER.

There are two methods in general use for making brazing solder. By the first, rods or blocks of the desired alloy are pulverized and graded—coarse, medium and fine—and as we have got quite beyond the age of "mortar and pestel," special plant and machinery are required to accomplish this. The second method is simpler: the molten alloy is poured in a thin stream direct from the crucible into a tank or barrel of water placed in position to receive the dropping metal, about 10 ft. or 12 ft. below. Of course, there are other styles of casting solder; in some cases it is passed through a screen or strainer before falling into the water; in others, it falls on to a stream of water, which is forced through a nozzle; but as there is no material advantage either way, the direct pouring is commonly employed.

On falling into the water the metal is split up into little globules which sink to the bottom. Then the tank is emptied, and the solder, before it is ready for use, gets a thorough good washing to free it from oxide.

TO SOLDER ALUMINUM.

A solder for aluminum consists of aluminum 5 parts, antimony 5 parts, and zinc 90 parts. To make it harder a little more antimony and a little less zinc is used. The aluminum is first melted, the zinc is then added and when this is melted the antimony is added. Sal ammoniac is used as a flux. When the surface is quite clear and white, it should be poured into sticks ready for use, the cinder being first removed.

TO GALVANIZE CASTINGS.

Cleanse the castings in an ordinary tumbler or rattler. When the sand is all removed, take them out and heat one by one, plunging, while hot, into a liquid composed as follows: Ten pounds hydrochloric acid and sufficient sheet zinc to make a saturated solution. In making this solution, when the evolution of gas has ceased, add muriate, or, preferably, sulphate of ammonia, 1 pound, and let it stand until dissolved. The castings should be so hot that, when dipped into this solution and instantly removed, they will immediately dry, leaving the surface crystallized, like frostwork on a window pane. Next, plunge them while hot, but perfectly dry, into a bath of melted zinc, previously skimming away the oxide on the surface, and throwing thereon a small amount of powdered salammoniac. If the articles are very small, enclose them in a wrought-iron basket on a pole and lower them into the metal. When this is done, shake off the superfluous metal, and cast into a vessel of water to prevent them from adhering when the zinc solidifies.

TO MAKE BLUE PRINT PAPER.

The following proportions give as good results as any which we have seen: First solution, $\frac{1}{2}$ oz. red prussiate of potash, $3\frac{1}{2}$ oz. water; second solution, $\frac{3}{4}$ oz. citrate of iron and ammonium, $3\frac{1}{2}$ oz. water. For the coating solution, mix in equal parts. Apply with a camel's-hair brush similar to those used with press copy books. Apply freely, but not so freely as to have the solution stand in puddles. The paper should dry hanging by its edge, in order to drain off superfluous solution, and should be so far as possible nonabsorbent. The chemicals should be bought in original packages to insure their being fresh, and the citrate should be kept in a tin box, or otherwise in absolute darkness. Especially and particularly absolute cleanliness must be observed. A brush on which the solution has been allowed to dry exposed to the sun is ruined for all time. Immediately after use, the brush should be rinsed repeatedly, until there is no show of solution in the water.

TO MAKE RUST JOINTS.

Rust joints are usually made with sifted cast-iron turnings, salammoniac and a little sulphur mixed to a rather stiff paste with water and packed into the joint with a chisel or calking iron. One part sal ammoniac, 2 flowers of sulphur and 80 of iron turnings, by weight, is given for quick setting, and 1 sal ammoniac, $\frac{1}{2}$ sulphur and 100 of iron for slow setting. It is better to omit the sulphur entirely.

CASE HARDENING.

Case hardening in general consists of introducing sufficient carbon into the outer surface of wrought iron. The carbon is communicated by certain animal matters such as hoofs, horns, bones, leather, etc. The articles to be case-hardened are usually placed in an iron box and packed with bone dust. A better way is to use leather and animal hoofs cut up into pieces one inch square and adding common salt in a proportion of about 4 pounds salt, 20 pounds leather and 15 pounds hoofs. Care should be taken in packing the articles so that when the surrounding material burns away the articles will not press upon one another sufficiently to bend them out of shape. The iron box is covered with a lid, and all seams cemented with fire clay. The box is then heated to redness in a charcoal or coke fire and kept there from ten to twelve hours, after which it is allowed to cool in the air. The case-hardening penetrates about $\frac{1}{16}$ of an inch.

A very good formula for making case-hardening mixture out of chemicals is King's formula. It consists of 16 parts lamp black, 18 parts sal soda, 4 parts muriate of soda, and 1 part oxide of manganese.

POTASHING.

The process of case-hardening, often called potashing, is very much quicker than ordinary case-hardening with bone dust, etc. It consists in heating the article to be treated to a bright red, taking care not to let it scale, and applying the pulverized chemical. This is the prussiate of potash which is a yellow, tough, crystalline salt (K_4FeCy_6), called by chemists potassium ferrocyanid. As the potash fuses it can be spread over the entire surface, after which the article is again heated and dipped in cold water. In dipping, care must be taken not to cause the article to warp by uneven cooling. Sometimes a mixture of prussiate of potash 3 parts and sal ammoniac 1 part is used. Another formula is 1 part prussiate of potash, 2 parts bone dust, and 2 parts sal ammoniac. But prussiate of potash used alone is satisfactory.

TO STAIN IRON OR STEEL BLACK.

The following solution for producing a dark color on iron and steel has been recommended: Ferric chloride, 10 parts; water, 200 parts; potassium sulphide, 1 part. The articles may be immersed in the solution or painted with it, then allowed to dry by exposure to the air, and finally brushed with a waxed brush. A fairly good black bronze may be obtained in this way. This solution, with the omission of the potassium chloride may be used for bronzing iron or steel. The color is brown after two immersions, with subsequent air drying, and uniformly distributed over the surface. A dense and fairly uniform grayish-black color can be produced on iron by digesting flowers of sulphur with turpentine, painting the work with the liquid, allowing to dry, and then heating over a clear fire or on a hot stove.

TO SWEAT BRASSES.

To sweat brasses together, the surfaces of the castings which are to be united are first scraped or filed; they are then tinned or covered with solder. After this the surfaces are placed against each other, and the castings are heated until the tin or solder melts; the surfaces are then pressed together, and thereby become united. The pressure, sufficient to hold the pieces together, must be maintained until the tin sets.

BABBITT METAL.

Babbitt metal consists of 3.7 parts of copper, 7.4 parts antimony, 88.9 parts of tin. Imitations of babbitt metal have different mixtures, but they are inferior to the true babbitt. One which has been greatly used contains 8 parts of lead to 1 of antimony and 91 parts of tin.

RATIO OF ADHESION.

There are two expressions used very often in engineering publications and elsewhere which it is well to clearly understand. One is, ratio of adhesion, and the other is, co-efficient of adhesion, as applied to locomotives. The ratio of adhesion for a locomotive engine, is found by dividing the weight on the driving wheels by the tractive force developed in the cylinders. The co-efficient of adhesion is found by dividing the tractive power, by the weight on the driving wheels.

TO TAKE IRON STAINS OUT OF LINEN.

Dissolve a level teaspoonful of oxalic acid in half a tumbler of water and wet the spots with the solution, renewing the application until the spots disappear, and then rinse in clear water. Finally, sponge with dilute ammonia—a teaspoonful of "household" ammonia to half a tumbler of water—and allow it to dry. The oxalic acid is poison.

BRAZING STEEL.

Sheet steel or thin pieces, such as band saws, are generally brazed with silver solder, which is sold in strips. For brazing a band saw, the ends are to be tapered off so as to form a common scarfed joint. The ends are to be securely held in position, leaving a space all about the joint. A piece of silver solder, wet with soldering fluid, is to be placed between the joint; then with a pair of blacksmith's tongs, previously heated to a white heat, grasp the joint. Sufficient heat will be transmitted to the steel to melt the solder and firmly unite the ends. The tongs should be held in contact with the saw until the solder has set, otherwise the parts will be imperfectly united.

COATING FOR BELTS.

For leather belts, take of common glue and American isinglass equal parts; place them in a glue pot and add water sufficient to cover the whole. Let it soak ten hours, then bring the whole to a boiling heat, and add pure tannin until the whole appears like the white of an agg. Apply warm. Buff the grain of the leather where it is to be cemented, rub the joint surfaces solidly together, let it dry for a few hours, and the belt will be ready for use. For rubber belts, take 16 parts gutta percha, 4 parts india rubber, 2 parts common caulker's pitch, 1 part linseed oil; melt together and use hot. This cement can also be used for leather.

CORRODING ACID.

The threads should be thoroughly cleaned and the parts which are not to be touched by the acid should be protected by wax. This may be done by warming the dies sufficiently to melt the wax, and then pressing the points of the teeth into a cake of wax; or the teeth may be entirely covered by dipping into melted wax, and the wax may then be scraped away from the surfaces to which the acid is to be applied. Use a mixture of equal parts nitric acid and muriatic acid, applying with a feather, and when the steel is supposed to be sufficiently eaten, wash in water, which stops the process. It would be well to experiment with some unimportant piece of similar steel first.

ENAMELING.

Enamel is a vitreous substance or glass, opaque or transparent, and variously colored, applied as a coating on a surface of metal or porcelain for purposes of decoration. It consists of easily fusible salts, such as the silicates and borates of sodium, potassium, lead, etc., to which various earths and metallic oxides are added to give the desired colors. These enamels are now prepared in the form of sticks, like sealing wax, and for use are pulverized and applied to the surface either dry or moistened to form a paste. The object to be enameled is then exposed to a moderate temperature in a muffle, and the vitreous substance becomes sufficiently fluid to form a brilliant and adhesive coating. The exact temperature to which the object is to be exposed depends on the class of work to be enameled. These are various operations of enameling, and they require skilful manipulations, a knowledge of which can only be obtained by long practice.

FOR COPPER PLATING.

The articles must first be well cleaned, and then painted over with a solution of protochloride of tin, and immediately afterward with an ammoniacal solution of sulphate of copper. The layer of copper thus produced adheres so firmly to the iron or steel that the different objects can be rubbed and polished with fine chalk without injuring the deposit. The tin solution is prepared with 1 part crystallized chloride of tin, 2 parts water, and 2 parts hydrochloric acid. The copper solution is prepared with 1 part sulphate of copper, 16 parts water, adding ammonia sufficient to precipitate and redissolve.

JAPANNING.

Japanning is done in clear transparent varnishes, in black and in body colors; but black japan is the most characteristic and common style of work. The varnish for black japan consists essentially of pure natural asphaltum with a proportion of gum anime dissolved in linseed oil and thinned with turpentine; but there are numerous receipts given for the varnish, and manufacturers generally conceal the composition of their own preparations. In thin layers such a japan has a rich, dark-brown color, and only shows a brilliant black in thicker coatings. For fine work, which has to be smoothed and polished, several coats of black are applied in succession, each being separately dried in the stove at a heat which may rise to near 300° Fahr. Body colors consist of a basis of transparent varnish mixed with special mineral paints of the desired colors or with bronze powders. The transparent varnish used by japanners is a copal varnish which contains less drying oil and more turpentine than is contained in ordinary painters' oil varnish.

LACQUERS.

Lacquers have various ingredients, according to the depths and shades of color required. The following is for a gold lacquer of brass: Mix ½ pound shellac, picked clean, and clear of all pieces, with ½ pint rectified spirits of wine; keep them in a warm place, and shake them repeatedly. When the shellac is quite dissolved, it is fit for use. If the brass work is old, clean it first in the following manner: Make a strong lye of good ashes, which may be strengthened by soap lees; put in brass work, and the lacquer will soon come off; then have ready a mixture of aquafortis and water, sufficiently strong to take off the dirt; wash it afterwards in clean water, and lacquer it with the above mixture. If the brass work is new, it merely requires to be free from dust, and rubbed with a piece of wash leather to make it as bright as possible. Put the work on a hot iron plate (or upon the top of a stove) till it is moderately heated, but not too hot, or it will blister the lacquer; then make the above mixture warm, lay hold of the work with a pair of pincers or pliers, and with a soft brush apply the lacquer. Care must be taken not to rub it on, but stroke the brush lightly one way, and place the work on the hot plate again until the varnish is hard; but the work should not remain on plate too long. Experience will indicate when it should be removed. Some, indeed, do not place it on the stove or plate a second time. If it should not be quite covered, repeat the lacquering carefully. If pains be taken with the lacquer, the work will look like metal gilt.

METAL THAT EXPANDS IN COOLING.

Receipt for making a metal that will expand instead of contracting when cooling; to be used in filling small holes in castings, etc., is made of lead, 9 parts; antimony, 2 parts; bismuth, 1 part.

NICKEL PLATING.

Light nickel plating can be made by heating a bath of pure granulated tin, argol and water to boiling and adding a small quantity of red-hot nickel oxide. A brass or copper article immersed in this solution is instantly covered with pure nickel.

It has been noticed that copper when melted with salt and subsequently cooled is much tougher than ordinary copper, this being due in all probability to the removal of cupreous oxide, which is present in greater or less quantities and has a breaking effect.

SOLDERING FLUID.

A teaspoonful of chloride of zinc in two ounces of alcohol will make a soldering fluid that will not tarnish or rust the work.

TO BLACKEN BRASS.

Into 6 gallons muriatic acid put 2 pounds yellow arsenic and 1 pound black oxide of iron. Have the pieces thoroughly clean and dry and dip them until the desired shade is produced; then rinse them in clear water and dry in fine sawdust. A much smaller quantity of the chemicals may of course be used if the approximate proportions are secured.

Another recipe is: Make a strong solution of nitrate of silver in one vessel and nitrate of copper in another. Mix the two together and plunge in the brass. The brass after being removed from the bath should be heated evenly until the required degree of dead blackness is obtained. This method is of French origin and was kept a secret for years, being used for the ornamenting of optical and other scientific instruments.

Another recipe is the following solution, recommended for obtaining a deep black color on brass: Dissolve 100 parts of copper nitrate in 100 parts of water. If the article is large, then paint it with this solution; if small, immerse it in the solution. After draining off or shaking off the excess of the solution, heat the article until the copper salt is decomposed into a black copper oxide. The work may be heated over a clear coal fire, but better results may be obtained by heating the articles in a closed muffle furnace. For some kind of work you may obtain more uniform results by using a weaker solution than given above, namely, 100 parts of copper nitrate to 300 parts of water.

Another recipe is the following solution recommended for obtaining a deep black color on copper and its alloys: Copper nitrate, 100 parts; water, 300 parts. The article, if large, is painted with it; if small, the article may be immersed in the solution. It is then heated over a clear coal fire and lightly rubbed. The article is next placed in or painted with a solution of the following composition: Potassium sulphide, 10 parts; water, 100 parts; hydrochloric acid, 5 parts. This composition need not be used in all cases. Small work can be much more conveniently treated by immersion in the solution first given, and after straining off or shaking off the excess of the solution, to heat the work on a hot plate until the copper salt is decomposed into a black copper oxide. It would be difficult to heat large articles upon a hot plate; a closed muffle furnace should give better results than an open fire. In any case, the heating process should not be continued longer than is necessary to produce the change mentioned above.

TO DARKEN COPPER.

Copper may be darkened by washing its surface with sulphuret of ammonia. The solution should be dilute, and after its application the metal should be dried at a gentle heat, and may then be polished with a hard hair brush; or dissolve 5 drachms nitrate of iron in 1 pint of water and immerse the copper, or 5 drachms perchloride of iron in 1 pint of water will answer the same purpose.

TO WRITE ON GLASS.

It is said that a solution of fluoride of ammonium may be used with a quill pen, or you can cover the glass with wax, trace through, and eat with fluoric acid.

As a substitute for oil upon oil stones, which often thickens and makes the stones dirty, a mixture of glycerine and alcohol can be used with good results.

TO DRILL GLASS.

Put a piece of brass tubing in the drill spindle, the outside of the tube being equal to the size of the hole you desire to make. Revolve rapidly, and feed with emery and water. For making holes in thin glass, put a piece of stiff clay or putty on the part where you wish to make a hole. Make a hole in the putty or clay equal in diameter to that of the hole you wish to make, letting the hole reach the glass, of course; into this hole pour a little molten lead and the piece will drop out.

TO ETCH ON STEEL.

For etching on steel, the etching ground is composed of equal parts of beeswax, Burgundy pitch and asphaltum; these are melted together and should be thoroughly incorporated. Warm the steel to a degree which will readily melt the wax by contact. Spread a small quantity of the etching ground evenly over the surface with a dabber or a ball of cotton covered with silk. When cold, remove the ground where the metal is to be etched and apply the etching fluid, which consists of nitric acid 1 part and water 4 to 6 parts. After the biting is done, which will take a few minutes only, dip in hot water and wash off the acid. After this the surface can be cleaned by wiping with benzine. Sometimes the following method is adopted: Make a varnish of asphalt and turpentine mixed with a few drops of linseed oil to make it tacky. Procure a rubber stamp on which the required design is depressed, and having a border around the design. Apply the varnish with the stamp in the same manner as in stamping goods; on border put a small rim of beeswax;

then apply the acid within the border. After it has etched deep enough, which may take a few minutes only, pour off the acid, rinse the surface with clean water, take off the putty, and clean off the varnish with turpentine.

Another composition is recommended for this purpose: Pyroligneous acid 4 oz., alcohol 1 oz., nitric acid 1 oz., by measure. Before applying this fluid to the object to be etched it is important to have the iron or steel clean; after which the surface of the metal on which the etching is to be done should be evenly covered with a thin film of wax, the object of which is to protect that part of the surface not to be etched from the action of the mordant. The lines are then cut through the wax and the fluid poured on. As soon as the metal is sufficiently etched the fluid may be washed off.

STRENGTH OF VARIOUS METALS.

The breaking strain on various metals is shown in the following table, the size of the rod tested being in each case one inch square, and the number of pounds the actual breaking strain:

	Pounds.
Hard steel	150,000
Soft steel	120,000
Best Swedish iron	84,000
Ordinary bar iron	70,000
Silver	41,000
Copper	35,000
Gold	22,000
Tin	5,500
Zinc	2,600
Lead	860

To harden copper, melt together, and stir till thoroughly incorporated, copper and from one to six per cent. of manganese oxide. The other igredients for bronze and other alloys may then be added. The copper becomes homogeneous, harder and tougher.

A workman in the Carson mint has discovered that drill points, heated to a cherry-red and tempered by being driven into a bar of lead, will bore through the hardest steel or plate glass without perceptibly blunting.

DEFINITIONS OF ENGINEERING EXPRESSIONS.

Readers of engineering literature are constantly meeting with expressions that mean much when properly understood. The following selection of such expressions will be found useful:

Absolute: Complete in itself.

Absolute pressure of steam is its pressure reckoned from vacuum; the pressure as shown by an ordinary steam gauge, plus the pressure of the atmosphere.

Acceleration: Advance in the velocity of a body. Decrease of velocity is called negative acceleration.

Accumulator: A secondary or storage battery—a Leyden jar.

Acoustics: That branch of natural law which treats of sound.

Actinism: The property or power possessed by the sun's rays to produce a chemical effect or decomposition (as shown in photography).

Adhesion: The force by which particles of different and unlike bodies stick together.

Affinity (chemical): The force which combines together chemical elements to form compounds, sometimes termed "chemical attraction."

Alloy: A mixture or combination of two or more metallic substances.

Alternating: A motion up and down, or backward and forward, instead of revolving.

Amalgam: The combination of a metal with mercury.

Amorphous: Without definite crystalline form.

Ampere: The unit of electric current. Such a current as would pass with electromotive force of one volt through a circuit whose resistance is equal to one ohm.

Analysis: The process of determining the composition of a compound substance by dividing it into the simple elements of which it is composed.

Anode: The positive pole or electrode of a battery.

Armature: That part of a dynamo-electric machine in which the useful currents are generated.

Axis: An imaginary line passing through a body, which may be supposed to revolve around it.

Atmosphere: The mass of air that envelopes the earth. A pressure of a gas or fluid equal to 15 pounds per square inch.

Atom: The smallest quantity of simple matter which exists.

Back pressure is the loss, expressed in pounds per square inch, due to getting the steam out of the cylinder after it has done its work. On the diagram from a non-condensing engine it is indicated by the distance apart of the atmospheric line and the line of counter-pressure; on the diagram from a condensing engine, it is indicated by the distance apart of the line of counterpressure and the line representing the pressure in the condenser.

Boiler pressure, or gauge pressure, is the pressure above atmosphere; the pressure as shown by a correct steam gauge.

Caliber: The inner diameter; bore.

Caloric: A term applied to that something supposed to be the cause of heat.

Calorimeter: A device for measuring the quantity of heat.

Cam: An irregular eccentric.

Cell: A jar containing the elements and liquid of a battery. The combination of two metals (elements) and a liquid or liquids in such a manner as to produce a current of electricity.

Centrifugal force: The force which tends to urge a rotating or whirling body directly away from the center of rotation.

Circuit: The path of an electric current.

Clearance is the space between the piston at the end of its stroke and the valve face. It is usually reckoned in per cent. of the piston displacement, or in its equivalent in length added to the cylinder.

Closure: Completing an electrical current.

Coil: The arrangement of an insulated wire in symmetrical convolutions through which an electric current can pass.

Commutator: That part of a dynamo-electric machine which collects the currents generated, and the changes of the direction of these currents.

Compression: The action of the piston in compressing the steam remaining in the cylinder at exhaust closure, into the clearance space.

Condenser: The vessel used for condensing steam in a condensing engine. A device for condensing a large amount of electricity on a small surface.

Conductivity: The ability to convey electricity, opposite of resistance.

Conductors: Anything which will convey an electric current.

Core: The heart of certain fruit. Part used to make a casting hollow. The iron of an electro magnet.

Coulomb: The unit of electrical quantity.

Current: The flow of electricity in a conductor. Alternating: A current which periodically reverses. Continuous: A current which does not change its direction.

Dash pot: A mechanical device for checking a sudden motion by means of a plunger working against a cushion of air, water or spring.

Diaphragm: Plate used to regulate flow of gases in smoke box. A thin plate or partition placed across a tube or other hollow body; a disk; a flat circular piece.

Dynamo: A machine which furnishes electricity.

Dynamometer: A device for measuring the power of an engine or motor.

Eccentric: Out of center; a modification of a crank; a circular plate attached to a revolving shaft, but not having the same center, for producing an alternating motion.

Electricity: That which is the cause of electric phenomenon.

Electrodes: The poles of a battery.

Electrolyte: A liquid which permits an electric current to pass through it, only by means of the decomposition of the liquid. Electrolysis: Chemical decomposition effected by means of an electric current.

Electro-Magnet: A magnet produced by passing a current of electricity around a soft iron core.

E. M. F.: Electro-motive force.

Element: Matter which cannot be further decomposed.

Energy: The power of doing work.

Erg: The unit of electrical work.

Expansion, initial: The fall of pressure in the cylinder of an engine as the piston advances and before the steam is cut off. Ratio of expansion: The proportion of total volume of steam in the cylinder—the exhaust not being opened till the end of the stroke—bears to the volume at cut off.

Farad: The unit of electrical capacity.

Field, magnetic: That space surrounding the poles of a magnet which is within the magnetic influence.

Foot pound: A unit of work. To raise one pound one foot.

Force: That which produces a change in the condition of rest or motion of the body.

Formulæ: Mathematical expressions for some general rule or principle.

Friction: The resistance occasioned to the motion of bodies by the pressure of their surfaces against each other.

Fulcrum: Anything which supports a lever, or against which a lever presses in exerting its force.

Galvanism: A term to express the effects of voltaic electricity.

Galvanometer: A device for measuring the strength of an electric current.

Gravity: The force which causes masses of matter to tend to move toward each other.

Heat, latent of steam: The quantity of heat, expressed in heat units required to vaporize or evaporate water already heated to the temperature as shown by a thermometer. Sensible heat of steam is its temperature as shown by thermometer.

Heat unit: The quantity of heat required to raise a given weight of water one degree.

(1) The Thermal Unit, or the amount of heat required to raise one pound of water at its great density, 1° Fahr. This unit represents work equal to 778 foot pounds.

(2) The Greater Calorie, or the amount of heat required to raise the temperature of 1,000 grams of water 1° C.

(3) The Smaller Calorie, or the amount of heat required to raise the temperature of 1 gram of water 1° C.

Helices: Spirals. Coils of wire which acquire all the properties of a magnet when traversed by an electrical current.

Horse power: 33,000 pounds lifted to a height of one foot in one minute of time, or equivalent motion against resistance. Indicated horse power: The horse power as shown by the indicator. It is the product of the mean net area of the piston, its speed in feet per minute, and the mean effective pressure, divided by 33,000. Net horse power is the indicated horse power less the friction of the engine.

Hydrodynamics: That branch of general mechanics which treats of the equilibrium and motion of fluids.

Hydrostatics: Same as hydrodynamics.

Impact: The effect of a blow or stroke from one source to another, whether in motion or at rest.

Impetus: Effect produced by the velocity of a moving body.

Incandescense, electrical: The electric heating of a solid to luminosity. Glowing white heat.

Inertia: That property of matter which tends to cause matter when at rest to remain so, or when in motion to keep going.

Jackscrew: A lifting instrument which acts by the rotation of a screw in a threaded socket.

Journal: That part of an axle or shaft which rests on the bearings.

Joule: The unit of electric energy or work. One joule equals .73732 foot pounds. One joule per second equals 1 watt.

Kathode: The negative pole or electrode of a battery.

Key: A wedge piece of iron or steel for holding pulleys in place.

Keyway: A slot in the center of pulleys or on a shaft, for the reception of a key, which holds the pulley or wheel in place.

Kilowatt: 1,000 watts.

Kinematics: The mechanics of motion.

Kinetic energy: The work a body can do in virtue of its motion.

Lap: The part of a valve that extends over steam ports when valve is on center of seat.

Lead: Extent of valve opening at beginning of stroke.

Lever: A bar or other rigid device having a fixed point, or fulcrum, in the use of which an increase of power, speed or facility is gained or other exercise of power. When the fulcrum is between the weight and power, the lever is of the first class; when the fulcrum is opposite the power, the lever is of the second class; when the fulcrum is opposite the weight, the lever is of the third class.

Link motion: A form of reversing valve gear.

Live steam: Steam direct from the boiler at full pressure.

Magnet: A body possessing the power of attracting iron, steel, etc. Electro: A magnet produced by the passage of a current of electricity around a core of soft iron.

Malleable: Capable of being hammered into different shapes. Castings high in carbon with slight malleability.

Mass: The quantity of matter contained in a body.

Matter: That which occupies space and prevents other matter from occupying the same space at the same time. Matter is composed of atoms, which unite to form molecules.

Molecule: The smallest portion of matter capable of being divided.

Momentum: The rate of change of velocity—and may be either positive or negative.

Mover, prime: The initial motor, or that which drives secondary movers.

Negative: Opposite to positive. One of the phases (not kinds) or states of electrical excitement.

Non-conductors: Insulators of heat. Substances which offer considerable resistance to the passage of electricity.

Ohm: The unit of electrical resistance.

Piston displacement: The space, usually reckoned in cubic inches, swept through by the piston in a single stroke. It is found by multiplying the area of the piston in inches by the stroke in inches.

Potention: The power of doing electric work.

Power: A measure of doing work. Mechanical power is generally calculated in horse power which is equal to the work of raising 33,000 pounds one foot per minute or 550 foot pounds per second.

Pressure, initial: The pressure in the cylinder of an engine at or near the beginning of the forward stroke.

Pressure, mean effective: The average pressure urging the piston forward during its entire stroke in one direction, less the pressure that resists its progress.

Pressure, terminal: The pressure that would be in the cylinder at the end of the stroke of the piston if the exhaust valve did not open until the stroke was completed. It may be found by extending the expansion curve to the end of the diagram. The theoretical terminal pressure is found by dividing the pressure at cut off by the ratio of expansion.

Radiation: The transference of energy by means of ether waves.

Reciprocals: The quotient arising from dividing units by any number.

Resultant: A force which represents the effect of two or more forces acting in different directions.

Shunt: A branch or additional current provided at any part of a circuit; a short circuit.

Superheated steam: Steam which has an excess of heat; this excess may be parted with, without condensation.

Tenacity: The quality of holding together.

Tension: Strain caused by pulling. Act or degree of stretching. Elastic power.

Tortion: Act of twisting; state of twist.

Unit of work: Foot pound—is one pound lifted to a height of one foot. One unit of heat is equal to 778 units of work.

Vacuum: A space from which all air or gas has been removed.

Velocity: The rate of motion.

Vibration: A to-and-fro motion.

Volt: The unit of electromotive force. Electromotive force that would cause a current of one ampere to flow against the resistance of one ohm.

Watt: The unit of electric power. The power developed when 44.25 foot pounds of work are done per minute. The $\frac{1}{746}$ of a horse power.

Wire drawing: The operation, accidental or intentional, of reducing the pressure of steam between boiler and cylinder. Wire drawing generally, but not always, brings about initial expansion.

Work: That which is done by force. It is the product of the force and the distance through which it acts.

HOW TO MEND PATTERNS.

For mending patterns needing temporary repairs, or for making additions where but one or two molds are to be made, the following material will be found very useful. Melt together 1 lb. beeswax, 1 lb. rosin and 1 lb. paraffine wax. It is well to note here that the beeswax intended is the wax made by the bees, and not the wax made by the wholesale dealers. The cheap wax sold to the shipping houses contains but a small portion of the article made by the bees, and a large proportion of soft paraffine wax. The result of using this compound wax instead of the genuine article, in any mixture, is to introduce too much paraffine and only a little beeswax.

HOW TO SET YOUR LUBRICATOR FEED.

By counting in the way here given no mistake can be made.

$\binom{\text{O}}{\text{drop}}$ 1, and 2, and 3, and 4, and 5, and 6, and $\binom{\text{O}}{\text{drop}}$

This count will give you ten drops feed per minute. Count in the same way up to twelve, and this gives you five drops feed per minute. Always use an "and" between every count up to twenty.

MELTING POINTS OF METAL.

Metals.	Centigrade.	Fahrenheit.
Aluminum	degrees 700	degrees 1,292
Antimony	" 425	" 797
Arsenic	" 185	" 365
Bismuth	" 264	" 507.2
Cadmium	" 320	" 608
Cobalt	" 1,200	" 2,192
Copper	" 1,091	" 1,995.8
Gold	" 1,381	" 2,485.6
Indium	" 176	" 348 8
Iron, wrought	" 1,530	" 2.786
" cast	" 1,200	" 2,192
" steel	" 1,400	" 2,552
Lead	" 334	" 617
Magnesium	" 235	" 455
Mercury	" 40	" 40
Nickel	" 1,600	" 2,912
Potassium	" 62	" 143.6
Platinum	" 2,600	" 4.712
Silver	" 1,040	" 1.904
Sodium	" 96	" 172 8
Tin	" 235	" 455
Zinc	" 412	" 773.6

WEIGHT AND SPECIFIC GRAVITY METAL.

Metals.	Wt. pr. cubic ft.	Wt. pr. cubic ft.	Specific grav.
	Lbs.	Lbs.	
Aluminum	166	.096	2.67
Antimony, cast	419	.242	6.72
Bismuth	613	.353	9 822
Brass, cast	524	.3	8.4
Bronze	534	.308	8.561
Copper, cast	537	.31	8.607
" wire	555	.32	8.9
Gold, 24 carat	1208	.697	19 361
" standard	1106	.638	17 724
Gun-metal	528	.304	8 459
Iron, cast	450	.26	7.21
" wrought	485	.28	7.78
Lead, cast	708	.408	11.36
" rolled	711	.41	11.41
Mercury	849	.489	13.596
Platinum	1344	.775	21.531
" sheet	1436	.828	23.
Silver, pure	654	.377	10.474
" standard	644	.371	10 312
Steel	490	.284	7.85
Tin, cast	455	.262	7.291
Zinc	437	.252	7.

A WARNING TO ENGINEERS.

Never take the cap off a bearing and remove the upper brass to see if things are working well, for you never can replace the brass exactly in its former position, and you will find that the bearing will heat soon afterward, on account of your unnecessary interference. If there is any trouble you will find it out soon enough.

DIMENSIONS AND APPEARANCE OF MODERN LOCOMOTIVES.

DEVELOPMENT OF LOCOMOTIVES.

The Twentieth Century Locomotive represents the steady progress of evolution during seventy years. When the primitive locomotives of the decade extending from 1830 to 1840 were built their designers were experimenting to find the fittest form for the work to be done. When John B. Jervis in 1832 placed a four wheel guiding truck in the front of an engine and a pair of driving wheels behind he gave to the railway world the type that in a direct line produced the variety of types that constitute the railway motive power of to-day.

The first locomotive to do practical work on a railroad in the United States was Peter Cooper's Tom Thumb, which demonstrated that the crooked track of the Baltimore & Ohio could be operated by locomotives. That engine developed about one and a half horse power, and the chief objection raised was that it was not powerful enough. That objection has been repeated year after year ever since by the officials responsible for moving traffic at low cost, and the men in charge of the motive power have gone on increasing the weight and power of the locomotive until we have passed the hundred ton mark for engine alone with drawbar pull of about 60,000 pounds.

There have been periods of railroad history when the increasing weight and power of the locomotive advanced very slowly; at other times the demand for more powerful engines has been strenuous. Never was this demand so urgent as it was during the last five years of the 19th century, and the stimulus brought forth the speedy and powerful engines that seem to have reached the full capacity for a track having a gauge of 4 ft. 8½ ins.

The principal improvement effected on the locomotive since it assumed the form given by Jervis has mostly been done by increasing weight and dimensions, adding driving wheels and putting on conveniences for operating. Great efforts were made to give the pioneer locomotives an ornate appearance, but they never had the real finish possessed by the vital parts of the 20th century somber decapod. The line of progress has been in the improvement of the quality and finish of material. Among the beneficial changes effected were: The putting of iron and steel into frames and driving wheels that formerly were partly of wood; counterbalancing the driving wheels; making the fire box and boiler suitable for burning any kind of fuel that could be purchased at the lowest price; using equalizer levers between the driving wheels; placing the cylinders horizontally instead of vertically or inclined; using steel tires instead of iron; using steel for fire boxes and boilers instead of copper or iron; using iron or steel for tubes instead of brass or copper; introducing reliable boiler-feeding appliances; and equipping the engines with reliable cylinder lubricating apparatus.

All these improvements helped to increase the efficiency and durability of the engine and therefore enabled it to reduce the cost of hauling passengers and freight. The demands for increased efficiency and economy which have been rampant in the last five years of the 19th century have brought forth many compound locomotives, increase of size, higher steam pressure, piston valves, longer boiler tubes, larger proportion of grate area to heating surfaces. The utility of some of the "improvements" may be in doubt but the changes are in evidence.

PROPORTIONS OF LEADING TWENTIETH CENTURY LOCOMOTIVES.

Abridged from paper by Mr. Lawford H. Fry,
for New York Railroad Club.

Weight on drivers *to* tractive effort	A
Tractive effort *to* heating surface, factor of boiler capacity	B
Heating surface *to* grate area	C
Factor B x driving wheel diameter	BD
Total weight ÷ heating surface	E

TYPE—PRAIRIE (2-6-2). CLASS—SING. EXP.

ROAD.	Total Weight.	Weight on Drivers.	Cylinder Diameter and Stroke.	Diameter of Drivers.	Boiler Pressure.	Cylinder Tractive Effort.	Heating Surface.	Grate Area.	A: Weight on Drivers / Tractive Effort.	B: Tractive Effort / Heating Surface.	C: Heating Surface / Grate Area.	BD: Tract. Effort x Driv. Dia. / Heating Surface.	E: Total Weight / Heating Surface.
Ill. Cent	203,600	144,000	20 x 28	75	200	25,500	3,534	51.0	5.65	7.21	69.2	541	57.6
E. P. & N. E.	183,900	125,200	21 x 28	69	180	27,400	3,520	53.5	4.57	7.78	65.8	537	52.2
C. B. & Q.	181,900	134,600	21 x 26	69	200	28,200	3,055	42.0	4.77	9.24	72.8	637	59.6
L. S. & M. S.	174,500	130,000	20½ x 28	80	200	25,000	3,362	48.6	5.20	7.43	69.1	594	51.8
C. B. & Q.	168,500	129,500	20 x 24	64	200	25,600	2,888	42.0	5.06	8.86	68.7	568	58.3
C. B & Q.	140,000	96,000	19 x 24	64	190	21,900	2,076	42.0	4.38	10.55	49.5	676	67.5

TYPE—PRAIRIE (2-6-2). CLASS—4-CYL. COMP.

ROAD.	Total Weight.	Weight on Drivers.	Cylinder Diameter and Stroke.	Diameter of Drivers.	Boiler Pressure.	Cylinder Tractive Effort.	Heating Surface.	Grate Area.	A: Weight on Drivers / Tractive Effort.	B: Tractive Effort / Heating Surface.	C: Heating Surface / Grate Area.	BD: Tract. Effort x Driv. Dia. / Heating Surface.	E: Total Weight / Heating Surface.
A. T. & S. F.	209,900	140,300	$\frac{17}{28}$ x 28	69	220	34,600	3,738	53.5	4.06	9.25	70.0	639	56.3
A. T. & S. F.	209,000	144,600	$\frac{17}{28}$ x 28	79	200	27,500	3,738	53.5	5.25	7.36	70.0	581	55.9
C. G. W. (T)	191,700	133,200	$\frac{16}{28}$ x 28	63	200	32,500	3,250	48.5	4.09	10.00	67.1	630	59.0
C. B. & Q.	176,200	132,800	$\frac{16}{27}$ x 24	64	200	26,400	2,888	42.0	5.03	9.15	68.8	585	60.9

TYPE—ATLANTIC (4-4-2). CLASS—SING. EXP.

ROAD.	Total Weight.	Weight on Drivers.	Cylinder Diameter and Stroke.	Diameter of Drivers.	Boiler Pressure.	Cylinder Tractive Effort.	Heating Surface.	Grate Area.	A Weight on Drivers / Tractive Effort.	B Tractive Effort / Heating Surface.	C Heating Surface / Grate Area.	BD Tract. Effort x Driv. Dia. / Heating Surface.	E Total Weight / Heating Surface.
C. R. R. N. J.	191,000	99 400	20½ x 26	85	210	23,000	2,967	82.0	4.32	7.75	36.2	658	64.3
Ill. Cent	188,000	102,000	20 x 28	79	200	24,200	3,129	35.0	4.21	7.73	89.5	611	60.1
C. B. & Q.	187,000	85,000	20 x 26	84¼	210	22,100	2,769	44.2	3.85	7.99	62.6	673	67.4
C. C. C. & St. L.	186,000	100,000	20½ x 26	78	200	24,000	3,340	51.7	4.17	7.20	64.6	561	55.6
Ill. Cent	178,600	95,700	20 x 28	79	200	24,200	3,192	51.0	3.96	7.59	62.5	600	56.0
P. R. R.	176,600	109,000	20½ x 26	80	205	23,800	2,640	55.5	4.58	9.04	47 6	723	66.9
N. Y. C. & H. R.	176,000	95,000	21 x 26	79	200	24,700	3,505	50.3	3.84	7.05	69.8	556	50.2
N. Y. C. & H. R.	176,000	95,000	20½ x 26	79	200	23,500	3,505	50.3	4.04	6.71	69.8	535	50.2
P. & R.	173,600	88,300	21 x 24	84¼	200	21,500	2,948	80.0	4.10	7.30	36.9	615	58.8
P. R. R.	173,500	101,600	20½ x 26	80	185	21,500	2,320	69.2	4.71	9.26	33.5	741	74.5
B. R. & P.	173,000	99,000	20¼ x 26	72	220	27,800	3,008	54.4	3.56	9.24	55.3	665	57.5
C. & O.	173,000	93,000	21 x 26	72	200	27,100	3,505	50.3	3.43	7.74	69.8	556	49.4
C. R I. & P.	167,500	93,500	20¼ x 26	78½	210	24,400	2,806	55.7	3.84	8.69	50.5	674	59.8
Long Isl.	166,000	97,900	19½ x 26	76	200	22,300	2,657	75.5	4.39	8.40	35.2	638	62.5
Vandalia.	164,500	91,500	20½ x 26	78	200	24,000	2,987	43.4	3.81	8.04	64.5	626	55.0
Wabash.	159,600	91,900	19 x 26	73	200	21,900	2,366	29.8	4.19	9.25	79.5	675	67.5
B. C. R. & N.	158,600	88,000	19½ x 26	75	200	22,400	2,569	46.4	3.93	8 73	55.4	655	61.8
C. N. W.	158,000	91,000	20 x 26	80	200	22,200	3,016	46.3	4.10	7.37	65.1	590	52.3
Wabash.	157,900	83,500	19 x 26	73	200	21,900	2,436	29.9	3.81	9.00	81.5	657	64.7
B. R. & P.	153,500	86,400	19½ x 26	72	200	23,400	2,950	46.9	3.69	7 94	63.0	571	52.0
C. R. R. N. J.	151,000	84,600	18 x 26	84¼	200	17,100	2,174	73.0	4.95	7.86	29.8	663	69.5
Pere Marq.	142,000	83,000	18 x 26	72	200	20,000	2,074	42.3	4.15	9.64	49.1	695	68.4
L. V	141,000	81,800	19 x 26	83	180	17,400	2,230	64.0	4.71	7.81	34.9	648	63.3
French State.	139,000	71,900	17¼ x 26	84¼	213	16,700	2,096	35.0	4.30	7 98	60.0	672	66.4

TYPE—TEN-WHEEL (4-6-0). CLASS—2 CYL. COMP.

ROAD.	Total Weight.	Weight on Drivers.	Cylinder Diameter and Stroke.	Diameter of Drivers.	Boiler Pressure.	Cylinder Tractive Effort.	Heating Surface.	Grate Area.	A Weight on Drivers / Tractive Effort.	B Tractive Effort / Heating Surface.	C Heating Surface / Grate Area.	BD Tract. Effort x Driv. Dia. / Heating Surface.	E Total Weight / Heating Surface.
Nor. Pac.	175,500	134,200	22/34 x 30	63	200	30,700	3,013	34.2	4.37	10.18	88.6	643	58.4
Nor. Pac	172,500	126,000	22/34 x 26	63	200	26,600	2,895	34.2	4.74	9.19	84.7	579	59.4
C. P. R.	168,000	124,000	22/35 x 26	69	210	25,500	2,445	30.7	4.86	10.41	79.6	719	68.6
C. P. R.	165,500	126,100	22/36 x 26	69	210	25,800	2,416	31.0	4.88	10.70	78.5	736	68.5
C. & N. W.	163,000	120,000	22½/35 x 26	63	200	27,900	2,346	28.7	4.30	11.89	81.8	748	69.5
R. G. W.	161,500	117,500	22/34 x 26	67	205	25,700	2,486	30.3	4.57	10.31	82.0	691	65.0
Nor. Pac.	155,500	112,000	22/34 x 26	69	200	24,300	2,485	30.8	4.57	9.78	80.8	675	62.5
B. & M.	141,000	103,000	21/32 x 26	63	200	24,300	1,994	27.4	4.24	12.18	72.8	768	70.8
So. Ry.	134,300	103,100	20/32 x 24	66	200	19,400	1,810	27.9	5.32	10.71	64.9	708	74.2
T. H. & P.	127,000	101,000	19/26 x 26	56	180	20,100	1,805	24.0	5.02	11.30	75.2	624	70.4

TYPE—TEN-WHEEL (4-6-0). CLASS—SING. EXP.

ROAD.	Total Weight.	Weight on Drivers.	Cylinder Diameter and Stroke.	Diameter of Drivers.	Boiler Pressure.	Cylinder Tractive Effort.	Heating Surface.	Grate Area.	A Weight on Drivers / Tractive Effort.	B Tractive Effort / Heating Surface.	C Heating Surface / Grate Area.	BD Tract. Effort x Driv. Dia. / Heating Surface.	E Total Weight / Heating Surface.
A. T. & S. F.	158,600	123,400	20 x 26	69	180	23,100	2,148	28.6	5.34	10.75	75.1	742	73.7
Wis. Cen.	158,000	122,000	20 x 26	57	200	31,000	2,430	54.4	3.94	12.75	44.7	728	65.0
Ill. Cen.	157,200	122,300	20 x 28	63	180	27,100	2,396	27.2	4.52	11.30	88.2	712	65.6
A. T. & S. F.	157,000	132,000	20 x 28	62	200	30,800	2,598	48.0	4.28	11.85	54.2	735	60.4
So. Ry.	156,700	117,700	20 x 26	70	200	25,300	2,310	31.5	4.65	10.95	73.4	767	67.8
P. R. R.	156,200	121,000	20 x 28	62	225	34,400	2,814	30.8	3.52	12.22	9[illegible].4	758	55.5
Rutland.	155,000	118,000	20 x 26	69	200	25,600	2,446	30.0	4.61	10.45	81.5	723	63.3
Plant Sys	153 900	111,800	19 x 28	73	200	23,760	2,279	32.2	4.98	10.40	70.8	760	67.5
B. A. & P.	152,100	118,400	19 x 26	67	200	23,900	2,420	34.0	4.95	9.89	71.2	662	62 8
So. Pac.	150,500	117,300	19 x 26	63	200	25,400	1,803	76.0	4.62	14.10	23.7	889	83.5
Plant Sys.	150,000	111 000	20 x 28	65	200	29,300	2,530	33.0	3.79	11.58	76.7	753	59.4
B. & O	147,000	113,000	21 x 26	78	190	23,800	2,160	34.3	4.75	11.00	63.0	858	68.1
Fitchburg	147,000	110,300	21 x 26	78	200	25,100	2,478	34.5	4.40	9.14	79.8	712	53.4
Plant Sys.	146 000	108,000	19 x 28	73	200	23,800	2,313	33.0	4.54	10.30	70.1	751	63.2
B. R. & P.	142,000	108,000	18 x 26	69	200	20,800	2,028	30.6	5.19	10.23	66.4	707	69.9
C. H. & D.	135,000	117,000	19 x 25	57	180	24,200	1,937	26.6	4.60	12.50	72.9	712	69.6
Paulista.	134,400	103,000	19 x 26	68	200	23,500	1,968	23.9	4.38	11.92	82.5	812	68.3
Maine Cen.	134,300	104,000	19 x 24	69	200	21,400	2,029	27.3	4.85	10.53	74.3	727	66.2
T. St. L. & W.	128,200	94,900	19 x 24	68	180	19,600	1,736	27.4	4.82	11.28	63.4	768	74.0

TYPE—AMERICAN (4-4-0). CLASS—SING. EXP.

ROAD.	Total Weight.	Weight on Drivers.	Cylinder Diameter and Stroke.	Diameter of Drivers.	Boiler Pressure.	Cylinder Tractive Effort.	Heating Surface.	Grate Area.	A Weight on Drivers / Tractive Effort.	B Tractive Effort / Heating Surface.	C Heating Surface / Grate Area.	BD Tract. Effort x Driv. Dia. / Heating Surface.	E Total Weight / Heating Surface.
N. Y. C. & H. R......	146,400	94,400	19 x 24	77	190	18,250	2,404	30.7	5.18	7.59	78.4	585	60.9
D. & H...............	146,000	94,000	20 x 24	69	190	22,600	2,261	79.9	4.15	10.00	28.3	690	64.5
D. L. & W............	139,000	93,000	20 x 26	69	185	23,700	2,143	87.7	3.92	11.05	24.5	763	64.8
C. & A...............	139,000	90,300	19 x 26	73	210	23,100	2,177	31.8	3.92	10.60	68.4	776	63.9
C. & O...............	138,000	88,000	20 x 26	72	200	24,650	2,483	31.3	3.57	9.91	79.4	714	55.5
C. N. W............	137,000	87,000	19½ x 26	75	190	21,300	2,508	30.3	4.08	8.50	82.8	637	54.6
B. & A...............	136,400	88,500	20 x 26	75	190	22,500	2,505	30.3	3.93	8.98	82.7	674	54.5
G. S. & F............	136,000	88,000	19 x 26	69	200	23,300	2,364	30.3	3.78	8.82	78.1	609	57.5
N. Y. N. H. & H.	135,000	88,000	20 x 26	78	200	22,600	2,103	30.2	3.89	10.75	69.7	837	64.2
N. Y. C. & H. R......	134,600	90,100	19 x 24	78	190	17,900	1,974	30.7	5.03	9.07	64.4	707	68.1
N. Y. O. & W........	133,000	88,000	18 x 28	68	200	22,700	1,863	24.5	3.88	12.18	76.1	828	71.4
N. Y. C. & H. R......	131,000	86,500	19 x 24	70	190	20,100	1,974	30.7	4.30	10.17	64.4	713	66.4
Fitchburg	130,400	85,000	19 x 26	72	200	22,300	2,164	30.3	3.81	10.30	71.5	741	60.2
Rutland..............	127,000	81,000	18½ x 26	68	200	22,300	2,115	30.3	3.63	10.54	69.8	716	60.1
G. H. & H............	125,700	82,800	19 x 22	72	200	18,800	2,170	31.5	4.40	8.68	68.9	624	57.3
West Md.	104,800	67,200	18 x 24	62	180	19,200	1,606	29.2	3.50	11 95	55.0	742	65.8

TYPE—TEN-WHEEL (4-6-0). CLASS—SING. EXP.

ROAD.	Total Weight.	Weight on Drivers.	Cylinder Diameter and Stroke.	Diameter of Drivers.	Boiler Pressure.	Cylinder Tractive Effort.	Heating Surface.	Grate Area.	A Weight on Drivers / Tractive Effort.	B Tractive Effort / Heating Surface.	C Heating Surface / Grate Area.	BD Tract. Effort x Driv. Dia. / Heating Surface.	E Total Weight / Heating Surface.
D. L. & W............	179,000	137,000	20 x 28	69⅜	210	28,900	2,700	82.2	4.74	10.70	32.9	742	65.3
N. Y. C. & H. R......	175,000	134,200	20 x 28	75	200	25,500	2,916	30.3	5.26	8.75	96.2	657	60.0
Mich. Cent...........	174,600	136,000	20 x 28	75	200	25,500	3,125	34.6	5.33	8.16	87.5	612	57.7
C. R. R. N. J.........	174,500	132,000	20 x 28	69	210	29,000	2,512	83.3	4.54	11.55	30.2	798	69.5
C. C. C. & St. L.......	174,200	134,000	20 x 28	78	200	24,500	2,858	34.3	5.47	8.59	83.4	670	61.0
So. Pac..............	173,000	134,000	20 x 28	69	200	27,700	2,502	30.2	4.84	11.05	83.0	763	69.1
Mex. Nat.......	172,000	133,000	20 x 28	68	200	28,000	2,754	35.2	4.75	10.02	78.0	693	62.5
L. S. & M. S.........	171,800	133,000	20 x 28	80	210	25,100	2,917	36.0	5.30	8.60	79.6	688	59.0
N. Y. C. & H. R......	169,600	128,800	20 x 28	75	200	25,500	2,914	30.5	5.05	8.75	95.6	656	58.2
Gt. North............	166,600	130,000	20 x 30	63	210	34,100	2,386	32.6	3.81	14.28	73.4	900	70.7
G. T. R..............	166,000	125,000	20 x 26	72	200	24,650	2,471	33.4	5.07	9.97	74.0	718	67.2
C. N. W..............	164,000	129,000	21 x 26	63	200	30,800	3,027	46.3	4.19	10.18	65.5	641	54.1
N. Y. C. & H. R......	164,000	126,000	20 x 28	70	200	27,300	2,886	30.3	4.62	9.45	94.5	662	57.2
M. K. & T............	163,400	123,400	20 x 26	72	200	24,650	2,472	31.0	5.01	9.98	79.8	718	66.1
A. T. & S. F.........	162,200	125,900	20 x 28	67	200	28,400	2,329	29.8	4.43	12.20	78.2	817	69.6
C. R. R. N. J.........	161,000	120,000	19 x 26	69	210	24,400	2,187	67.7	4.91	11.15	32.4	720	73.6

TYPE—CONSOLIDATION (2-8-0). CLASS—4-CYL. COMP.

ROAD.	Total Weight.	Weight on Drivers.	Cylinder Diameter and Stroke.	Diameter of Drivers.	Boiler Pressure.	Cylinder Tractive Effort.	Heating Surface.	Grate Area.	A Weight on Drivers / Tractive Effort.	B Tractive Effort / Heating Surface.	C Heating Surface / Grate Area.	BD Tract. Effort x Driv. Dia. / Heating Surface.	E Total Weight / Heating Surface.
L.V.	225,100	202,200	18/30 x 30	55	200	48,100	4,106	90.0	4.20	11.75	45.7	645	54.8
N. Y. C. & H. R ...	225,000	200,000	16/30 x 30 T.	51	210	46,600	4,116	58.0	4.30	11.30	71.0	576	54.7
No. Pac..............	210,000	186,000	15/28 x 34 T.	55	225	48,100	3,669	52.3	3.87	13.10	70.2	734	57.2
So. Pac..............	210,000	185,000	17/28 x 30	57	200	40,700	3,604	54.5	4.56	11.29	66.2	644	58.3
Erie................	209,000	185,000	16/30 x 30 T.	56	220	42,000	2,983	76.3	4.41	14.09	39.1	788	70.1
So. Pac..............	204,800	181,200	17/28 x 3	57	200	40,700	3,599	54.5	4.45	11.32	66.0	645	57.0
A. T. & S. F.........	204,700	182,300	17/28 x 32	57	210	45,300	2,930	47.4	4.02	15.45	61.8	881	69.9
A. T. & S. F.........	201,000	176,000	16/28 x 32 T.	57	210	43,200	2,965	50.0	4.07	14.56	59.3	831	67.8
L. V.................	200,200	177,500	17/28 x 30	55	200	42,100	2,969	76.3	4.22	14.15	38.9	779	67.5
N. Y. C. & H. R....	200,000	172,500	15/28 x 34	63	210	39,100	3,480	50.3	4.41	11.25	69.3	709	57.5
R. G. W..............	198,700	177,200	17/28 x 30	57	200	40,700	3,330	35.0	4.35	12.22	95.2	697	59.6
No. Pac....	198,000	175,000	15/28 x 34 T.	63	225	42,000	2,997	52.3	4.16	14.02	57.3	884	66.1
L. V.................	195,000	171,000	17/28 x 30	62	200	37,500	2,987	76.3	4.56	12.54	39.2	777	65.3

TYPE—CONSOLIDATION (2-8-0). CLASS—4-CYL. COMP.

ROAD.	Total Weight.	Weight on Drivers.	Cylinder Diameter and Stroke.	Diameter of Drivers.	Boiler Pressure.	Cylinder Tractive Effort.	Heating Surface.	Grate Area.	A Weight on Drivers / Tractive Effort.	B Tractive Effort / Heating Surface.	C Heating Surface / Grate Area.	BD Tract Effort x Driv. Dia. / Heating Surface.	E Total Weight / Heating Surface.
No. Pac.	195,000	170.000	15 / 28 x 34 T.	55	225	48,100	3,080	35.0	3.53	15.61	88.0	860	63.4
D. R. G.	188,100	163 500	17 / 28 x 30	54	200	43,000	2,769	46.8	3.80	15.51	59.4	839	67.9
U. P.	188,600	162,800	16 / 27 x 30	55	200	38.300	2,569	33.8	4.25	14.90	76.1	820	73.4
B. & O.	186,500	167,000	15½ / 26 x 30	54	200	36.500	2,334	76.0	4.57	15.64	30.7	845	80.2
U. P.	185,300	161,000	15½ / 26 x 30	57	200	34.500	2,475	33.8	4.67	13.95	73.2	795	74.9
O. A. & P. S.	183,900	164,600	15½ / 26 x 30	56	200	35,100	2,455	35.0	4.69	14.28	70.2	800	74.9
B. & O.	182.300	166,300	15½ / 26 x 30	54	200	36,500	2,348	33.7	4.48	15.52	69.8	839	77.6
E. P. & R. I.	180,400	155,600	17 / 28 x 30	60	200	38.700	2,626	35.0	4.02	14.75	75.1	885	68.6
Colo. Mid.	180,000	157.500	17 / 28 x 30	60	200	38,700	2,626	35.0	4.07	14.75	75.1	885	68.6
C. G. W.	178,400	160,200	17 / 28 x 30	55	200	42,100	2,434	31.5	3.81	17.31	77.3	953	73.2
B. & O. S. W.	162,000	145,000	15½ / 26 x 28	56	200	32.700	2,096	32.7	4.43	15.60	64.1	874	77.4
C. O. & G.	161,900	142,500	15 / 25 x 26	56	200	28,200	2,192	70.0	5.05	12 90	31.3	723	73.9
G. T. R.	161,300	143,400	15½ / 26 x 28	56	200	32,700	2,055	32.7	4.37	15.95	63.0	894	78.4
Va. S. W.	158.000	140,000	15½ / 26 x 28	50	200	36.700	2.437	32.7	3.81	15.08	74.5	754	64.9

TYPE—CONSOLIDATION (2-8-0) CLASS—2-CYL. COMP.

ROAD.	Total Weight.	Weight on Drivers.	Cylinder Diameter and Stroke.	Diameter of Drivers.	Boiler Pressure.	Cylinder Tractive Effort.	Heating Surface.	Grate Area.	A Weight on Drivers. / Tractive Effort.	B Tractive Effort / Heating Surface.	C Heating Surface / Grate Area.	BD Tract. Effort x Driv. Dia. / Heating Surface.	E Total Weight / Heating Surface.
So. Pac.	200,000	176,000	23 / 35 x 34	57	220	46,300	3,599	54.5	3.80	12.87	66.1	734	55.6
So. Pac.	193,000	173,000	23 / 35 x 34	57	220	46,300	3,028	35.5	3.73	15.30	86.1	872	63.7
N. Y. C. & H. R.	192,000	166,000	23 / 35 x 34	63	210	39,300	3,480	50.3	4.23	11.30	69.1	712	55.2
N. Y. C. & H. R.	190,000	164,000	23 / 35 x 32	63	210	37,600	3,217	50.3	4.36	11.70	63.9	736	59.1
No. Pac.	189,200	169,000	23 / 34 x 34	55	225	49,000	3,080	35.0	3.45	15.45	83.7	875	64.6
Mich. Cent.	189,000	164,500	23 / 35 x 32	63	210	37,600	3,250	50.3	4.37	11.56	64.7	728	58.2
N. & W.	186,000	166,000	23 / 35 x 32	56	200	40,300	2,789	34.8	4.12	14.45	80.2	809	66.7
R. G. W.	184,000	167,500	23½ / 36 x 30	56	200	39,500	2,873	34.7	4.24	13.75	82.8	770	64.3
M. St. P. & Ste. M.	177,500	156,500	2½ / 35 x 30	55	210	38,700	2,522	34.4	4.05	15.35	73.2	845	70.5
M. St. P. & Ste. M.	177,000	152,000	22½ / 35 x 30	55	210	38,700	2,633	46.0	3.93	14.71	57.3	809	67.3
W. & L. E.	167,400	146,300	22 / 33 x 28	57	200	31,700	2.008	30.0	4.62	15.78	67.1	900	83.4
S. C. & Ga.	150,000	133,000	23 / 35 x 26	56	200	32,800	2,281	31.5	4.06	14.36	72.5	804	65.7
So. Ry.	144,000	122,400	20 / 32 x 24	56	200	32,900	1,944	26.3	3.72	16.91	74.0	948	74.0

TYPE—MOGUL (2-6-0). CLASS—SING. EXP.

ROAD.	Total Weight.	Weight on Driver.	Cylinder Diameter and Stroke.	Diameter of Drivers.	Boiler Pressure.	Cylinder Tractive Effort.	Heating Surface.	Grate Area.	A Weight on Drivers / Tractive Effort.	B Tractive Effort / Heating Surface.	C Heating Surface / Grate Area.	BD Tract. Effort x Driv. Dia. / Heating Surface.	E Total Weight / Heating Surface.
N. Y. C. & H. R.	170,000	145,000	20 x 28	57	190	31,700	2,733	34.5	4.57	11.60	79.1	661	62.2
Ill. Cent	169,100	149,800	20 x 28	56½	200	33.700	2,462	32.5	4.45	13.68	75.8	773	68.6
Mich. Cent	162,000	141,000	20 x 28	64	200	29.700	2,583	34.6	4.74	11.50	74.7	736	62.7
P. R. R.	162,500	140,300	20 x 28	62	205	31,400	2,469	48.9	4.47	12.70	50.5	788	65.8
C. & A.	160,600	136,300	20 x 28	62	200	30,800	2,608	48.0	4.43	11.80	54.4	731	61.6
P. R. R.	160,000	139,100	20 x 28	62	205	31,400	2.432	30.3	4.43	12.95	80.5	805	65.8
A. T. & S. F.	157,100	132,000	20 x 28	62	200	30,800	2,598	48.0	4.28	11.85	54.2	735	60.5
N. Y. C & H R.	155,200	135,500	20 x 28	57	190	31,700	2.508	30.3	4.26	12.15	82.8	721	62.0
G. T. R.	152.900	127.700	20 x 26	62	200	28,600	2,015	33.4	4.47	14.20	60.3	880	76.0
N. Y. O. & W.	151.000	134,000	19½ x 28	69	200	26,200	2,120	80.0	5.11	12 35	26.5	853	71 2
So. Pac.	142,600	123.700	20 x 28	63	190	27,600	2.115	30.2	4.48	13.05	70.0	823	67.5
M. & St.L.	141,100	120,000	20 x 26	64	200	27 700	2,193	27 0	4.33	12.61	77.5	808	64.5
Pere Marq.	138 500	122,000	19 x 26	56	200	28,500	1,886	30.8	4.28	15.12	61.3	846	73.4
T. St. L. & W.	133.400	116,300	19½ x 26	62	200	27,200	1,829	29.0	4.27	14.88	63.0	924	73.1
Ill. Cent.	126,000	106,400	19 x 26	57	165	23 200	1,531	26.5	4.59	15.15	57.8	864	82.2

TYPE—TEN WHEEL (4-6-0). CLASS—4-CYL. COMP.

ROAD.	Total Weight.	Weight on Drivers.	Cylinder Diameter and Stroke.	Diameter of Drivers.	Boiler Pressure.	Cylinder Tractive Effort.	Heating Surface.	Grate Area.	A Weight on Drivers / Tractive Effort.	B Tractive Effort / Heating Surface.	C Heating Surface / Grate Area.	BD Tract. Effort x Driv. Dia. / Heating Surface.	E Total Weight / Heating Surface.
L. V.	191,800	138,300	17 / 28 x 26	72	200	28,000	2,708	71.3	4.94	10.35	38.0	745	70.8
No. Pac.	190,100	144,800	15½ / 26 x 30	63	200	31,200	3,059	50.9	4.64	10.20	60.0	642	62.2
St. L. & S. F.	189,000	141,800	15½ / 26 x 28	63	200	29,100	2,880	43.6	4.87	10.10	66.0	636	65.6
U. P.	185,200	140,100	15½ / 26 x 28	62	200	29,600	2,993	47.5	4.74	9.90	63.0	614	61.6
U. P.	184,200	142,400	15½ / 26 x 28	69	200	26,600	3,011	32.0	5.35	8.85	94.1	610	61.2
U. P.	182,900	141,300	15½ / 26 x 28	78	200	23,600	3,011	32.0	5.98	7.85	94.1	610	60 7
C. G. W.	182,100	132,700	15½ / 26 x 30	63	200	31,200	2,360	33.0	4.26	13.22	71.6	833	77.2
L. V.	182,000	135,000	17 / 28 x 26	72	200	28,000	2,708	71.3	4.82	10.34	38.0	744	67.2
C. & A.	180,800	131,200	15½ / 26 x 28	68	200	27,000	3,480	34.9	4.86	7.76	99.7	528	51.9
C. R. I. & P.	179,300	134,600	15½ / 26 x 28	78½	200	23,300	2,750	32.8	5.78	8.48	83.8	666	65.2
D. & R. G.	178,600	131.500	15½ / 26 x 26	63	210	28,400	2,614	34.4	4.65	10.87	76.0	685	68.4
C. M. & St. P.	176,200	126,500	15 / 25 x 28	62	200	27,600	2,903	46.5	4.59	9.50	62.5	589	60.7
C. R. I. & P.	173,000	130,200	15½ / 26 x 28	64¾	200	28,400	2,750	32.8	4.58	10.31	83.9	668	62.9
B. & O.	156,100	114,800	15 / 25 x 28	78	200	21,900	2,199	34.4	5.24	9.86	63.9	776	71.1
Iowa Cent.	153,200	111,900	14 / 24 x 26	62	200	23,100	2,226	30.0	4.84	10.37	74.2	644	68.8
Fitchburg	149,300	110,600	15 / 25 x 26	78	200	20,200	2,748	34.5	5.48	7.35	79.8	590	54.3
Paulista	138,700	103,000	14 / 24 x 26	68	200	21,000	1,968	23.9	4.90	10.69	82.3	726	70.5

TYPE—CONSOLIDATION (2-8-0). CLASS—SING. EXP.

ROAD.	Total Weight.	Weight on Drivers.	Cylinder Diameter and Stroke.	Diameter of Drivers.	Boiler Pressure.	Cylinder Tractive Effort.	Heating Surface.	Grate Area.	A: Weight on Drivers / Tractive Effort.	B: Tractive Effort / Heating Surface.	C: Heating Surface / Grate Area.	BD: Tract. Effort x Driv. Dia. / Heating Surface.	E: Total Weight / Heating Surface.
P. B. & L. E.	250,300	225,200	24 x 32	54	220	63,800	3,805	36.8	3.53	16.75	130.5	905	65.8
Union	230,000	208,000	23 x 32	54	205	54,600	3,322	33.5	3.81	16.41	99.3	887	69.2
Ill. Cent	216,000	196,000	23 x 30	57	210	49,700	3,203	38.5	3.95	15.35	83.3	876	67.4
C. B. & Q	207,000	181,000	22 x 28	57	210	42,300	3,828	54.2	4.27	11.05	70.6	630	54.1
Ill. Cent	203,000	184,000	22 x 30	57	210	49,700	3,203	38.5	3.71	15.48	83.3	884	63 3
C. R. I. & P.	202,500	182,000	22 x 30	63	200	39,200	3,264	50.0	4.65	12.40	65.3	781	62.0
C. & A.	198,400	178,900	22 x 28	57	215	43,300	3,573	54.5	4.13	12.10	65.6	690	55.5
N. Y. O. & W.	198,100	170,200	21 x 32	55	200	43,600	3,289	87.4	3.90	13.25	37.7	729	60.2
E. & W. V.	196.000	176,000	22 x 30	54	190	43,400	3,661	90.2	4.06	11.85	40.6	639	53.5
O. S. L.	196,000	174,000	21 x 32	55	200	43 600	2,973	33.0	3 99	14.67	90.1	807	65.9
P. R. R.	193,500	173.900	22 x 28	56	205	42,000	2,843	49.1	4.14	14.76	58.0	826	68.1
C. T. T.	190,300	169,100	22 x 28	51	220	49,600	2,786	46.7	3.41	17.80	59.6	968	68.3
Erie	189,400	165,900	21 x 28	63	200	33,000	2,391	75.0	3.98	13.93	31.9	878	79.2
P. & L. E.	189,150	168,150	21 x 30	51	200	44,000	3,041	33.4	3.82	14.45	91.1	737	62.2
P. R. R	188,500	168,000	22 x 28	56	205	42,000	2,843	49.1	4.00	14.76	58.0	826	66.3
C. & O.	186,500	167,500	22 x 28	56	200	41,100	2,805	36.1	4.08	14.60	77.8	826	66.4
B. & O.	186,500	162,000	21 x 30	57	190	37,600	3,475	50.3	4.31	10.81	69.1	616	53.6
R. G. W.	185,000	168,400	22 x 28	56	185	37,900	2.873	34.7	4.44	13.20	82.8	738	64.3
A. T. & S. F.	185,000	166,400	21 x 32	57	200	42,000	2,699	35.0	3.96	15.55	77.2	887	68.4
C. C. C. & St. L.	185,000	165.000	22 x 30	56	200	44,100	2,801	34.0	3.74	15.70	82.7	880	65.9
C. U. T.	185,000	165,000	21 x 26	51	200	38,200	2,831	48.0	4.31	13.50	59.0	689	65.4
B. R. & P.	184,600	164,600	21 x 28	57	210	38,500	2.878	54.4	4.27	13.39	52.8	761	64.0
R. G. W.	183,000	166,400	22 x 28	56	190	38,900	2,873	34.7	4.28	13.55	82.7	759	63.7

TYPE—ATLANTIC (4-4-2). CLASS—4-CYL. COMP.

ROAD.	Total Weight.	Weight on Drivers.	Cylinder Diameter and Stroke.	Diameter of Drivers.	Boiler Pressure.	Cylinder Tractive Effort.	Heating Surface.	Grate Area.	A: Weight on Drivers / Tractive Effort.	B: Tractive Effort / Heating Surface.	C: Heating Surface / Grate Area.	BD: Tract. Effort x Driv. Dia. / Heating Surface.	E: Total Weight / Heating Surface.
So. Pac.	200,000	102,200	15/25 x 28	79	200	21,600	3,038	....	4.74	7.11	....	562	65.9
So. Pac.	192.300	109,600	15/25 x 28	84¼	200	20,300	3,193	47.4	5.40	6.37	67.4	536	62.3
C. B. & Q	183,100	95,900	15/25 x 26	84¼	210	20,700	3,002	44.1	4.63	6.90	68.0	580	61.0
Erie	183,000	88,300	15/25 x 28	76	200	22,500	2,811	46.8	3.92	8.01	60.1	609	65.1
C. M. & St. P.	181,500	100,300	15/25 x 28	84	200	20,300	3,192	46.7	4.95	6.36	68.3	534	56.8
P. & R.	179.600	91,900	15/25 x 24	84¼	200	17,400	2,948	80.0	5.28	5.91	36.9	497	60.0
C. M. & St. P.	177,500	92,500	15/25 x 28	84¼	200	20,300	3,182	46.7	4.55	6.38	68.3	536	55.8
Can. Atl.	168,900	86,000	13½/23 x 26	84¼	210	16,400	2,336	33.6	5.25	7.04	69.5	592	72.4
C. R. R. N. J.	163,500	87,900	14/24 x 26	84¼	200	17,800	2,669	76.0	4.94	6.67	35.1	562	61.2
C. P. R.	162,000	82,000	13½/23 x 26	84	210	16,500	2,401	32.3	4.96	6.87	74.5	576	67.5
C. B. & Q.	160,000	86,000	13½/23 x 26	84¼	210	16,400	2,511	33.6	5.25	6.54	74.8	550	63.8
Atl. City	150.400	72,500	13/22 x 26	84¼	200	14,300	1,827	76.0	5.06	7.83	24.0	660	82.4
B. & O.	149,600	83,400	15/25 x 28	78	200	22,900	2,663	42.5	3.65	8.60	62.8	670	56.2
Erie	148,300	77,900	13/22 x 26	76	200	15,900	2,270	64.0	4.90	7.01	35.5	533	65.5
C. M. & St. P.	140,700	71,600	13/22 x 26	78	200	15,500	2,233	30.2	4.62	6.91	73.9	543	63.1
Bavarian St.	132,700	68,400	13/22 x 26	72	200	16,800	2,210	30.4	4.07	7.60	72.7	546	60.0

TYPE—CONSOLIDATION (2-8-0). CLASS—SING. EXP.

ROAD.	Total Weight.	Weight on Drivers.	Cylinder Diameter and Stroke.	Diameter of Drivers.	Boiler Pressure.	Cylinder Tractive Effort.	Heating Surface.	Grate Area.	A: Weight on Drivers / Tractive Effort.	B: Tractive Effort / Heating Surface.	C: Heating Surface / Grate Area.	BD: Tract. Effort x Driv. Dia. / Heating Surface.	E: Total Weight / Heating Surface.
E. P. & N. E.	179,600	161,000	22 x 28	57	200	40,400	3,027	49.5	3.99	13.32	61.2	760	59.3
P. D. C. & St. L	178,700	161,200	22 x 28	56	200	41,100	2,501	29.4	3.92	16.45	85.2	921	71.4
D. & H.	176,000	157,500	22 x 28	50	180	41,100	3,348	90.2	3.83	12.28	37.2	614	52.5
N. & W.	175,100	157,900	21 x 30	56	200	40,100	2,478	45.0	3.94	16.20	55.1	907	70.7
B. R. & P.	174,500	155,200	22 x 28	56	200	41,100	2,797	46.7	3.78	14.72	59.9	825	62.4
L. S. & M. S.	174,000	154,000	21 x 30	62	200	36,300	2,874	33.5	4.24	12.63	85.9	785	60.5
C. F. & I. Co.	170,000	155,200	22 x 28	50	170	39,000	2,630	37.0	3.98	14.82	71.0	741	64.6
B. R. & P.	169,600	151,900	22 x 28	56	200	41,100	2,585	33.0	3.70	15.85	78.5	888	65.5
N. & W.	168,000	150,000	21 x 30	56	200	40,100	2,474	47.3	3.73	16.25	52.4	910	67.9
L. S. & M. S.	168,000	149,000	21 x 30	62	200	36,200	2,682	33.5	4.13	13.45	80.2	835	62.6
W. V. C. & P.	167,000	154,200	22 x 28	51	190	42,900	2,630	37.0	3.59	16.31	71.2	831	63.4
N. & W.	165,800	147,500	21 x 30	56	200	40,100	2,409	32.6	3.66	16.70	74.0	936	68.6
Pere Marq.	163,000	148,000	20 x 26	56	200	31,450	2,470	55.0	4.70	12.75	44.9	714	66.0
B. & M.	162,000	142,000	20 x 30	60	200	34,000	2,860	46.5	4.17	11.90	61.5	714	56.6
St. L. & S. F.	160,300	143,200	21 x 28	56	200	37,600	2,343	30.2	3.81	16.05	77.6	898	68.4
West Md.	159,000	141,700	22 x 28	56	180	37,000	2,285	33.6	3.83	16.20	68.0	906	69.5
N. Y. C. & St. L.	158,000	140,000	19 x 28	62	200	27,800	2,514	45.2	5.04	11.05	55.7	685	62.8
So. Ry.	156,900	140,700	21 x 28	60	200	35,000	2,220	30.0	4.02	15.74	74.0	946	70.6
N. C. & St. L.	156,900	140,700	21 x 28	55⅝	180	34,000	2,265	46.6	4.14	15.00	48.7	820	69.2
L. & N.	156,000	139,000	21 x 26	52	175	32,800	2,022	28.4	4.24	16.20	71.3	842	77.1
L. I.	155,000	135,000	21 x 28	51	180	37,100	1,952	69.0	3.64	19.00	28.3	969	79.4
B. & S.	154,500	139,000	22 x 26	51	200	41,900	2,281	52.0	3.32	18.35	43.9	936	67.7
C. O. & G.	141,900	124,200	21 x 26	56	160	28,000	2,109	23.8	4.44	13.29	88.6	745	67.2
Simpson Log. C.	131,000	115,400	20 x 24	50	180	29,400	1,910	33.5	3.93	15.40	57.0	770	68.6
C. N. O. & T. P.	121,700	105,000	20 x 24	52	180	28,300	1,712	37.9	3.71	16.50	45.2	858	71.0

FAST PASSENGER 4-4-2 FOR THE BIG FOUR.

The Dunkirk shops of the American Locomotive Company supplied the Peoria & Eastern, which is now part of the Big Four system, with some fast passenger power of the 4-4-2 type, shown on page 505. The engine is simple, with cylinders $20\frac{1}{2}$x26 ins. and driving wheels 78 ins. in diameter. The weight resting on the drivers is about 100,000 lbs., and the total weight in working order is 184,000 lbs. There is therefore 84,000 lbs. borne by the engine truck and by the carrying wheels at the rear. The weight of the engine and tender is 213,000 lbs.

The valves are of the piston type and the valve gear is direct acting, having transmission bar passing, with an easy curve, over the axle of the leading driver. The rocker has both arms of equal length hanging down from the rocker box. The eccentrics are placed, as is necessary with direct motion, so that the center of each of them is on the side of the vertical center line of the axle, remote from that of the crank pin. The springs are overhung with cast-steel equalizers between drivers, and between main drivers and carrying wheels.

The boiler is an extension wagon-top one, and is $68\frac{3}{8}$ ins. at the smoke-box end. The staying of the crown sheet is radial and the dome is well forward on the third-barrel course, with its center about 60 ins. away from the flue sheet. The heating surface is 3,196 sq. ft. in all, about 3,015 sq. ft., being in the flues, which are 362 in number and 16 ft. long. The grate area is 44.8 sq. ft.

The running board is raised in its central section to accommodate the main reservoir, and a cast-iron step at the front end of it enables a man to pass on to the foot rest over the cylinders.

The tank has a water bottom and will hold 6,000 U. S. gallons, and 12 tons of fuel can be carried. A few of the principal dimensions are appended for reference:

General dimensions—Wheel base, driving, 7 ft. 6 ins.; wheel base, total, 28 ft. 5 ins.; wheel base, total, engine and tender, 54 ft.

Cylinders—$20\frac{1}{2}$x26 ins.

Valves—Greatest travel of valves, $5\frac{9}{16}$ ins.; outside lap of valves, $1\frac{1}{8}$ ins.; lead of valves in full gear, $\frac{1}{16}$ in.

Wheels, etc.—Dia. and length of driving journals, $9\frac{1}{4}$ ins. dia. x 12 ins.; dia. and length of main crank-pin journals, $6\frac{1}{2}$ ins. dia. x 7 ins.; dia. and length of side-rod crank-pin journals, 7 ins. dia. x $4\frac{1}{4}$ ins.

Boiler—Working pressure, 200 lbs.; thickness of plates in barrel and outside of fire box, $\frac{11}{16}$, $\frac{3}{4}$, $\frac{25}{32}$, $\frac{9}{16}$, $\frac{1}{2}$, $\frac{9}{16}$ ins.; fire box, length, 97 ins.; fire box, width, 68 ins.; fire box, depth, front, 80 ins.; back, 71 ins.; fire-box plates, thickness, sides, $\frac{3}{8}$ in.; back $\frac{3}{8}$ in.; crown, $\frac{3}{8}$ in.; tube sheet, $\frac{5}{8}$ in.; water space, front, 4 ins.; sides, $3\frac{1}{2}$ ins.; back, $3\frac{1}{2}$ ins.; smoke stack, inside dia., 15 ins.; length. 19 ins.

SOUTHERN PACIFIC OIL BURNER.

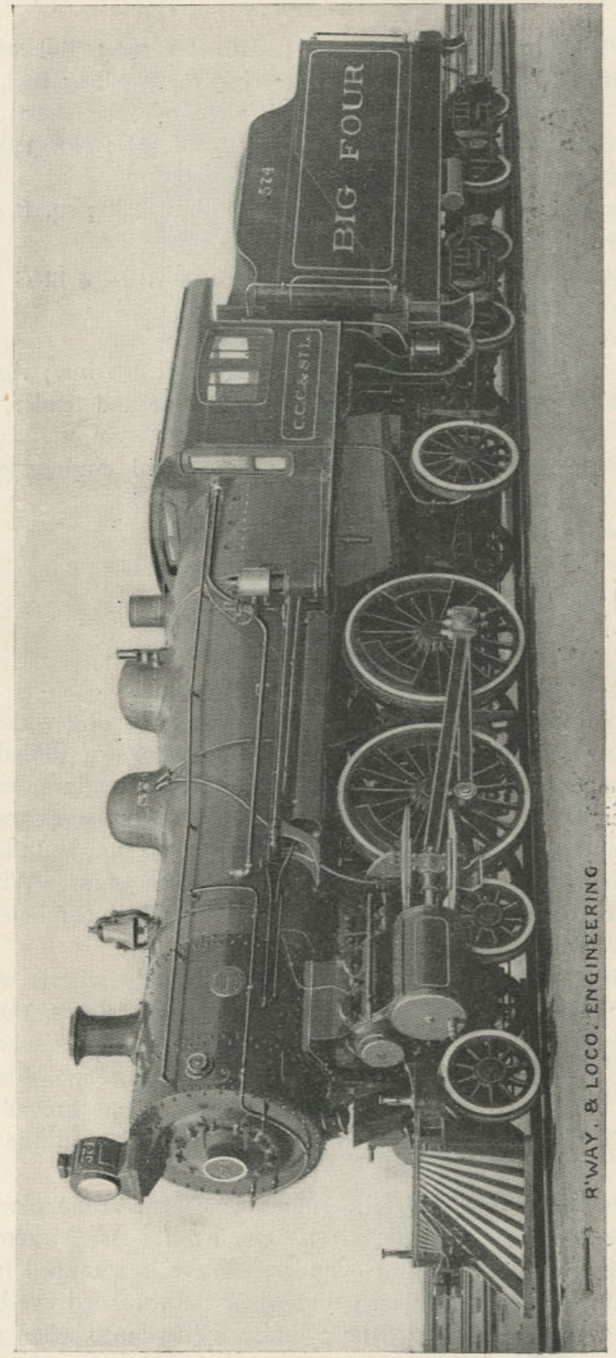
The 4-4-2 engine, shown on page 507 is interesting in several particulars. The cylinders are 15 and 25 ins., and the stroke is 28 ins. The driving wheels measure 79 ins. outside tires, and the main driver is forward. The total weight of the engine is about 200,000 lbs., of which about 102,190 lbs. are borne by the drivers. The pressure carried is 200 lbs., and this with other data gives a calculated tractive effort of about 21,700 lbs. The piston-valve gear is driven by indirect motion in the usual way. The diameter of the carrying wheels is $54\frac{1}{4}$ ins., and they and the driving wheels are equalized together.

The boiler is of the extended wagon-top type, 66 ins. at the smoke-box end. The dome course is 82 ins., and the circular back head is 76 ins. The boiler is supplied with a Vanderbilt corrugated fire box arranged for burning oil. There are 346 tubes, each 16 ft. long. The total heating surface is 3,038 sq. ft. The furnace is 63 ins. diameter by $117\frac{1}{2}$ ins. long, and has an ordinary fire door. Below the fire door is small circular opening for the oil injector.

The tender is of the semi-circular section adopted for oil burners by the Southern Pacific, and it is carried on a steel-channel frame. The tank contains two compartments; the one next the engine holds 3,300 gallons of oil, and the one at the rear can contain 7,300 gallons of water. There is a running board and hand rail along the side of the novel tank. The tender is standard and is used with passenger or freight engines with equal facility.

The engine has a driving-wheel base of 6 ft. 10 ins. and a rigid-wheel base of 15 ft., and the wheel base of the whole engine is 31 ft. $3\frac{1}{2}$ ins., and the total of engine and tender amounts to 65 ft. $5\frac{1}{2}$ ins. The weight of the entire machine, engine and tender, taken together is about 340,000 lbs. The absence of any grate or ash pan gives this engine a clear-cut appearance at the back, and the general design suggests a "high stepper." The cab is made of steel plate and the window arrangement looks as if the comfort of the engineer had been taken into consideration.

A few of the principal dimensions are appended for reference:



American Locomotive Company, Builders.

W. Garstang, Supt. Motive Power.

FAST 4-4-2 ENGINE WITH DAVIS COUNTERBALANCE, FOR THE BIG FOUR.

Boiler—Type, extended wagon-top; dia., 66 ins.; thickness of sheets, $\frac{11}{16}$ in. and $\frac{3}{4}$ in.; working pressure, 200 lbs.; fuel, oil.

Fire box—Vanderbilt corrugated; thickness of tube sheet, $\frac{1}{2}$ in.; tubes, material, steel; wire gauge, .125 M. M.; No. 346; dia., 2 ins.; length, 16 ft.

Heating surface—Fire box, 155.0 sq. ft.; tubes, 2,883 sq. ft.; total, 3,038 sq. ft.

Driving wheels—Dia., outside, 79 ins.; journals, 9x12 ins.; engine truck wheels (front), dia., $36\frac{1}{2}$ ins.

Journals—6x10 ins.; carrying wheels, dia., $54\frac{1}{4}$ ins.

Journals—$8\frac{1}{2}$x12 ins.; wheel base, driving, 6 ft. 10 ins.; rigid, 15 ft.; total engine, 31 ft. $3\frac{1}{2}$ ins.; total engine and tender, 65 ft. $5\frac{1}{2}$ ins.

Weight—On driving wheels, 102,190 lbs.; total engine, 200,030 lbs.; total engine and tender, about 340,000 lbs.

Tank capacity, water, 7,300 gals.; oil, 3,300 gals.

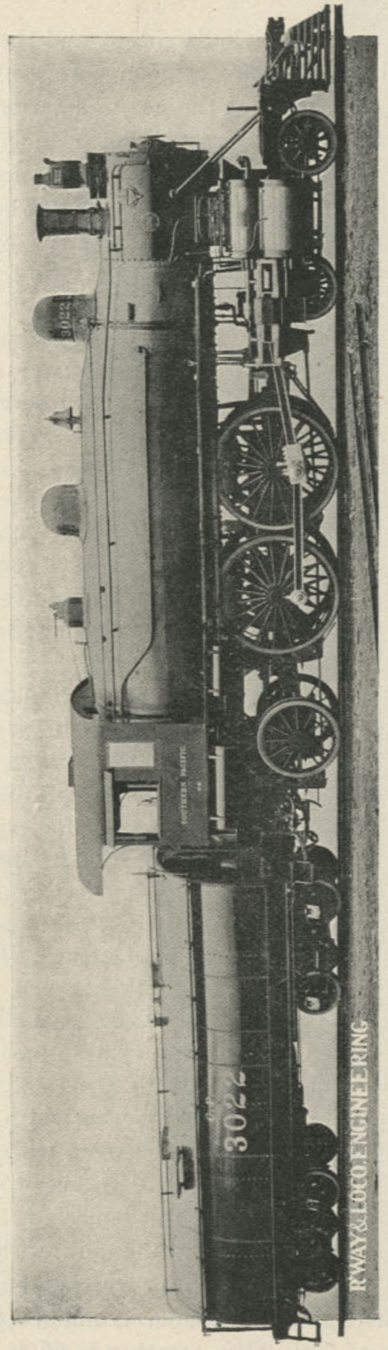
Tender wheels—Dia., $38\frac{1}{2}$ ins.; journals, $5\frac{1}{2}$x10 ins.

BALDWIN 2-10-2 FOR THE SANTA FE.

The Atchison, Topeka & Santa Fe has been buying very heavy freight power from the Baldwin Locomotive Works of Philadelphia in the shape of some tandem compound 2-10-2 engines, each of which weighs 287,240 lbs., one of which is shown on pages 509, 510, 561, 563 and 565. The cylinders are 19 and 32x32 ins., and the driving wheels, of which there are five pairs, measure 57 ins. With 225 lbs. steam pressure the calculated tractive force which can be exerted on the level, at slow speed, is about 62,730 lbs.

In this engine the main drivers are the only wheels without flanges. In the matter of equalizing, the main drivers, the back intermediate, and the trailer are, with the rear-carrying wheel, all equalized together, and the forward intermediate, the leader and the pony truck are equalized together. The springs are all overhung. The valves are actuated by indirect motion in the usual way.

A noticeable feature is the small permanent crane placed on the smoke box on each side. It is intended for use in removing the forward or high-pressure cylinder. There is a tapped hole in the cylinder which is so placed that when the threaded eye-bolt of the crane is screwed into it, the cylinder will balance when swung by the crane.



Baldwin Locomotive Works, Builders.

ATLANTIC TYPE, OIL-BURNING COMPOUND FOR THE SOUTHERN PACIFIC.

H. J. Small, Supt. Motive Power.

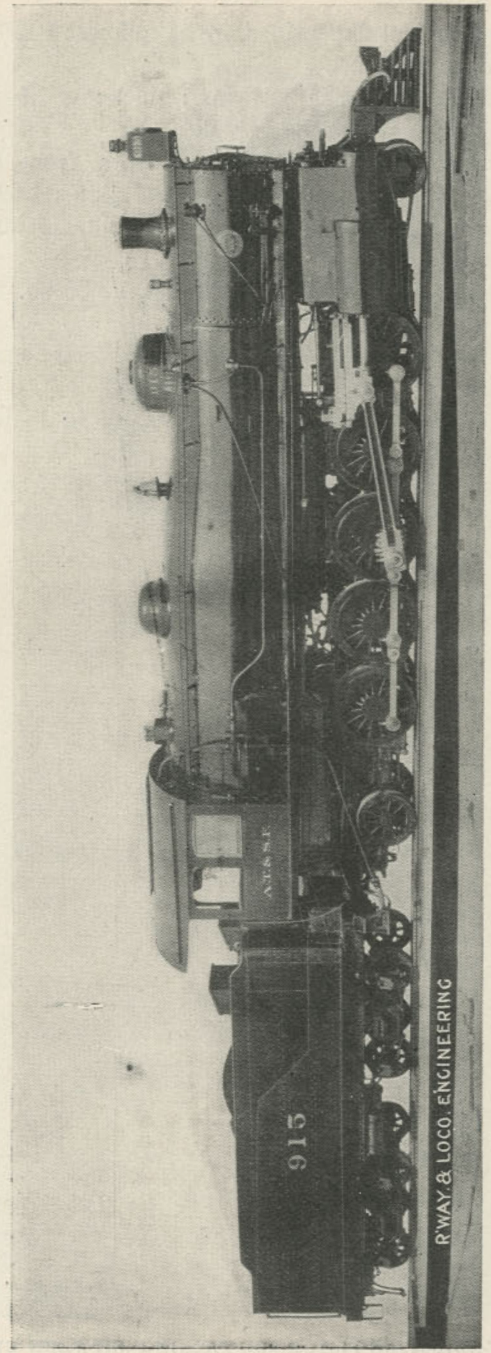
The arrangement of the cylinder heads and the connection between the high and low-pressure cylinders are such that they are securely held in position without the use of interior bolts. By removing the external bolts, which hold the cylinders together, the high-pressure cylinder and the front head of the low-pressure cylinder can be easily taken down, giving free access to the piston and interior of the low-pressure cylinder, without removing the guides, breaking the joints of the back head, or interfering with the steam-chest valve.

A piston rod packing between the two cylinders, shown on page 510, is so conveniently arranged that the parts are confined between the two heads and held in place without internal bolts. This is accomplished by means of a casing or packing box in which the segmental sections of the packing are held and kept in contact with the piston rod by means of suitable springs. The whole packing box has a steam-tight bearing in the recess between the two cylinder heads, but is free to move on this bearing without breaking the joint, thus accommodating itself to any slight variation in the position of the rod. A piston valve is used and so arranged as to avoid all necessity of crossed ports.

The steam-pipe joint between the steam chest and the cylinder saddle is made with a stuffing box and gland in order to give a certain amount of flexibility, and by its use a tight joint is secured after the cylinder has been bolted permanently to the saddle.

There is a relief valve inserted in the dry pipe, the stem of which valve comes out through the top of the smoke box about midway between the sand box and the smoke stack. This valve is for the purpose of admitting air into the steam pipes in the smoke box, when the engine is drifting. The boiler is of the wagon-top type, and measures 78¾ ins. at the smoke-box end. There are 391 tubes 2¼ ins. diameter, 20 ft. long, and these give a heating surface of 4,586 sq. ft. When the amount in the fire box is added to this it brings the total heating surface up to 4,796 sq. ft. An idea of this area may be had by saying that if the width of the regular right of way of a single-track railroad between fences is 66 ft., then it would require a strip of that width 72⅔ ft. long to equal the heating surface which is stowed away in this boiler.

The tender has a steel frame, and the tank, with its deep-water bottom, can contain 8,500 gallons, with corresponding coal capacity. The total weight of engine and tender is about 450,000 lbs., and the total wheel base of both taken together is 66 ft.



Alfred Lovell, Act. Supt. Motive Power. VAUCLAIN TANDEM COMPOUND 2-10-2, FOR THE SANTA FE. Baldwin Locomotive Works, Builders.

A few of the principal dimensions are as follows:

Cylinders—19 and 32 x 32 ins.

Boiler—Type, wagon top; dia., 78$\frac{3}{4}$ ins.; thickness of sheets, $\frac{7}{8}$ and $\frac{15}{16}$ ins.; working pressure, 225 lbs.

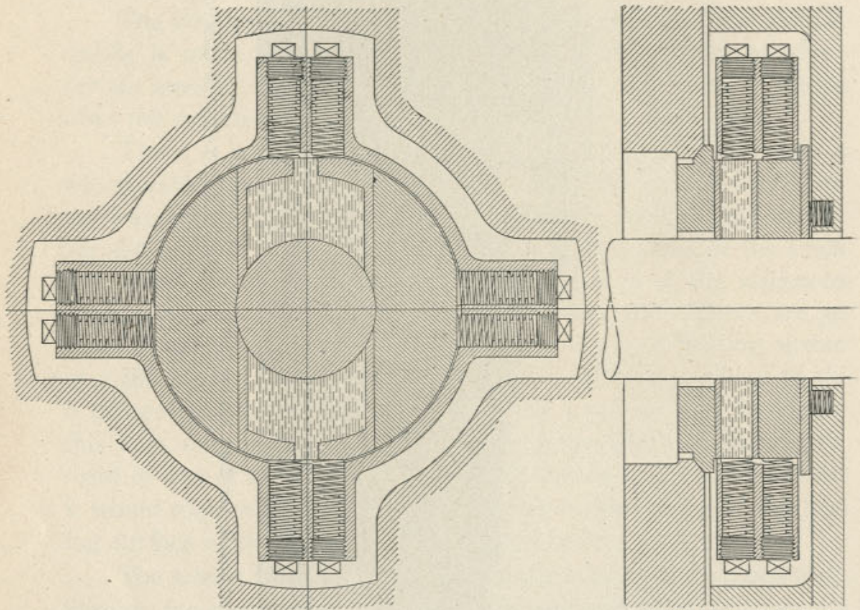
Fire box—Length, 108 ins.; width, 78 ins.; depth, front, 80$\frac{1}{4}$ ins.; back, 78$\frac{1}{4}$ ins.; thickness of sheets, sides, $\frac{3}{8}$ in.; back, $\frac{3}{8}$ in.; crown, $\frac{3}{8}$ in.; tube, $\frac{9}{16}$ in.; water space, front, 4$\frac{1}{2}$ ins.; sides, 5 ins.; back, 4 ins.

Heating surface—Fire box, 210 sq. ft.; tubes, 4,586 sq. ft.; total, 4,796 sq. ft.; grate area, 58.5 sq. ft.

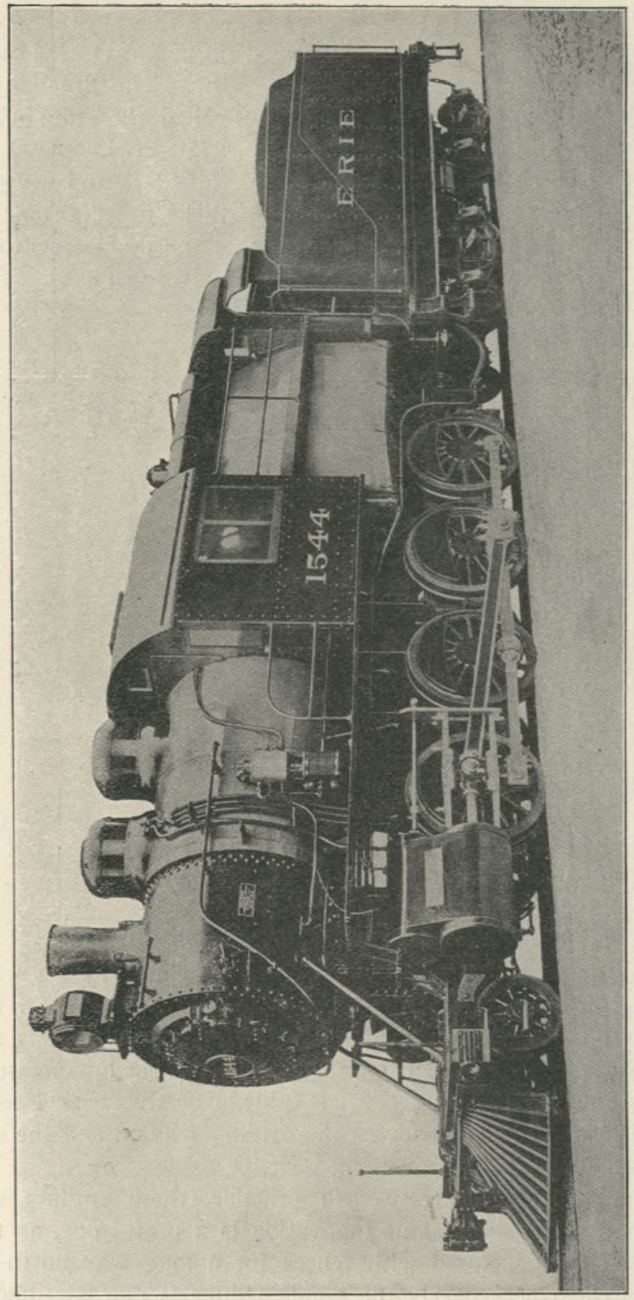
Driving wheels—Dia., outside, 57 ins.; journals, main, 11x12 ins.; others, 10x12 ins.

Wheel base—Rigid, 19 ft. 9 ins.; total engine, 35 ft. 11 ins.; total engine and tender, 66 ft.

Weight—On driving wheels, 234,580 lbs.; on truck, front, 23,420 lbs.; on truck, back, 29,240 lbs.; total engine, 287,240 lbs.; total engine and tender, about 450,000 lbs.



SANTA FE 2-10-2 SELF-ADJUSTING PISTON-ROD PACKING BETWEEN CYLINDERS.



Rogers Locomotive Co., Builders.

100-TON CONSOLIDATION FOR THE ERIE R. R.

W. S. Morris, Supt. Motive Power.

ERIE.

The consolidation locomotive illustrated on page 511 was built by the Rogers Locomotive Works for the Erie. The fire box is one of "high Wootten," as they are sometimes called, the grate being 8 ft. wide and 9½ ft. long, giving 76 sq. ft. of grate area.

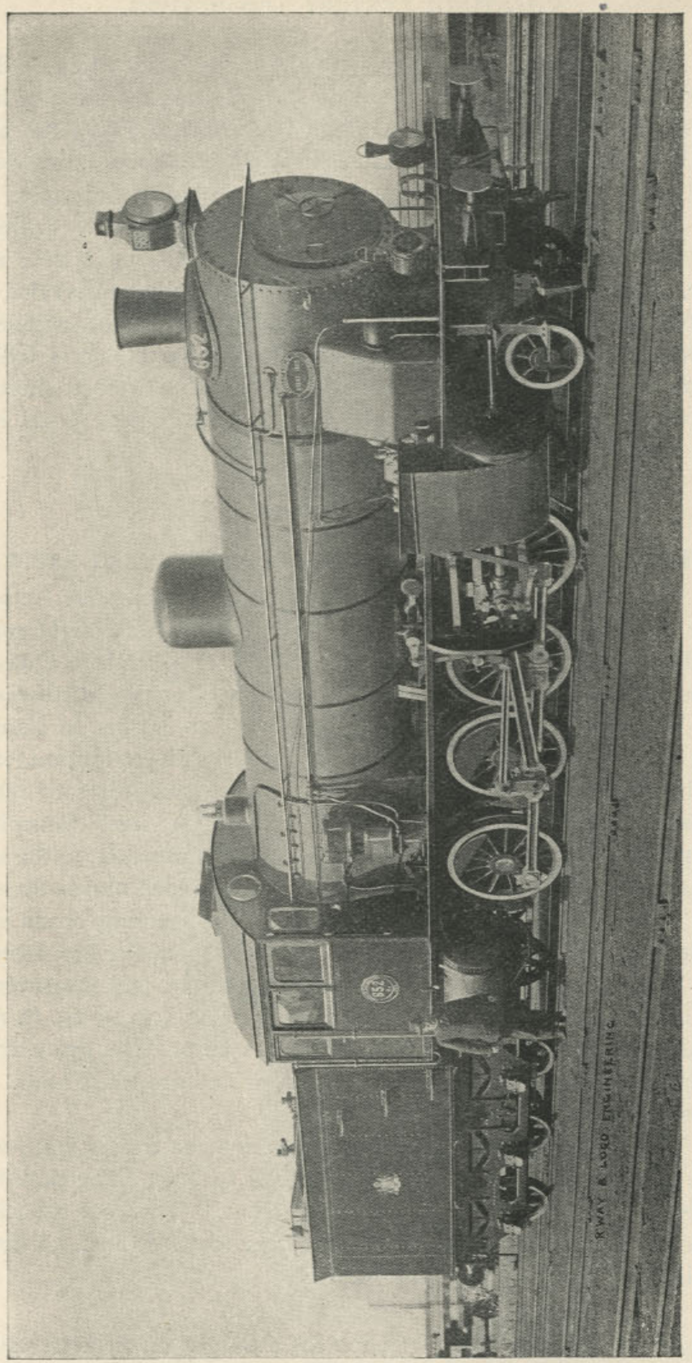
It has a clean-cut look for an engine of this class and weight, some of which lack this characteristic. It will be noted that it is well supplied with sanding apparatus and that the main reservoirs are over the fire-box end of the boiler. Piston valves are used. The leading dimensions are as follows:

Cylinder, 22x30 ins.
Drivers, diameter, 56 ins.
Driving axle journals, main, 9½x12 ins.; others, 9x12 ins.
Driving-wheel base, 17 ft. 0 in.
Total wheel base of engine, 25 ft. 4 ins.
Weight on drivers, 130,000 lbs.
Weight on truck, 20,000 lbs.
Weight, total, 200,000 lbs.
Engine truck, wheels, 30 ins.
Tender, capacity, 12-ton coal; 6,000 gals.
Tender, wheels, diameter, 33 ins.
Heating surface, tubes, 3,288 sq. ft.
Heating surface, fire box, 235 sq. ft.
Heating surface, total, 3,523 sq. ft.
Tubes, 2 ins.; length, 15 ft. 4⅜ ins.; number, 410.
Boiler, diameter, outside front, 76⅛ ins. Working pressure, 200 lbs.

MELLIN COMPOUND, BUILT IN SWEDEN.

The handsome heavy 2-8-0 engine shown on page 513 is a cross compound, built according to the Mellin patents in Sweden for the Swedish State railways. The reducing and intercepting valves are contained in a box over the front deck ahead of the low-pressure cylinder, as shown. Heusinger von Waldegg's valve gear is employed, which is entirely outside of the driving wheels, and the cut off is regulated by a screw-reversing gear.

Contrary to the usual Swedish practice, these engines are equipped with headlights. This innovation is a useful one, as the railway line is not enclosed with fences for a long way north of the arctic circle, where nearly the whole winter is one continuous night.



TWO-CYLINDER COMPOUND ON THE SWEDISH STATE RAILWAYS.

Great care has been taken with the boiler-head fittings. There are two gauge glasses with automatic cut off and protectors of heavy glass. Two double de Simons sight-feed lubricators oil the piston and valve rods, cylinders and valves using the Malmros oiling device. The boiler is fed by two Gresham and Craven No. 10 injectors.

Some of the principal dimensions are as follows: Cylinders, $21\frac{1}{8}$ and 32x$25\frac{1}{4}$ ins.: diameter of driving wheels, $51\frac{3}{16}$ ins.; wheel base, engine and tender, 45 ft. $1\frac{3}{8}$ ins. Total weight in service, 75.6 metric tons; adhesive weight, 64.3 tons. Total weight, engine and tender, 114.3 tons. The inside diameter of the boiler is $68\frac{7}{8}$ ins. There are 304 tubes, 2 ins. outside diameter, The fire-box sheets are copper, $\frac{11}{16}$ ins. thick, and the tube sheet is also copper, $1\frac{1}{8}$ ins. thick. The steam pressure, 205 lbs.

SIMPLE 4-6-0 FOR THE CHICAGO & NORTHWESTERN RAILWAY.

The Schenectady shops of the American Locomotive Company have built for the Chicago & Northwestern some fast freight engines of the 10-wheel type, shown on page 515. Mr. Robert Quayle is superintendent of motive power and machinery of the Northwestern.

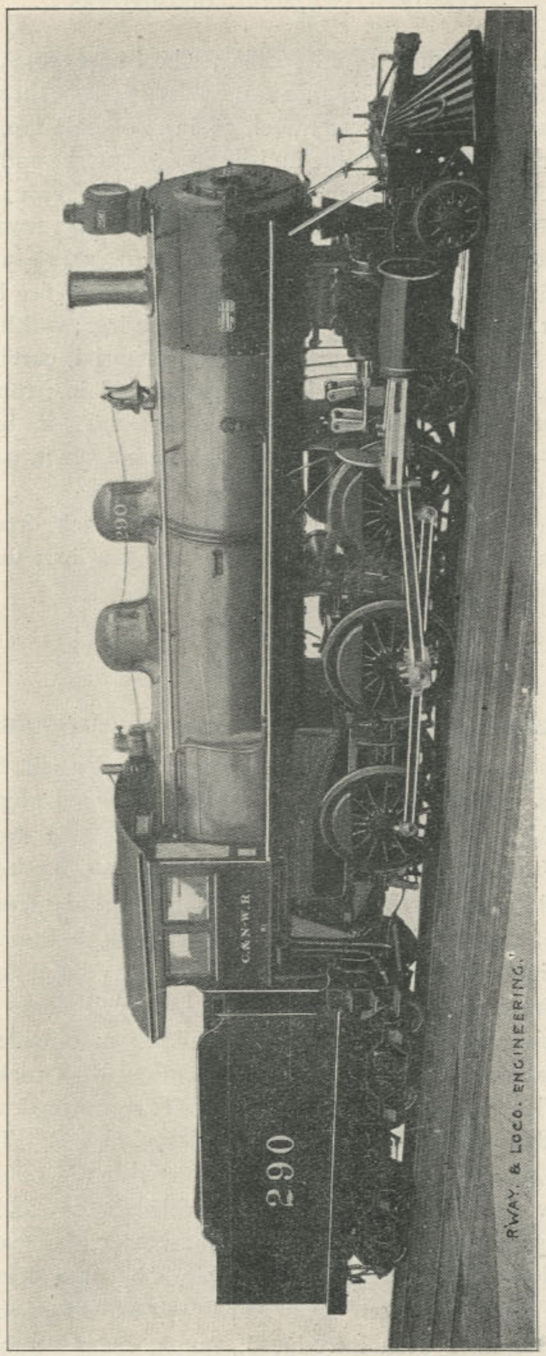
The cylinders are 21x26 and the drivers are 63 ins. in diameter. Our illustration on page 515 shows clearly the direct-motion feature of the valve gear. The center wheels are the main drivers and the eccentrics are placed upon the main axle, a cast-steel transmission bar passes over the forward driving axle and is attached to the lower end of a rocker of the same length as the one which moves the valve rod. The valves are of the piston type. The running board is extended the full length of the engine from cab to smoke-box front.

The boiler is a wide fire box, wagon-top one, and measures $66\frac{1}{2}$ ins. in the first course. The heating surface is 2,959.19 sq. ft. made up as follows: Tubes, 2,808.4; fire box, 150.79. The grate area is 46.27 sq. ft. The tubes are 337 in number and are 16 ft. long. The pressure carried is 200 lbs.

The tender has 10-in. steel channels and the trucks are 4-wheel Player cast-steel arch bar trucks with coil springs. The tank has a water bottom and holds 5,400 U. S. gallons. The coal capacity is 10 tons. The wheel base of the tender is 16 ft. 10 ins. A few of the leading dimensions are as follows:

GENERAL DIMENSIONS.

Weight in working order, 164,000 lbs.; weight on drivers, 129,000 lbs.; weight engine and tender in working order, 274,000 lbs.;



4-6-0 TYPE ENGINE FOR THE CHICAGO & NORTHWESTERN.

Robert Quayle, Supt. of Motive Power. American Locomotive Co., Builders.

wheel base, driving, 14 ft. 10 ins.; wheel base, total, 25 ft. 10 ins.; wheel base, total, engine and tender, 54 ft. $2\frac{3}{4}$ ins.

Valves—Piston type; greatest travel, $5\frac{3}{4}$ ins.; outside lap, 1 in.; inside clearance, $\frac{1}{16}$ in.; line and line full gear, F. and B.

Wheels, etc.—Dia. of driving wheels outside of tire, 63 ins.; driving-box material, main, cast steel; others, steeled cast iron; dia. and length of driving journals, $8\frac{1}{2}$ and 9 ins. dia. x $11\frac{1}{2}$ ins.

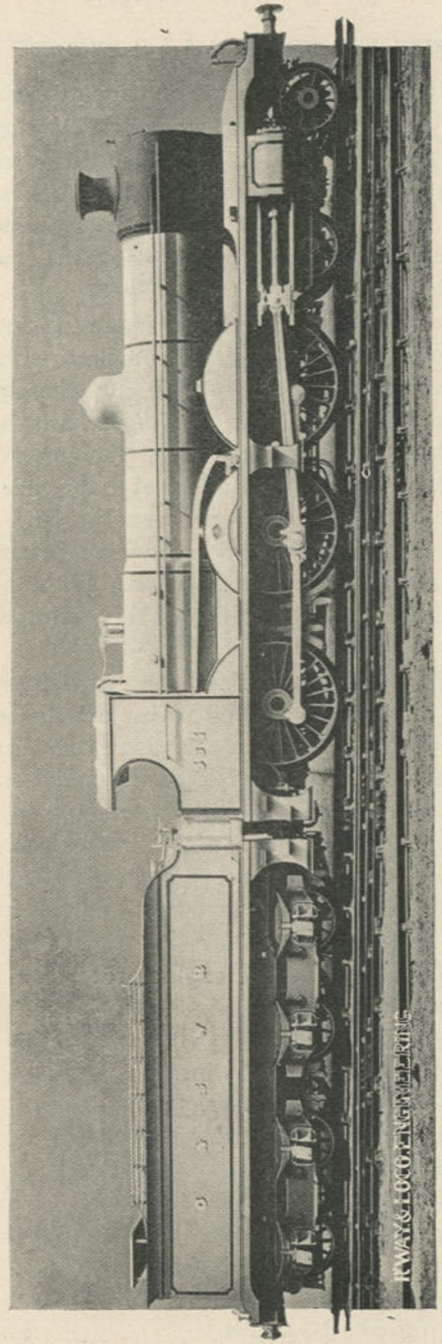
Boiler—Thickness of plates in barrel and outside of fire box, $\frac{11}{16}$, $\frac{3}{4}$, $\frac{23}{32}$, $\frac{1}{2}$, 1, $\frac{3}{4}$ and $\frac{9}{16}$ in.; fire box, length, 102 ins.; width, $65\frac{1}{4}$ ins.; depth, front, $72\frac{1}{2}$ ins.; back, $56\frac{1}{2}$ ins.; material, carbon; plates, thickness, sides, $\frac{3}{8}$ in.; back, $\frac{3}{8}$ in.; crown, $\frac{3}{8}$ in.; tube sheet, $\frac{1}{2}$ in.; water space, 4-in, front, 4-in. sides, 4 and 5-in. back.

Wheel base—Driving, 11 ft. 10 ins.; total engine, 30 ft. 9 ins.; total engine and tender, 60 ft. $7\frac{1}{2}$ ins.

Weight—On driving wheels, 132,500 lbs.; on truck, front, 36,800 lbs.; back, 40,200 lbs.; total engine, 209,500 lbs.; total engine and tender, about 340,000 lbs.

GLASGOW & SOUTH-WESTERN 4-6-0 ENGINE.

The influence of American practice on British locomotive designing is well illustrated by the engine shown on poge 517, designed by Mr. Munson, locomotive superintendent of the Glasgow & South-Western. These engines have been built for working the Scotch traffic in connection with the Midland Railway from London and most of the provincial towns, and previous to their introduction the trains have been worked by two ordinary bogie locomotives having 81-in. coupled drivers and $18\frac{1}{2}$x26-in. cylinders. The new type have six coupled wheels 78 ins. in diameter, outside cylinders 20x26-in. balanced valves placed on top worked by a rocking shaft, a large boiler and a Belpaire fire box. The heating surface obtained is 1,852 sq. ft. and the grate area is 24.5 sq. ft. The engine weighs 150,080 lbs. in working order and with the tender, which is of a new design running on four-wheeled bogies and carrying 4,100 gallons of water, the total weight is 262,080 lbs. Ten of these fine locomotives have been delivered by the North British Locomotive Company from their Atlas Works, Glasgow. Several novel features have been introduced, among them steam-reversing gear and steam-sanding apparatus.



GLASGOW AND SOUTH-WESTERN 4-6-0.

NORFOLK & WESTERN 4-4-2 ENGINE.

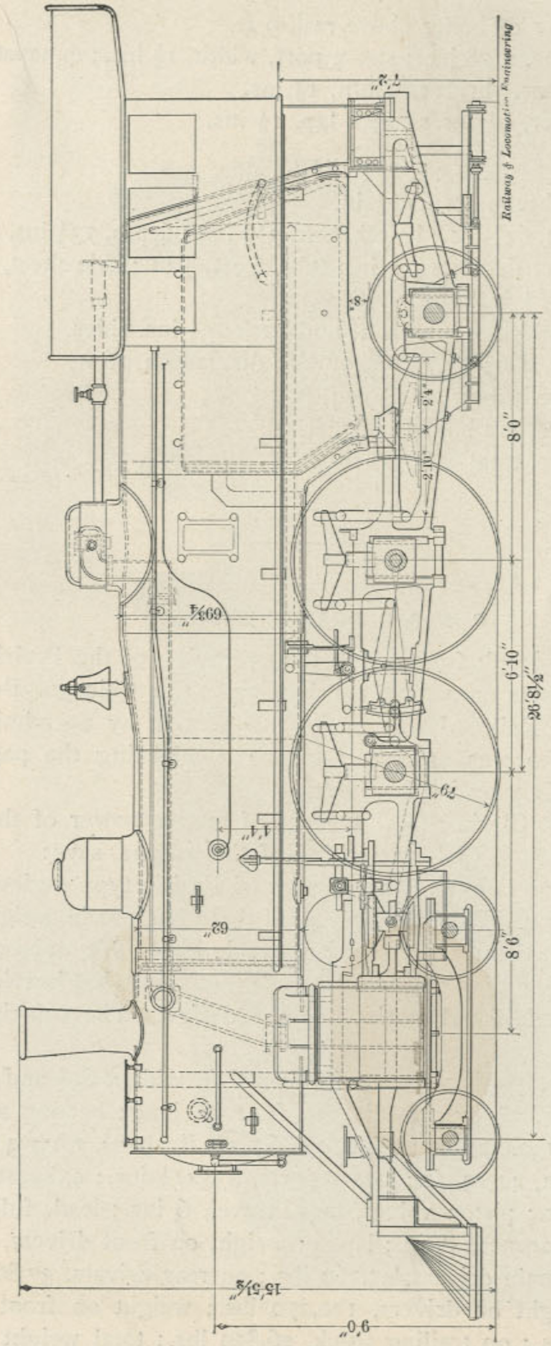
The engine illustrated by elevation on page 519 was built by the Baldwin Locomotive Works for the Norfolk & Western Railroad, and was designed by W. H. Lewis, superintendent of motive power of the road. The engines are simple, with cylinders 19x28 ins., driving wheels 79 ins. diameter. With an estimated adhesive weight of 84,000 lbs. and a boiler pressure of 200 lbs. to the square inch, the tractive force is about 21,700 lbs.

The frame of this engine is continuous, and the carrying wheels at the rear have inside journals and are equalized with the drivers. Semi-elliptic springs are used all through, and the equalization of the weight on the drivers and the carrying wheels is continuous. The rear spring hanger of the driver and the forward hanger of the carrying wheels on each side are attached to the ends of a trough-like steel casting. This casting is between the bars forming the frame, and contains a spring, the buckle of which, bearing up against the lower side of the top frame member, acts as the pivot point of the system. By shifting of the position of this spring the weight on drivers may be altered as desired.

The motion in this engine is indirect, with transmission bar curved below the axle of the leading driver and the valves are of the piston type. The crosshead is the usual two guide-bar type keyed through the rod. The boiler is of the radial stayed wagon-top type and measures 62 ins. at the smoke-box end. The total heating surface is 2,883.9 sq. ft. and the grate area is 45.9 sq. ft. The ash-pan hopper doors are operated by air. The tender carries 10 tons of coal and 6,000 gallons of water, and the frame is made out of 10-in. steel channels.

The leading dimensions of the engine are:

Driving-wheel base, 6 ft. 10 ins.
Rigid wheel base, 14 ft. 10 ins.
Total wheel base of engine, 28 ft. 8½ ins.
Total wheel base of engine and tender, 53 ft. $9\frac{1}{16}$ ins.
Weight on leading wheels, estimated, 38,000 lbs.
Weight on driving wheels, estimated, 84,000 lbs.
Weight on trailing wheels, estimated, 41,000 lbs.
Total weight of engine in working order, 163,000 lbs.
Total weight of engine and tender, 273,000 lbs.
Diameter of driving wheels, 79 ins.
Diameter of carrying wheels, 50 ins.
Diameter of truck, 36 ins.



FAST PASSENGER LOCOMOTIVE FOR THE NORFOLK & WESTERN.

Height of center of boiler above rail, 9 ft.
Cylinders, 19 ins. x 28 ins.; steam port, width, $1\frac{5}{8}$ ins.; exhaust port, width, $2\frac{1}{8}$ ins.; bridge, width, $1\frac{7}{8}$ ins.
Valves, diameter, $9\frac{1}{2}$ ins.; steam lap, $1\frac{1}{8}$ ins.

BOILER.

Thickness of sheets, $\frac{5}{8}$ and $\frac{11}{16}$ in.
Fire box, width, $64\frac{1}{4}$ ins.; length, 8 ft. $3\frac{15}{16}$ ins.; depth, $73\frac{1}{2}$ ins. front; crown sheet thickness, $\frac{3}{8}$ in.; tube sheet, $\frac{1}{2}$ in.; side sheet, $\frac{3}{8}$ in.; back sheet, $\frac{1}{2}$ in.
Water space, width, 4 ins. front and back; $3\frac{1}{2}$ ins. sides.
Tubes, number, 326; dia., 2 ins. outside dia. length, 16 ft.
Heating surface, tubes, 2,718.9 sq. ft.
Heating surface, fire box, 165 sq. ft.
Heating surface, total, 2,883.9 sq. ft.

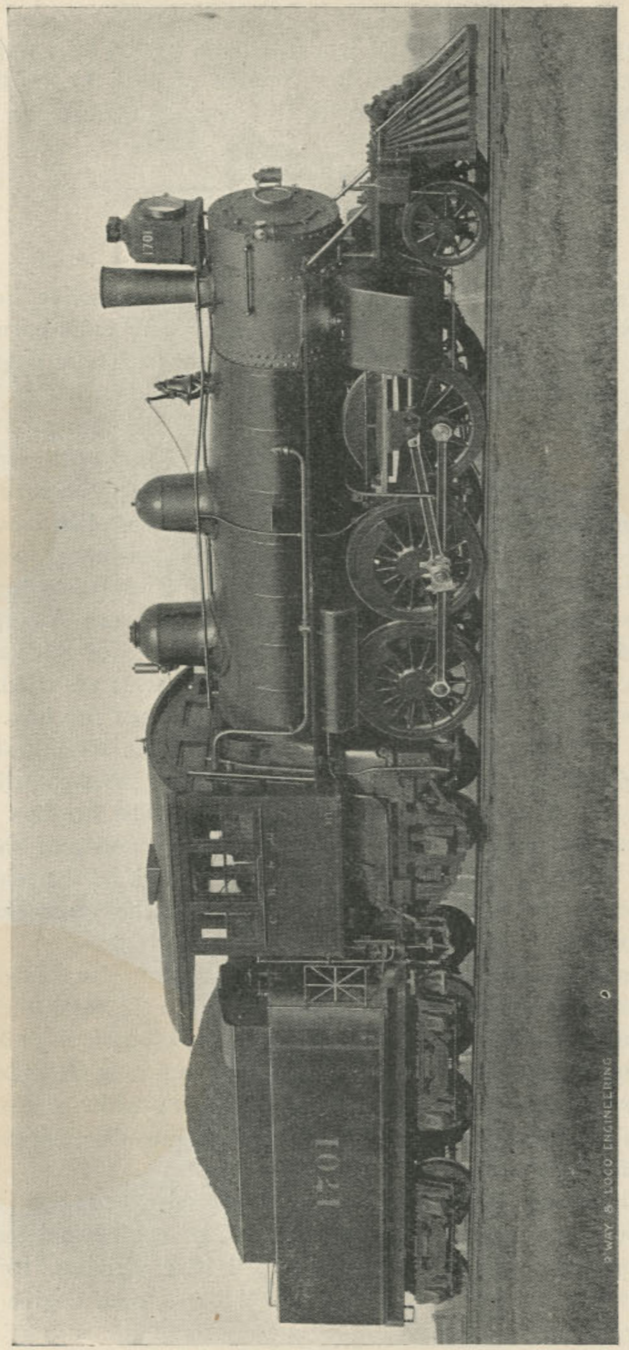
C., B. & Q. PRAIRIE ENGINE.

The photograph from which the engraving of the Prairie type locomotive, shown on page 521, belonging to the Chicago, Burlington & Quincy Railroad was made, was sent in by an admirer of the engine who was ambitious to see it adorning the pages of *Railway and Locomotive Engineering.*

Mr. F. H. Clark, superintendent of motive power of the Chicago, Burlington & Quincy, writing of this engine, says:

This engine is one of the first lot of Prairie type engines built by this company. We have only used these engines in freight service and find them very satisfactory, indeed. We subsequently built about 60 engines of the same type, but somewhat heavier, and last year 50 additional engines of the design. The principal dimensions are:

Boiler crown stay—Fire box, 7 ft. long, 6 ft. wide x $62\frac{1}{2}$ and 56 ft.; tubes, 194, $2\frac{1}{4}$ outside dia., 16 ft. 1 in. long; heating surface, fire box, 130.6 sq. ft.; tubes, 1,826.7 sq. ft.; total, 1,957.3 sq. ft.: grate area, 42 sq. ft.; steam ports, $23\frac{1}{8}$x$1\frac{1}{2}$ ins.; exhaust ports, $23\frac{1}{8}$x3 ins.; piston valves, max. travel, 6 ins.; lead, full gear; inside clearance, $\frac{1}{16}$ in.; lap, 1; weight on front drivers, 29,150 lbs.; on main drivers, 43,260 lbs.; on rear drivers, 37,860 lbs.; total weight on drivers, 110,270 lbs.; weight on front truck, 14,100 lbs.; on trailing truck, 26,850 lbs.; total weight of en-



C., B & Q. PRAIRIE TYPE ENGINE.

F. H. Clark, Supt. Motive Power. Chicago, Burlington & Quincy Railroad, Builders.

gine, 151,220 lbs.; weight of tender, empty, 35,000 lbs.; weight of water 5,000 gals., 41,700 lbs.; weight of coal, 17,500 lbs.; total weight of tender, 94,200 lbs.; of engine, 151,200 lbs.; in working order, 245,000 lbs.

TEN-WHEELER FOR THE D. & H.

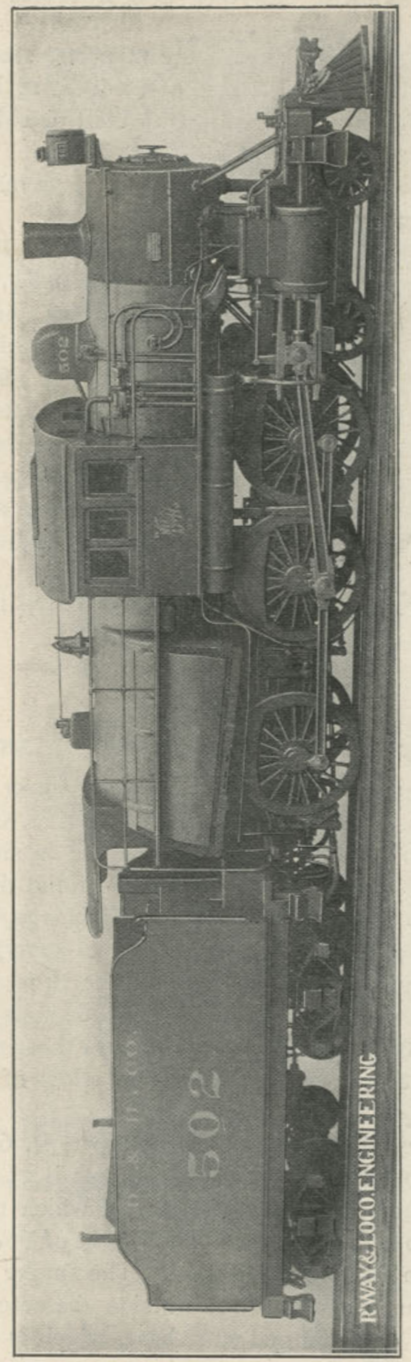
The Schenectady Works of the American Locomotive Company supplied the Delaware & Hudson with some culm-burning engines of the 10-wheel type, shown on page 523. These engines are simple, with 21x26-in. cylinders and 72-in. driving wheels. All the wheels are flanged. The cab is placed over the center of the boiler. The valve gear is indirect, the eccentrics being on the main driving axle and an extension bar curved slightly over the forward axle reaches the rocker in the usual way. The pedestal braces are bolts with thimbles between the jaws with cross-brace joining frames forward of the leading axle, and with cross-frame braces behind the main and trailing wheels. The valves are American balance-slide valves, and are used on all the engines of this order except two, upon which the Richardson balance valves are tried.

The boiler is a straight-top one, with a Wootten fire box. It is 63 ins. in diameter at the smoke-box end. The total heating surface 2,663.72 sq. ft., of which the 308 fifteen-foot tubes contribute 2,405.5 sq. ft. The grate area is 84.85 sq. ft. The fire box has one wide door, and the staying between the crown and roof sheets is radial. There is a cab roof overhanging the deck of the tender, which protects the fireman when at work, and the grate slopes lightly forward.

The total weight of this engine is about 175,000 lbs., of which 131,500 lbs. rest upon the drivers. The tender is carried on a steel-channel frame. It has a water capacity of 6,500 U. S. gallons, and is designed to carry 8 tons of coal. The engine is an example of good serviceable medium passenger power in which excessive weight has not been desired. A few of the leading dimensions are appended for reference:

General dimensions—Weight in working order, 175,000 lbs.; weight on drivers, 131,500 lbs.; weight of engine and tender in working order, 292,250 lbs.; wheel base, driving, 16 ft.; wheel base, total, 26 ft. 4 ins.; wheel base, total, engine and tender, 53 ft. $7\frac{1}{2}$ ins.

Fuel—Fine anthracite coal.



4-6-0 FOR DELAWARE & HUDSON.
J. R. Slack, Supt. Motive Power.
American Locomotive Co., Builders.

Cylinders—Dia., 21x26 ins.; size of steam ports, 18x1$\frac{3}{8}$ ins.; size of exhaust ports, 18x3 ins.; size of bridges, 1$\frac{3}{8}$ ins.

Valves—Greatest travel of slide valves, 5$\frac{1}{2}$ ins.; outside lap of slide valves, 1 in.; lead of valves in full gear, $\frac{1}{16}$ in.

Wheels—Dia. of driving wheels outside of tires, 72 ins.; dia. of engine truck wheels, 33 ins.

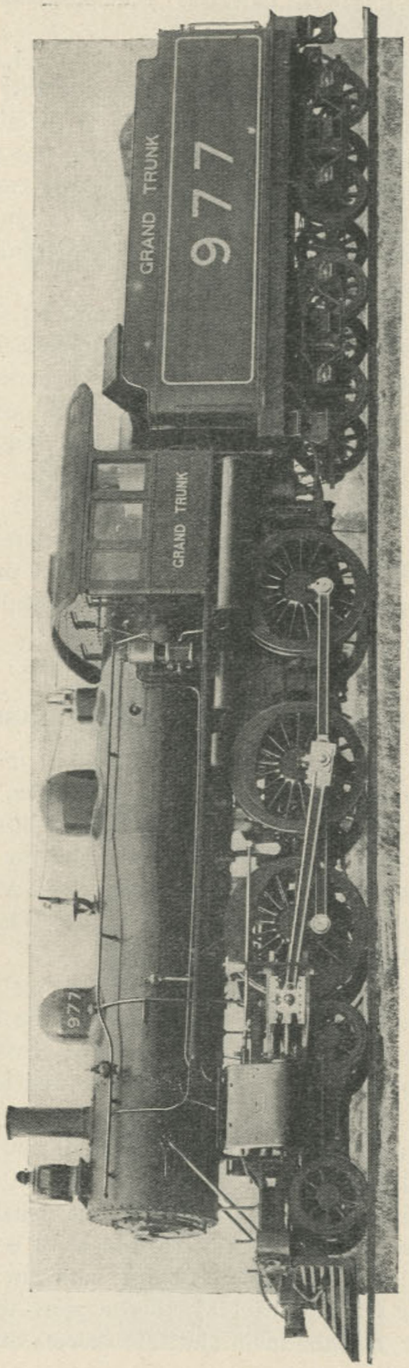
Boiler—Style, Wootten type; working pressure, 200 lbs.; thickness of plates in barrel and outside of fire box, $\frac{5}{8}$, $\frac{21}{32}$, $\frac{1}{2}$, $\frac{3}{4}$ in.; fire box, length, 119$\frac{7}{8}$ ins.; fire box, width, 102 ins.; fire box, depth, front, 64 ins.; back, 42 ins.; fire-box plates, thickness, sides, $\frac{3}{8}$ in.; back, $\frac{3}{8}$ in.; crown, $\frac{3}{8}$ in.; tube sheet, $\frac{1}{2}$ in.; fire box, water space, 3$\frac{1}{2}$ ins. front; 3 ins. sides; 3$\frac{1}{2}$ ins. back; fire box, crown staying, radial; tubes, number, 308; heating surface, tubes, 2,405.5 sq. ft.; heating surface, water tubes, 78.54 sq. ft.; heating surface, fire box, 179.68 sq. ft.; heating surface, total, 2,663.72 sq. ft.; grate surface, 84.85 sq. ft.; grate, style, water grate.

Tender—Weight, empty, 47,100 lbs.; wheel base, 18 ft. 5 ins.; tender frame, 10 ins. steel channels.

GRAND TRUNK TEN-WHEEL PASSENGER ENGINE.

A good example of ten-wheel passenger power built by the Grand Trunk Railway of Canada at their Point St. Charles shops, Montreal, is shown on page 525. The engine is simple and has cylinders 20x26 ins. The outside diameter of the driving wheels is 73 ins., and the weight carried by them is 132,608 lbs. The weight of the engine itself in working order is 177,772 lbs., which leaves 45,164 lbs. on the engine truck. The tires of the main driving wheels are without flanges and the side rods are solid-end rods of I-section. With 200 lbs. boiler pressure these engines would be capable of exerting a calculated tractive effort of about 24,200 lbs.

The boiler is of the extended wagon-top type, 62 ins. outside diameter at the smoke-box end. The grate area is 33.43 sq. ft., and the total heating surface is 2,460.1 sq. ft., of which 188.1 is in the fire box and 2,272,0 is in the tubes. The height of the center line of the boiler is 8 ft. 10 ins. above rail level. The smoke stack for this class of engine measures 16$\frac{1}{4}$ ins. outside diameter and is 38$\frac{3}{4}$ ins. high. It rests on a flanged steel base, which is Grand Trunk standard.



W. D. Robb, Supt. Motive Power. Grand Trunk Railway Co., Builders

TEN-WHEEL PASSENGER POWER FOR THE GRAND TRUNK SYSTEM.

The valve gear is indirect and the valves are of the piston type. Cylinder and valve chamber are placed close together and are neatly enclosed in one casing. The cross head is of the alligator pattern, and carries an oil cup on the side in addition to the usual guide-bar cup. All the drivers are braked and so is the engine truck, the wheels of which are 38 ins. in diameter. The driving tires are held in position by shrinkage and a retaining ring is also used on the inside of each wheel.

The tender frame is made of steel channels; the outside sills have the flanges turned inward. The water capacity of the tank is 6,000 U. S. gallons and 20,000 lbs. of coal is carried. The tender wheels are 42 ins. in diameter, and the weight of the tender is 130,856 lbs. The total weight of engine and tender in working order is 308,628 lbs.

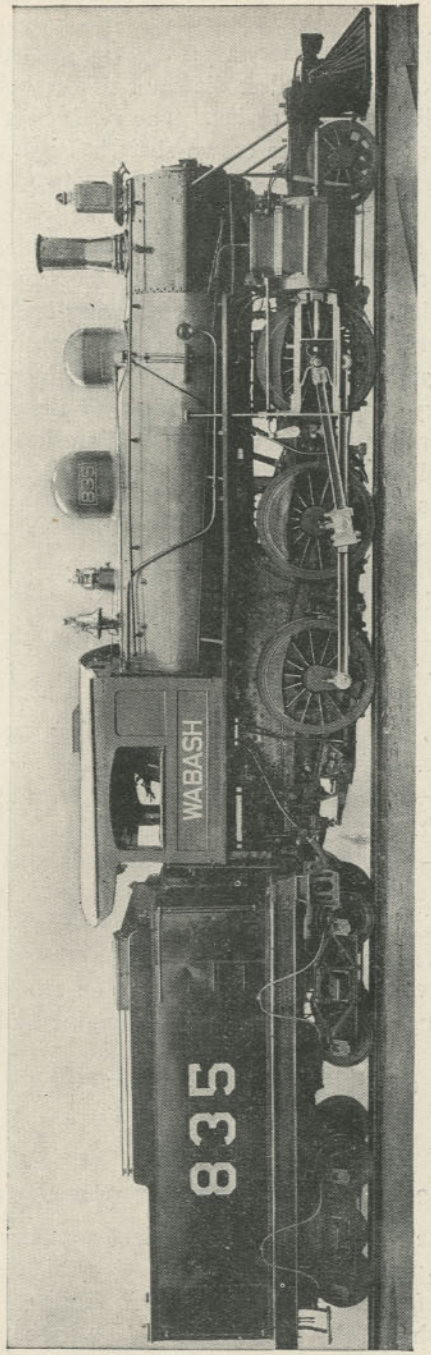
We are indebted to the courtesy of Mr. W. D. Robb, superintendent of motive power of the Grand Trunk system, for the photograph and data which we reproduce. The engine presents the neat and trim appearance which is the result of careful designing and compact grouping of parts.

BALDWIN ENGINES FOR THE WABASH.

The Wabash Railroad have received 32 fast freight moguls of the two-cylinder or cross-compound type from the Baldwin Locomotive Works, of Philadelphia, a cut of which is shown on page 527. The cylinders are 20½ ins. and 32½x28 ins., and the driving wheels are 63 ins. in diameter. The pressure carried is 200 lbs., and the calculated tractive effort is about 24,900 lbs. The main driving wheels are the only ones not flanged.

The weight of the engine in working order is 148,880 lbs., of which 139,660 lbs, rest on the drivers, while the total weight of engine and tender are about 269,000 lbs. The cross head is of the two-guide bar type, and the piston rod is secured to it by nut and shoulder.

The motion is of the usual indirect kind, and the valves are balanced slide valves. The yoke or what may be called the spectacle plate is secured across the frames in the usual way, but as it does not entirely surround the guide-bar blocks, it is supported from a bracket on the boiler by means of a bar with pin connections top and bottom. The leading drivers and the pony truck wheels are equalized together, and the main and rear drivers are also equalized together.



J. B. Barnes, Supt. Motive Power. 2-6-0 ENGINE FOR THE WABASH RAILROAD. Baldwin Locomotive Works, Builders.

The boiler is an extension wagon top, the gussett sheet sloping to the smoke box. The smallest diameter of the boiler is $63\frac{1}{4}$ ins. and the largest diameter is $71\frac{1}{4}$ ins. The roof sheet slopes $3\frac{3}{8}$ ins. toward the back sheet, and the crown sheet has also the same slope toward the back.

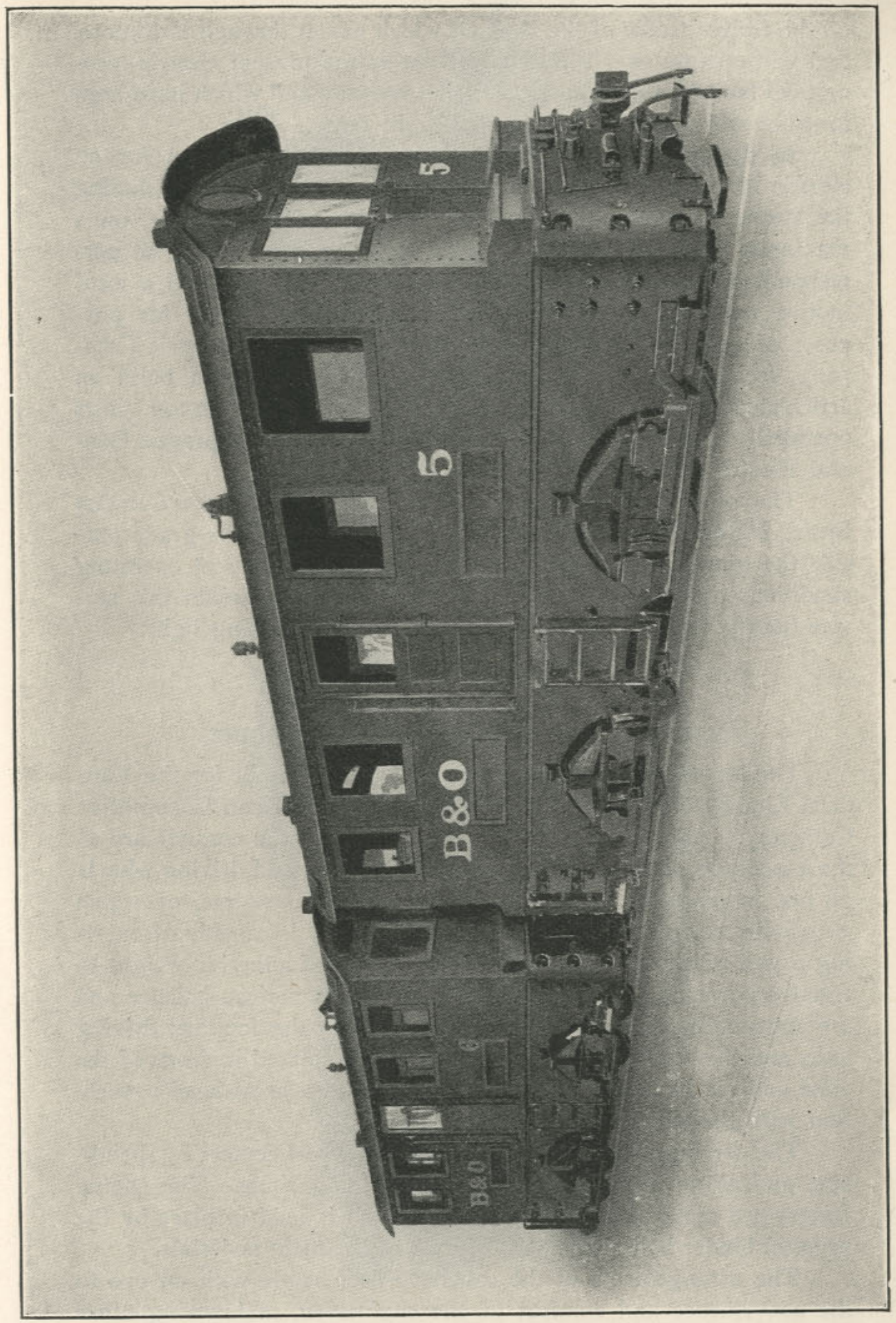
The tender has arch-bar trucks, and the tank, which holds 6,000 gallons, is supported on a steel-channel frame. The tender-axle boxes are provided with rubber-hose tubes so that cold water may be used in the event of a hot box showing itself.

The whole machine presents a neat appearance and reflects credit upon designer and builder alike. The engineer has been provided with a very ample window and has all the light which can be obtained in that way. A few of the leading dimensions of these engines are as follows:

Cylinder—$20\frac{1}{2}$ ins. and $32\frac{1}{2}$x28 ins.
Boiler—Thickness of sheets, $\frac{5}{8}$ and $\frac{11}{16}$ in.; working pressure, 200 lbs.; fuel, soft coal; staying, radial.
Fire box—Length, 114 ins.; width, 42 ins.; depth, front, $77\frac{13}{16}$ ins.; back, $63\frac{1}{16}$ ins.; thickness of sheets, sides, $\frac{5}{16}$ in.; back, $\frac{5}{16}$ in.; crown, $\frac{3}{8}$ in.; tube, $\frac{1}{2}$ in.; water space, front, 4 ins.; sides, $3\frac{1}{2}$ ins.; back, 4 ins.
Tubes—Material, iron; wire gauge, 12; number, 290; dia., 2 ins.; length, 11 ft. $4\frac{5}{8}$ ins.
Heating surface—Fire box, 169 sq. ft.; tubes, 1,712.7 sq. ft.; total, 1,881.7 sq. ft.; grate area, 33.2 sq. ft.
Driving wheels—Dia., outside, 63 ins.; journals, 9x11 ins.
Engine truck wheels—Dia., 36 ins.; journals, 6x10 ins.
Wheel base—Driving, 14 ft. 0 in.; total engine, 22 ft. 7 ins.; total engine and tender, 51 ft. $2\frac{1}{2}$ ins.
Weight—On driving wheels, 129,660 lbs.; on truck, front, 19,220 lbs.; total engine, 148,880 lbs.; total engine and tender, about 269,000 lbs.
Tank—Capacity, 6,000 gals.

ELECTRIC LOCOMOTIVE FOR THE B. & O. TUNNEL.

Probably the most powerful electric locomotive in the world is illustrated on page 529, built by the General Electric Company at Schenectady, for the Baltimore & Ohio Railroad for use in its tunnel underneath the city of Baltimore. This locomotive marks a very distinct advance in electric locomotive design. It will handle



DOUBLE ELECTRIC LOCOMOTIVE FOR THE B. & O.

General Electric Company, Builders

all the freight traffic of the B. & O. which passes through Baltimore, and will operate over the same section as the present electric locomotives built by the General Electric Company and which have been in successful operation for the past eight years.

In designing this locomotive the specifications called for an electric locomotive capable of handling a 1,500-ton train, including the steam locomotive, but excluding the electric locomotive, on a maximum grade of $1\frac{1}{2}$ per cent. at 10 miles per hour, with corresponding higher speed on lighter grades. This required a locomotive weighing approximately 160 tons on the drivers for purposes of adhesion, and the engineers of the General Electric Company decided that the most practicable scheme was to build an articulated locomotive consisting of two complete 80-ton units operated together as one locomotive by means of the Sprague General Electric Multiple Unit Control.

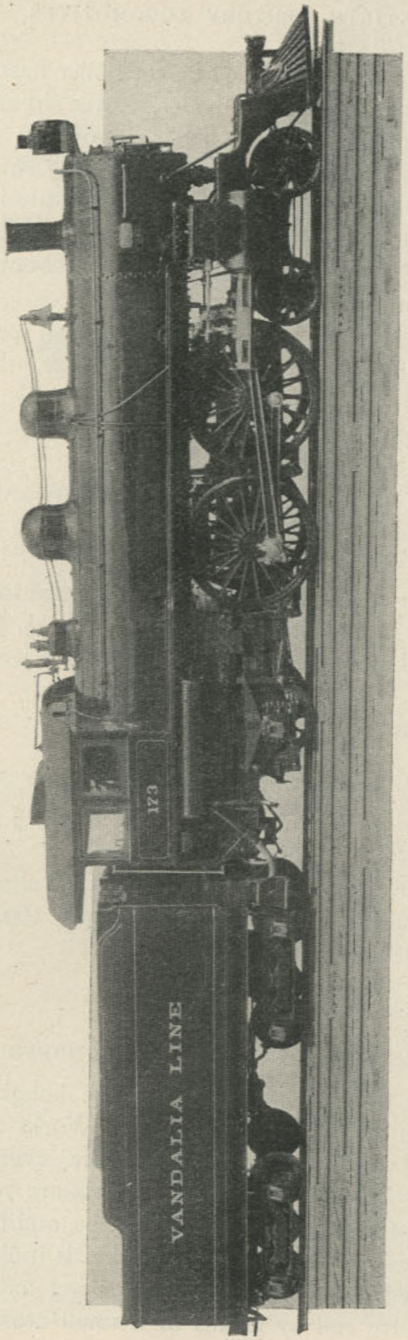
The section of the road to be operated runs from Camden Street Station through the tunnel to the summit of the grade outside the tunnel, a distance of $3\frac{1}{2}$ miles. Under practical operating conditions the motors have sufficient capacity to maintain this service hourly running loaded up the grade and returning light.

VANDALIA LINE 4-4-2 PASSENGER ENGINE.

The locomotive illustrated on page 531 was built for the Vandalia Line by the Schenectady Works of the American Locomotive Company. As will be seen by our illustration, the engines are of the 4-4-2 type, simple, with $20\frac{1}{2}$x26-in. cylinders, and driving wheels 78 ins. in diameter. The total weight is 164,500 lbs., of which 91,500 lbs. rest upon the drivers. The machine is capable of exerting a pull of about 23,800 lbs., and the ratio of adhesive weight to tractive power is 3.84. The slide valves are American balance and are actuated by an extension rod passing over the forward driving axle, and the motion is direct. The rocker is placed in front of the yoke and makes therefore what may be called a cross-head connection with the valve rod.

The driving-wheel tires are held on the wheel centers by shrinkage, and as an extra precaution, by retaining rings. The engine frames are cross braced by a flat bar which is held in place by the pedestal binder bolt at the back of each of the main pedestals.

The arrangements in the cab have been made with an eye to the convenience and comfort of the enginemen, and among other



W. C. Arp, Supt. Motive Power.

American Locomotive Co., Builders.

FAST PASSENGER, ATLANTIC TYPE ENGINE FOR THE VANDALIA LINE.

things the injectors have been placed on the boiler head, the delivery pipes running through, inside the boiler, to the front, with downwardly pointing openings. The boiler is of the radial stayed straight-top type, with wide fire box. The heating surface is ample, being in all $2,986\frac{1}{2}$ sq. ft., of which about 2,816 ft. are in the tubes.

The tank is made with a water bottom, and the fuel space is of the gravity hopper type. The coal capacity is about 12 tons, and the water carried amounts to 7,000 gallons.

Some of the principal dimensions are subjoined for reference:

Cylinders, $20\frac{1}{2}$x26 ins.

VALVES.

Greatest travel of slide valves, 6 ins.

Outside lap, $1\frac{1}{8}$ ins.; inside, line and line.

Lead of valves in full gear, line and line, full forward motion, $\frac{1}{4}$ in. lead at 6 ins. cut off.

BOILER.

Outside dia. of first ring, 68 ins. Work. pres., 200 lbs.

Thickness of plates in barrel and outside fire box, $\frac{11}{16}$, $\frac{1}{2}$, $\frac{3}{4}$ and 1 in.

Horizontal seams, butt-joint sextuple riveted with welt strips inside and outside.

Circumferential seams, double riveted.

FIRE BOX.

Length, 102 ins.; width, $65\frac{3}{8}$ ins.; depth, $75\frac{3}{4}$ ins. F, 66 ins. B.

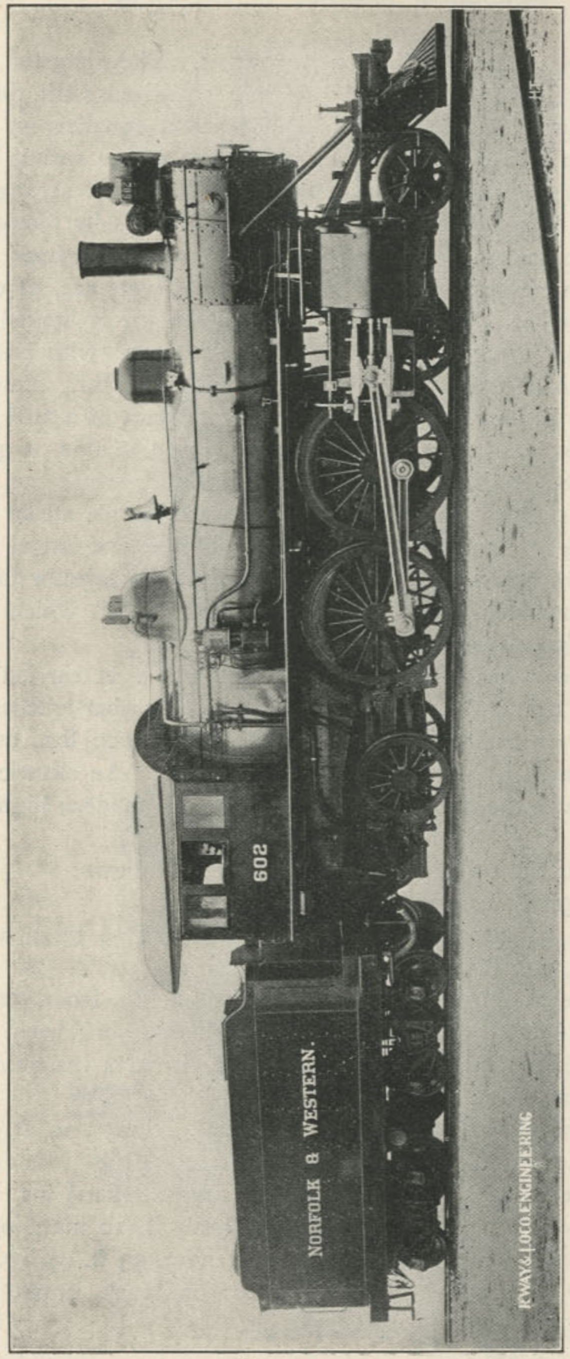
Plates, thickness, sides, $\frac{5}{16}$ in.; back, $\frac{3}{8}$ in.; crown, $\frac{3}{8}$ in.; tube sheet, $\frac{1}{2}$ in. Stay bolts, 1 in. dia.

Tubes, number, 338; dia., 2 ins.; length over tube sheets, 16 ft.

Heating surface, tubes, 2,816.87 sq. ft.; fire box, 169.8 sq. ft.; total, 2,986.67; grate area, 46.36 sq. ft.

BALDWIN FAST PASSENGER ENGINE FOR THE NORFOLK & WESTERN

The Norfolk & Western Railway have bought some simple 4-4-2 engines from the Baldwin Locomotive Works of Philadelphia, which are illustrated on page 533. The cylinders of these engines are 19x28 ins. and the driving wheels are 79 ins. diameter. The total weight of the machine is 168,650 lbs. and there are 85,790 lbs. carried by the drivers. The valve motion is indirect with transmission bar curved below the forward driving axle. The rocker arm works the valve rod by means of a small cross-head arrangement as the rod passes through a guide in the yoke. The valve is of the balanced piston type and placed immediately over the



BALDWIN 4-4-2 ENGINE FOR THE NORFOLK & WESTERN.

W. H. Lewis, Supt. Motive Power. Baldwin Locomotive Works, Builders.

cylinder whose steam distribution it governs. The diameter of the carrying wheels is 50 ins. and they are equalized with the rear drivers by means of what may be called a box equalizer in which a semi-elliptic spring is placed, the upper side of the spring buckle acting as the fulcrum for the equalizer. With this arrangement it is possible to readjust the weight on the drivers by temporarily lifting the engine and moving the spring forward or back in the "box," within certain restricted limits. The drivers are, of course, equalized together. Every wheel under the engine is braked.

The boiler is of the ordinary wagon-top type with wide fire box. The smallest ring measures 62 ins. in diameter. There are 326 tubes, 16 ft. long, which give a heating surface of 2,716$\frac{3}{4}$ sq. ft. When the 162 sq. ft. in the fire box are added to this, it gives a total of 2,878$\frac{3}{4}$ sq. ft. The roof sheet is level, while the crown sheet slopes slightly to the back, and there is ample steam space. There is a 3$\frac{1}{2}$-in. hand hole in the bottom of the first barrel course nearly straight below the point of entrance of the injector delivery pipe, through which, when washing out, the deposit which necessarily forms in this region may be easily removed.

The tender has a 6,000-gallon tank which is carried on a steel-channel frame, the whole carried on two arch-bar trucks. The total weight of engine and tender is about 289,000 lbs., and the total wheel base of both together is 53 ft. 9$\frac{1}{2}$ ins. An electric headlight illuminates the track at night ahead of this modern high-speed machine.

A few of the principal dimensions are as follows:

Cylinders—19x28 ins.

Boiler—Dia., 62 ins.; thickness of sheets, $\frac{5}{8}$ and $\frac{11}{16}$ ins.; working pressure, 200 lbs.; staying, radial.

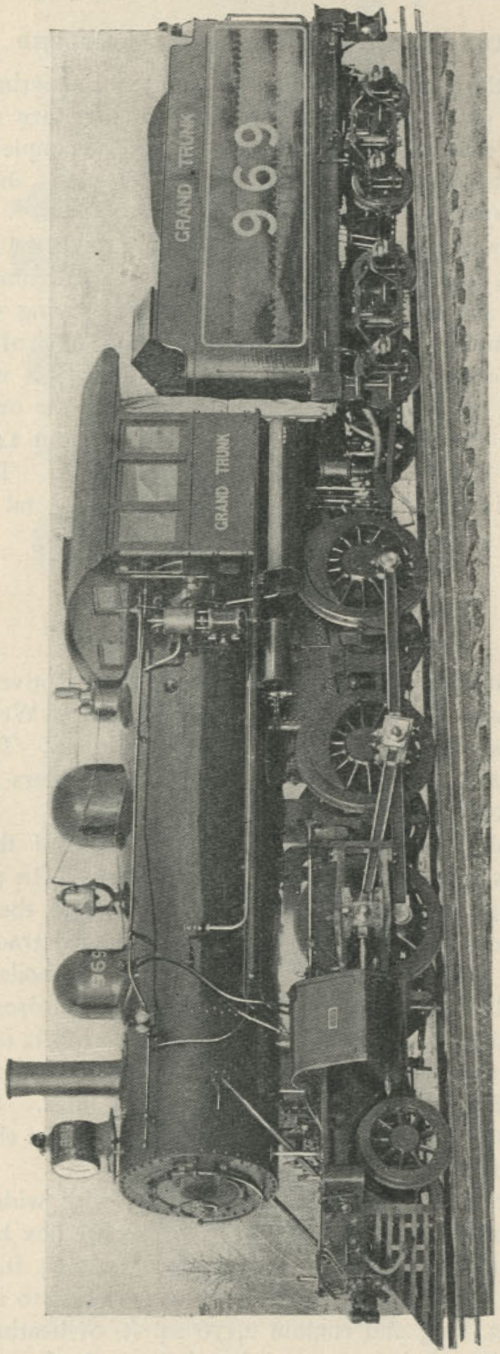
Fire box—Length, 100 ins.; width, 64$\frac{1}{4}$ ins.; depth, front, 72$\frac{3}{4}$ ins.; back, 61$\frac{5}{8}$ ins.; thickness of sheets, sides, $\frac{3}{8}$ in.; back, $\frac{1}{2}$ in.; crown, $\frac{3}{8}$ in.; tube, $\frac{1}{2}$ in.; water space, front, 4 ins.; sides, 3$\frac{1}{2}$ ins.; back, 4 ins.

Heating surface—Fire box, 162 sq. ft.; total, 2,878.75 sq. ft.; grate area, 45.1 sq. ft.

Driving wheels—Dia. outside, 79 ins.; journals, 8$\frac{1}{2}$x10$\frac{1}{2}$ ins.

Wheel base—Driving, 6 ft. 10 ins.; rigid, 14 ft. 10 ins.; total engine, 26 ft. 8$\frac{1}{2}$ ins.; total engine and tender, 53 ft. 9$\frac{1}{2}$ ins.

Weight—On driving wheels, 85,790 lbs; on truck, front, 39,480 lbs.; on carrying wheels, 43,380 lbs.



W. D. Robb, Supt. Motive Power. COMPOUND MOGUL, GRAND TRUNK RAILWAY SYSTEM. Grand Trunk Railway, Builders

GRAND TRUNK RAILWAY CROSS COMPOUND.

Through the courtesy of Mr. W. D. Robb, superintendent of motive power of the Grand Trunk Railway, we are enabled to present to our readers on page 535 a very good example of freight power which has been built in the Point St. Charles shops of the Grand Trunk system.

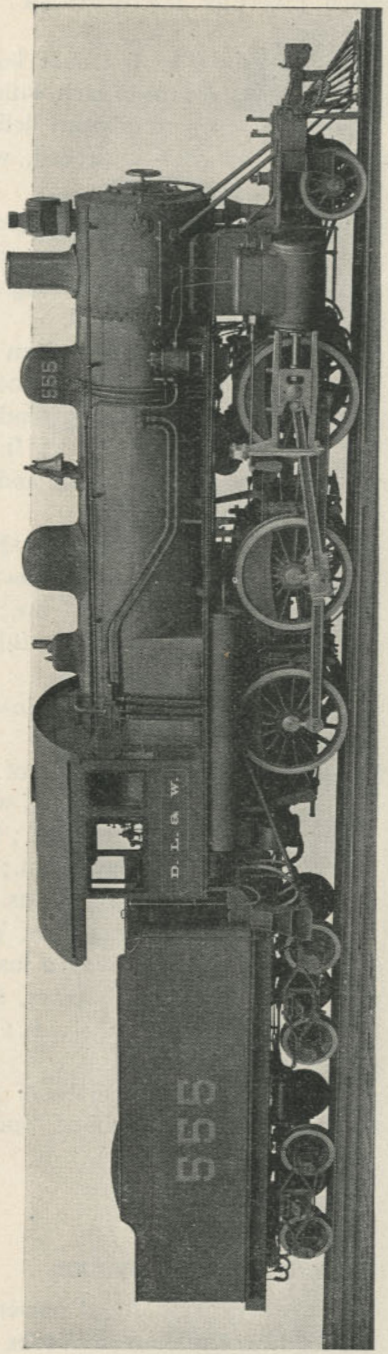
The engine is a mogul, or 2-6-0 engine, as will be seen from the illustration, and is a cross compound of the "Richmond" type. The cylinders are 22½ and 35x26 ins. and the driving wheels are 63 ins. in diameter. The valves are piston on some of this class and slide on others, and the usual indirect motion is used. The springs are all underhung and the main driver is the only pair of wheels without flanges. The adhesive weight is about 140,744 lbs., while the total weight of the machine is 163,704 lbs. The weight of the tender is about 130,856 lbs., thus giving a total weight in working order of 294,560 lbs.

MOGUL FOR THE LACKAWANNA.

The Schenectady shops of the American Locomotive Company have recently supplied the Delaware, Lackawanna & Western with fast freight power in the shape of some 2-6-0 engines. They weigh each about 140,000 lbs., and are classified by the builders as 260-140 type, as are shown on page 537.

The cylinders are 20½x26 and the diameter of the driving wheels amounts to 63 ins. All wheels are flanged. The pony truck and the leading driver are equalized together, and the two rear drivers are also equalized together. The calculated tractive effort of this engine with 200 lbs. steam pressure in the boiler is about 29,500 lbs. The engine is simple, with Allen-Richardson balanced valves, actuated by indirect motion. The cross head is of the two-guide bar type and has a lip cut on each side of the upper guide, so that outside of guide and cross-head side are flush. The piston rod is not secured to the cross head by key, but has a shoulder on the rod drawn up tightly with a couple of nuts.

The boiler is of the straight-top variety, with wide fire box. The diameter of the first ring is 66¼ ins. The fire box has a grate area of 53.43 sq. ft. The heating surface is 2,342.2 sq. ft. in all, the fire box giving 166.2 sq. ft. The tubes, which are 310 in number, are 13 ft. 6 ins. long and contain 2,176 sq. ft. of heating surface. The crown and roof sheets are level and the back sheet is perpen-



LACKAWANNA FREIGHT MOGUL.

American Locomotive Co., Builders.

T. S. Lloyd, Supt. Motive Power

dicular, and the staying is radial. The fire door has curved and flat lines in its contour. The sides are made each with 6 ins. radius, and the bottom upon which the scoop rests when delivering coal is flat, while the upper edge of the door is arched, with a $22\frac{3}{4}$-in. radius.

The tender has an ordinary U-shaped tank, which holds 6,000 U. S. gallons of water. The tender weighs, empty, 49,400 lbs., and is carried on two diamond arch-bar trucks. There are two main reservoirs for air. Ten tons of coal is carried.

A few of the principal dimensions are here given for reference:

General dimensions—Weight in working order, 161,000 lbs.; weight on drivers, 140,000 lbs.; weight engine and tender in working order, 280,400 lbs.; wheel base, driving, 15 ft.; wheel base, total, 23 ft. 10 ins.; wheel base, total, engine and tender, 52 ft. 54 ins.

Cylinders—$20\frac{1}{2}$x26 ins.; size of steam ports, 18x$1\frac{3}{4}$ ins.; size of exhaust ports, 18x3 ins.; size of bridges, $1\frac{3}{8}$ ins.

—Valves—Allen-Richardson; greatest travel, $5\frac{1}{2}$ ins.; outside lap, 1 in.; inside clearance, $\frac{1}{16}$ in.; lead of valves in full gear, $\frac{1}{16}$ in.; lead, $\frac{1}{4}$ in. at 6-in. cut off.

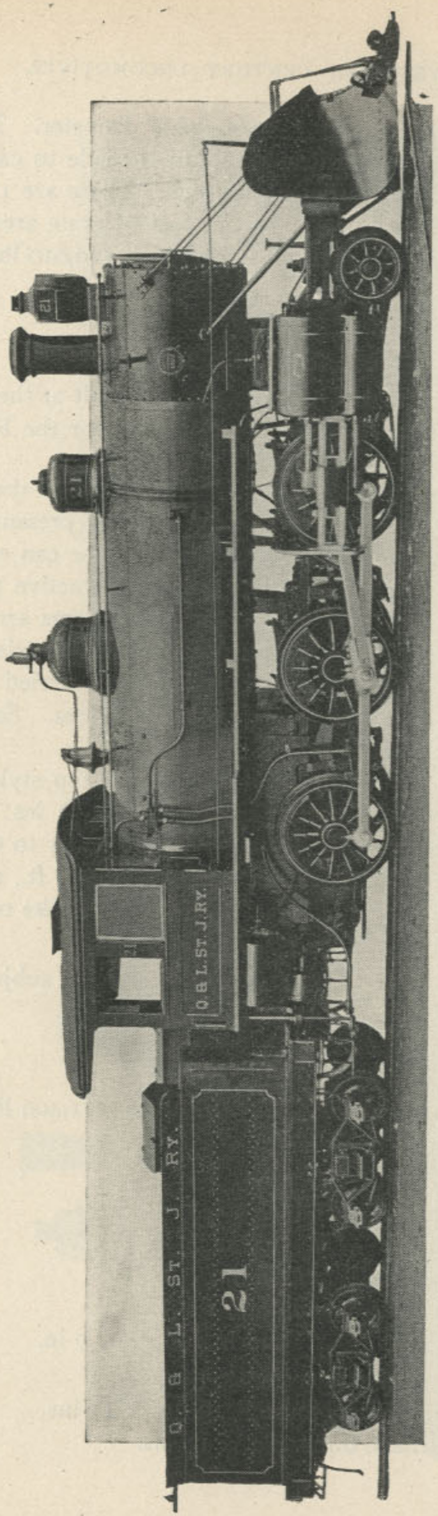
Wheels—Dia. of driving wheels outside of tire, 63 ins.; engine truck wheels, steel-tired spoke, tire $2\frac{1}{2}$ ins.

Boiler—Thickness of plates in barrel and outside of fire box, $\frac{5}{8}$, $\frac{1}{2}$, $\frac{3}{4}$, $\frac{11}{16}$ ins.; fire box, length, $102\frac{1}{4}$ ins.; fire box, width, $75\frac{1}{4}$ ins.; fire box, depth, front, $63\frac{3}{4}$ ins.; back, $56\frac{1}{2}$ ins.; fire-box plates, thickness, sides, $\frac{3}{8}$ in.; back, $\frac{3}{8}$ in.; crown, $\frac{3}{8}$ in.; tube sheet, $\frac{9}{16}$ in.; fire box, water space, 4 ins. front; $3\frac{1}{2}$ ins. sides; $3\frac{1}{2}$ ins. back; fire box, crown staying, radial; tubes, gauge, No. 12 B. W. G.; tubes, number, 310; tubes, dia., 2 ins.; heating surface, tubes, 2,176.00 sq. ft.; heating surface, fire box, 166.2 sq. ft.; heating surface, total, 2,342.2 sq. ft.; grate surface, 53.43 sq. ft.

Tender—Weight, empty, 49,400 lbs.; wheel base, 16 ft. $9\frac{1}{2}$ ins.; tender frame, 10-in. steel channels; water cap., 6,000 U. S. gals.; coal cap., 10 tons.

PASSENGER MOGUL ENGINE.

The illustration on page 539 is a Mogul passenger engine recently turned out of the Baldwin Locomotive Works for the Quebec & Lake St. John Railway. The cylinders are 14 and 24 by 26 ins.,



MOGUL PASSENGER ENGINE FOR Q. & L. ST. J. RY.

J. Clark Supt. Motive Power.

Baldwin Locomotive Works, Builders.

and the driving wheels are 57 ins. outside diameter. The boiler is 64 ins. diameter at the smallest ring and is made to carry working pressure of 200 pounds to the square inch. There are 1876.4 square feet of heating surface and 31.6 square feet of grate area. The total weight of the engine is 145,230 lbs., of which 120,010 lbs. are on the driving wheels.

RUTLAND 4-6-0 ENGINE.

The engine illustrated on page 541 was built at the Manchester shops of the American Locomotive Company for the Rutland Railroad.

The cylinders are 20x26 ins., the diameter of the drivers are 69 ins., they carry 118,000 lbs. and the working pressure is 200 lbs. The theoretical tractive effort which this machine can exert is about 25,600 lbs. The ratio of adhesive weight to tractive power is 4.6. The valve motion here is direct, as the rocker arms are both turned down and the transmission bar passes up over the axle of the leading driver. The springs are all underhung, carried by hangers, which are hooked over and rest on top of the boxes. Safety hangers surround both equalizers.

The boiler is one of the extension wagon-top style and carries the dome on the first circular sheet, which is 72 ins. in diameter; the gusset sheet reduces the diameter of the boiler to 61 ins. at the front end. The total heating surface is 2,446 sq. ft., and there are 30 sq. ft. of grate surface. The "Perfection" smoke consumers are used on these engines.

Some of the more important dimensions are subjoined:

DIMENSIONS.

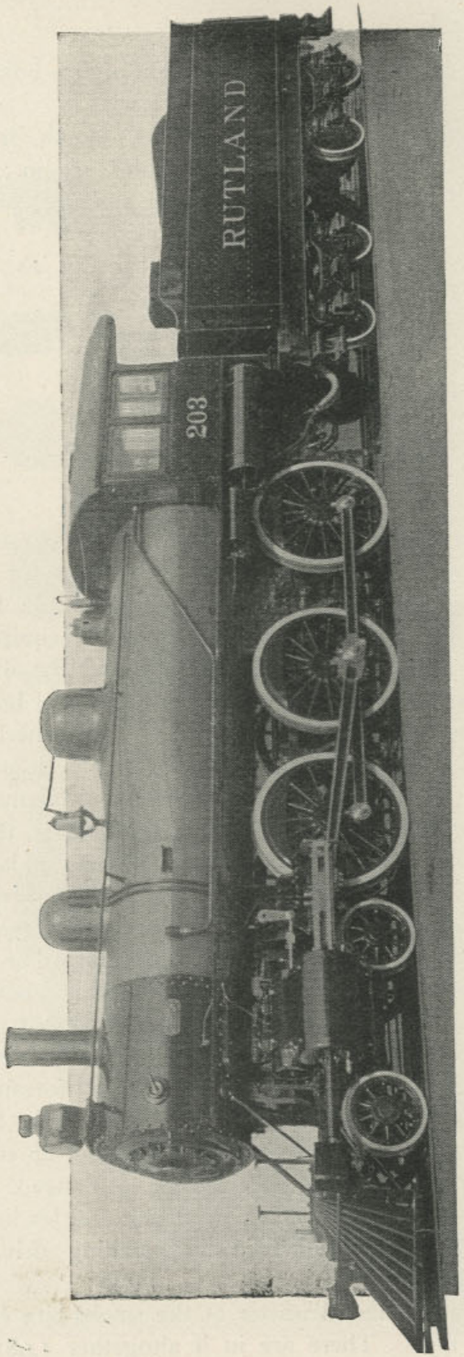
Weight in working order, 155,000 lbs.
Weight on drivers, 118,000 lbs.
Weight engine and tender in working order, 271,400 lbs.
Wheel base, driving, 14 ft. 10 ins.
Wheel base, total, 25 ft. 10 ins.
Wheel base, total, engine and tender, 56 ft. 3 ins.

VALVES.

Valves, piston type, inside admission.
Greatest travel, 6 ins.; outside lap, 1 in.
Inside lap, $\frac{1}{8}$ in. clearance. Lead in full gear, 0 in.

WHEELS, ETC.

Dia. and length of driving journals, 9 ins. x 11 ins.
Engine truck, journals, 6 ins. dia. x 11 ins.



C. E. Cleaver, Supt. Motive Power. American Locomotive Co., Builders

TEN-WHEEL, PASSENGER ENGINE FOR THE RUTLAND RAILROAD.

BOILER.

Thickness of plates in barrel and outside of fire box, $\frac{5}{8}$, $\frac{11}{16}$, $\frac{1}{2}$ and $\frac{3}{4}$ ins.

Fire box, length, 108 ins.; width, 41 ins.; depth, front, $76\frac{1}{2}$ ins.; back, $64\frac{1}{2}$ ins.; plates, thickness, sides, $\frac{5}{16}$ in.; back, $\frac{5}{16}$ in.; crown $\frac{3}{8}$ in.; tube sheet, $\frac{1}{2}$ in.; water space, $4\frac{1}{2}$ and 5 in. front, $3\frac{1}{2}$ and 4 in. sides, $3\frac{1}{2}$ and $4\frac{1}{2}$ in. back.

Tubes, iron, No. 11 gauge; number, 312; dia., 2 ins. Length over tube sheets, 168 ins.

Heating surface, tubes, 2,273.47 sq. ft.

Heating surface, fire box, 172.85 sq. ft.

Heating surface, total, 2,446.32 sq. in.

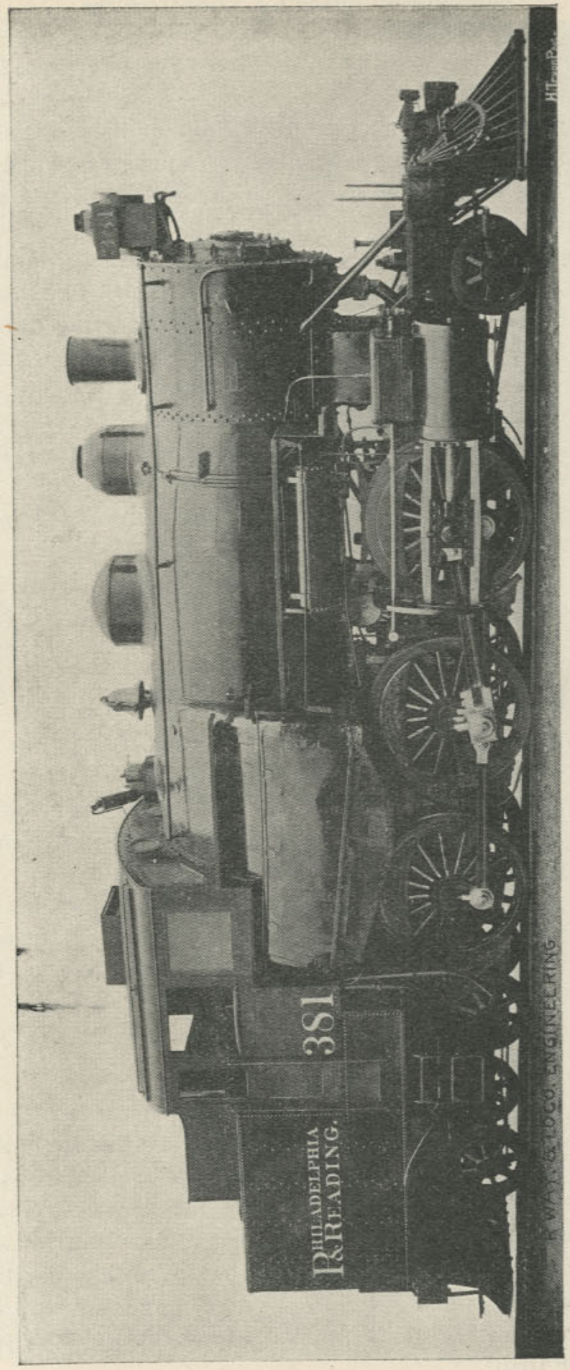
READING SUBURBAN ENGINE.

The illustration on page 543 shows a heavy suburban locomotive built by the Baldwin Locomotive Works for the Philadelphia & Reading Railway, of which road Mr. S. F. Prince, Jr., is the superintendent of motive power and rolling equipment.

The engine has 20x24 ins. cylinders and the driving wheels measure $61\frac{5}{8}$ ins. outside tires. The tank and coal box are carried on a rear projection of the main frame, and the wheel arrangement therefore makes it a 2-6-4 type. The reverse lever, unlike those in general use, is one which in text books on elementary mechanics would be called a lever of the first class. That is, the fulcrum is situated at some point between where the power is applied and where the resistance acts. This gives a backward motion to the reach rod when the lever is thrown forward. The reach rod, however, passes beneath the level of the lower frame bar and operates a tumbling-shaft arm which hangs down from above. This arrangement compensates for the backward motion of the reach rod in this case and lowers the links so that, when the reverse lever is thrown forward, the engine moves ahead in conformity with usual practice. When the reverse lever is thrown back, the links are raised and the valve gear is operated by the back-up eccentrics.

The main drivers are the only wheels not flanged. The springs are on top of the boxes and the pony truck and leading driver are equalized together, and the main and trailing drivers are also equalized together.

The boiler is 66 ins. diameter at the smoke-box end and is of the wagon-top type. There are in it altogether 1,981.8 sq. ft. of



S. F. Prince, Supt. Motive Power. PHILADELPHIA & READING 2-6-4 FOR SUBURBAN TRAFFIC. Baldwin Locomotive Works, Builders.

heating surface, of which the tubes give 1,825.5 sq. ft. The grate area is 68.5 sq. ft. and the fuel is anthracite buckwheat. There are 447 tubes 9 ft. long, diameter 1¾ ins. The auxiliary dome carrying the pop safety valves is so placed as to require the whistle, which has a long top, to be set at an agle in order not to stand above the level of the top of the smoke stack.

The tank has a capacity of 3,000 U. S. gallons, and the fuel space will hold 7,500 lbs. of the kind of coal used. The total weight of the machine is 201,700 lbs., the drivers carrying 120,860 lbs. There are 19,120 lbs. on the pony truck in front and 61,720 lbs. on the rear truck. The steam pressure carried is 200 lbs., and the calculated tractive effort is about 26,500 lbs.

A few of the principal dimensions are appended for reference:

Cylinder—20x24 ins.

Boiler—Dia., 66 ins.; thickness of sheets, 11/16 in. and ¾ in.; working pressure, 200 lbs.

Fire box—Length, 94 ins.; width, 105 ins.; depth, front, 59¼ ins.; back, 46¾ ins.; thickness of sheets, sides, ⅜ in.; back, ⅜ in.; crown, ⅜ in.; tube, ½ in.; water space, front, 3½ ins.; sides, 3½ ins.; back, 3½ ins.

Tubes—Number, 447; dia., 1¾ ins.; length, 9 ft. 0 in.

Heating surface—Fire box, 156.3 sq. ft.; tubes, 1,825.5 sq. ft.; total, 1,981.8 sq. ft.: grate area, 68.5 sq. ft.

Driving wheels—Dia. outside, 61⅝ ins.; journals, main, 8⅛x12 ins.;

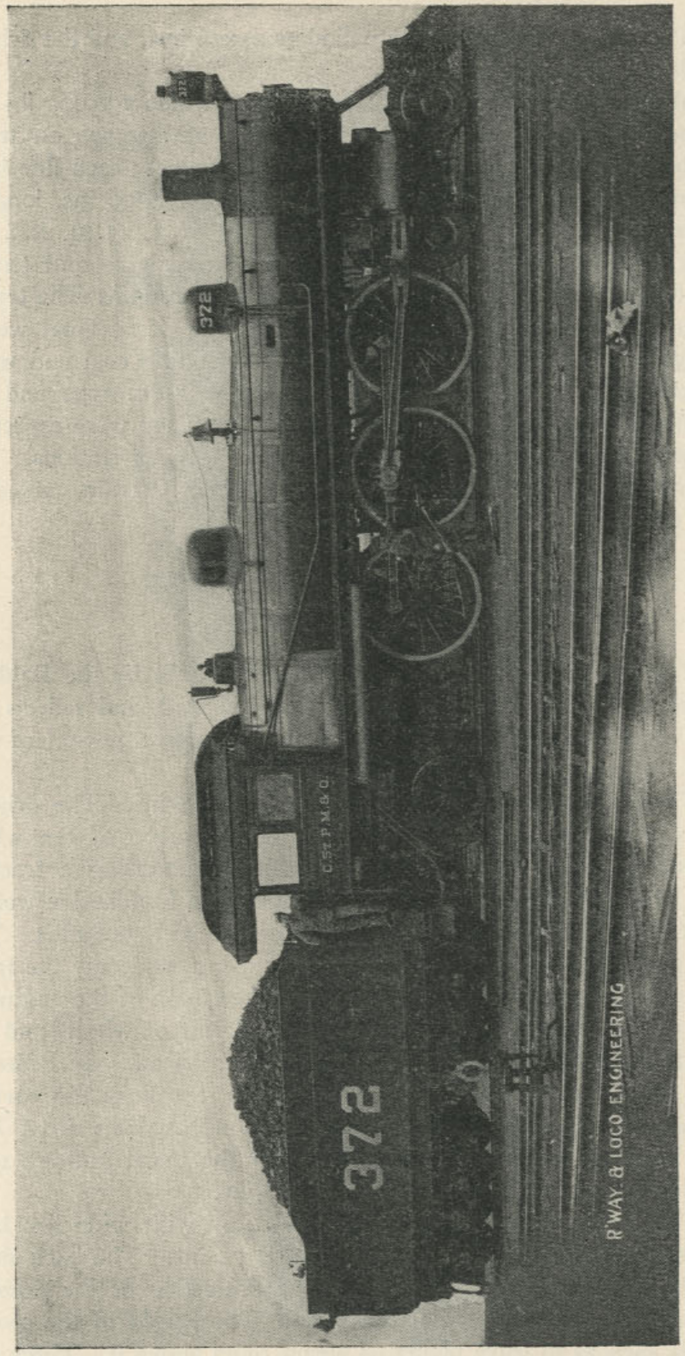
Engine truck wheels, front—Dia., 30 ins.; journals, 6x12 ins.; back, dia., 33 ins.; journals, 6x12 ins.

Wheel base—Rigid, 12 ft. 6 ins.; total, engine, 30 ft. 9 ins.

Weight—On driving wheels, 120,860 lbs.; on truck, front, 19,120 lbs.; on truck, back, 61,720 lbs.; total engine, 201,700 lbs.

FAST PASSENGER 4-6-2 FOR THE C., ST. P., M. & O.

The Chicago, St. Paul Minneapolis & Omaha Railway, of which Mr. J. J. Ellis is superintendent of motive power, has recently received from the Schenectady shops of the American Locomotive Company some 4-6-2 passenger engines. Our illustration shows No. 372 as she stands, with steam up, ready to take out her train. The photograph which is reproduced on page 545 was obtained through the courtesy of T. W. Teasdale, the general passenger agent of the road.



J. J. Ellis, Supt. Motive Power. American Locomotive Co., Builders.

CHICAGO, ST. PAUL, MINNEAPOLIS & OMAHA 4-6-2 EXPRESS ENGINE.

The engine is simple, with cylinders 21x26 ins., and the driving wheels are 75 ins. in diameter.

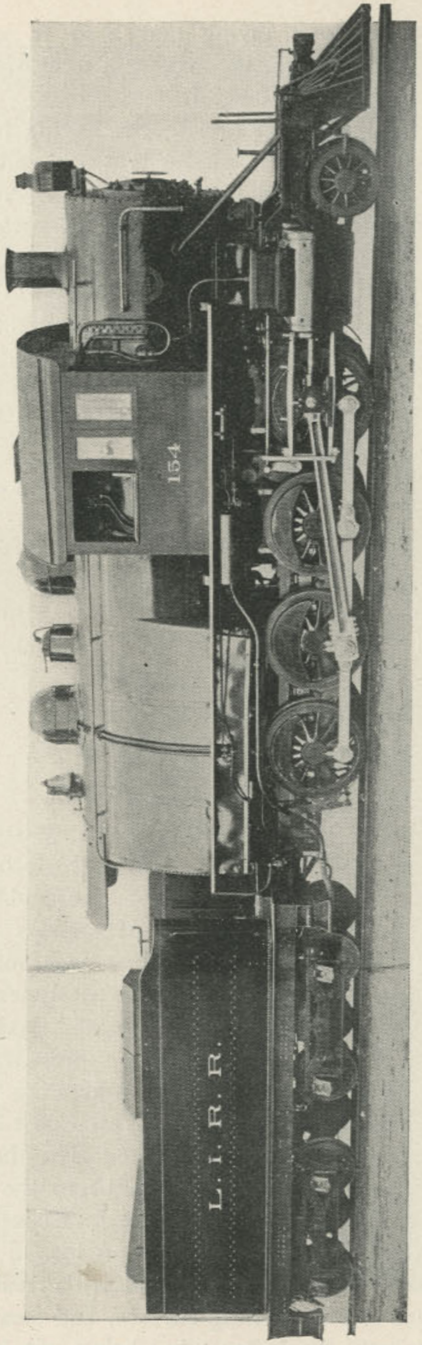
Weight of the engine is 192,000 lbs., of which 130,000 lbs. are on the drivers, 32,000 on carrying wheels, and 30,000 on truck. The boiler is 64 ins. in diameter and has 275 flues; each flue is $2\frac{1}{4}$ ins. in diameter and 20 ft. long. The fire box is 90 ins. long by 75 ins. wide and has a total heating surface of 3,425 sq. ft. The wheel base of this engine is 32 ft. 4 ins.; of engine and tender, 59 ft. 6 ins.; the total length of engine and tender, 65 ft. The tender carries 13 tons of coal and 6,200 gallons of water. Total weight of engine and tender is 242,000 lbs., and including coal and water 320,000 lbs. These engines are of the new 4-6-2 type and are capable of maintaining a high rate of speed. They were especially designed for getting up speed quickly in leaving stations. The total weight of the Northwestern Limited Chicago train, pulled by these engines, not including engine, is 410 tons.

LONG ISLAND 2-8-0 ENGINES.

The engine illustrated on page 547 was built by the Baldwin Locomotive Works for the Long Island Railroad, and reflects the ideas of Philip Wallis, superintendent of motive power of the road.

The engine is simple, with cylinders 21x28 ins. The driving wheels measure 51 ins. outside tires. The weight of the whole machine is 165,080 lbs., and it is capable of exerting a tractive effort of 41,160 lbs. The ratio of tractive force to adhesive weight is as 1 is to 3.47, the weight on the drivers being 143,080 lbs. The driving-wheel base of this engine is 14 ft. 6 ins., and only the front and rear drivers are flanged. The total wheel base of the engine is 22 ft. 9 ins. The pistons drive on the third pair of wheels and the eccentrics are placed on the axle of the pair ahead. In order to make the eccentric rods of sufficient length, the links are carried beyond the rocker and a short-transmission bar runs from link block back to rocker. The valve gear is the usual indirect type and the valves are the ordinary balanced slide.

The boiler is of the straight-top variety with wide fire box. The outside diameter of the first course is 72 ins. The back sheet is $84\frac{3}{16}$ ins. high, and the hood for the protection of the fireman is bolted flat down upon the roof sheet. The height of the crown sheet is such as to leave plenty of steam room above it. There are



Philip Wallis, Supt. Motive Power. CONSOLIDATION FOR THE LONG ISLAND RAILROAD. Baldwin Locomotive Works, Builders.

330 tubes 11 ft. 7¼ ins. long, giving 1,993.2 sq. ft. of heating surface; the fire box gives 192 sq. ft., making a total of 2,185.2 sq. ft. The grate area amounts to 70.6 sq. ft.

The tender has steel frame and trucks having boxes working in jaws with equalizers. The tank holds 5,000 gallons of water. The weight of the engine and tender in working order is about 265,000 lbs. Some few of the principal dimensions are as follows:

Cylinder—21x28 ins.

Boiler—Dia., 72 ins.; thickness of sheets, $\frac{11}{16}$ in.; working pressure, 200 lbs.; fuel, anthracite or bituminous; staying, radial.

Fire box—Length, 119⅛ ins.; width, 85½ ins.; depth, front, 62 ins.; back, 60½ ins.; thickness of sheets, sides, ⅜ in.; back, ⅜ in.; crown, ⅜ in.; tube, ½ in.; water space, front, 4 ins.; sides, 3½ ins.; back, 3½ ins.

Heating surface—Fire box, 192 sq. ft.; tubes, 1,993.2 sq. ft.; total, 2,185.2 sq. ft.

Driving wheels—Dia., outside, 51 ins.; journals, 8x10 ins.; engine truck wheels, dia., 30 ins.; journals, 5½x10 ins.

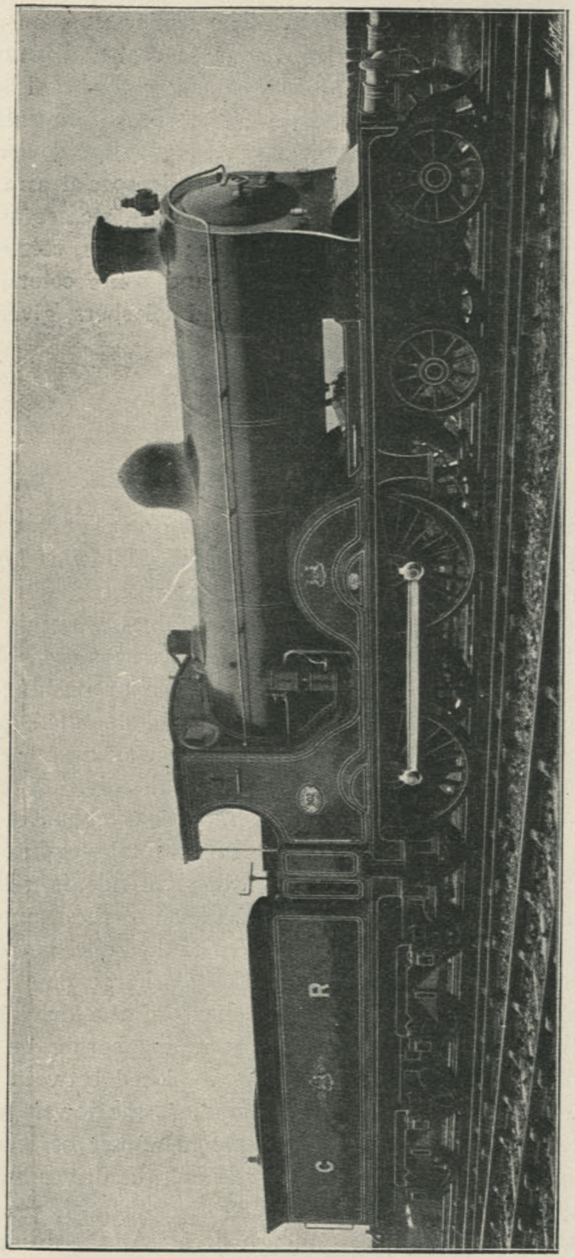
Wheel base—Total engine and tender, 48 ft. 11⅜ ins.

Weight—On driving wheels, 143,080 lbs.; on truck, front, 22,000 lbs.; total engine, 165,080 lbs.

CALEDONIAN EXPRESS ENGINE.

The engraving on page 549 shows the latest style of express locomotive designed by Mr. John F. McIntosh, locomotive superintendent of the Caledonian Railway of Scotland. This is an enlargement of the "Dunalistair" class of express engine, which proved one of the most efficient locomotives ever put in service in the British Isles, and which brought the designer international celebrity. This engine is called the "Bredalbane" class, and has been making an excellent record in pulling heavy express trains.

The new engines are intended by the directors to cope single handed with the increasing loads of the West Coast expresses over the heavy mountain grades of their main line. They have been given very powerful dimensions, as will be seen from the figures given below. The new engines, which are of the four-coupled with leading bogie type, have driving wheels 6 ft. 6 ins. in diameter; the cylinders are 19x26 ins., and are supplied with steam by a boiler having 1,600 square feet of heating surface, and steam pressure of 200 pounds to the inch, the boiler tubes being 269 in number and



CALEDONIAN EXPRESS ENGINE

John F. McIntosh, Supt. Motive Power. Caledonian Railway, Builders.

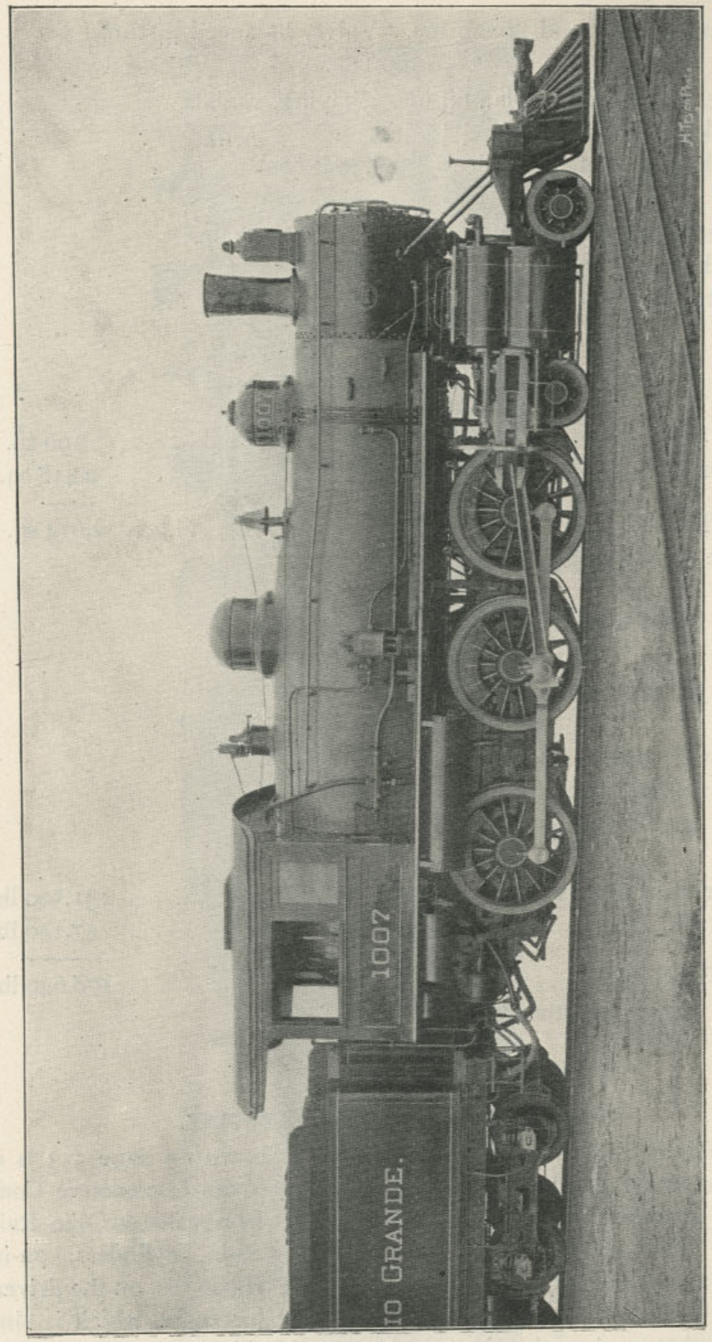
11 ft. 7 ins. in length. The engines weigh 125,800 pounds, of which 80,000 are on the driving wheels. The tender runs on a pair of four-wheeled bogies, and carried 5 tons of coal and 4,125 gallons of water, the weight being 45 long tons, or the total weight of engine and tender 226,600 pounds. The special fitments include McIntosh's patent gauge protectors, steam-saving devices, steam train-heating and Westinghouse brakes, while special arrangements include the concealment of all pipes, brake rods, etc., so as to make the engine look as symmetrical as possible; and this, combined with the Caledonian well-known blue, black and white colors, and the company's coat-of-arms on the tenders and splashers, gives the new engines a fine appearance.

BALDWIN TEN-WHEEL ENGINE FOR THE DENVER & RIO GRANDE.

The illustration of the locomotive shown on page 551 is a Vauclain 4-cylinder compound, built at the Baldwin Locomotive Works for the D. & R. G. R. R.

The idea in ordering these Vauclain engines, was that the compound feature with its economical use of steam would enable the operating department to dispense with the use of pushing engines, which, considering the character of the road operated, practically amounted to double heading each train half way over the division, and then returning a light engine to one of the division termini.

The passenger engine here illustrated has cylinders 15½ and 26x26 ins, 63-in. drivers, 68-in. boiler, and a total weight of 290,000 lbs. The air pump, though placed on the right side, is well forward and the air cylinder is slightly below the level of the running board. The blow-off cock is placed in the bottom of the boiler barrel as close to the smoke box as it can be, and its discharge pipe comes out beside the yoke plate. The arrangement of the driving springs is interesting. The leading wheel carries its spring on a saddle in the usual way. The second spring is placed between the main and rear drivers, and bears upward against the lower frame bar, the hangers from this spring terminate in a pair of levers, independently pivoted on the pin used to suspend the driver brake. The rear spring, which is semi-elliptical like the others, is placed below the top frame bar, behind the trailing wheel. All the driving wheels of this engine are flanged. A few of the principal dimensions are here given:



Baldwin Locomotive Works, Builders.

BALDWIN TEN-WHEEL LOCOMOTIVE FOR THE DENVER & RIO GRANDE.

F. Mertsheimer, Supt Motive Power.

Cylinders, $15\frac{1}{2}$ and 26x26 ins. Valve, balanced piston.

BOILER.

Type, wagon top. Dia., 68 ins. Staying, radial.
Thickness of sheets, $\frac{3}{4}$ and $\frac{13}{16}$ ins.
Working pressure, 210 lbs. Fuel, soft coal.

FIRE BOX.

Material, steel. Length, 121 ins. Width, 41 ins.
Depth, front, 80 ins.; back, $68\frac{1}{4}$ ins.
Water space, front, $4\frac{1}{2}$ ins.; sides, 4 ins.; back, 4 ins.

TUBES.

Dia., 2 ins. Length, 13 ft. 8 ins.

HEATING SURFACE.

Fire box	196 sq. ft.
Tubes	2,418 sq. ft.
Total	2,614 sq. ft.

Grate area, 34.4 sq. ft.

DRIVING WHEELS.

Dia., outside, 63 ins. Journals, $9\frac{1}{2}$x12 ins.

ENGINE TRUCK WHEELS.

Dia., 30 ins. Journals, 6x12 ins.

WHEEL BASE.

Driving, 13 ft. 6 ins.
Total engine, 24 ft. 10 ins.
Total engine and tender, 53 ft. $1\frac{1}{2}$ ins.

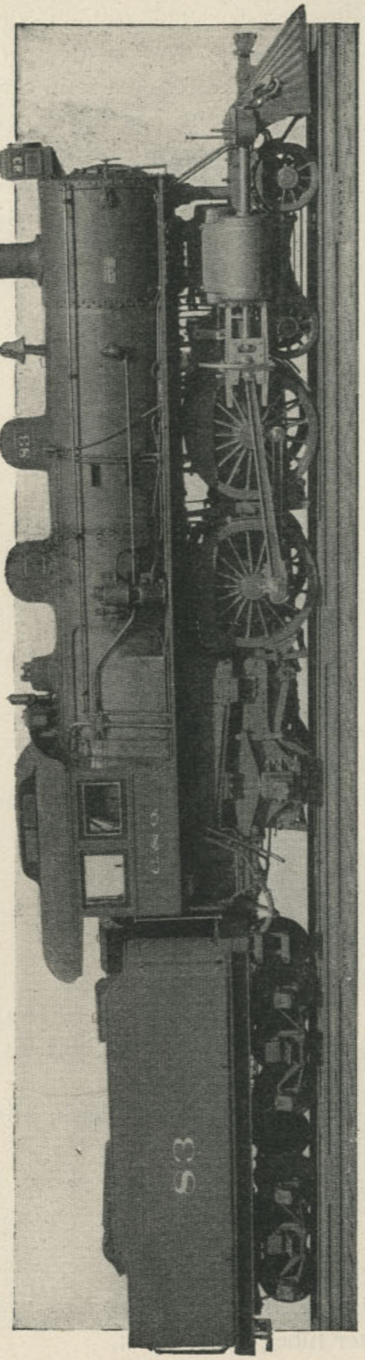
WEIGHT.

On driving wheels	131,500 lbs.
On truck, front	47,140 lbs.
Total engine	178,640 lbs.

Total engine and tender, 290,000 lbs.

C. & O. ATLANTIC TYPE ENGINE.

The illustration of the Atlantic type shown on page 553 is of very recent date, and was built by the American Locomotive Company, at their Schenectady shops, for the Chesapeake & Ohio Railroad. This engine is simple, with 21x26-in. cylinders, 72-in. drivers, and weighs 173,000 lbs. There are 93,000 lbs. on the drivers under ordinary circumstances; the traction increaser, which is similar to that used on the New York Central, will put about 12,000 lbs.



J. F. Walsh, Supt. Motive Power. C. & O. LATEST ATLANTIC TYPE EXPRESS ENGINE. American Locomotive Co., Builders.

additional on the driving wheels. The engine has piston valves, and the cast-steel valve rod extension bar passes up over the forward driving axle in an easy curve and terminates in a rocker, with arms hanging down, so that the engine has therefore direct-connected valve motion. The cross head is of the two-guide bar type and is secured to the piston rod by a nut. The fire box is, of course, of the wide type for bituminous coal, and the total heating surface is 3,505 sq. ft.

A few of the principal dimensions are as follows:

GENERAL DIMENSIONS.

Gauge, 4 ft. 9 ins. Fuel, bituminous coal.
Weight in working order, 173,000 lbs.
Weight on drivers, 93,000 lbs.
Wheel base, driving, 7 ft.
Wheel base, rigid, 16 ft. 6 ins.
Wheel base, total, 27 ft. 6 ins.

CYLINDERS.

Size of cylinders, 21x26 ins.
Dia. of piston rod, $3\frac{1}{2}$ ins.

VALVES.

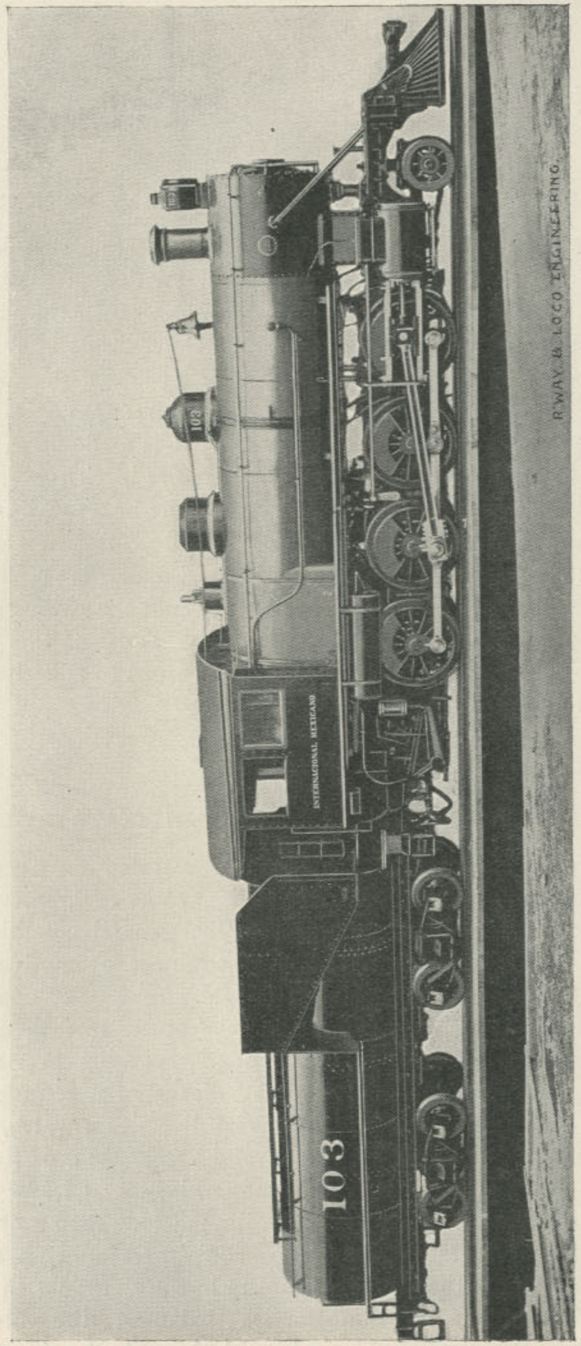
Greatest travel of piston valves, 6 ins.
Outside lap of piston valves, 1 in.
Inside clearance, $\frac{1}{8}$ in.
Lead of valves in full gear, line and line, $\frac{9}{32}$ in. lead at 6-in. cut off.

WHEELS, ETC.

Dia. of driving wheels outside of tire, 72 ins.
Dia. and length of driving journals, $9\frac{1}{2}$ ins. dia. x 12 ins.

BOILER.

Working pressure, 200 lbs.
Thickness of plates in barrel and outside of fire box, $\frac{1}{2}$, $\frac{3}{4}$, $\frac{5}{8}$ and 1 in.
Fire box, length, $96\frac{1}{8}$ ins. Fire box, width, $75\frac{3}{8}$ ins.
Fire box, depth, $80\frac{1}{4}$ ins. F.; 69 ins. B.
Fire box, plates, thickness, sides, $\frac{5}{16}$ in.; back, $\frac{3}{8}$ in.; crown, $\frac{3}{8}$ in.; tube sheet, $\frac{1}{2}$ in.
Fire box, water space, 4x5 ins. front, $3\frac{1}{2}$x$5\frac{1}{2}$ ins. sides, $3\frac{1}{2}$x$4\frac{1}{2}$ ins. back.
Tubes, number, 396. Tubes, dia., 2 ins.
Tubes, length over tube sheets, 16 ft.
Heating surface, tubes, 3,298.08 sq. ft.
Heating surface, water tubes, 27.09 sq. ft.



J. J. Waters, Mechanical Superintendent. BALDWIN 2-8-0 FOR THE INTERNACIONAL MEXICANO. Baldwin Locomotive Works, Builders.

Heating surface, fire box, 180.7 sq. ft.
Heating surface, total, 3,505.87 sq. ft.
Grate surface, 50.32 sq. ft.

BALDWIN 2-8-0 FOR THE INTERNACIONAL MEXICANO.

The Mexican International received some simple consolidation engines from the Baldwin Locomotive Works, at Philadelphia, shown on page 555. The cylinders are 22x28 ins., the valves are balanced slide, and the diameter of the driving wheels is 57 ins.

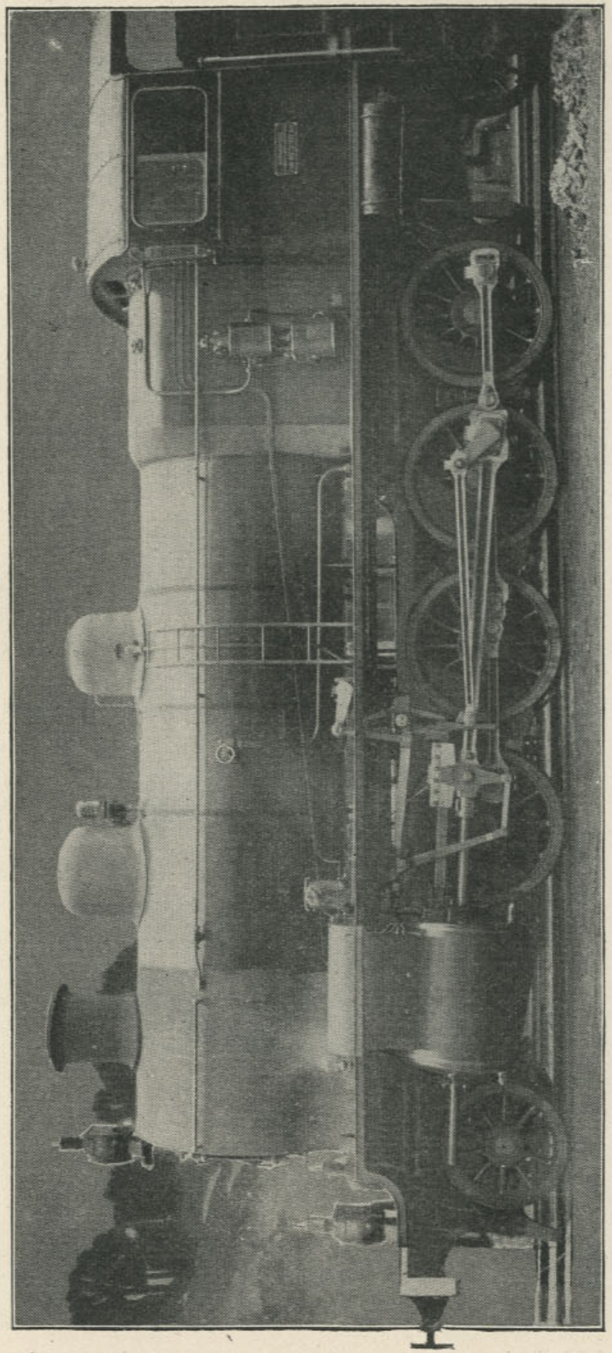
The boiler is a straight-top one and is 74 ins. at the smoke-box end. The pressure carried is 200 lbs. The tubes are 365 in number, and are 15 ft. 1 in. long. The heating surface is made up as follows: Fire box, 163 sq. ft.; tubes, 2,864.5 sq. ft.; fire-brick tubes, 25.3 sq. ft., making a total of 3,052.8 sq. ft. The grate area is 54.3 sq. ft.

The weight on the drivers is 169,500 lbs.; the weight of the engine is 185,750 lbs.; that of the engine and tender is about 336,000 lbs. The tender is of the Vanderbilt type and the cylindrical tank holds 8,000 gallons. The calculated tractive effort of this machine is about 40,400 lbs., and the ratio of tractive effort to adhesive weight is as 1 is to 4.19.

CONSOLIDATION ENGINE FOR NORWEGIAN STATE RAILWAYS.

The 8-wheel connected locomotive illustrated on page 557 is one of a number constructed at the Swiss works of Winterthur for the Norwegian State railroads and to the general conditions laid down by Henri Paul Hoff, the chief engineer of motive power. They are the largest and heaviest freight engines yet constructed for Norway, and embody several original features in their construction. There are two compound cylinders, working in single expansion at the will of the engineer by means of a connection between the reversing gear and a special live-steam valve, and in such manner that with all cut offs beyond 70 per cent. of the piston stroke this valve is opened automatically, whereas at lesser cut offs it is closed by the reversing gear, and the machine then works compound. This device is an adaptation upon a well-known system, by the works of Winterthur, and appears to be very efficient in service.

The slide valves are Von Borries', balanced; the valve gear, Walschaerts'; the pistons are prolonged through the front covers



A NORWEGIAN CONSOLIDATION ENGINE.

Henri Paul Hoff, Chief of Motive Power. Swiss Works, Winterthur, Builders.

to mitigate grooving of the cylinder; all the cylinder covers have safety valves; both the steam chests are fitted with air valves, and the receiver has a combined air and relief valve; oiling of the valves and pistons is done by a force pump.

The whole of the motion and valve gear is designed with the end of obtaining great lightness with a maximum of strength. All the bearings are ample and well proportioned and the valve movement is specially devised to avoid torsional strains. The blast pipe has a fixed nozzle and the smoke arch has the American form of spark arrester. The wheel springs have equalizers connecting them —the balance levers or yokes being hung upon the axle-box crowns in the American way. The lateral play of the second and fourth axles is $\frac{5}{8}$ in. on each side and the driving pins of the latter allow, of course, for this movement in the bushes of the connecting side rods. The front Bissel truck allows a radial movement of 2 ins., the recoil of the axle being effected by means of springs and of inclined planes on the axle boxes.

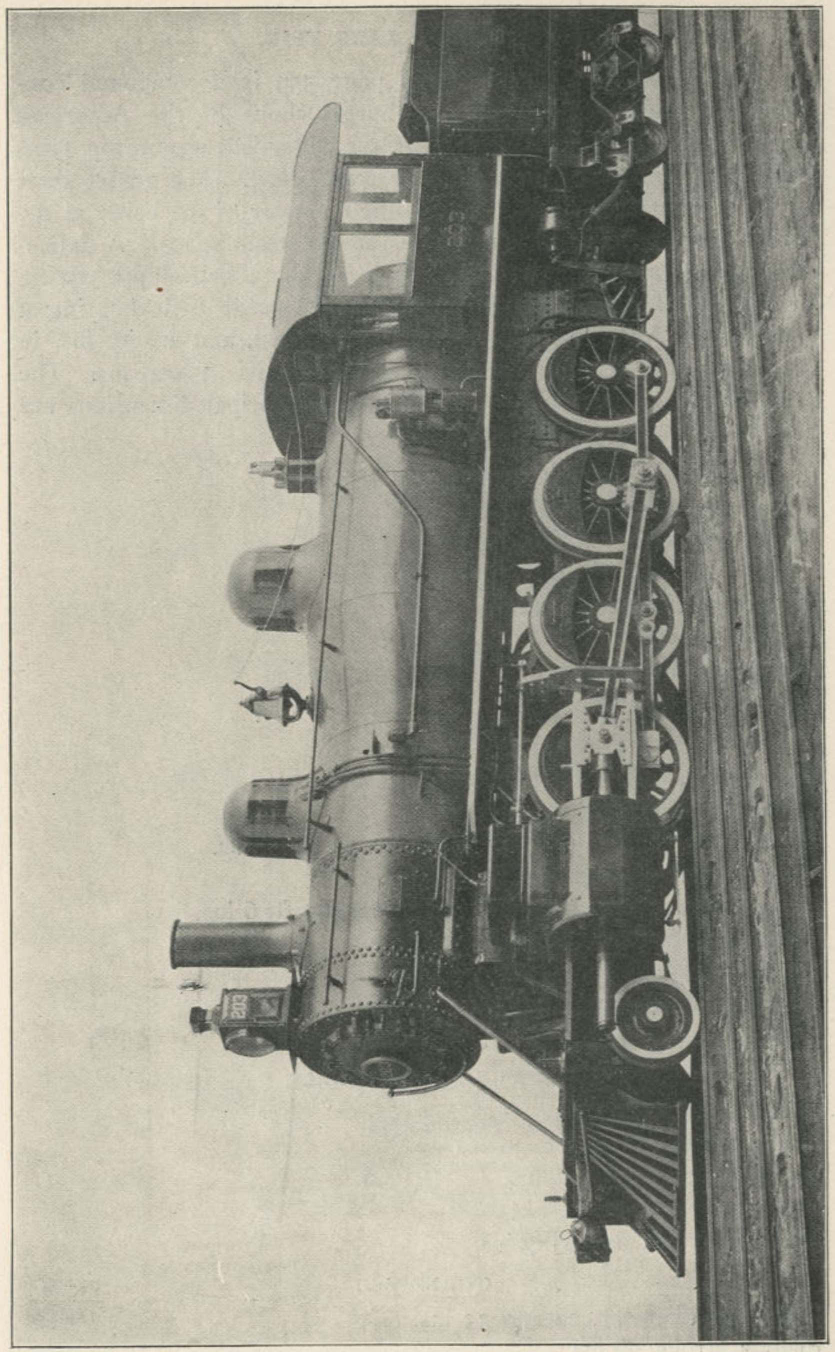
The inside fire box is rectangular, spreading outward to the foundation ring. The smoke box is not circular, but of horseshoe form, allowing plenty of room for cinders. It has a clean-out pipe below.

The engine is built and finished in admirable style and with a first-class equipment. Among these are two automatic oilers, one speed indicator, two safety valves, three Freedman injectors, United States gland packing, pneumatic sanders, and Westinghouse air brake.

The tender is carried upon two 4-wheel trucks with frames of the Norwegian diamond pattern.

PRINCIPAL DIMENSIONS, ETC.

Cylinders, high pressure, $21\frac{5}{8}$ ins.
Low pressure, $32\frac{1}{4}$ ins. Stroke, $25\frac{1}{4}$ ins.
Wheels, driving, dia., $49\frac{1}{8}$ ins. Truck, $38\frac{5}{8}$ ins.
Driving-wheel base, 13 ft. $8\frac{1}{2}$ ins.
Weight on drivers, 68 tons.
Weight on pony truck, 11 tons.
Total weight, 79 tons.
Tender, loaded, 38.5 tons.
Boiler pressure, 175 lbs.
Tractive effort, maximum, 25,300 lbs.



J. E. O'Hearne, Supt Motive Power. WHEELING & LAKE ERIE CONSOLIDATION. American Locomotive Co., Builders.

WHEELING & LAKE ERIE.

The locomotive illustrated on page 559 is a compound consolidation engine built by the Pittsburgh shops of the American Locomotive Co. The boiler is of the extended wagon-top type, having a diameter of 60 ins. at the front sheet. The gusset sheet is placed forward of the dome and the diameter of the boiler at the throat sheet is 70⅛ ins., which gives ample steam space. A noticeable feature about the spring rigging is that a half-elliptic spring at the rear of the whole system replaces the usual helical spring at that point. All the driving wheels are flanged, and are 57 ins. in diameter. The tractive power of these engines is 35,000 lbs. The total weight is 251,700 lbs. Some of the principal dimensions are as follows:

GENERAL DESCRIPTION.

Type, compound consolidation.
Weight on drivers, 146,300 lbs.
Weight on truck wheels, 21,100 lbs.
Weight on total, 167,400 lbs.
Weight of tender, loaded, 84,300 lbs.
Weight total of engine and tender, 251,700 lbs.
Tractive power, 35,000 lbs.

DIMENSIONS.

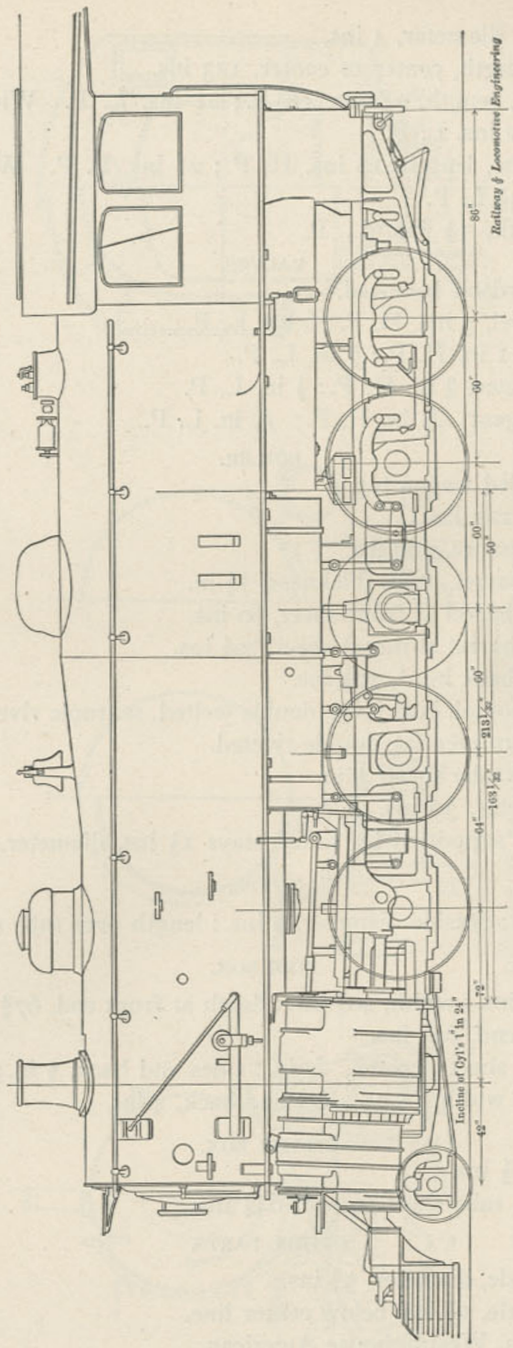
Wheel base, total of engine, 23 ft. 10 ins.
Wheel base, driving 15 ft. 8 ins.
Wheel base, total of engine and tender, 52 ft. 3⅜ ins.
Length over all, engine, 38 ft. 6⅞ ins.
Length over all, total, engine and tender, 62 ft. 6 ins.
Heating surface, fire box, 159 sq. ft.
Heating surface, tubes, 1,849 sq. ft.
Heating surface, total, 2,008 sq. ft.
Grate area, 30 sq. ft.

WHEELS AND JOURNALS.

Drivers, diameter, 57 ins.
Truck wheels, diameter, 30 ins.
Journals, driving, 8x11 ins.
Journals, engine truck, 5½x10 ins.
Main crank pin, size, 6¾x7 ins.

CYLINDERS.

Cylinders, diameter, 22 and 33 ins.
Pistons, stroke, 28 ins.



OUTLINES OF BALDWIN TANDEM FOR THE SANTA FE.

Piston, rods, diameter, 4 ins.
Main rod, length, center to center, 123 ins.
Steam ports, length, 18 ins. H. P.; 21 ins. L. P. Width, $1\frac{3}{8}$ ins. H. P.; 2 ins. L. P.
Exhaust ports, length, 18 ins. H. P.; 21 ins. L. P. Width, 3 ins. H. P.; $3\frac{1}{2}$ L. P.
Bridge, width, $1\frac{1}{2}$ ins. L. P.

VALVES.

Type, Richardson balanced.
Greatest travel, 5 ins. H. P.; 6 ins. L. P.
Outside lap, 1 in. H. P.; $\frac{3}{4}$ in. L. P.
Inside clearance, $\frac{3}{8}$ in. H. P.; $\frac{1}{2}$ in. L. P.
Lead in full gear, $\frac{1}{16}$ in. H. P.; $\frac{3}{32}$ in. L. P.

BOILER.

Type, extended wagon top.
Steam test, 220 lbs.
Working pressure, 200 lbs.
Material in barrel, steel, thickness, $\frac{11}{16}$ in.
Diameter of barrel at front sheet, 60 ins.
Diameter of barrel at throat sheet, $70\frac{1}{8}$ ins.
Diameter at back head, $70\frac{1}{8}$ ins.
Seams; horizontal, butt joint, double welted, sextuple riveted.
Seams; circumferential, double riveted.
Thickness of tube sheet, $\frac{1}{2}$ in.
Dome, diameter, 30 ins.
Crown sheet supported by radial stays $1\frac{1}{8}$ ins. diameter.

TUBES.

Number, 260; outside diameter, 2 ins.; length over tube sheet, 13 ft. 8 ins.

FIRE BOX.

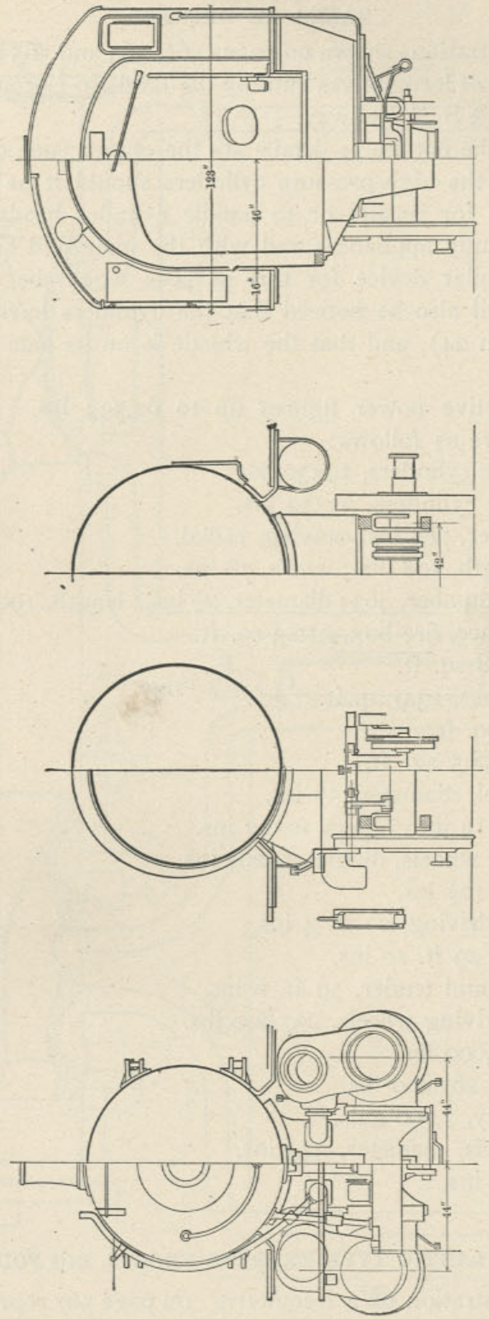
Length, 108 ins.; width, $40\frac{1}{4}$ ins.; depth at front end, $67\frac{3}{4}$ ins.; depth at back end, $64\frac{1}{2}$ ins.
Thickness of sheets, crown, $\frac{7}{16}$ in.; sides and back, $\frac{3}{8}$ in.; tube, $\frac{1}{2}$ in.
Water space, width, front, sides and back, 4 ins.

SMOKE BOX.

Diameter, $61\frac{1}{2}$ ins.
Length from tube sheet to end, $64\frac{3}{4}$ ins.

OTHER PARTS.

Exhaust nozzle, diameter, $5\frac{3}{4}$ ins.
Exhaust nozzle, $1\frac{1}{2}$ ins. below center line.
Power brakes, Westinghouse American.



DETAILS OF BALDWIN TANDEM FOR THE SANTA FE.

SANTA FE DECAPOD.

The illustrations shown on pages 561, 563 and 565 are those of a large number of locomotives built by the Baldwin Locomotive Works for the A., T. & S. F. Railway.

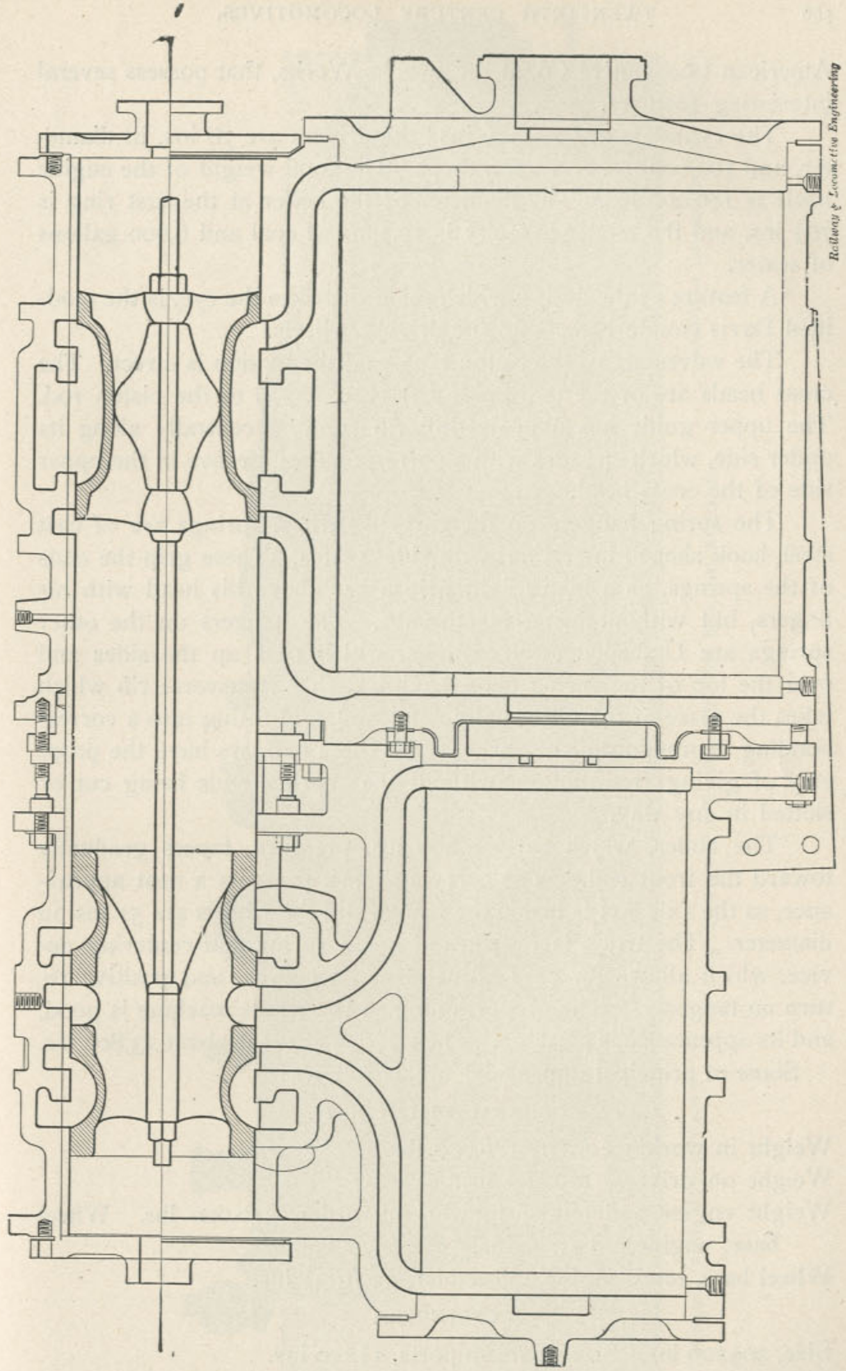
Among the noticeable details are the cranes (one on each side) for handling the high-pressure cylinders should it be necessary to remove them for repairs or to handle cylinder heads and valves. These are handy appliances and with the main and side rods now in use, a similar device for this purpose would be welcomed by many. It will also be noticed that the cylinders have a slight incline (1 in. in 24), and that the whistle is on its side to save head room.

The tractive power figures up to 62,593 lbs. The leading dimensions are as follows:

High-pressure cylinders, 19x32 ins.
Low-pressure cylinders, 32x32 ins.
Boiler diameter, 78¾ ins., staying, radial.
Fire box, length, 108 ins.; width, 78 ins.
Tubes, iron; number, 463; diameter, 2¼ ins.; length, 190 ins.
Heating surface, fire box, 210.3 sq. ft.
Tubes, 5,155.8 sq. ft.
Fire-brick tubes, 23.9 sq. ft.
Total, 5,390 sq. ft.
Grate area, 58.5 sq. ft.
Driving wheel, diameter, 57 ins.
Journals, 11x12 ins., others 10x12 ins.
Engine truck wheels, diameter, 29¼ ins.
Journals, 6½x10½ ins.
Wheel base, driving, 20 ft. 4 ins.
Total engine, 29 ft. 10 ins.
Total engine and tender, 59 ft. 6 ins.
Weight on driving wheels, 237,800 lbs.
On truck, 30,000 lbs.
Total engine, 267,800 lbs.
Tank, capacity, 7,000 gals.
Tender wheels, diameter, 34¼ ins.
Journals, 5x9 ins.

ATLANTIC TYPE EXPRESS ENGINE, BIG FOUR.

The illustration of a locomotive on page 567 represents one of a class of heavy express locomotives built for the Big Four by the



CYLINDERS AND VALVES OF BALDWIN TANDEM FOR THE SANTA FE.

American Locomotive Co. at the Brooks Works, that possess several interesting features.

The cylinders are 20$\frac{1}{2}$x26 ins., the drivers are 78 ins. in diameter, and 100,000 lbs. rest upon them. The total weight of the engine itself is 186,000 lbs. The diameter of the boiler at the first ring is 70$\frac{1}{8}$ ins. and the tender capacity is 10 tons of coal and 6,000 gallons of water.

A feature of the design which at once strikes the eye, is the modified Davis counterbalance in the driving wheels.

The valves are of the piston type, and the motion is direct. The cross heads are of the two-guide bar type, keyed to the piston rod. The upper guide has a projecting rib running centrally along its under side, which engages with a corresponding groove in the upper side of the cross head.

The spring hangers on the carrying wheel springs are of cast steel, hook shaped in section, with side plates. These grip the ends of the springs, as a man might grip a bar above his head with his fingers, but without using his thumbs. The hangers on the other springs are U-shaped steel castings, which pass up the sides and over the top of the spring ends, having each a transverse rib which takes the place of the gib usually employed, and fitting into a corresponding depression in the spring. All these hangers have the property of giving free motion, without the spring ends being cut or slotted in any way.

The boiler, which carries 200 lbs. pressure, tapers gradually toward the front end. The carrying truck presents a neat appearance, as the axle box is inside the frame, and the wheels are 51 ins. in diameter. The truck is radial, and has a spring self-centering device, which allows for easy adjustment on curves, and positive return on tangents. The proportioning of the whole machine is good, and its appearance is pleasing. The tractive effort is about 23,800 lbs.

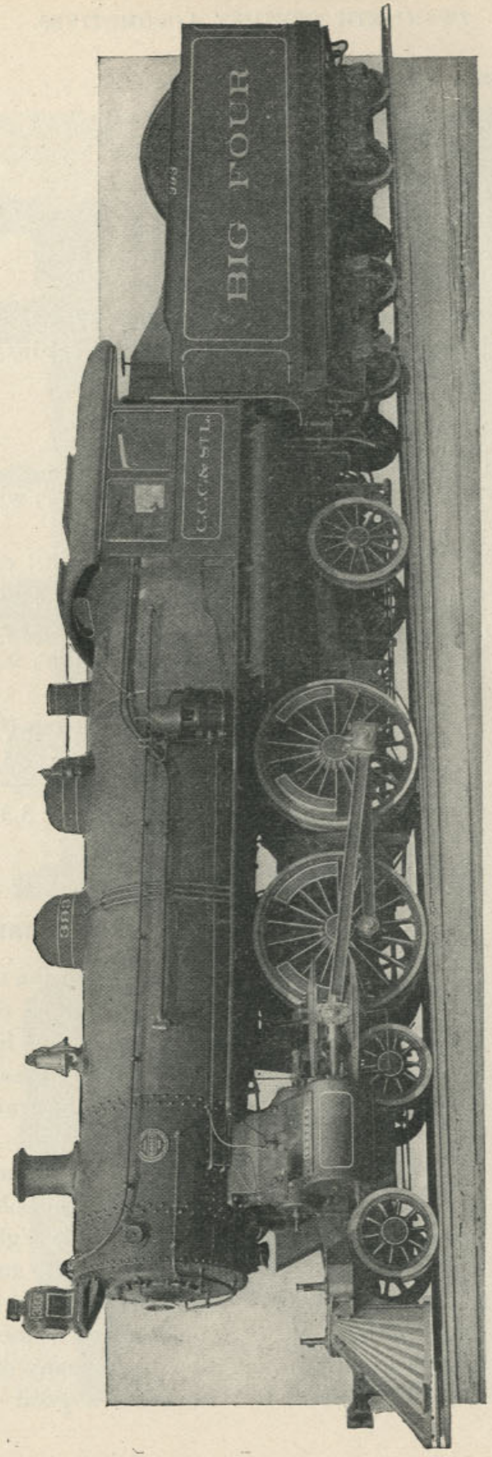
Some of principal dimensions are as follows:

GENERAL DIMENSIONS.

Weight in working order, 186,000 lbs.
Weight on drivers, 100,000 lbs.
Weight engine and tender in working order, 310,000 lbs. Wheel base, engine, 28 ft. 5 ins.
Wheel base, total, engine and tender, 55 ft. 3$\frac{5}{8}$ ins.

CYLINDERS.

Size, 20$\frac{1}{2}$x26 ins. Size of steam ports, 1$\frac{7}{8}$x20 ins.
Size of exhaust ports, 6.5 ins. Size of bridges, 3 ins.



American Locomotive Co., Builders.

ATLANTIC TYPE ENGINE FOR BIG FOUR ROAD.

W. Garstang, Supt. Motive Power.

Valves, piston. Outside lap, $1\frac{1}{8}$ ins.
Lead in full gear, $\frac{1}{16}$ in.

WHEELS, ETC.

Dia. of driving wheels outside of tire, 78 ins.
Material of driving wheel centers, cast steel.
Tire held by shrinkage and retaining rings.
Dia. and length of driving journals, $9\frac{1}{4}$x12 ins.
Dia. and length of main crank pin journals, $6\frac{1}{2}$x7 ins.
Dia. and length of side rod crank pin journals, 7x$4\frac{1}{4}$ ins.

BOILER.

Style, radial stayed, wagon top.
Outside dia. of first rings, $70\frac{1}{8}$ ins.
Working pressure, 200 lbs. Fire box, length, 97 ins.; width, 76 ins.; depth, front, $78\frac{1}{2}$ ins.; back, $69\frac{1}{2}$ ins.
Fire box plates, thickness, sides, $\frac{3}{8}$ in.; back, $\frac{3}{8}$ in.; crown, $\frac{3}{8}$ in.; tube sheet, $\frac{5}{8}$ in. Fire box, water space, front, 4 ins.; sides, $3\frac{1}{2}$ ins.; back, $3\frac{1}{2}$ ins.
Tubes, gauge, No. 11, B. W. G.; number, 380; dia., 2 ins.; length over tube sheets, 16 ft. $\frac{1}{8}$ in.

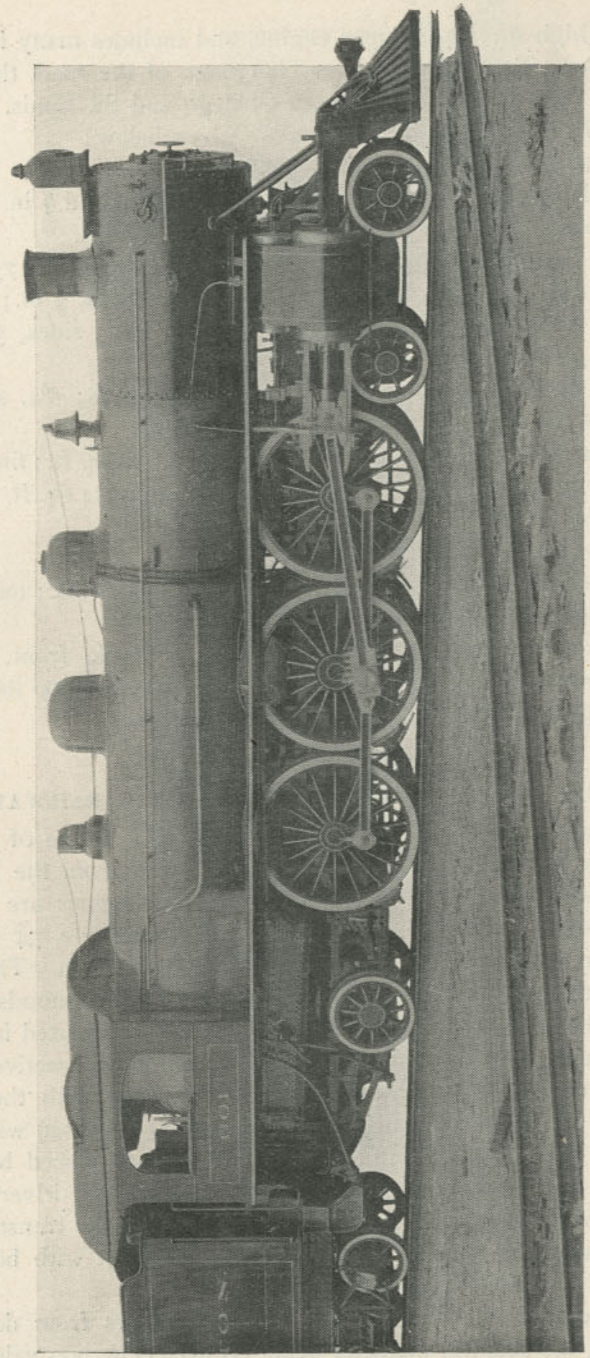
Heating surface, tubes........................	3,164.96	sq. ft.
Heating surface, fire box........................	175.1	sq. ft
Total	3,340	sq ft.

Grate surface, 51.66 sq. ft.

CHICAGO & ALTON 4-6-2 PASSENGER ENGINE.

The engine shown on page 569, which is one of the most powerful passenger engines ever built, was turned out of the Baldwin Works for the Chicago & Alton Railroad. The engine has cylinders 22x28 ins. and driving wheels 73 ins. diameter. A pressure of 220 lbs. per square inch is carried on the boiler, and the tractive power is 34,700 lbs., with a ratio of 4.08 of adhesion.

The motion of the engine is indirect, the transmission bar being arched over the leading driving axle, with bolt and filler underneath. Piston valves are used. The cab is lighted in the ordinary way with ample window for the engineer, and above in the sloping roof there is what may be called a dormer window on each side. The tender carries 9 tons of coal and 8,400 gallons of water, and is built up high after the manner of many of the Alton passenger tenders. This locomotive furnishes a good example of



A. L. Humphrey, Supt. Motive Power. Baldwin Locomotive Works, Builders.

CHICAGO & ALTON "PACIFIC" TYPE EXPRESS ENGINE.

a modern high-speed passenger engine, and includes many interesting features. To use the ordinary language of the road, these engines will "pull passenger" between Chicago and St. Louis.

Some of the principal dimensions are given below:

Cylinder, 22x28 ins.

Boiler—Dia., 70 ins.; thick. of sheets, $\frac{11}{16}$ in., $\frac{23}{32}$ in. and $\frac{3}{4}$ in.; working pres., 220 lbs.; staying, crown bar, $5\frac{1}{4}$x6 ins.

Fire box—Length, 108 ins.; width, $72\frac{1}{4}$ ins.; depth, front, $75\frac{5}{8}$ ins.; back, $64\frac{1}{8}$ ins.; thick. of sheets, sides, $\frac{3}{8}$ in.; back, $\frac{3}{8}$ in.; crown, $\frac{3}{8}$ in.; tube, $\frac{5}{8}$ in.; water space, front, $4\frac{1}{2}$ ins.; sides, $3\frac{1}{2}$ ins.; back, $3\frac{1}{2}$ ins.

Tubes—Material, iron, gauge No. 11; Number 328; dia, $2\frac{1}{4}$ ins.; length, 20 ft.

Heating surface—Fire box, 202 sq. ft., tubes, 3,848 sq. ft.; fire brick, tubes, 27 sq. ft.; total, 4,078 sq. ft.; grate area, 54 sq. ft.

Dia. driving wheels, 73 ins.

Trailing wheels—Dia., 42 ins.; jour., 8x12 ins.

Wheel base—Rigid, 13 ft. 9 ins.; total eng., 32 ft. 8 ins.; total eng. and tender, 62 ft.

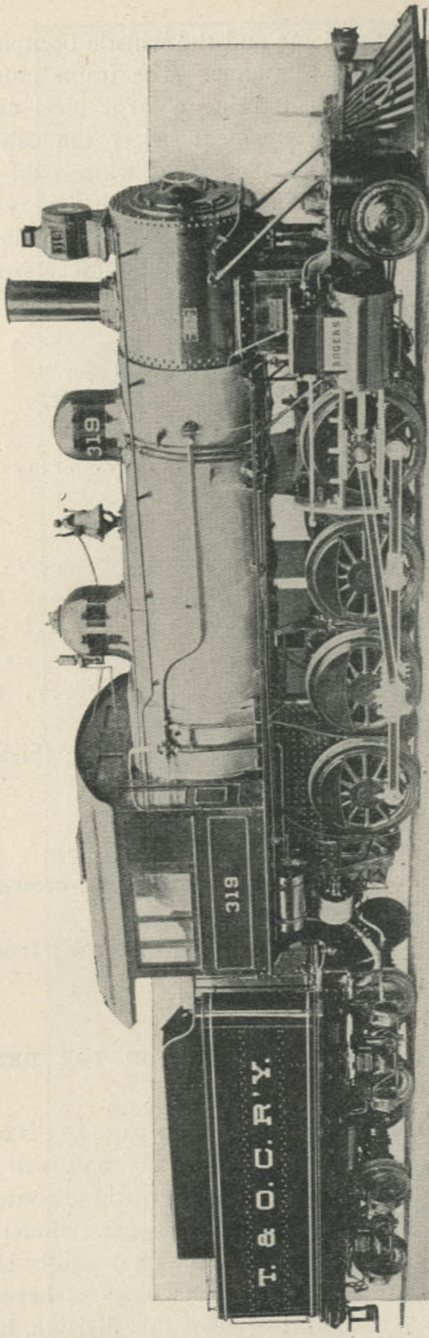
Weight—On driving wheels, 141,700 lbs.; on truck, front, 36,300 lbs.; on truck, back, 41,500 lbs.; total engine, 219,500 lbs.

Tank—Capacity, coal, 9 tons; water, 8,400 gals.

ROGERS CONSOLIDATION FOR THE T. & O. C. RAILWAY.

The heavy 2-8-0 engine shown on page 571 is one of twenty received by the Toledo & Ohio Central Railway from the Rogers Locomotive Works at Paterson, N. J. These engines are simple with cylinders 20x26 ins. The driving wheels are 54 ins. in diameter and there is 133,000 pounds resting upon them. The total weight of the machine is 150,000 pounds. With 180 pounds steam pressure, the calculated tractive force which can be exerted is about 29,500 pounds, and the ratio of adhesive weight to tractive force is 4.5. The leading pair of drivers are equalized with the pony truck, and the three rear drivers are equalized together with coil springs in front and rear and semi-elliptic springs placed between the wheels and between the frame bars. The second driver is the only one not flanged. The valve motion is indirect, the transmission bar here takes the form of an arched steel casting, with bolt and filler below the axle of the second driver.

The boiler has a Belpaire fire box and tapers from dome to smoke box, the smallest diameter being 60 ins. The pop valves are



ROGERS CONSOLIDATION FOR TOLEDO & OHIO CENTRAL.

S. S. Stiffey, Supt. Motive Power. Rogers Locomotive Co., Builders.

placed in the top of the dome and the whistle occupies a somewhat protected position behind the dome. The frame cross bracing has been well looked after, there being a large steel casting back of the cylinders, and the arrangement below the cab is very substantial. The tender frame is made of white oak, and the tank, which holds 5,000 gallons of water, is finished very neatly with a deep coping which helps to hold coal, and which does not enclose the manhole. A low railing around the rim serves as a sort of guard around the edge of the tank. A few of the principal dimensions are as follows:

Cylinders, 20x26 ins. Drivers, dia., 54 ins.
Driv. journals, 8x10 ins. Driv. wheel base, 15 ft.
Total wheel base of engine, 23 ft.

Weight on drivers	133,000 lbs.
Weight on truck	17,000 lbs.
Total	150,000 lbs.
Heating surface, tubes	1,760.04 sq. ft.
Heating surface, fire box	165.74 sq. ft.
Total	1,925.78 sq. ft.

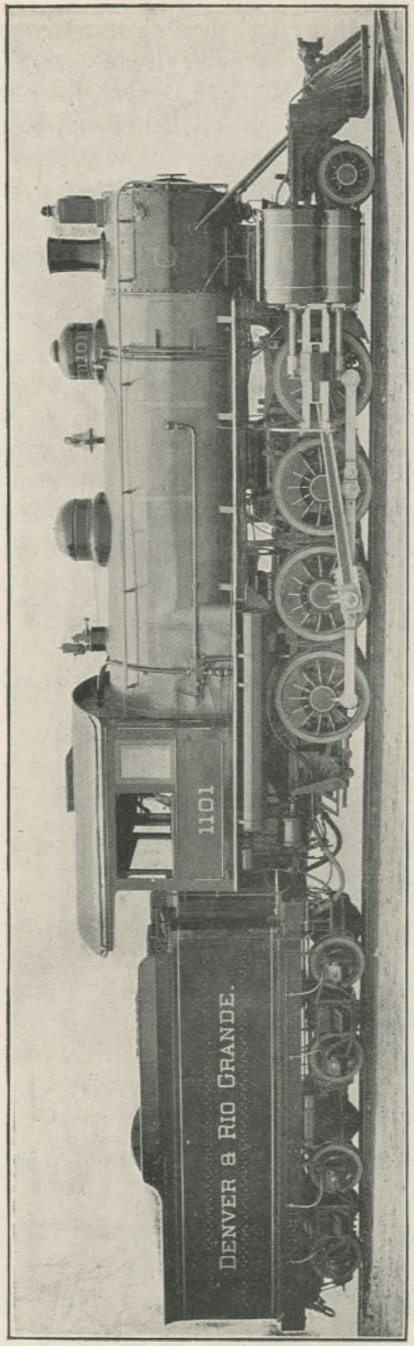
Grate area, 30.34 sq. ft.
Tubes, dia., 2 ins. o. d.; length, 13 ft. 10 ins.; thickness, No. 11 gauge; total number, 243.

BOILER.

Dia., outside front, 60 ins.; working press., 180 lbs.
Thickness of barrel, $\frac{9}{16}$ in.; dome course, $\frac{5}{8}$ in.; crown, $\frac{3}{8}$ in.; tube, $\frac{1}{2}$ in.; side, $\frac{5}{16}$ in.
Tender, capacity, 5,000 gals.; frame, white oak; trucks, diamond arch bars.

COMPOUND CONSOLIDATION ENGINES FOR THE DENVER & RIO GRANDE.

Our illustration of the D. & R. G. on page 573 is one of a large number built by the Baldwin Locomotive Co., and is of the Vauclain 4-cylinder compound type. The cylinders of these consolidations are 17 and 28 in. by 30-in. stroke with low-pressure cylinder on top. The driving wheels are 54 ins. in dia., and the total weight is 188,095 lbs. The work cut out for these heavy machines is between Denver, Pueblo and Salida. The first district of this division, between Denver and Pueblo, is about 120 miles long and is over the "divide"



Baldwin Locomotive Works, Builders.

COMPOUND CONSOLIDATION.—DENVER & RIO GRANDE RAILWAY.

F. Mertsheimer, Supt. Motive Power.

separating the South Platte and the Arkansas rivers. From Pueblo to Palmer Lake there is a continuous rise of 2,569 ft. in a distance of 67 miles, and from Palmer Lake to Denver, the remaining 53 miles, a descent of 2,039 ft. is made. The maximum grades between stations vary from less than 1 per cent. to 1.42 per cent., and the curves encountered in the steepest climbs are 6 degrees. From Toluca to Husted, a distance of 40 miles, there is no compensation in the grading to allow for the presence of curves, which adds to the work the engines' are called on to perform. On the second district, from Pueblo to Salida, there is a continuous rise of 2,378 ft., the minimum grade being 0.66 per cent., and the maximum 1.42 per cent., with curves ranging from 3 deg. to 12 deg. 30 min.

The engines in question have wide fire boxes, which is an innovation on the D. & R. G. The balanced piston valves are driven by direct connection gear, and the engine truck center castings have 3-point suspension links. The main and intermediate drivers are not flanged, and the stroke being 30 ins. brings the center of the crank pin within 12 ins. of the outside of the tire. The theoretical tractive power of these mountain climbers on level track at slow speed is about 43,180 lbs.

A few of the principal dimensions are given below:

BOILER.

Type, straight. Diameter, 74 ins.
Thickness of sheets, $\frac{5}{8}$ in.
Working pressure, 200 lbs. Fuel, soft coal.
Staying, radial.

FIRE BOX.

Material, steel. Length, $102\frac{1}{8}$ ins.; width, $65\frac{7}{8}$ ins.
Depth, front, 70 ins.; back, $62\frac{1}{4}$ ins.
Thickness of sheets, sides, $\frac{5}{16}$ in.; back, $\frac{3}{8}$ in.; crown, $\frac{5}{16}$ in.; tube, $\frac{1}{2}$ in.
Water space, front, 5 ins.; sides, 5 ins.; back, 5 ins.

TUBES.

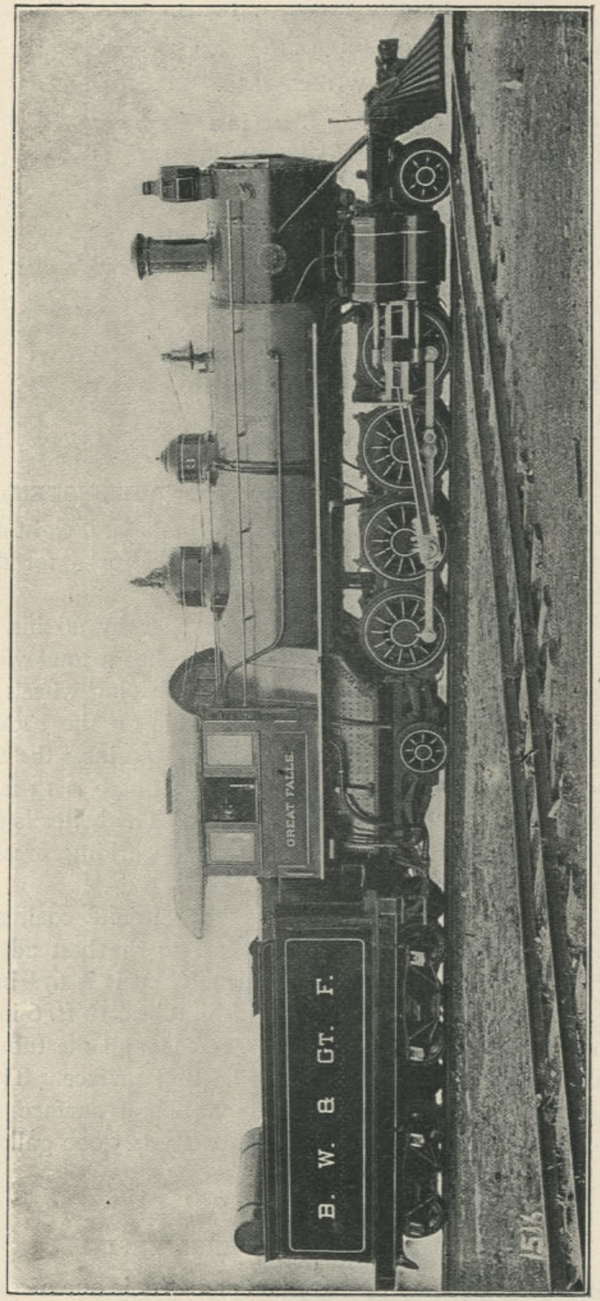
Material, iron. Wire gauge, No. 11.
Number, 344. Diameter, 2 ins. Length, 14 ft. 6 ins.

HEATING SURFACE.

Fire box, 172.5 sq. ft. Tubes, 2,596 sq. ft.
Total, 2,768.5 sq. ft. Grate area, 46.75 sq. ft.

DRIVING WHEELS.

Diameter outside, 54 ins. Journals, all $9\frac{1}{2}$x12 ins.



BISMARCK, WASHBURN & GREAT FALLS RAILWAY.

Baldwin Locomotive Works, Builders.

ENGINE TRUCK WHEELS.

Diameter, 30 ins. Journals, 6x12 ins.

WHEEL BASE.

Driving, 15 ft. Total engine, 23 ft. 10 ins.
Total engine and tender, 53 ft. 6½ ins.

WEIGHT.

On driving wheels, 163,445 lbs.
On truck, front, 24,650 lbs. Total engine, 188,095 lbs.

TANK.

Capacity, 6,000 gals.

TENDER.

Wheels, diameter, 33 ins. Journals, 5x8½ ins.

B., W. & GT. F. 2-8-2 COMPOUND (ST. PAUL SYSTEM).

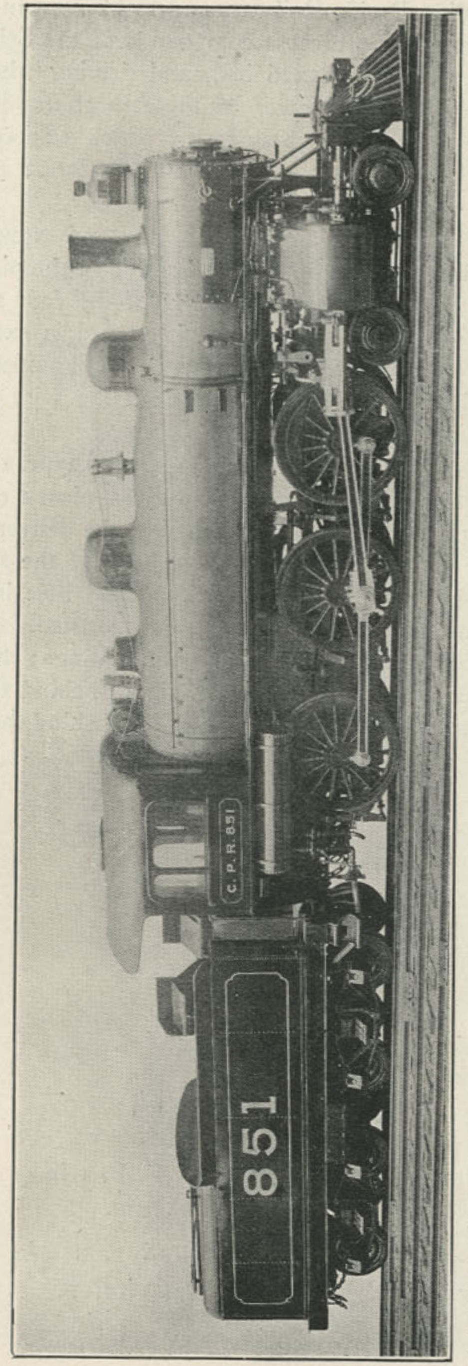
The engine shown on page 575 is a compound, eight-coupled, double-truck locomotive built by the Baldwin Works for the Bismarck, Washburn & Great Falls Railway.

The cylinders are 14 and 26 ins. diameter by 26 ins. stroke. Balanced piston valves are used. The engine has a total weight of 166,910 lbs., of which 128,010 lbs. rest on the driving wheels, 16,900 pounds on the front truck and 22,000 pounds on the back truck. The outside diameter of the driving wheels is 50 ins.; the driving-wheel journals are 8x9 ins. The driving-wheel base is 13 ft. 3 ins., and the total engine-wheel base 26 ft. 11 ins. The boiler is 68¾ ins. diameter at the front course, and carries a working pressure of 200 lbs to the square inch.

This engine has been designed to burn lignite coal, and the fire box is made to burn this kind of fuel to the best advantage. It is 96¼ ins. long and 84 ins. wide. In the front it is 67¼ ins. deep and in the back 64¼ ins. There are 270 2-in. tubes, 16 ft. 6 ins. long. The fire box has 174 sq. ft. of heating surface, and the tubes 2,322 sq. ft., making a total of 2,496 sq. ft. of heating surface. The grate area is 56 sq. ft., which will provide a liberal surface for the combustion of inferior fuel. The tank capacity is 5,000 gallons.

CANADIAN PACIFIC TEN-WHEEL ENGINE.

The illustration of a locomotive on page 577 is one of a number built by the Schenectady shops of the American Locomotive Co.



E. A. Williams, Supt. of Rolling Stock. American Locomotive Co., Builders.

TEN-WHEEL COMPOUND LOCOMOTIVE—CANADIAN PACIFIC RAILWAY.

for the Canadian Pacific Railway, and to be used in passenger service. These engines are cross compounds of the Schenectady type, with cylinders 22 and 35x26 ins., and driving wheels 69 ins. in diameter. The tractive power of these machines is about 25,530 lbs. They weigh 168,000 pounds, of which 124,000 lbs. rests on the drivers. These engines represent the latest practice in the design of heavy 10-wheel power.

The valve motion is indirect; the valve-rod extension bar passes over the leading axle. The valve itself is of the piston type, with outside admission. The cross head is of the four-guide bar type, with wrist pin cast solid, and the piston rod is extended through the front cylinder cover. The springs are all underhung, and the driving-box hangers rest on top of the boxes with broad flat feet, which insure an even bearing.

The boiler is of the extended wagon-top type, the gusset sheet sloping forward to the smoke box, gives plenty of steam room. The injectors are placed one on each side, the delivery pipe entering the boiler on the center line, $18\frac{1}{2}$ ins. back of the front flue sheet. About 24 ins. below each top check a hand hole is placed, which facilitates the removal of sediment which is usually deposited below the checks. The steam dome has no mountings; the safety valves are carried on a separate mounting placed behind the dome. The whistle grows straight out of the boiler just behind the pop valves.

GENERAL DIMENSIONS.

Fuel, bituminous coal.
Weight in working order, 168,000 lbs.
Weight on drivers, 124,000 lbs.
Wheel base, driving, 14 ft. 10 ins.
Wheel base, rigid, 14 ft. 10 ins.
Wheel base, total, 25 ft. 11 ins.

CYLINDERS.

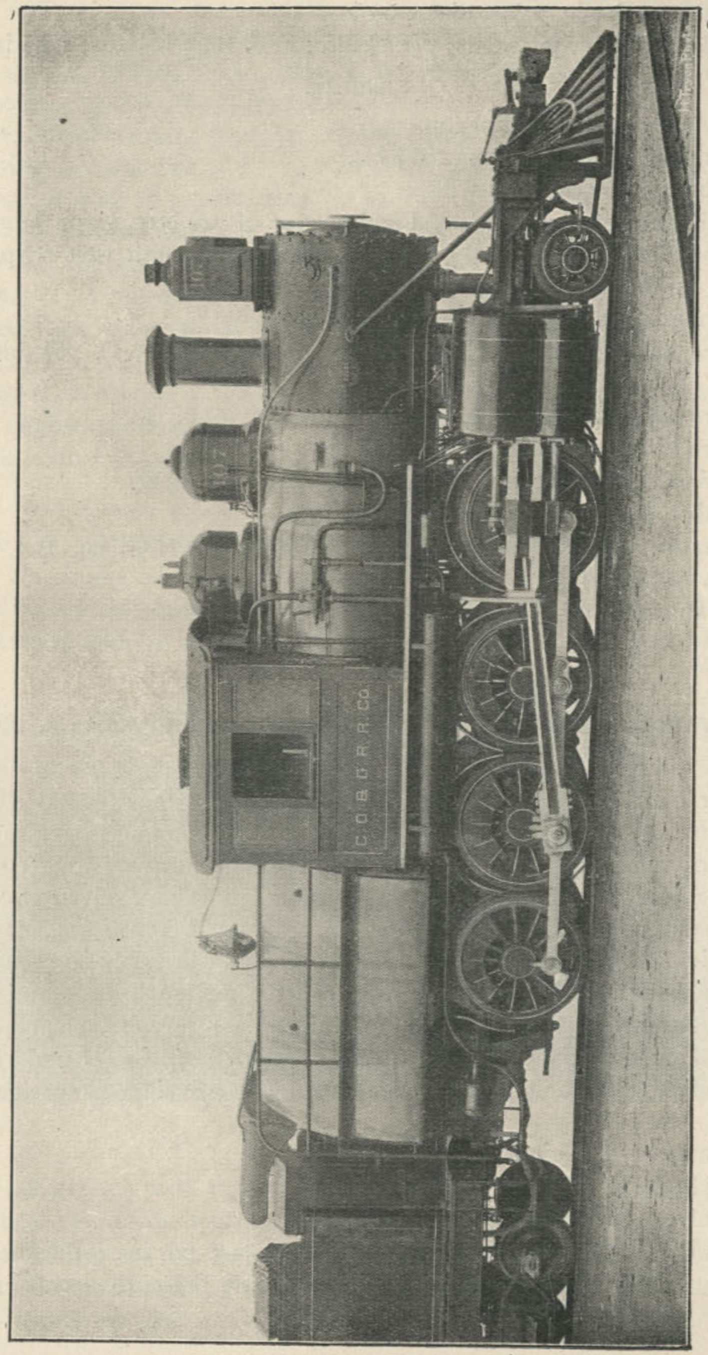
Dia. and stroke of cylinders, 22x35x26 ins.
Dia. of piston rod, $3\frac{3}{4}$ ins.

VALVES.

Slide valves, piston type, 6-in. travel.
Outside lap of valves, H. P. $1\frac{1}{4}$ ins., L. P. 1 in.
Inside lap, clearance, H. P. $\frac{1}{4}$ in., L. P. $\frac{3}{8}$ in.

WHEELS, ETC.

Dia. of driving wheels outside of tire, 69 ins.
Driving journals, 9x12 ins.



Jno. McGie, Supt. Motive Power. CHOCTAW, OKLAHOMA & GULF LOCOMOTIVE. Baldwin Locomotive Works, Builders.

Main crank pin, 7 ins. dia. x 6½ ins.
Side-rod crank pin, main, 7½x4¾ ins.; F. & B., 5 ins. dia. x 4½ ins.

BOILER.

Style, extension wagon top.
Outside dia. of first ring, 62½ ins.
Working pressure, 210 lbs.
Thickness of plates in barrel and outside of fire box, ½ and ⅜ ins.
Horizontal seams, butt joint, sextuple riveted, with welt strips inside and outside.
Circumferential seams, double riveted.
Fire box, length, 108 ins.; width, 41 ins.; depth, F. 76½ ins., B 64½ ins.
Fire box, crown staying, radial, 1⅛ ins. dia.
Fire box, stay bolts, iron, 1 in. dia.
Tubes, 2 ins. dia., No. 11, B. W. G.; 312 in number.
Tubes, length over tube sheets, 14 ft.
Heating surface, 2,273.3 sq. ft.; fire box, 171.96 sq. ft.; total, 2,445.26 sq. ft.
Grate surface, 30.71 sq. ft.

VAUCLAIN COMPOUND FOR THE CHOCTAW, OKLAHOMA & GULF.

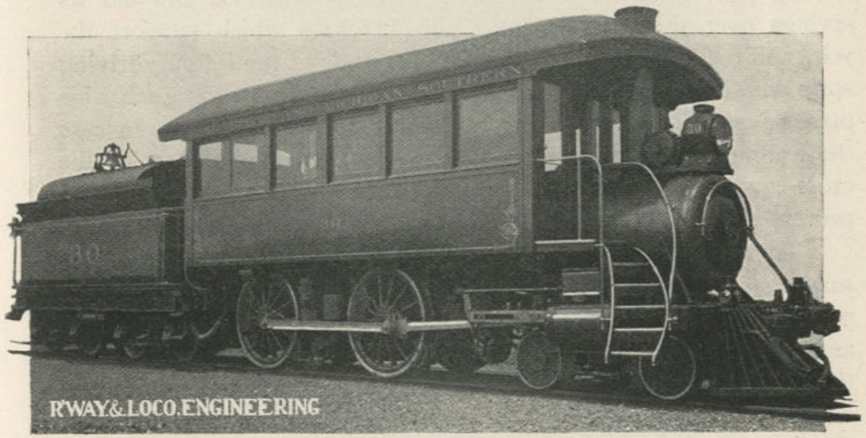
The illustration of the locomotive on page 579 is one of a number built by the Baldwin Locomotive Co. for the Choctaw, Oklahoma & Gulf Railway. The fuel which these engines have to burn is of very inferior quality, and this fact accounts for the Wootten fire box and the centrally placed cab. They have given excellent results in service. The cylinders are 15 and 25x26 ins., and the driving wheels are 56 ins. in diameter. As can easily be seen from the half-tone, the general design of the engine is neat and symmetrical, and the disposition of injectors, reservoirs, etc., appears to be very satisfactory. The tank is carried on a steel underframe and has a capacity of 5,000 gallons. The principal dimensions are as follows:

Gauge, 4 ft. 8½ ins.
Cylinders, 15 and 25x26 ins.
Valve, type, piston.
Boiler, type, Wootten, straight; diameter, 66 ins.; thickness of sheets, $\frac{11}{16}$ in.; staying, radial; working pressure, 200 lbs.; fuel, slack coal.

Fire box, material, steel; length, 105$\frac{1}{16}$ ins.; width, 96 ins.; depth, front, 61¼; back, 48¼; thickness of sheets, sides, ⅜ in.; back, $\frac{5}{16}$ in.; crown, ⅜ in.; tube, ½ in.; water space, front, 4 ins.; sides, 3½ ins.; back, 3½ ins.
Tubes, number, 241; diameter, 2¼ ins.; length, 14 ft. 3½ ins.
Heating surface, fire box, 174.6 sq. ft.; tubes, 2,016.8 sq. ft.; total, 2,191.4 sq. ft.; grate, area, 70 sq. ft.
Driving wheels, diameter outside, 56 ins.; diameter of center, 50 ins.; journals, main, 9x8½ ins.; others, 8x8½ ins.
Engine truck wheels, diameter 29¼ ins.; journals, 5x8 ins.
Wheel base, driving, 15 ft. 0 in.; rigid, 15 ft. 0 in.; total engine, 23 ft. 1 in.; total engine and tender, to turn on 60-ft. table.
Weight, on driving wheels, 142,490 lbs.; on truck, 19,380 lbs.; total engine, 161,870 lbs.
Tank, capacity 5,000 gals.

INSPECTION ENGINE ON THE L. S. & M. S.

The Lake Shore & Michigan Southern Railway are using a very handy inspection engine. We are indebted to Mr. H. F. Ball, superintendent of motive power, for the photograph from which



LAKE SHORE INSPECTION ENGINE.

our illustration was made. The machine consists of an ordinary 8-wheel locomotive which is housed over with a car-like cab. The cylinders are 17x24 ins. and the drivers 62 ins. The weight is about 80,000 lbs., of which 53,000 are on the drivers. The steam pressure is 150 lbs.

HEAVY CONSOLIDATION FOR THE L. S. & M. S.

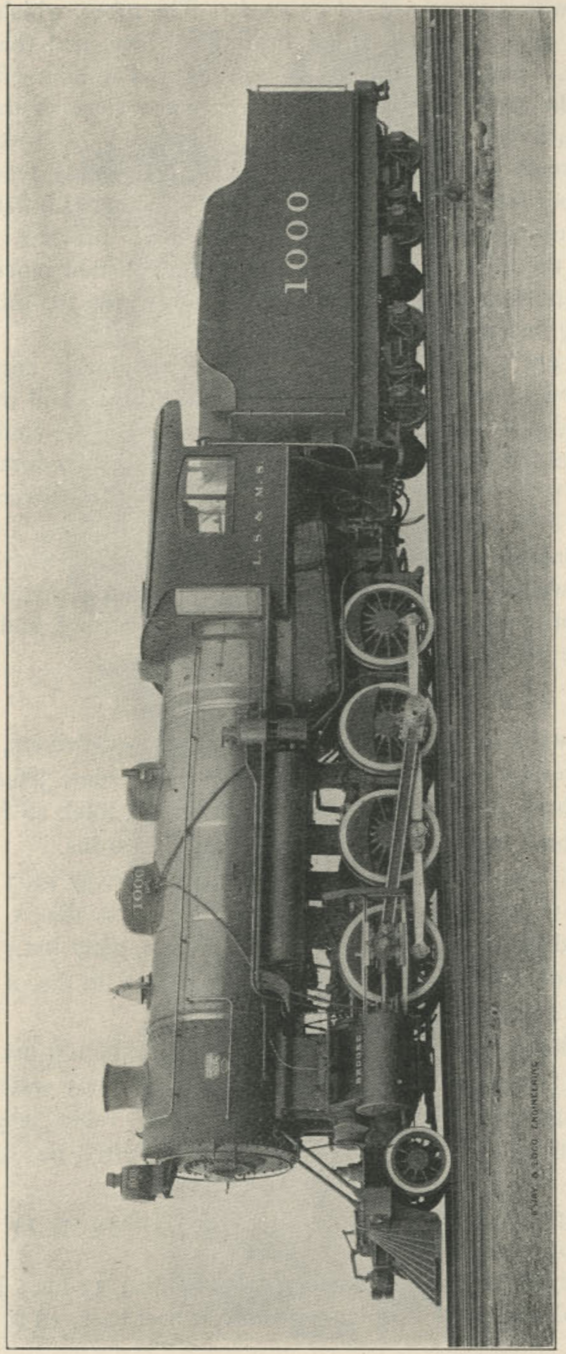
On page 583 we illustrate an example of heavy freight power bought by the Lake Shore & Michigan Southern Railway. It is a consolidation, or 2-8-0 engine, built at the Brooks works of the American Locomotive Company, and it weighs, in working order, 235,400 lbs. This makes engine No. 1000 a good second to the 2-10-2 Vauclain compound belonging to the Santa Fe. That engine weighs about 143 tons, and this Lake Shore engine is a little more than 117 tons.

The cylinders are 23x30 ins., simple, the drivers are 57 ins. in diameter, the steam pressure is 200 lbs., and the calculated tractive effort is 47,300 lbs. The weight on the driving wheels is 207,000 lbs., and the ratio of tractive power to adhesive weight is as 1 is to 4.37. All the wheels are flanged, and the main drivers are the third pair. The valve motion is direct, with almost straight transmission bar passing over the second driving axle. The valve is of the piston type, 12 ins. in diameter, with maximum travel of $5\frac{7}{16}$ ins.

The weight of the engine is carried on springs placed between the frame bars and between the wheels with the exception of the leading pair, which is equalized with the pony truck, and has its springs over the driving box. The brackets which support the yoke and rocker boxes also take the back ends of the leading driving springs. There is a bracket carried on the frame on each side placed just below the cross-equalizer bar for front truck. In case the leading spring becomes weak or if a back hanger breaks, the cross-equalizer bar would then rest upon these brackets, and so prevent the back end of the truck equalizer dropping down.

The smoke-box arrangement is such that more than half the smoke stack is inside. The visible stack is 22 ins. high, while the portion out of sight is $24\frac{1}{2}$ ins. long; it is flared out to about 28 ins. and rests upon the netting. The stack is really a taper stack, but the choke is about 8 ins. below the level of smoke-box top and is 20 ins. in diameter. The top of the stack, which is 24 ins. diameter, stands 15 ft. $2\frac{1}{2}$ ins. from the rail. The dome and sand box are flattened and the cab roof is close to the boiler, so that the whole engine is evidently near what our friends in England would call the loading-gauge limit for bridges and tunnels.

The boiler is of the straight-top type and measures 80 ins. diameter at the smoke-box end. The center of the boiler is 9 ft. 11 ins. from top to rail. The fire box has a heating surface of



H. F. Ball, Supt. Motive Power. HEAVY CONSOLIDATION ENGINE FOR THE LAKE SHORE. American Locomotive Co., Builders.

203 sq. ft. with a grate area of 55 sq. ft. The tubes, which are 460 in number, give 3,725 sq. ft. of heating surface, and the total is 3,957 sq. ft. The water tubes give 29 sq. ft. The blow-off cock is placed in the bottom of the first boiler course close to the smoke box, and just back of the blow-off cock is placed the injector connection through which the boiler is fed. This casting receives the delivery pipes from both injectors and inside the boiler a flat-spreading elbow directs the flow of water toward the fire box. In this way, while the injector is working, there is a constant movement of cooler water along the bottom of the boiler towards the most effective heating surface.

There are several interesting features about this engine; the main reservoirs are carried under the running board and the driver brake cylinder is between the frames and close to the smoke arch. The pedestal binders are steel, made with a lug which comes down far enough to just hold a nut on the wedge-bolt stem between binder and lug. Two check nuts hold the wedge in place, and when these are slacked off the nut between lug and binder when turned, moves the wedge up or down. There are, of course, many Brooks details about the engine. The whole design is pleasing, and, though the machine is heavy, it is not clumsy in appearance.

GENERAL DIMENSIONS.

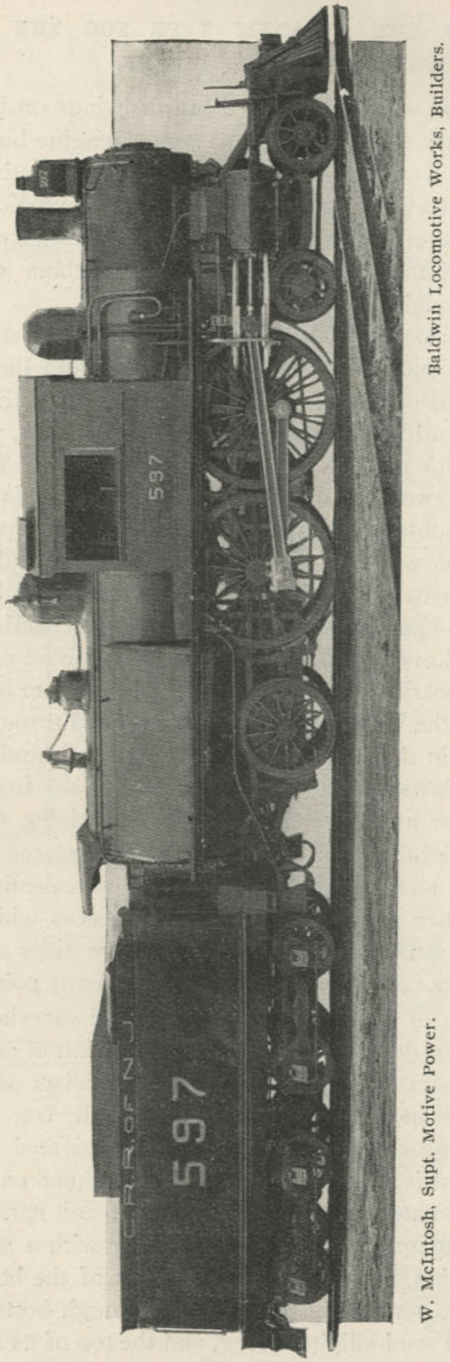
Weight in working order, 235,400 lbs.; weight on drivers, 207,000 lbs.; weight engine and tender in working order, 386,400 lbs.; wheel base, driving, 17 ft. 3 ins.; wheel base, total, 26 ft. 5 ins.; wheel base, total, engine and tender, 57 ft. 10 ins.

Wheels, etc., dia. of driving wheels, outside of tire, 57 ins.; dia. and length of driving journals, 9½ and 10 ins. in dia. x 12 ins.; dia. and length of main crank-pin journals, 7½x7 ins.; dia. and length of side-rod crank-pin journals, 8¼ ins. in dia. x 5½ ins.; dia. of engine truck wheels, 33½ ins.

Boiler, working pressure, 200 lbs.; fire box, length, 109 ins.; width, 74 ins.; depth, front, 83½ ins.; back, 69½ ins.; water space, front, 4½ ins.; sides, 4½ ins.; back, 4½ ins.; tubes, length over tube sheets, 15 ft. 6⅛ ins.; fire brick, supported on four 3-in. tubes.

Heating surface, tubes, 3,725 sq. ft.; water tubes, 29 sq. ft.; fire box, 203 sq. ft.; total, 3,957 sq. ft.

Tender, weight, empty, 56,580 lbs.; wheels, dia., 33 ins.; journals, dia. and length, 5½ ins. dia. x 10 ins.; wheel base, 18 ft. 0 in.



W. McIntosh, Supt. Motive Power. Baldwin Locomotive Works, Builders.

NEW JERSEY CENTRAL—ATLANTIC EXPRESS ENGINES.

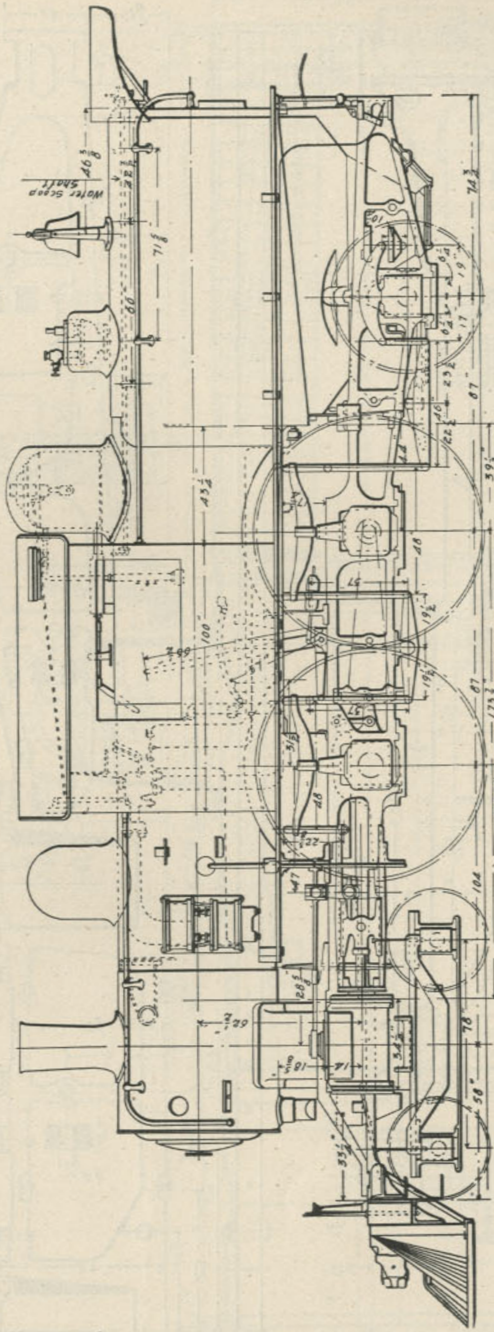
FAST ENGINES OF THE ATLANTIC TYPE FOR THE CENTRAL RAILROAD OF NEW JERSEY.

The illustrations of line cut and detail drawings on pages 585, 587, 588, 589, 590 are those of a fast passenger engine built for the Central Railroad of New Jersey by the Baldwin Locomotive Works, for limited fast service between Atlantic City and New York.

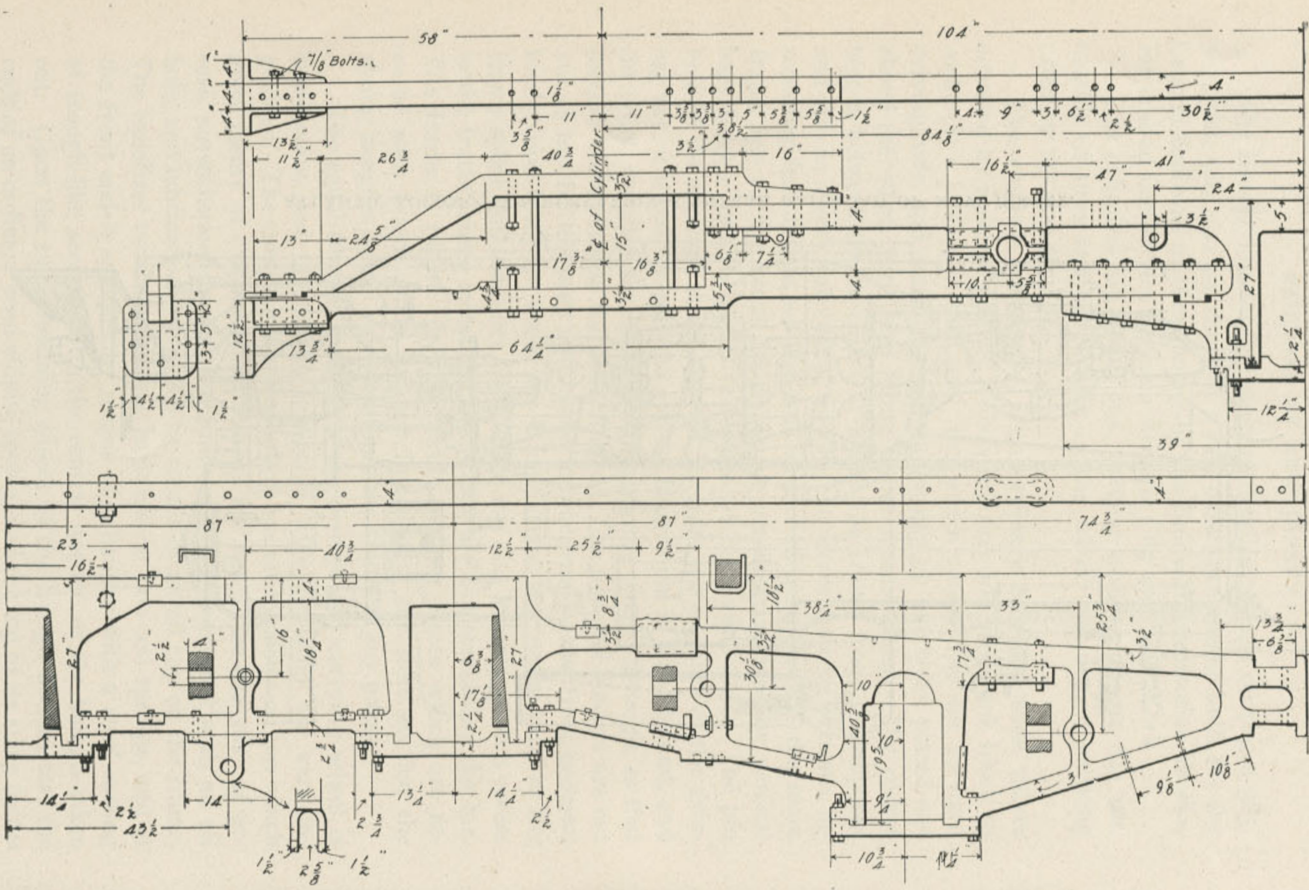
The cylinders are 18x26 ins., driving wheels measure $84\frac{1}{4}$ ins. outside of tires and the weight of the whole machine in working order is 151,000 pounds.

The engines are simple, with ordinary balanced slide valves actuated by indirect motion. The extension rod from link block to rocker is a U-shaped cast steel bar which passes over the forward driving axle, and is stiffened across the gap by two bolts, placed one above the other, with pipe filling pieces around them. The rocker box is between the two bars of which the frame front is composed and acts as a very substantial filler. The frame splicing presents interesting features as will be seen in our illustration, and the main frame has all the usual brake hanger brackets replaced by vertical bars forged solid, being in fact parts of the frame itself. The pin hole in the forward one is bushed, as from the position of the driving tire, it is only possible to get the hanger pin in from behind, and the point, carrying the brake hanger, is cross pinned through, so that motion takes place in the bushed hole. The pedestal binders are cut out $1\frac{3}{4}$ ins. for the jaws and in the forward end of the front pedestal binder two bolts are used, one a long collar bolt doing duty in the frame splice and the other with upper nut and key placed in a recess in the frame where metal can be cut out without weakening the bar. The frame is further provided with rubbing pieces which are secured with $\frac{1}{2}$-inch studs and are lipped over the sides so that the spring hangers cannot rub or cut into the frame at any point.

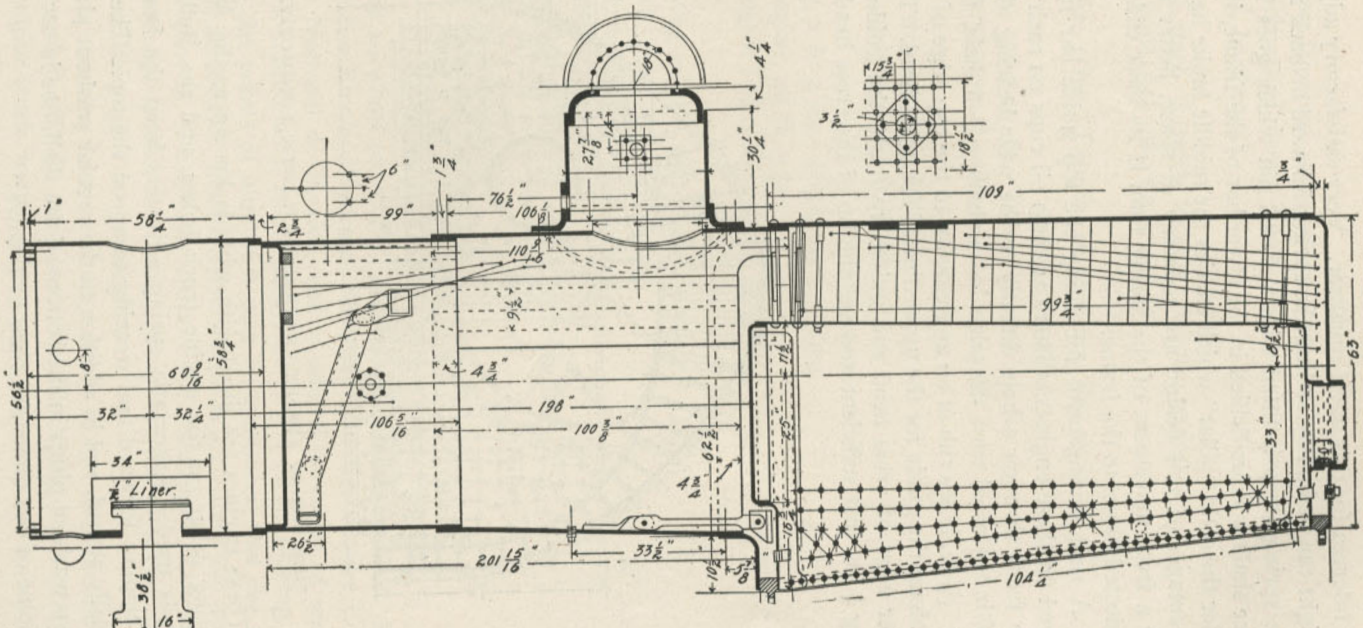
The equalizing of weight on the drivers and carrying wheel is continuous, and the details connected with the latter are very ingenious. The carrying wheel axle box has an equalizer on top which gives plenty of clearance and renders the top of the box easy of access, notwithstanding that the frame above it is pierced with an oil hole, and lubrication is effected by means of an oil cup on the frame. The equalizer terminates at the back end in two coil springs, and at the front end it engages by means of a hanger with a steel casting of trough-like section, with the central portion of the bottom taken out. Upon the two remaining pieces of the trough bottom rest the ends of an ordinary semi-ellipitc spring, and the top of its strap forms



ATLANTIC LOCOMOTIVE ELEVATION—CENTRAL RAILROAD OF NEW JERSEY.



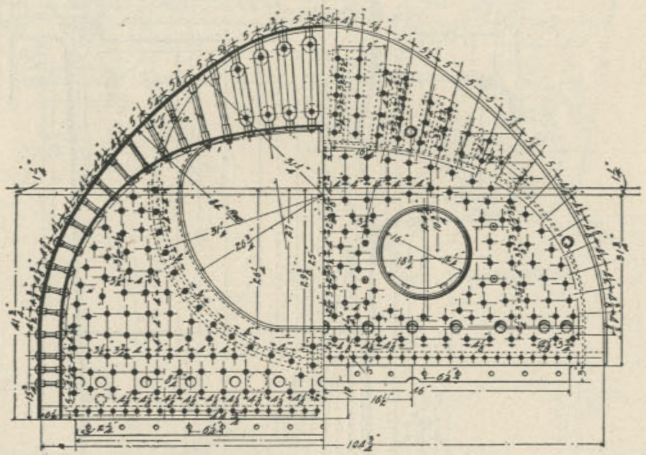
DETAIL OF FRAMES FOR ATLANTIC LOCOMOTIVE—CENTRAL OF NEW JERSEY.



BOILER OF JERSEY CENTRAL'S ATLANTIC LOCOMOTIVE.

the fulcrum for this novel equalizer. Very satisfactory adjustment of weight can be had by sliding the spring forward or back as required. The spring strap is fitted with a dowel pin which goes into one of three shallow holes drilled in the lower bar of the frame, immediately under the solid "pillar" which carries the middle brake hanger. The advantages of this design are economy of space, better adjustment and a freer movement of the spring than if its back ends had been connected direct to the frame.

A neat arrangement for oiling the top guide bar may be observed on these engines. There are two oil cups on each top guide. One feeds through a hole directly to the wide bearing of the cross head in the usual way, the other has a shallow $\frac{3}{8}$-in. hole, from which two $\frac{5}{16}$-in. holes run at an angle down to the top edge of the recess cut along the guide for the upper lips of the cross head. The outside upper edge of cross head and guide are flush, the guide overhang being $\frac{1}{2}$ in., just sufficient to cover the lip of the cross head.



FIRE BOX OF JERSEY CENTRAL'S ATLANTIC LOCOMOTIVE.

These engines are fitted with what is known as the Acme self-adjusting cellar on the engine truck boxes, and the Reflex water gauge is used. Automatic spring adjusters keep the brake shoes from tipping forward and wearing away on the top. The fire box is radially stayed, and in addition to the regular washout plugs there are two washout plugs in the bottom of the shell, one in each course.

Some of the dimensions are as follows:

BOILER.

Type, Wootten, straight top. Diameter, $58\frac{3}{4}$ ins.
Thickness of sheets, $\frac{5}{8}$ in. Pressure, 200 lbs.
Fuel, hard coal.

FIRE BOX.

Material, steel. Length, 109 ins. Width, 97 ins.
Depth, front, $54\frac{1}{2}$ ins.; back, $41\frac{1}{2}$ ins.

TUBES.

233. Dia., 2 ins. Length, 16 ft. 6 ins. No. 12 B. W. G.

HEATING SURFACE.

Fire box, 170.7 sq. ft. Tubes, 2,002.8 sq. ft.
Total, 2,173.5 sq. ft. Grate area, 73 sq. ft.

WHEELS.

Wheels, driving, dia., $84\frac{1}{4}$ ins.
Wheels, trailing, dia., $54\frac{1}{4}$ ins.

WHEEL BASE.

Driving, 7 ft. 3 ins. Rigid, 14 ft. 6 ins.
Total engine, 26 ft. 5 ins.
Total engine and tender, 53 ft. 2 ins.

WEIGHT.

On driving wheels, 84,100 lbs.
On truck, front, 32,300 lbs.
On carrying wheels, 34,600 lbs.
Total engine, 151,000 lbs.
Total engine and tender, about 250,000 lbs.

TANK.

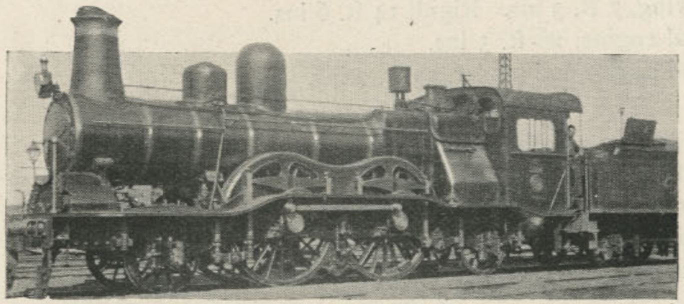
Capacity, 5,000 gallons.

MEXICAN NATIONAL TEN-WHEEL ENGINE.

The 10-wheel passenger engine illustrated on page 593 was built at the Brooks Works of the American Locomotive Company for the Nacional de Mexico, and is one of an order of ten. The engine is simple, with 20x28-in. cylinders and 68-in. driving wheels. Among the points of interest it may be mentioned that the starting power is 28,000 lbs. The adhesive weight is 4.75 times the maximum tractive power. This value insures the maximum draw-bar pull under average conditions of rail, without the use of sand. The total weight of the engine is 172,000 lbs.

Cast steel has been used very freely in the construction of this engine, and it may be mentioned that the lifting-shaft arms, guide yoke, engine-truck frame, center plate and suspension links are of this material. A clever oiling arrangement is to be found in the cast-steel suspension links. Small projections are cast on, just above the eccentric rod-pin holes. These projections are each drilled almost through, transversely, thus forming a $\frac{5}{8}$-in. hole. This cavity is intended to be filled with curled hair, kept in place by a small plug. An oil hole $\frac{1}{4}$ in. in diameter is drilled from the top, through to the eccentric rod pins. These are inclosed in case-hardened steel bushings. The inner faces of the link are also case hardened. The cross head is of the two-guide bar type and is made of cast steel, as are also the driving wheel centers, pistons, driving boxes, motion-rod hangers, and spring saddles.

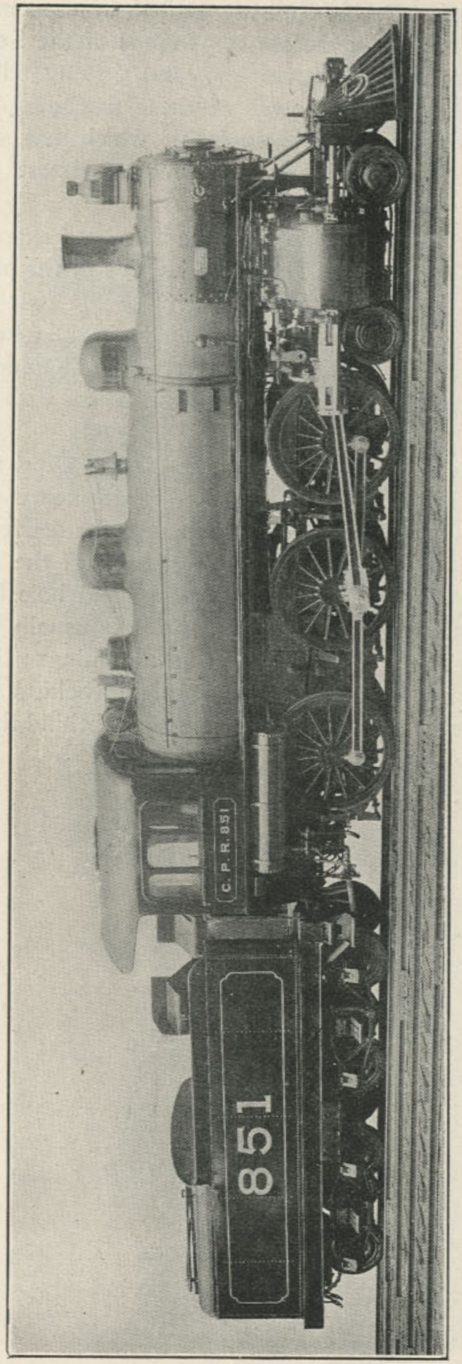
The boiler contains 348 iron tubes, and the total heating surface is 2,753 sq. ft. The staying is radial, and the position of the crown sheet, which is level, insures large steam room. The diameter of the barrel outside the first course is $67\frac{7}{8}$ ins.



OLD BELGIAN ENGINE. WIDE FIRE BOX. PROTOTYPE OF A POPULAR MODERN CLASS.

The appearance of the engine is that of a well-proportioned machine, in which the clear-cut lines of the various mechanical details help to make up a harmonious whole. The headlight has an acetylene gas burner, and the gas generator may be seen as an upright cylinder on the running board just in front of the fireman's cab window. The 7,000-gallon tender, with 12-ton fuel capacity, indicates that this engine has about reached the limit for passenger service in this respect.

A few of the leading dimensions are as follows:
Fuel, bituminous coal. Cylinders, 20x28 ins.
Weight, leading truck, 30,000 lbs.
Weight, driving wheels, 133,000 lbs.
Weight, total, 172,000 lbs.



E. A. Williams, Supt. of Rolling Stock. American Locomotive Co., Builders.

TEN-WHEEL COMPOUND LOCOMOTIVE—CANADIAN PACIFIC RAILWAY.

PASSENGER POWER FOR THE EL PASO & SOUTHWESTERN.

The El Paso & Southwestern purchased four simple engines for passenger service from the Baldwin Locomotive Works, of Philadelphia, shown on page 609. The engines, as will be seen from our illustration, belong to the 4-6-2, or Pacific type, and have cylinders 22x26 ins. and driving wheels 63 ins. in diameter. The adhesive weight is 132.500 lbs., and with 200 lbs. boiler pressure the calculated tractive effort of the engine is about 33,950 lbs. The valves are of the ordinary balanced D-slide type, and the motion is indirect. All the wheels on the engine are flanged, and they and the carrying wheels at the back are all equalized together.

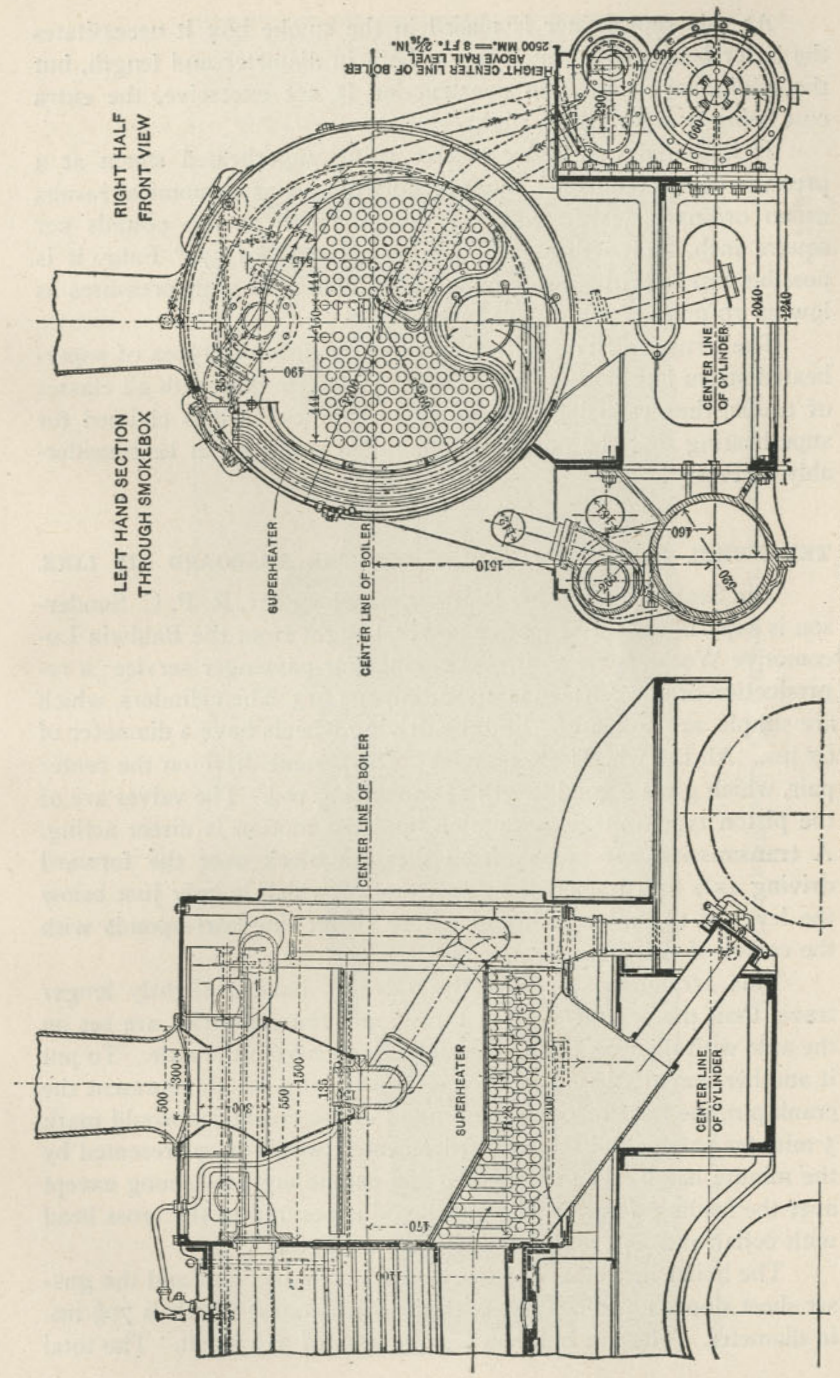
The boiler is of the straight-top type, with wide fire box, and is designed to burn soft coal, with grate area of 52¼ sq. ft. The diameter of the boiler at the smoke-box end is 74 ins. The total heating surface is 3,818.5 sq. ft., of which 3,624 is contributed by the tubes. These are 2¼ ins. in diameter and 19½ ft. long. There is a mud drum placed in the boiler barrel just back of the smoke box, and the injectors are placed one on each side.

The tender is carried on a channel iron frame. The tank with its water bottom will hold 7,000 U. S. gallons.

SCHMIDT STEAM SUPERHEATER.

Varied attempts have been made at different times to establish the use of superheated steam on locomotives, says the *Locomotive Magazine,* from which we reproduce illustrations and description, but hitherto the majority of the efforts have resulted in failure due to the difficulties of construction and trouble of the superheating devices. The Prussian State Railway Administration, however, claims to have secured a more favorable arrangement of apparatus, and has applied it to some 60 or 70 locomotives. The device is known as the Schmidt superheater, and we give a drawing of the apparatus as installed in the smoke box of a locomotive. Applied originally to stationary engines, considerable doubt existed for a time among German locomotive engineers as to the advisability of adopting it on locomotives, but apparently in service it has convinced critics of its economy.

Superheated steam must possess certain advantages, and among them are the increase in the boiler efficiency (25 per cent. is claimed) and the absence of condensation in the cylinders, a serious element of loss on ordinary locomotives.



SCHMIDT STEAM SUPERHEATER.

As this superheater is placed in the smoke box it necessitates the latter being made much larger both in diameter and length, but the additional expense in construction is not excessive, the extra cost being comparatively slight.

It is stated that a locomotive using superheated steam at a pressure of 85 pounds per square inch will give as economical results as an ordinary "saturated" steam engine will at 170 pounds per square inch, and with steam at a temperature of 572° Fahr. it is possible to run without any cylinder condensation with pressures as low as 70 pounds per square inch.

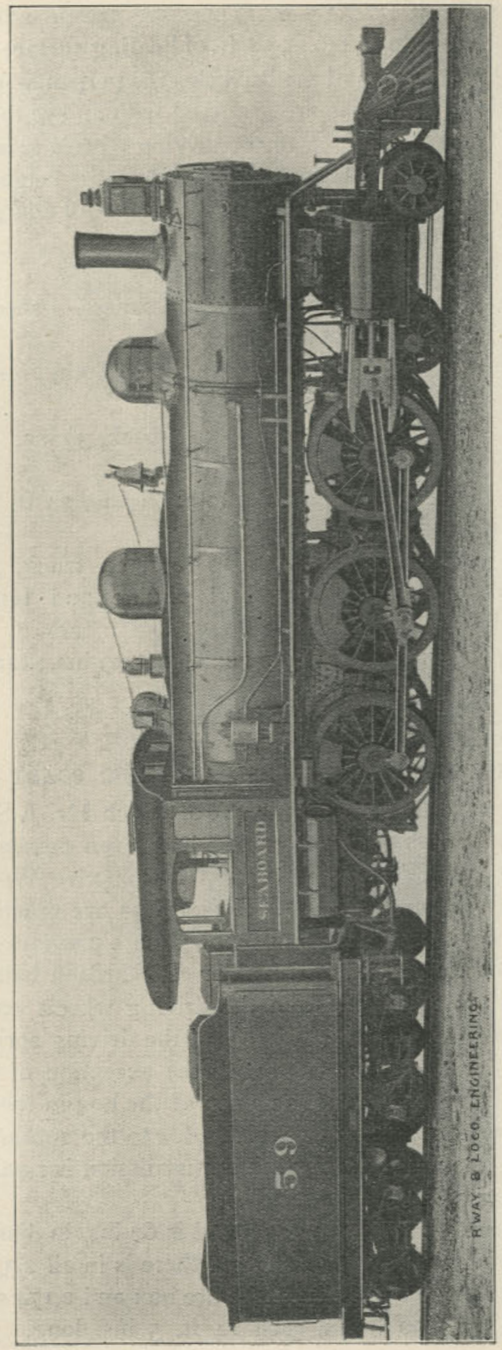
The Prussian State railways have four different types of superheated steam locomotives, which are intended to deal with all classes of traffic, thus reducing the variety in engines, as it is claimed for superheating that the power of individual engines can be considerably increased.

TEN-WHEEL PASSENGER ENGINE FOR THE SEABOARD AIR LINE.

The Seaboard Air Line Railway, of which Mr. R. P. C. Sanderson is superintendent of motive power, bought from the Baldwin Locomotive Works some ten-wheel engines for passenger service; a reproduction of one of them is given on page 613. The cylinders, which are simple, are 20x28 ins., and the driving wheels have a diameter of 67 ins. All the wheels are flanged. The pistons drive on the center pair, which gives a good length of connecting rod. The valves are of the piston type, outside admission, and the motion is direct acting. A transmission bar passes from the link block over the forward driving axle to a rocker, the upper end of which is only just below the level of the valve rod, and whose center line corresponds with the center of the valve-stem rocker.

This arrangement causes the valve to have a slightly longer travel than the eccentrics have throw, and the eccentrics are set on the axle with their centers on the side, remote from the axle. To put it another way, if the figure IX on the dial of a watch represent the crank pin, the lines through the centers of the eccentrics would mark 5 minutes past 5, and the forward eccentric would be represented by the minute hand. The springs of this engine are underhung except over the leading driver. The piston rod is secured to the cross head with collar and nut, and the side rods are fluted.

The boiler measures $63\frac{1}{4}$ ins. at the smoke-box end and the gusset sheet slopes up to connect with the third course which is $70\frac{5}{8}$ ins. in diameter. The fire box has a grate area of $31\frac{1}{2}$ sq. ft. The total



TEN-WHEEL PASSENGER ENGINE FOR THE SEABOARD AIR LINE.

R. P. C. Sanderson, Supt. Motive Power. Baldwin Locomotive Works, Builders.

heating surface is 2,613.87 sq. ft. There are 332 tubes 14 ft. $1\frac{7}{8}$ ins. long, and these contain 2,446.35 sq. ft. of heating surface. The crown and roof sheets are level and the back sheet is perpendicular.

The windows in the cab are arranged with an eye to the comfort of the men. The even spacing of the driving wheels gives the engine a symmetrical and solid appearance, which effect is heightened by the long, unbroken line of running board. A few of the principal dimensions are as follows:

Cylinder, 20x28 ins.; valve, balanced piston.

Boiler—Type, wagon top; dia. $63\frac{1}{4}$ ins.; thickness of sheets, $\frac{5}{8}$ and $\frac{11}{16}$ ins.; working press., 200 lbs.

Fire box—Length, 108 ins.; width, 42 ins.; depth, front, $75\frac{1}{4}$ ins.; depth, back, $63\frac{1}{4}$ ins.

Water space—Front, 4 ins.; sides, $3\frac{1}{2}$ ins.; back, $3\frac{1}{2}$ ins.

Driving wheels, dia. of outside, 67 ins.

Wheel base—Driving, 13 ft. 6 ins.; total engine, 24 ft. 4 ins.; total engine and tender, 51 ft. 6 ins.

Weight—On driving wheels, 132,610 lbs.; on truck, 32,480 lbs.; total engine, 165,090 lbs.; total engine and tender, about 265,000 lbs.

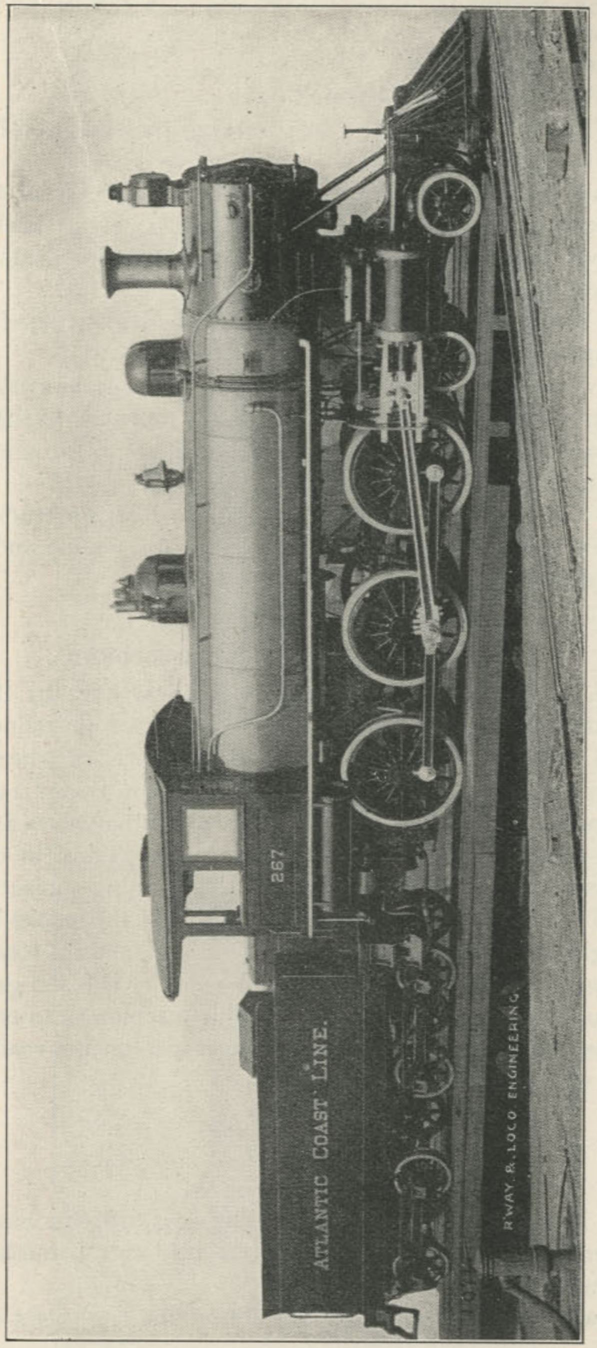
Tender—Wheels, dia., 33 ins.; journals, 5 ft.x9 ins.; tank capacity, 5,000 gals.

PASSENGER POWER FOR THE ATLANTIC COAST LINE.

The Atlantic Coast Line Railroad, of which Mr. J. S. Chambers is superintendent of motive power, has had seven passenger engines of the 4-6-0 type built at the Baldwin Locomotive Works, one of which is illustrated on page 615. The engines are practically duplicates of some engines which were supplied on a previous order.

The engines are simple, with Allen-Richardson balance valves. The cylinders ars 19x26 ins. and the driving wheels are 68 ins. in diameter. All the wheels are flanged and the driving springs are between and under the frame bars with the exception of the leading drivers which have their springs on top of the box in the usual way. The drivers are equally spaced, which adds to the appearance of the machine. The motion is indirect, the transmission bar passing below the first driving axle to a rocker arm.

The boiler is a straight-top one, and is 62 ins. in diameter at the front. The grate area is 28 sq. ft., and there is in all 2,336 sq. ft. of heating surface made up of 162 in the fire box and 2,174 sq. ft. in the tubes. There are 290 tubes, each 14 ft. 5 ins. long. The crown



J. S. Chambers, Supt. Motive Power. Baldwin Locomotive Works, Builders.

BALDWIN SIMPLE TEN-WHEEL ENGINE FOR THE ATLANTIC COAST LINE.

sheet slopes slightly down toward the back. A few of the principal dimensions are as follows:

Cylinders—19x26 ins.

Valve—Allen-Richardson, balance.

Boiler—Thickness of sheets, $\frac{5}{8}$ in.; working pressure, 200 lbs.; fuel soft coal; staying, radial.

Fire box—Length, 96$\frac{3}{8}$ ins.; width, 42 ins.; depth, front 69$\frac{3}{4}$ ins.; back, 67$\frac{1}{4}$ ins.; thickness of sheets, sides, $\frac{3}{8}$ in.; back, $\frac{3}{8}$ in.; crown, $\frac{1}{2}$ in.; tube, $\frac{1}{2}$ in.; water space, front, 4 ins.; sides, 3 ins.; back 3 ins.

Heating surface—Fire box, 162 sq. ft.; tubes, 2,174 sq. ft.; total, 21,336 sq. ft.; grate area, 28 sq. ft.

Driving wheels—Diameter outside, 68 ins.; journals, 8$\frac{1}{2}$x10$\frac{1}{2}$ ins.

Engine truck wheels—Diameter, 30$\frac{5}{8}$ ins.; journals, 5x10$\frac{1}{2}$ ins.

Wheel base—Driving, 13 ft. 6 ins.; total engine, 24 ft. 4 ins.; total engine and tender, 51 ft. 6 ins.

Weight—On driving wheels, about, 106,000 lbs.; on truck, about, 39,000 lbs.; total engine, 145,000 lbs.; total engine and tender, about 245,000 lbs.

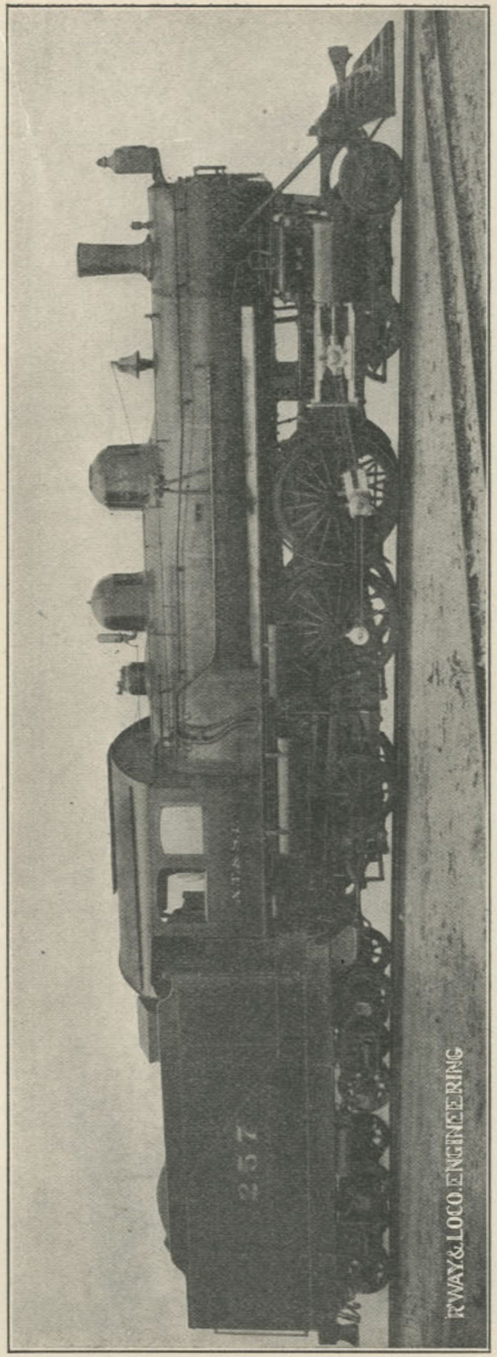
FOUR-CYLINDER BALANCED COMPOUND.

The engine we illustrate on page 617 was built by the Baldwin Locomotive Works for the Santa Fe. It is a four-cylinder compound in which the four pistons drive on the forward wheels which are mounted on a cranked axle. The cylinders are 15 and 25x26 ins., the low-pressure ones being on the outside and the valves are of the balanced-piston type. The driving wheels are 73 ins. in diameter. The pressure carried is 220 lbs. and the total heating surface is 3,083 sq. ft. The boiler measures 66 ins. diameter at the smoke-box end. The weight carried on the drivers is 101,420 lbs., and the total weight of the machine is 193,760 lbs. The tank capacity is 8,400 gals. The cranks and crank pins are so placed in this machine as to practically form a self-balanced engine. Her performance on the road will be watched with considerable interest.

ILLINOIS CENTRAL.

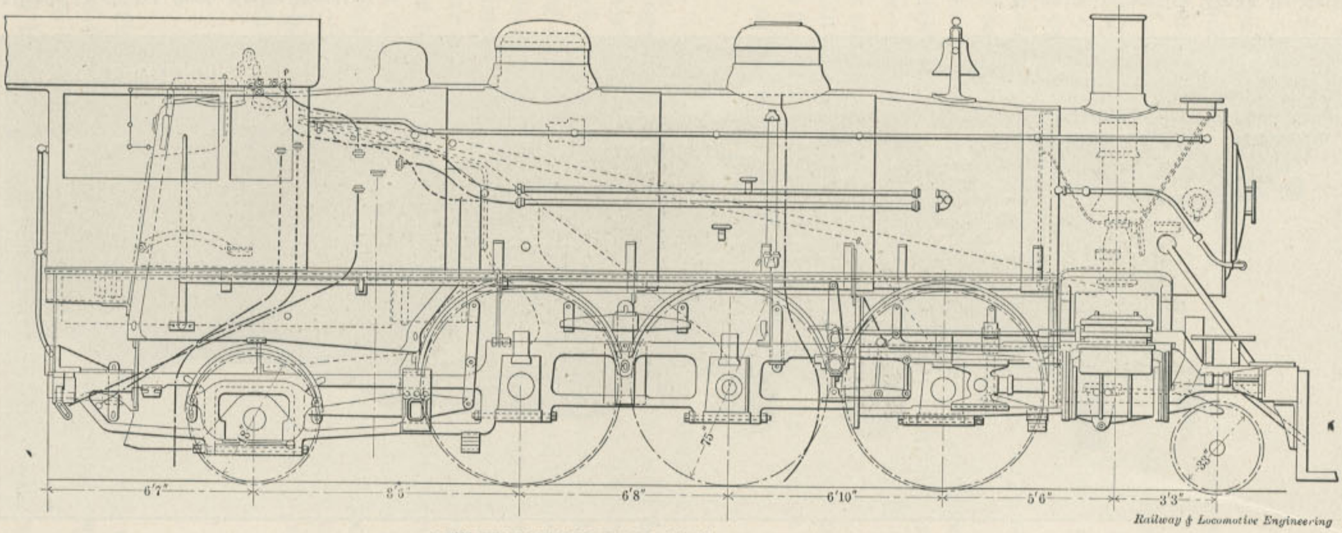
The Prairie type of engine shown on pages 618, 619 was built by the Rogers Locomotive Works for the Illinois Central, and has 75-in. drivers, with cylinders 20x28 ins.

As will be seen, both injectors are on the engineer's side and

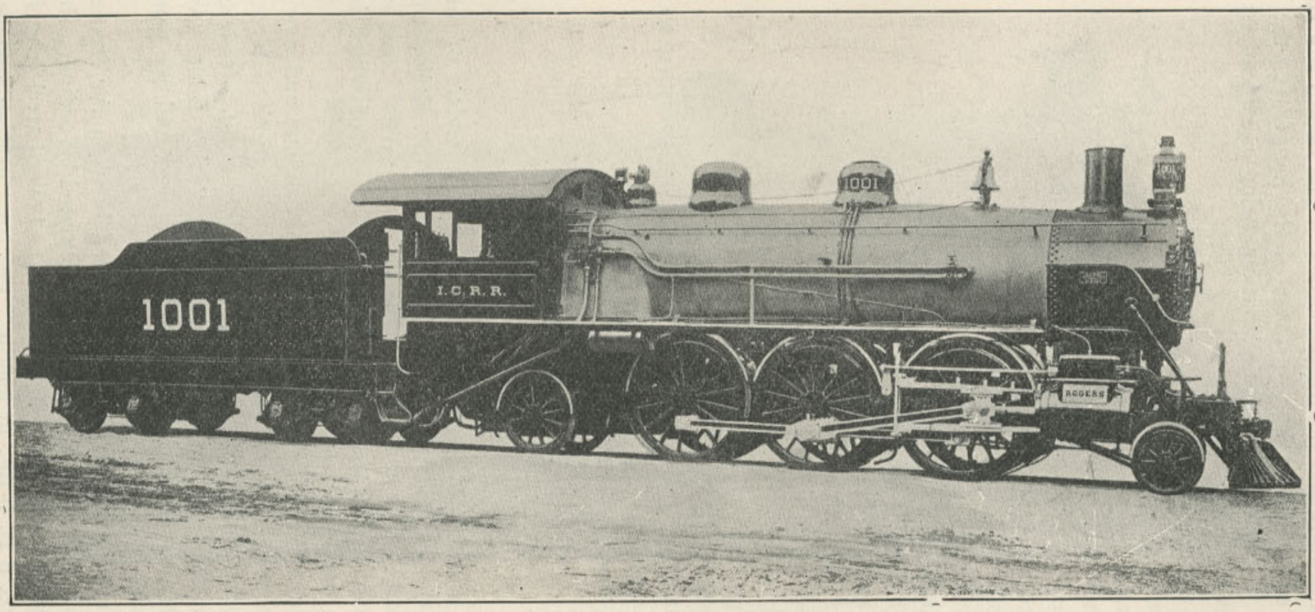


Alfred Lovell, Act. Supt. Motive Power. Baldwin Locomotive Works, Builders.

BALDWIN FOUR-CYLINDER BALANCED COMPOUND.



DETAILS OF ILLINOIS CENTRAL PRAIRIE TYPE.



W. Renshaw, Supt. Motive Power. Rogers Locomotive Co., Builders.

ROGERS PRAIRIE LOCOMOTIVE FOR ILLINOIS CENTRAL.

the sanding device is double pneumatic. The details are shown in the line engraving as well as those of the hangers of the trailing wheels. These need little explanation, being modifications of the regular swing truck.

The main dimensions are given below:

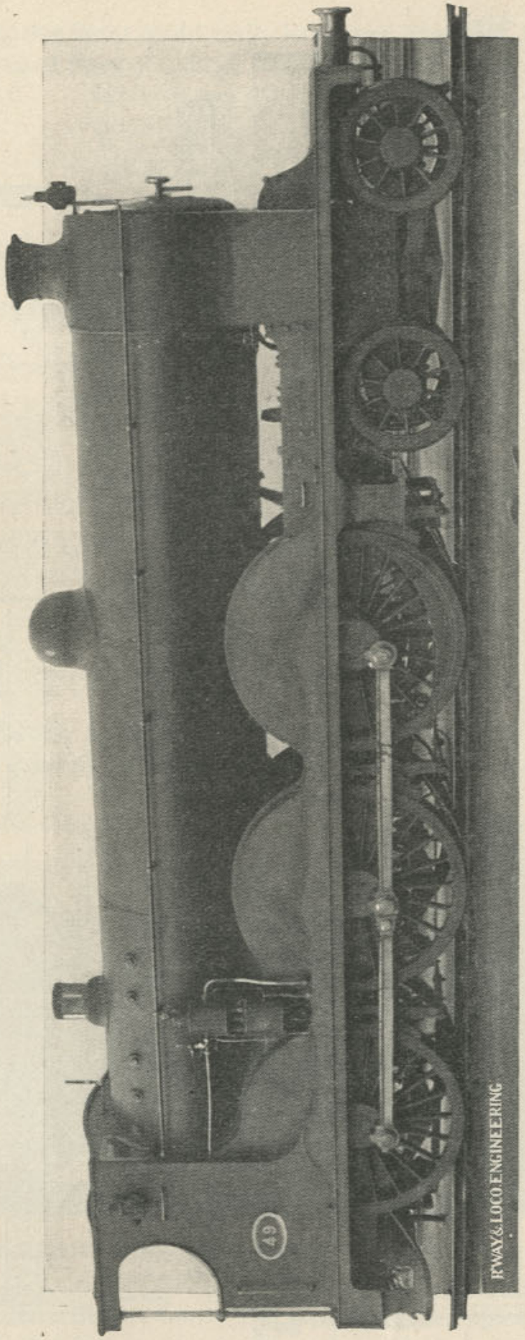
Fuel, bituminous coal.
Driving-axle journals, $9\frac{1}{2}$x$12\frac{1}{2}$ ins.
Driving-wheel base, 13 ft. 6 ins.
Total wheel base of engine, 30 ft. 9 ins.
Weight on drivers, 130,000 lbs.
Weight on truck, 21,500 lbs.
Weight on trailers, 23,500 lbs.
Total weight, 175,000 lbs.
Heating surface, tubes, 3,333.25 sq. ft.
Heating surface, fire box, 201.26 sq. ft.
Heating surface, total, 3,534.51 sq. ft.
Grate area, 51.08 sq. ft.
Tubes, diameter, 2 ins.; length, 19 ft. 0 in.
Tubes, number, 335.
Grate, length, 102 ins.; width, 72 ins.
Boiler, diameter, outside front, 68 ins.; working pressure, 200 lbs.
Tender capacity, 15 tons coal; 7,000 gals.
Tender wheels, diameter, 38 ins.

M'INTOSH'S TEN-WHEELERS.

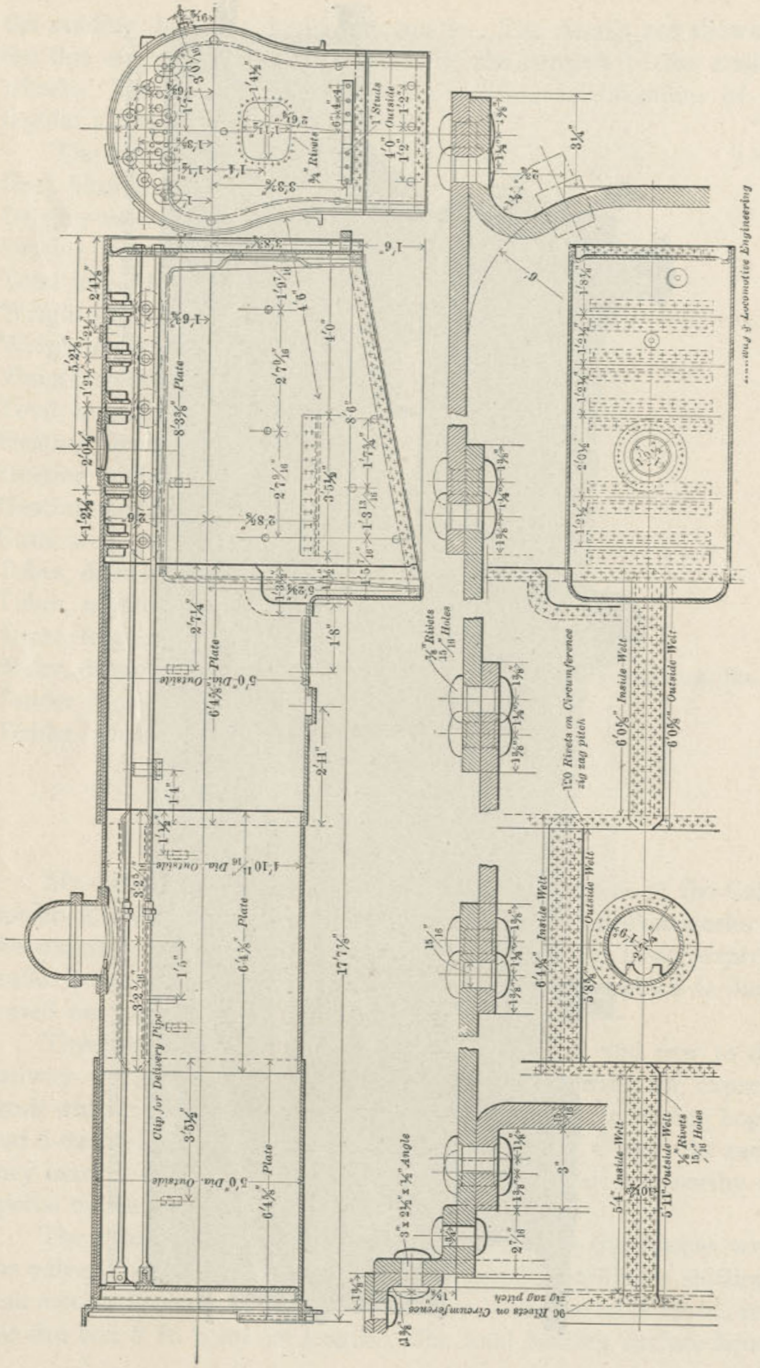
Mr. John McIntosh, the locomotive superintendent of the Caledonian Railway, designed and completed at the St. Rollox works of the company two locomotives intended for the West Coast express traffic between Carlisle, Glasgow and Perth, one of which is illustrated on pages 621, 622, 623.

These engines are of a type absolutely unique and new to the railway world, being the first 10-wheeled locomotives for express work which combine inside cylinders, inside framing, a leading bogie and 6-coupled wheels of so large a diameter as 6 ft. 6 ins. As such, they mark a step or epoch in locomotive design, and are worthy of special notice.

The cylinders, 21x26 ins., are placed between the frames with the valves (ordinary slide) above and actuated by ordinary shifting-link motion through a rocking shaft. The boiler barrel is 17 ft., and the fire box 8 ft. 6 ins. in length. The total heating surface being

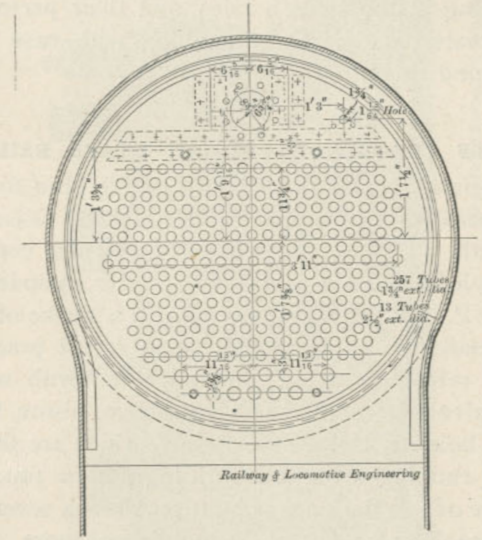


John F. McIntosh, Locomotive Superintendent. CALEDONIAN TEN-WHEELER. Caledonian Railway Company, Builders.



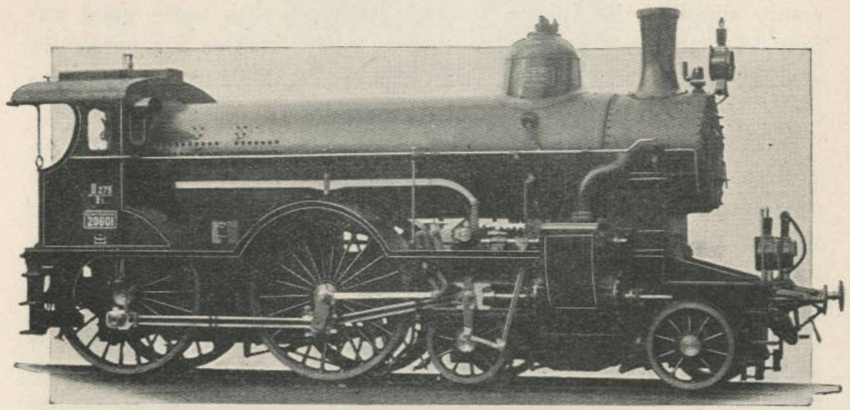
BOILER OF McINTOSH TEN-WHEEL EXPRESS ENGINES.

2,400 sq. ft., this latter could easily have been exceeded, but Mr. McIntosh has used flües of a large diameter for the lower rows, where



TRANSVERSE SECTION OF McINTOSH BOILER.

there is a liability of choking. The working pressure is 200 lbs. per sq. in., and 4 spring safety valves are provided, inclosed in the circu-



GOLSDORF COMPOUND—AUSTRIAN STATE RAILWAYS.

lar casing above the fire box. The weight of the engine in working order is 165,800 lbs., or greater than that of the average British goods engine and tender combined. The tender, which runs on two four-wheeled trucks, carries 6 tons (2,240 lbs. per ton) of coal and 5,000 imp. gallons of water. At present these are the largest locomotives working in the British Isles, and their performances are giving the greatest satisfaction, handling with ease the heaviest trains put behind them.

GOLSDORF COMPOUND—AUSTRIAN STATE RAILWAYS.

The Austrian State Railways have recently been supplied with a new class of passenger locomotive of Herr R. von Golsdorf's design, shown herewith. These engines are two-cylinder compounds and have four coupled drivers 2.14 meters diameter, cylinders H. P. 0.50 meters and L. P. 0.76 meters diameter, with a stroke of 0.68 meters. In general details the engines conform to recent practice of Herr Golsdorf and reference to the illustration herewith will show the Walschaert valve gear with the valves above, piston tail rods, extended smoke box, etc., etc. These engines, which are shown on page 623, weigh in running order 54,000 kilograms = 120,000 lbs.

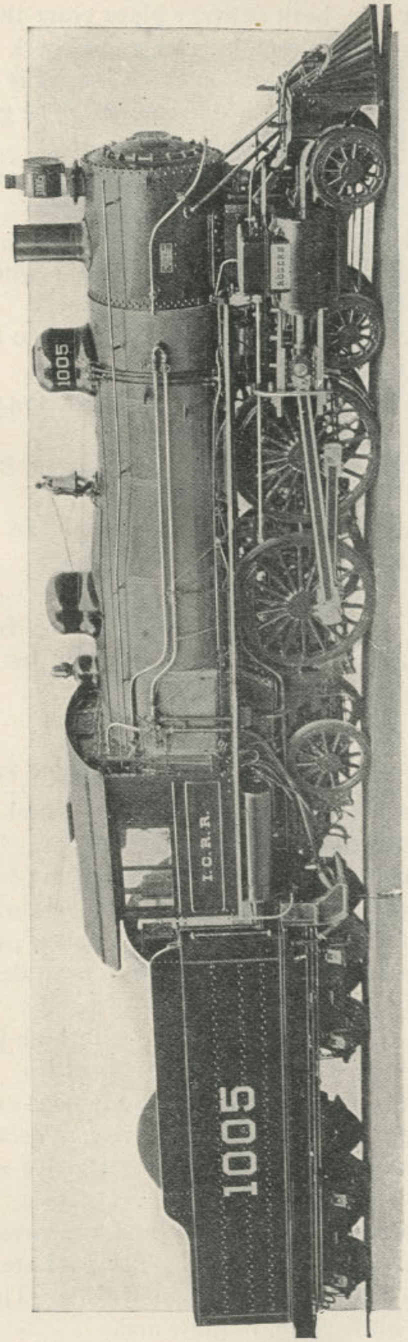
An engine of this design was built at Altoona several years ago. Its performance did not warrant the building of more.

FAST PASSENGER ENGINE FOR THE ILLINOIS CENTRAL.

The Rogers Locomotive Company, of Paterson, N. J., have recently supplied the Illinois Central Railroad with some good examples of the now popular 4-4-2 type of locomotive for passenger service, one of them being shown on page 625, built to suit the ideas of W. Renshaw, Superintendent of Machinery.

The cylinders are 20x28 ins. and the driving wheels are 79 ins. in diameter. The engine is simple, with ordinary slide valves, actuated by indirect motion. The rocker arm is between the driving wheels, and as the eccentric rods pass beyond the rocker the transmission bar works back from link to rocker. The crosshead is of the alligator type with top guide recessed so that outer edge of bar and guide are flush. The weight of the engine in working order is 188,000 lbs., of which 102,000 lbs. rest on the drivers. The engine truck carries 45,000 lbs., while the wheels at the rear bear 41,000 lbs.

The boiler is of the extended wagon-top type and measures 66 ins. at the smoke-box ring. The pressure carried is 200 lbs., and flexible or expansion stays are used in the critical rows in fire-box side sheets and in throat sheet. Water is supplied by two injectors



Rogers' Locomotive Works, Builders.

ATLANTIC ENGINE FOR ILLINOIS CENTRAL.

W. Renshaw, Supt. Motive Power.

The Vanderbilt tank contains 7,000 gallons of water and is provided with a running board on each side at the back end for the use of the fireman when taking water. The total weight of engine and tender in working order is 319,210 lbs. A few of the principal dimensions are as follows:

Cylinders, $15\frac{1}{2}$ and 26x28 ins. Valve balance piston.

Boiler, diameter, 66 ins.; thickness of sheets, $\frac{5}{16}$x$\frac{3}{4}$ in.; working pressure, 200 lbs.; staying radial.

Fire box, length, $101\frac{15}{16}$ ins.; width, $66\frac{1}{4}$ ins.; depth, front, $71\frac{1}{4}$ ins. back $58\frac{1}{2}$ ins.; thickness of sheets, sides, $\frac{3}{8}$ in.; back, $\frac{5}{16}$ in.; crown, $\frac{3}{8}$ in.; tube, $\frac{1}{2}$ in.; water space, front, 4 ins.; sides, 4 ins.; back, 4 ins.

Tubes, number 350; diameter, 2 ins.; length, 15 ft. 6 ins.

Heating surface, fire box, 168.2 sq. ft.; tubes, 2,825; total, 2,993.2 sq. ft.; grate area, 47.5 sq. ft.

Driving wheels, diameter outside, 62 ins.; journals, main, 9x12 ins.; others, 9x12 ins.

Engine truck wheels, diameter, 30 ins.; journals, $6\frac{1}{2}$x11 ins.; wheel base, driving, 14 ft. 6 ins.; total engine, 26 ft. 9 ins.

Weight, on driving wheels, 140,070 lbs.; on truck, 45,140 lbs.; total engine, 185,210 lbs.; total engine and tender, 319,210 lbs.

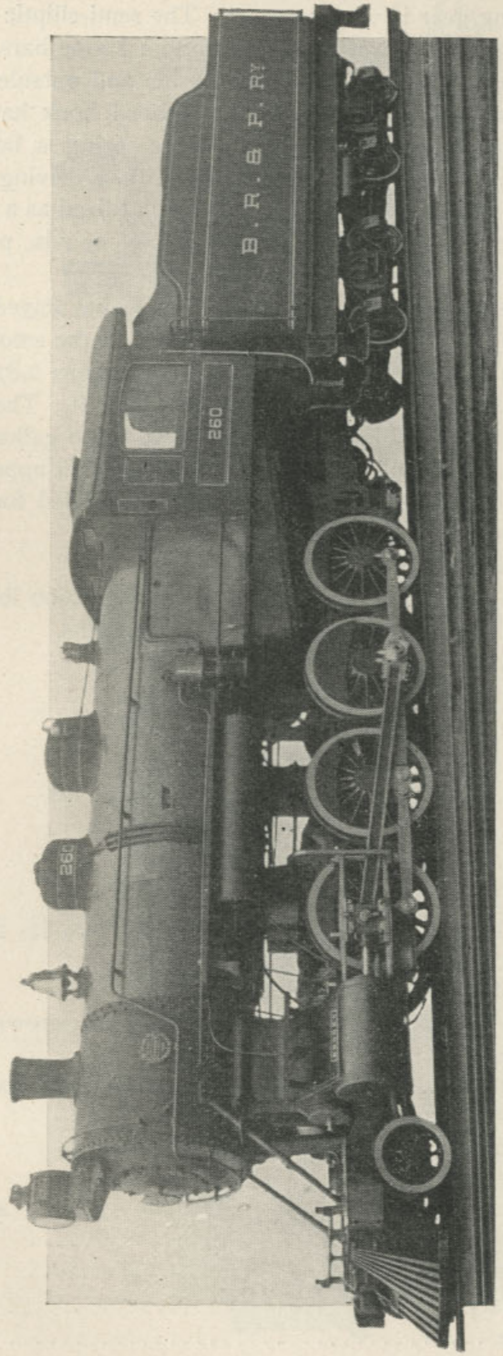
Tank, capacity, 7,000 gallons.

Tender, journals, $5\frac{1}{2}$x10 ins.

CONSOLIDATION FOR THE B., R. & P. RAILWAY.

A very good example of heavy freight power in the shape of a consolidation engine is shown on page 629. It was built at the Brooks shops of the American Locomotive Company for the Buffalo, Rochester & Pittsburgh Railway, and embraces the ideas of C. E. Turner, superintendent of motive power. The engines are simple, with 21x28 in. cylinders. The diameter of the driving wheels is 57 ins. and the adhesive weight is 164,600 lbs. With a steam pressure of 210 lbs. the calculated tractive force of this engine is about 38,500 lbs.

The valves are of the piston type and the old familiar square steam chest is replaced by the sloping of the valve chamber, on the outside of which a step has been placed for the convenience of those who may have to get from front foot plate to running board. The pistons drive on the third wheel, while the eccentrics are placed on the second axle, and a short and nearly straight transmission bar passing over the forward axle gives direct connection gear.



C. E. Turner, Supt. Motive Power. SIMPLE 2-8-0 ENGINE FOR THE B., R. & P. RY. American Locomotive Company, Builders.

The Vanderbilt tank contains 7,000 gallons of water and is provided with a running board on each side at the back end for the use of the fireman when taking water. The total weight of engine and tender in working order is 319,210 lbs. A few of the principal dimensions are as follows:

Cylinders, $15\frac{1}{2}$ and 26x28 ins. Valve balance piston.

Boiler, diameter, 66 ins.; thickness of sheets, $\frac{5}{16}$x$\frac{3}{4}$ in.; working pressure, 200 lbs.; staying radial.

Fire box, length, $101\frac{15}{16}$ ins.; width, $66\frac{1}{4}$ ins.; depth, front, $71\frac{1}{4}$ ins. back $58\frac{1}{2}$ ins.; thickness of sheets, sides, $\frac{3}{8}$ in.; back, $\frac{5}{16}$ in.; crown, $\frac{3}{8}$ in.; tube, $\frac{1}{2}$ in.; water space, front, 4 ins.; sides, 4 ins.; back, 4 ins.

Tubes, number 350; diameter, 2 ins.; length, 15 ft. 6 ins.

Heating surface, fire box, 168.2 sq. ft.; tubes, 2,825; total, 2,993.2 sq. ft.; grate area, 47.5 sq. ft.

Driving wheels, diameter outside, 62 ins.; journals, main, 9x12 ins.; others, 9x12 ins.

Engine truck wheels, diameter, 30 ins.; journals, $6\frac{1}{2}$x11 ins.; wheel base, driving, 14 ft. 6 ins.; total engine, 26 ft. 9 ins.

Weight, on driving wheels, 140,070 lbs.; on truck, 45,140 lbs.; total engine, 185,210 lbs.; total engine and tender, 319,210 lbs.

Tank, capacity, 7,000 gallons.

Tender, journals, $5\frac{1}{2}$x10 ins.

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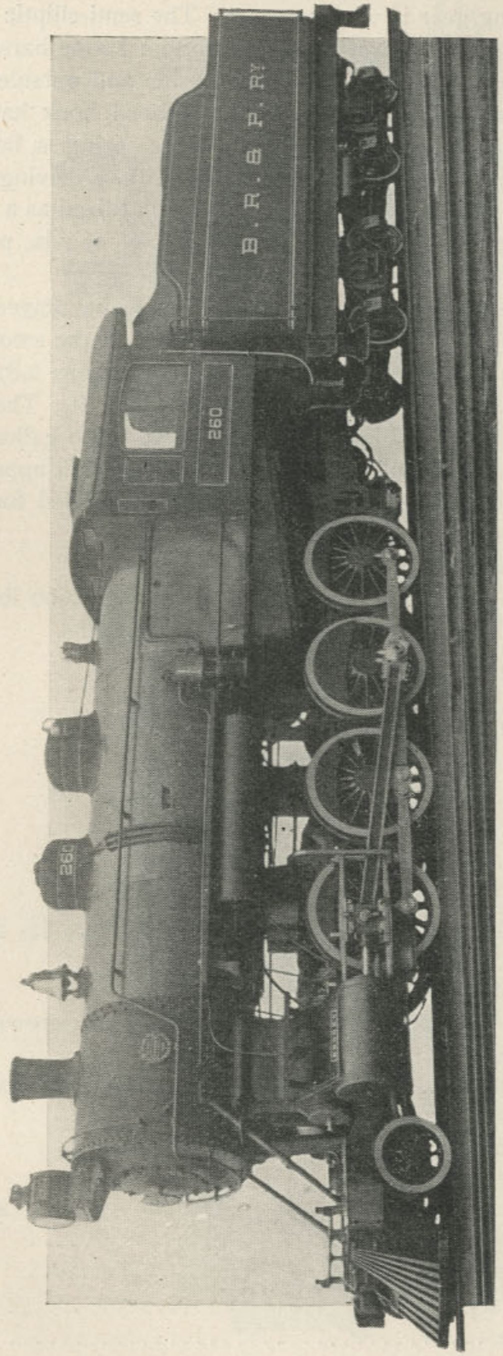


C. E. Turner, Supt. Motive Power. SIMPLE 2-8-0 ENGINE FOR THE B., R. & P. RY. American Locomotive Company, Builders.

The spring gear is very compact. The semi-elliptic springs are placed in the space between top and bottom frame bars. Two flat equalizer bars rest on each axle box, inside and outside the frame, their ends terminating in the Brooks webbed hook hanger which carry the spring ends. The forward driving spring is, however, carried above this frame in the usual way. All the driving wheels are flanged. The tumbling-shaft casting is also utilized as a bracket for the spectacle plate, and the reach rod is a piece of 2-in. pipe screwed into pin-connection castings at each end.

The boiler is of the wide fire-box type, radial stayed and measures 77 ins. in the waist and tapers to 70 ins. at the smoke-box end. There is ample steam space and the boiler contains 2,877 sq. ft. of heating surface. The grate area is about 54 sq. ft. The tender has a coal capacity of 12 tons and the tank holds 6,000 gallons of water. Altogether the machine presents a neat and clear-cut appearance.

A few of the principal dimensions are appended for reference:
Weight in working order, 184,600 lbs.
Weight on drivers, 164,600 lbs.
Weight engine and tender in work'g order, 308,600 lbs.
Wheel base, driving, 15 ft. 9 ins.; total, 24 ft. 6 ins.
Wheel base, total engine and tender, 54 ft. 7 ins.
Valves, kind of, piston; greatest travel, $5\frac{7}{32}$ ins.
Outside lap, 1 in.; inside lap, 0 in.

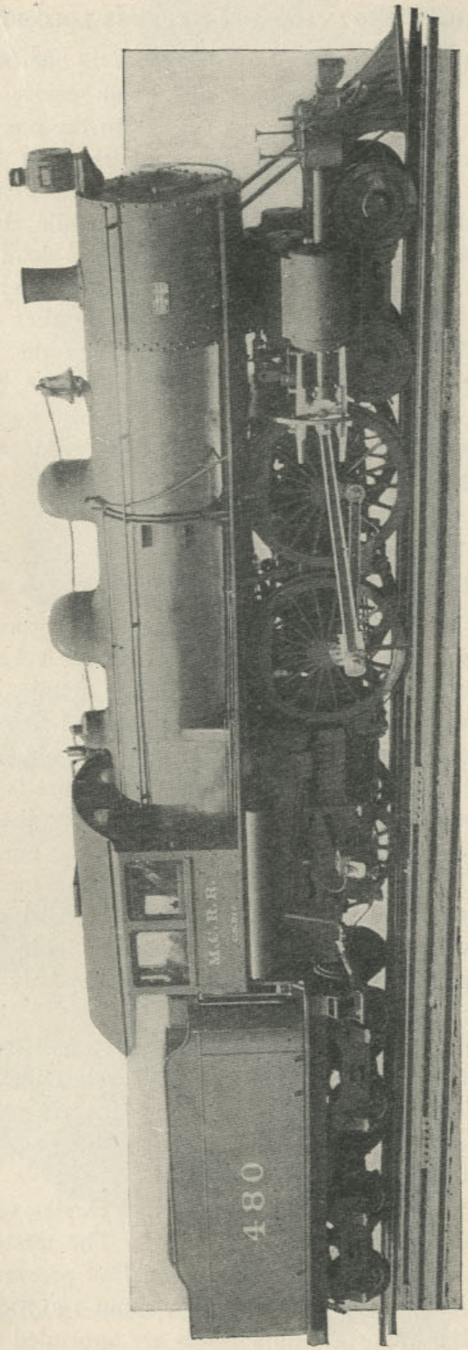
WHEELS, ETC.

Dia. and lgth. of driving journals, $8\frac{1}{2}$ and $9\frac{1}{2}$x11 ins.
Dia. and lgth. of main crank pin jour., $6\frac{1}{2}$x$6\frac{1}{2}$ ins.
Dia. and lgth. of side rod pin jour., $7\frac{1}{4}$x$4\frac{1}{2}$ ins.

BOILER.

Thickness of plates in barrel and outside of fire box, $\frac{23}{32}$, $\frac{25}{32}$, $\frac{9}{16}$, $\frac{1}{2}$ in.
Fire box, length, 108 ins.; width 74 ins.
Fire box, depth, front, 72 ins.; back, $58\frac{1}{2}$ ins.
Fire box plates, thickness, sides, $\frac{3}{8}$ in.; back, $\frac{3}{8}$ in.; crown, $\frac{3}{8}$ in; tube sheet, $\frac{5}{8}$ in.
Fire box, water space, 4 ins. front; 4 ins. sides; 4 ins. back.
Tubes, number, 354; dia., 2 ins.
Tubes, length over tube sheets, 14 ft. $6\frac{3}{8}$ ins.
Fire brick, supported on tubes.

Heating surface, tubes	2,672.7 sq. ft.
Heating surface, water tubes	28.5 sq. ft.
Heating surface, fire box	175.8 sq. ft.
Heating surface, total	2,877 sq. ft
Grate surface	54 sq. ft.



E. D. Bronner, Supt. Motive Power. MADE WONDERFUL RECORD OF POWER AND SPEED. American Locomotive Co., Builders.

MICHIGAN CENTRAL FAST EXPRESS LOCOMOTIVE.

The locomotive illustrated on page 631 is one of a number of this class that are giving exceptionally good service on the Michigan Central. A 4-4-2 type engine similar to the one shown in our illustration hauled sixteen passenger coaches from Bridgeburg to St. Thomas, Ont., a distance of 118.22 miles, in 127 minutes. The weight behind the tender was $605\frac{1}{2}$ tons, while the engine and tender together weighed $125\frac{1}{2}$ tons. A total load of 731 tons was, therefore, moved from one terminal to the other against eight slowdowns at a steady average rate of 55.8 miles an hour. The machine was built at the Schenectady shops of the American Locomotive Company, and has 21x26 in. cylinders, 79 in. drivers, $50\frac{3}{10}$ sq. ft. of grate area and 3,521 sq. ft. of heating surface. This exceptional performance was, no doubt, rendered possible by the liberal heating surface provided.

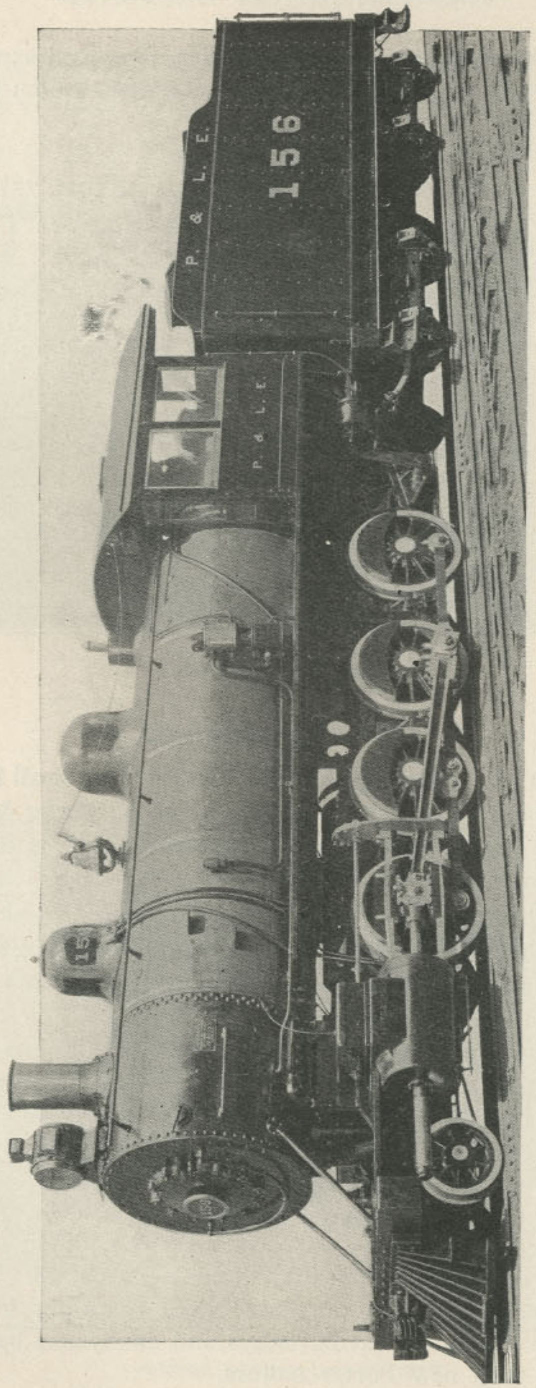
HEAVY CONSOLIDATION FOR THE PITTSBURGH & LAKE ERIE.

The Pittsburgh shops of the American Locomotive Company built the heavy 2-8-0 engines for the Pittsburgh & Lake Erie Railroad, shown on page 633. These engines are simple, with cylinders 21x30 ins., driving wheels 51 ins. in diameter, and represent the ideas of L. H. Turner, Superintendent of Motive Power. These wheels carry a weight of 168,150 lbs. The steam pressure is 200 lbs. The maximum calculated tractive effort is about 44,100 lbs. The motion of these engines is indirect, with transmission bar curved below the second axle. The three rear driving wheels are equalized together, while the pony truck equalizes with the leading drivers. The two leading drivers have overhung springs, and the main driver and the trailer have springs placed between the frame bars to economize space. All the wheels are flanged.

The boiler is of the straight-top type, the smallest ring being 76 ins. outside diameter. The crown sheet is level, while the roof sheet slopes toward the back about 6 ins. This insures plenty of steam room. There are 370 tubes, which give 2,858.82 sq. ft. of heating surface. The total being 3,040.6 sq. ft.

The tender is of the hopper variety and carries 14 tons of coal, the tank contains 7,000 gallons of water. The tender frames are steel channels, and the whole is carried on Fox pressed steel trucks. The tender weighs, with fuel and water, about 139,700 lbs.

A few of the important dimensions are appended for reference:



L. H. Turner, Supt. Motive Power. American Locomotive Company, Builders.

HEAVY CONSOLIDATION FOR THE PITTSBURGH & LAKE ERIE.

Total weight of engine in working order, 189,150 lbs.; on drivers, 168,150 lbs.; driving wheel base of engine, 16 ft.; total 24 ft. 8 ins.

Cylinders, diameter and stroke, 21x30 ins.

Boiler, dia. at smallest ring, outside, 76 ins.; throat, $77\frac{5}{8}$ ins.; back head, $74\frac{3}{4}$ ins.

Crown sheet supported by radial stays, $1\frac{1}{8}$ in. dia.

Staybolts, 1 in. dia., spaced 4x4 ins. centers.

Dia. of tubes, 2 ins.; length of tubes over tube sheets, 14 ft. 10 ins.; length of fire box, inside, 120 ins.; width of fire box, inside, $40\frac{1}{4}$ ins.

Boiler pressure, 200 lbs.; grate area, 33.4 sq. ft.

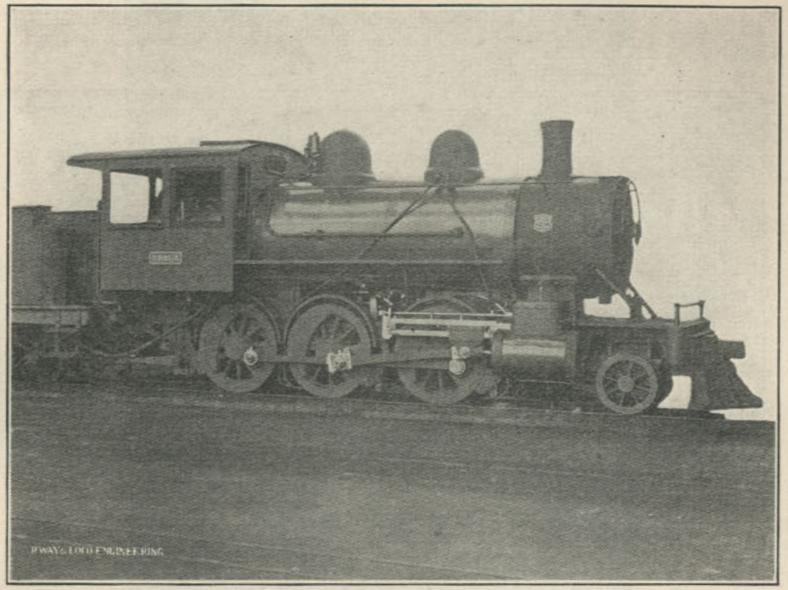
Heating surface in tubes, 2,858.82 sq. ft.; in fire box, 181.78 sq. ft.; total, 3,040.6 sq. ft.

Dia. of driving wheels outside of tires, 51 ins.; dia. and length of journals, $9\frac{1}{2}$x12 ins.; dia. of engine truck wheels, 30 ins.; dia. and length of journals, 6x10 ins.

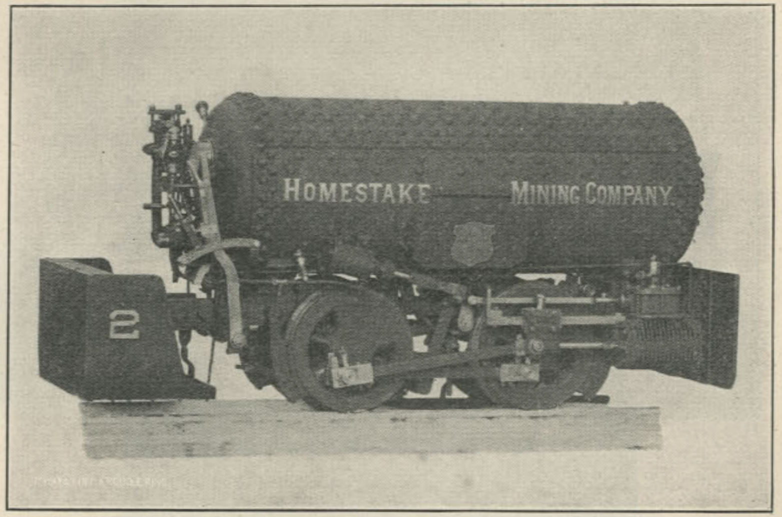
PORTER LOCOMOTIVES.

On the two following pages we illustrate two small locomotives and two compressed air motors made by H. K. Porter & Company, Pittsburgh, Pa., who are the most important makers in the world of that kind of motive power. The company make a specialty of manufacturing light locomotives, steam, compressed air, and electric in every variety, and for every practical gauge of track, and their machines are well adapted to requirements which the ordinary locomotive cannot meet.

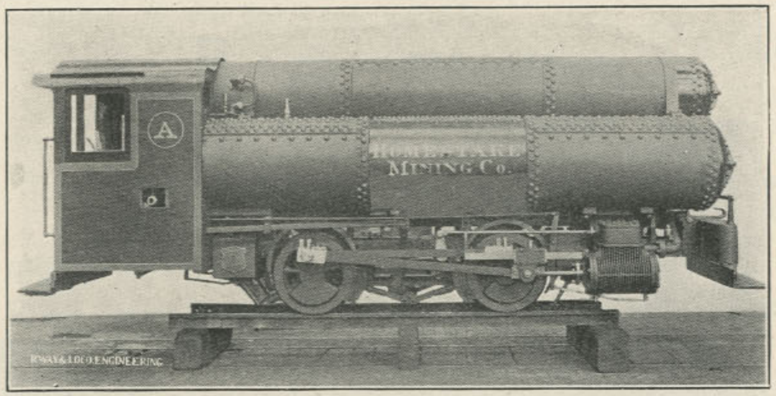
The makers are prepared to make new designs of motive power for peculiar cases, or to build to the specifications of customers. The location of the works in the city of Pittsburgh, the cheapest market in the country for the material that goes into locomotives, enables H. K. Porter & Company to sell their product at unusually low prices. Any person, firm, or company in want of light engines, for special purposes, ought to send for the Porter catalogue before they decide on a choice. Many contractors and other who purchase cheap worn-out locomotives, would save money and avoid delays and annoyance by providing themselves with new Porter motors.



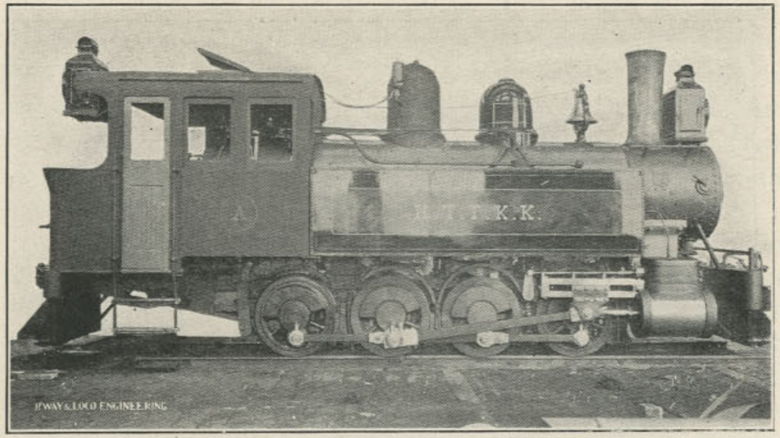
PORTER SMALL MOGUL.



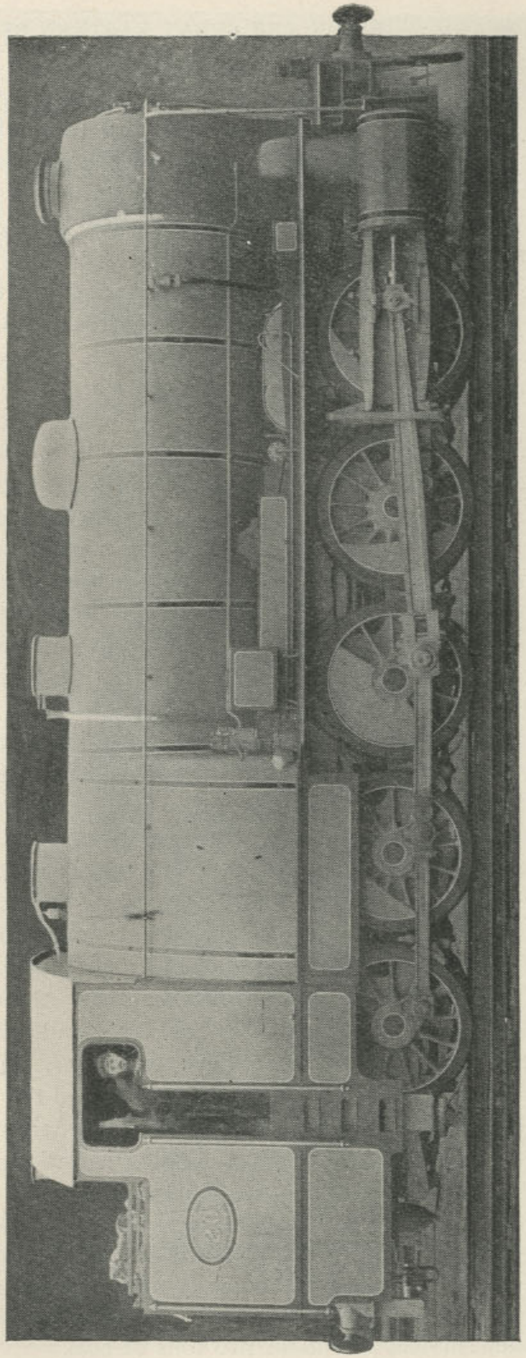
PORTER MINERS LOCOMOTIVE.



PORTER COMPRESSED AIR LOCOMOTIVE.



PORTER DOUBLE-ENDED LOCOMOTIVE.



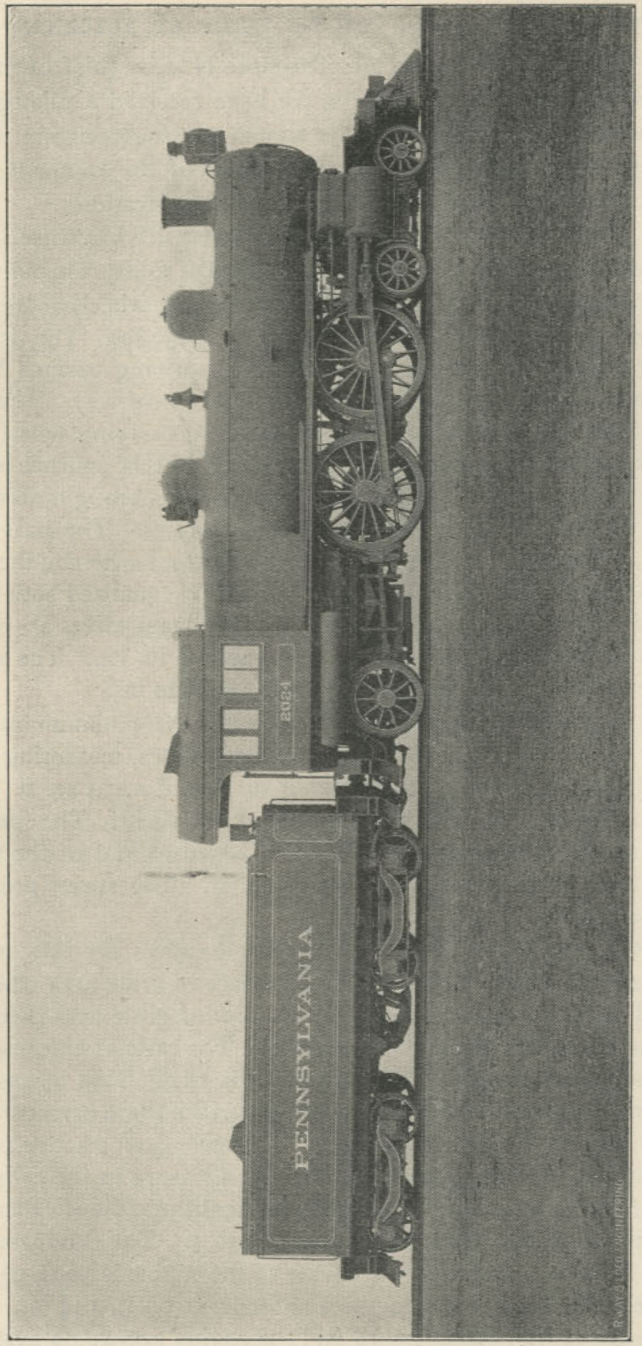
HEAVY THREE-CYLINDER SIMPLE SUBURBAN ENGINE, GREAT EASTERN RY.

NOVEL SUBURBAN ENGINE ON THE GREAT EASTERN OF ENGLAND.

Mr. James Holden, locomotive superintendent of the Great Eastern Railway, of England, has designed a powerful suburban engine, shown on page 637, which is intended to haul trains of about 370 long tons and carrying each about 1,200 passengers. The traffic is such as to require about 15 stops and starts in a distance of ten and three-quarter miles, between London and Enfield, and it is proposed to cover the distance in 30 minutes.

The engine is built up very close to the loading line of the road and weighs about 156,800 lbs. All the weight rests upon the five pairs of drivers, including that of fuel and water. The cylinders are three in number, all simple, $18\frac{1}{2}$x24 ins. The two outside ones drive on the third pair of wheels while the center cylinder, placed directly below the smoke box, drives upon a crank axle in the second pair. All the cylinders are horizontal, and the eccentrics are secured to the third axle. There are only two steam chests, one is for the left cylinder and one for the right and middle. A curious arrangement is the connecting rod for the center cylinder. It is a forked rod, and the wrist-pin connection is a separate piece bolted between the upper and lower bars of the forked end. When in place this rod entirely encloses the forward axle, and as the opening so made is not long enough to clear the axle when the piston is at the back end of the cylinder, the leading driving axle is offset in the center to suit As the leading pair of drivers are revolved by the side rods the forked rod and the off-set axle each work in perfect harmony.

The boiler has a wide fire box, with grate area of 42 sq ft., and the total heating surface is 3,010 sq. ft. The tubes are 395 in number and they are $1\frac{3}{4}$ ins. in diameter and are 15 ft. 11 ins. long. As the boiler stands so high, the chimney has been brought down in consequence, and is flared out inside the smoke box so as to be practically an upper petticoat pipe. The exhaust has three annular openings. The pressure carried is 200 lbs., and an estimate of the tractive effort places it about 36,500 lbs. The cranks are set at 120 degrees, and in balancing the total of all the reciprocating weights has been taken, instead of two-thirds of them, as is the usual practice. The provision against slipping in making a start is accomplished by a sanding device which uses compressed air, which latter is supplied from a separate reservoir. Air is pumped into the sander's reservoir and passes through a check valve into the main reservoir, so that even if air is temporarily used freely in sanding, it cannot affect the main reservoir pressure. There are 1,300 Imperial gallons of water carried, and about two tons of coal.



T. N. Ely, Chief of Motive Power. Pennsylvania Railroad Co., Builders.

ATLANTIC TYPE ENGINE FOR THE PENNSYLVANIA, BUILT AT THE ALTOONA SHOPS.

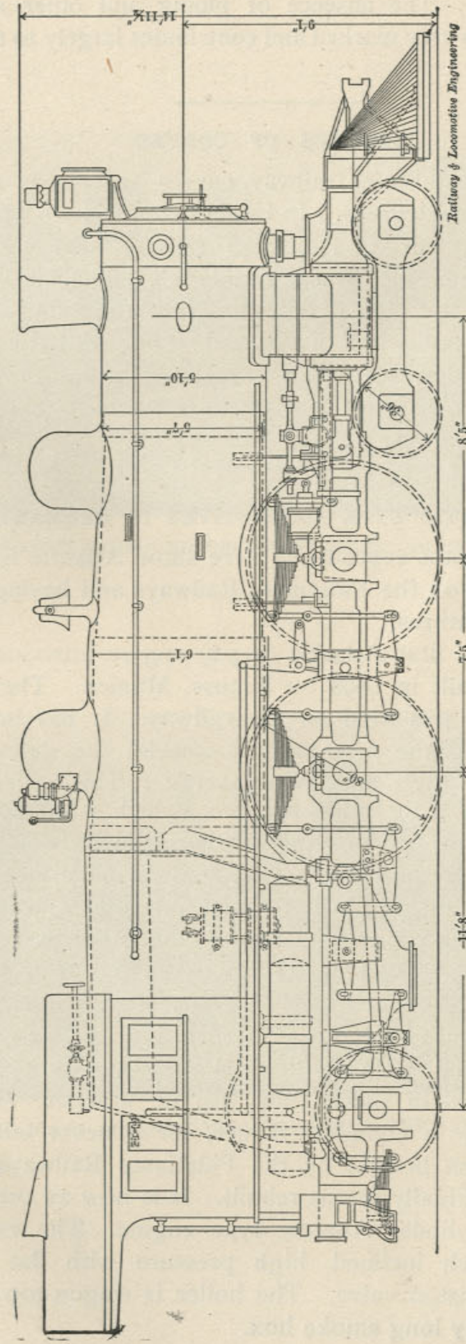
PENNSYLVANIA 4-4-2 ENGINE BUILT AT ALTOONA.

Through the courtesy of Mr. Theodore N. Ely, chief of motive power of the Pennsylvania system, we have received a photograph and some data about an E.3.a class simple passenger engine of the 4-4-2 type lately built at the Altoona shops of the company, and show it in two views, one half-tone and one line elevation.

The cylinders are 22x26 ins. and have 80-in. driving wheels. The weight of this machine in working order is 183,130 lbs. The adhesive weight amounts to 118,350 lbs., while the carrying wheels at the rear bear about 31,130 lbs., and the engine truck 33,650 lbs. The driving and carrying wheels are all equalized. The driving springs being carried upon saddles on top of the boxes in the usual way. The rear spring of the engine is placed behind the 50-in. carrying wheel, and an axle box equalized rests upon the carrying wheels' journal boxes. Between this and the rear driver the equalization is brought about by a series of three, pivoted equalizers and hangers. The half-tone, however, shows a modification of this arrangement whereby the rear spring is placed upon the lower frame bar and is equalized both ways to the rear driver and the carrying wheel. The main valves are of the balanced D-slide type, having 7 in. travel and $1\frac{1}{2}$ in. lap. The steam ports are $1\frac{1}{2}$x20 ins. and the exhaust ports are 3x20 ins.

The boiler has a Belpaire wide fire box and the minimum internal diameter of the boiler $65\frac{5}{8}$ ins. There are 315 tubes, measuring each 180 ins. in length which gives a heating surface of 2,474 sq. ft. The fire box is 72x111 ins. with a grate area of $55\frac{1}{2}$ sq. ft. The fire box has 166 sq. ft. of heating surface, which added to that of the flues, gives a total heating surface of 2,640 sq. ft. The steam pressure carried is 205 lbs.

Among the ratios worked out by the builders for this engine may be mentioned the ratio of heating surface to grate area which is 47.56. This means that for every square foot of grate area there are over 47 sq. ft. of heating surface provided. The ratio of external flue heating surface to fire box heating surface is 14.9. That means that for every square foot of fire-box heating surface there are nearly 15 sq. ft. of heating surface in the flues. The calculated tractive power of this engine, assuming the mean effective pressure in the cylinders to be $\frac{4}{5}$ of the boiler pressure, is 25,800 lbs. and the ratio of calculated tractive power to adhesive weight is as 1 is to 4.5. The driving-wheel base is 7 ft. 5 ins. The total wheel base of the engine is 30 ft. $9\frac{1}{2}$ ins., while the wheel base of the engine and tender is 60 ft. $1\frac{13}{16}$ ins. The whole design is well proportioned and the engine presents a neat and



SIDE ELEVATION OF PENNSYLVANIA 4-4-2 PASSENGER ENGINE.

trim appearance. The absence of piping and other attachments along the boiler is very marked and contributes largely to the pleasing effect produced.

DEGREES OF CURVES.

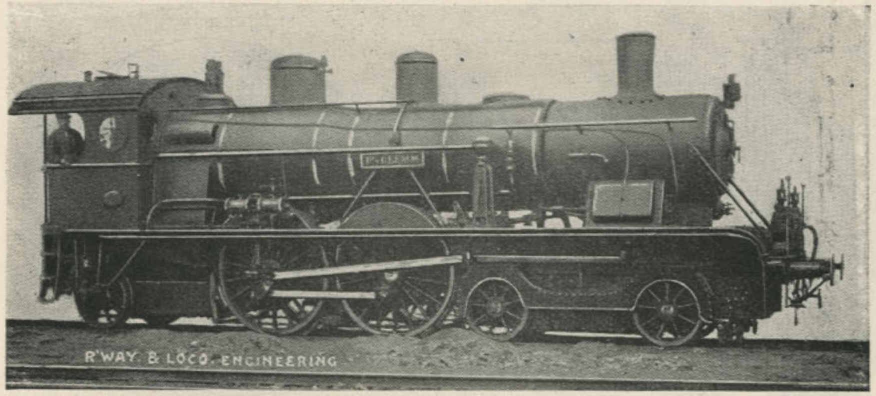
In the United States railway curves are nearly always described as so many degrees. In foreign countries so many feet radius describes the curve. American railway surveyors measure curves as part of a circle whose radius is established by the angle of deflection. If the angle of deflection is 1° the radius of the curve will be 5,730 feet; 2° is half of that and so on. A 10° curve is part of a circle having 573 feet radius. By memorizing the radius of a 10° curve any person can readily make a mental calculation of the sharpness of all curves.

ATLANTIC TYPE LOCOMOTIVES IN GERMANY.

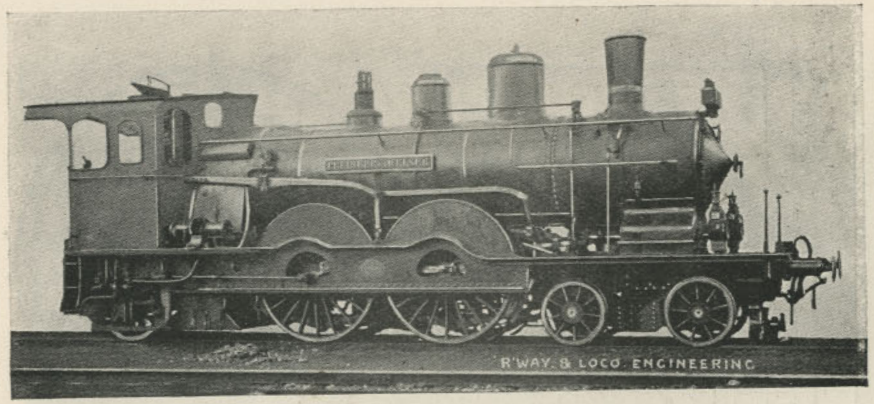
The two photos reproduced here show Atlantic type express engines running on the Palatinate Railways and having a number of interesting features.

No. 1 is the first Atlantic (4-4-2) engine introduced in Germany; it was built in 1898 by Krauss, Munich. There are now about twelve of this kind on the railway. It has inside simple cylinders, driving the first pair of wheels; the valve gear is a combination of Joy's and Walschaert's. The boiler is of the wagon-top type, with broad fire box, which is supported by an outside frame surrounding the driving wheels, which, however, have only inside bearings. The trailing axle is entirely free geared, and, having no pin nor radial axle boxes, it is controlled only by the spring pressure. This engine is the first "air cutter" of Germany, with conical smoke-box cover and prow-shaped front sheet of cab.

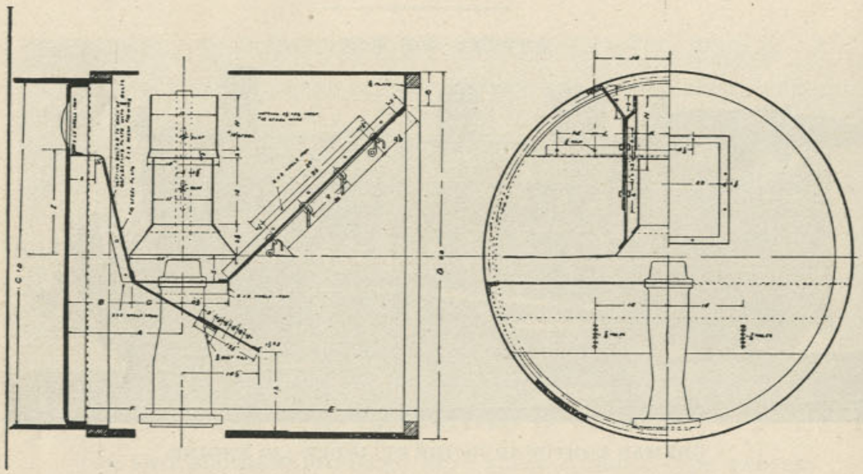
No. 2 was built by Krauss, Munich, for the Paris Exposition, 1900, and received there the "Grand Prix" for its novel features, which were good in theory but bad in practice. The engine turned out to be a complete failure, for it never left the shops after it had been bought by the Palatinate Railways and made several trials. Finally it was rebuilt. It is now an ordinary compound inside cylinder Atlantic type engine. The cylinders are inside and much inclined, high pressure with flat valve, low pressure with piston valve. The boiler is wagon-top with broad fire box and very long smoke box.



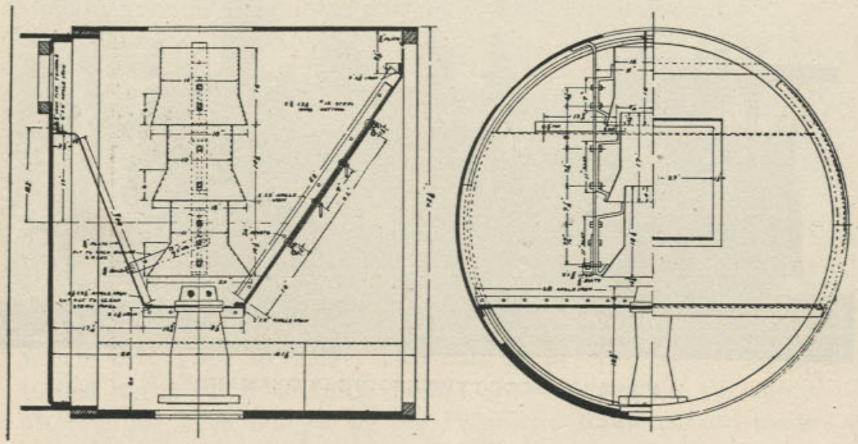
GERMAN COMPOUND INSIDE CYLINDER 4-4-2 ENGINE.



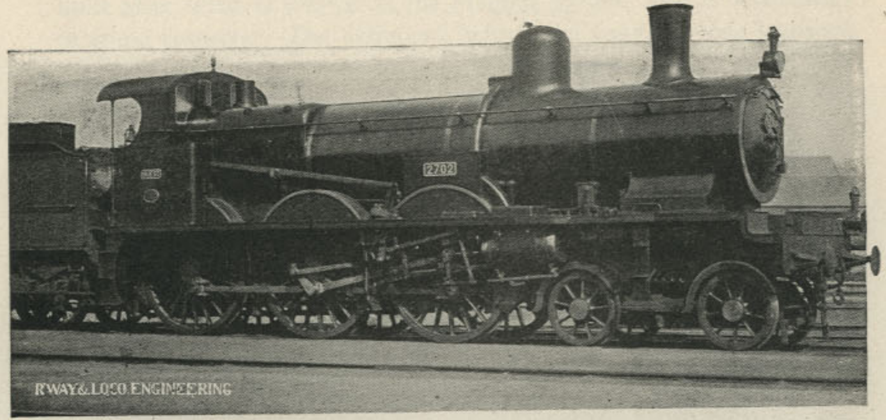
FIRST ATLANTIC-TYPE ENGINE IN GERMANY.



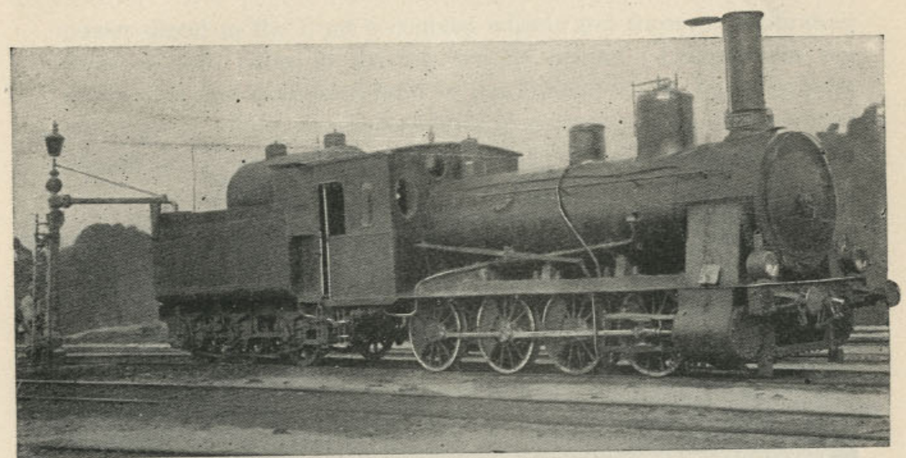
FRONT END USED BY COMMITTEE OF MASTER MECHANICS' ASSOCIATION.



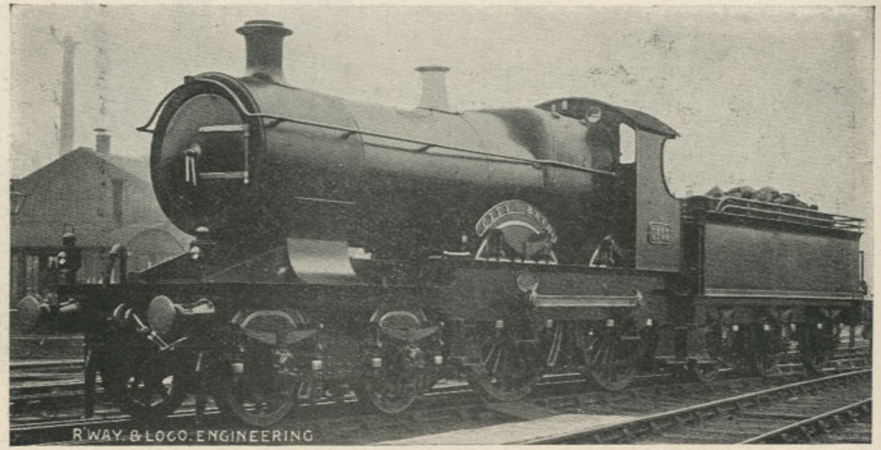
MASTER MECHANICS' FRONT END ON THE MICHIGAN CENTRAL.



FOUR-CYLINDER COMPOUND—DU BOUSQUET-DE GLEHN TYPE.

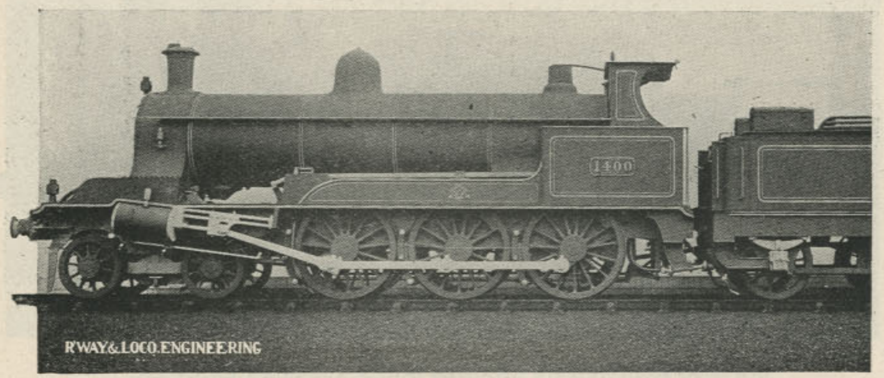


OIL BURNING FREIGHT ENGINE—TRANSCAUCASIAN RAILWAY.



Drivers, 70½-in. Diameter. Cylinders, 18-ins. x 26-ins.

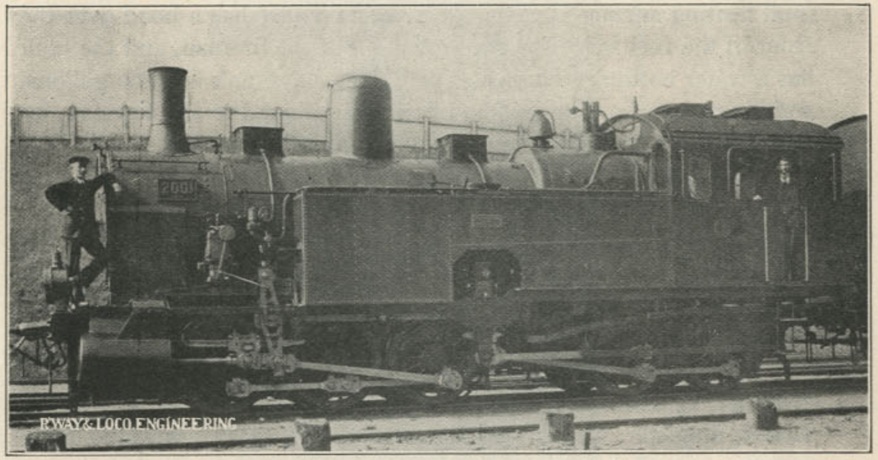
GREAT WESTERN RAILWAY OF ENGLAND HEAVY EXPRESS ENGINE



WEBB FOUR-CYLINDER COMPOUND GOODS ENGINE.

PRUSSIAN ARTICULATED TANK ENGINE.

Henschel & John, Cassel, built for the Prussian State Railways the heavy tank-articulated engine here illustrated. It was built after what is known as the Hagans system, and is a curiosity in some respects. The cylinders, which are 20½x24¾ ins., transmit



PRUSSIAN ARTICULATED TANK ENGINE.

power direct to the front 6-coupled wheels and through a vibrating lever to two pairs of driving wheels behind. Locomotives not unlike this one have been built in the United States, but they were not popular. This engine was built to operate a very crooked road having many steep gradients, and is reported to be a success.

ATLANTIC TYPE PASSENGER POWER FOR THE ERIE.

The Baldwin Locomotive Works have supplied the Erie with some very substantial Vauclain compound 4-4-2 passenger engines, shown on page 649. The sizes of the cylinders are 15 and 25x28 ins., and the high-pressure cylinders are placed on top. The driving wheels measure 76 ins. outside the tires, and the weight carried by them amounts to about 88,000 lbs. The total weight of the engine is about 180,000 lbs. The drivers and carrying truck wheels are equalized together, and the valve motion is indirect, with transmission bar passing below the leading driving axle. The valves are of the piston type. The guide bars are very securely fastened to the spectacle plate by a heavy steel casting which passes completely around the ends of the guides.

The boiler is of the straight-top variety, with wide fire box for bituminous coal, this, however, is not quite as wide as the ordinary Wootten type, thus allowing the cab to be placed at the rear of the engine. The boiler is 64 ins. in diameter at the smoke-box end. The total heating surface is 2,811 sq. ft. The tender has a hood over the front of the fuel space for the protection of the fireman, and the tank has a water bottom. The water capacity of the tank is 7,000 gallons, and there is a back step, hand rail and ladder for the fireman, so that the tank manhole may be conveniently reached.

These engines altogether are very similar to those built last year at the Baldwin Works for the Erie, except that the one here illustrated is arranged to burn soft coal. Though the position of the cab differs from that of the hard-coal burners, these engines have been made with parts interchangeable as far as possible, to suit the former design.

Some of the principal dimensions are as follows:

Cylinder, 15 and 25x28 ins.

Boiler, diameter, 64 ins.; thickness of sheets, $\frac{11}{16}$ in.; working pressure, 200 lbs.

Fire box, length, 102 ins.; width, 66 ins.; depth, front, $66\frac{1}{4}$ ins.; back, $57\frac{1}{2}$ ins.; thickness of sheets, side, $\frac{3}{8}$ in.; back, $\frac{3}{8}$ in.; crown, $\frac{3}{8}$ in.; tube, $\frac{1}{2}$ in.; water space, front, 4 ins.; sides, 4 ins.; back, 4 ins.

Tubes, wire gauge No. 12; number, 305; diameter, 2 ins.; length, 16 ft. 6 ins.

Heating surface, fire box, 172 sq. ft.; tubes, 2,639 sq. ft.; total, 2,811 sq. ft.; grate area, 46.75 sq. ft.

Driving wheels, diameter outside, 76 ins.; journals, 9x12 ins.

Engine truck wheels, diameter, 33 ins.; journals, 6x12 ins.

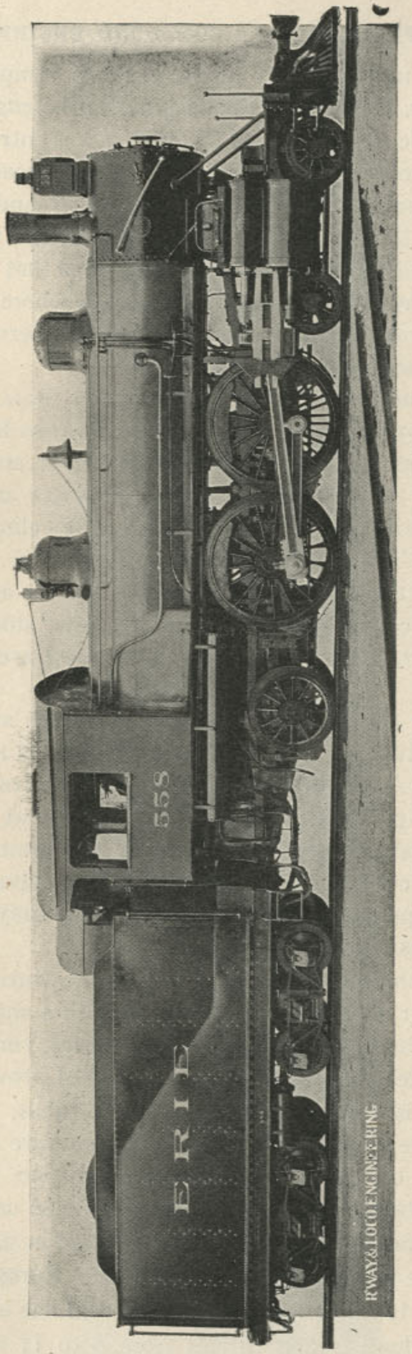
Trailing wheels, diameter, 50 ins.; journals, $8\frac{1}{2}$x12 ins.

Wheel base, driving, 6 ft. 7 ins.; rigid, 13 ft. 10 ins.; total engine, 26 ft. 3 ins.; total engine and tender, 52 ft. 2 ins.

Weight, on driving wheels, 88,000 lbs.; on truck, 48,000 lbs.; on trailer, 44,000 lbs.; total engine, 180,000 lbs.; total engine and tender, about 310,000 lbs.

Tank, capacity, 7,000 gals.

Tender, wheels, $33\frac{1}{2}$ ins.; journals, 5x9 ins.



W. S. Morris, Supt. Motive Power. ATLANTIC TYPE VAUCLAIN COMPOUND FOR THE ERIE Baldwin Locomotive Works, Builders.

ATLANTIC TYPE 4-CYLINDER COMPOUND ENGINE IN GERMANY.

In sending us particulars of the German compound reproduced on page 651, Mr. M. Richter, the designer of the engine ,says:

The Atlantic, or 4-4-2 type of engine, was introduced into Germany in 1898, and for the same reason that it became popular here, viz.: The necessary enlargement of the boiler and the increase of grate area. In the continental type, however, the pistons drive the forward axle, and for that practice it is claimed that the reciprocating parts are less heavy than they are in America, where the main drivers are usually the rear pair, and consequently the German engine has a longer wheel base and is better balanced.

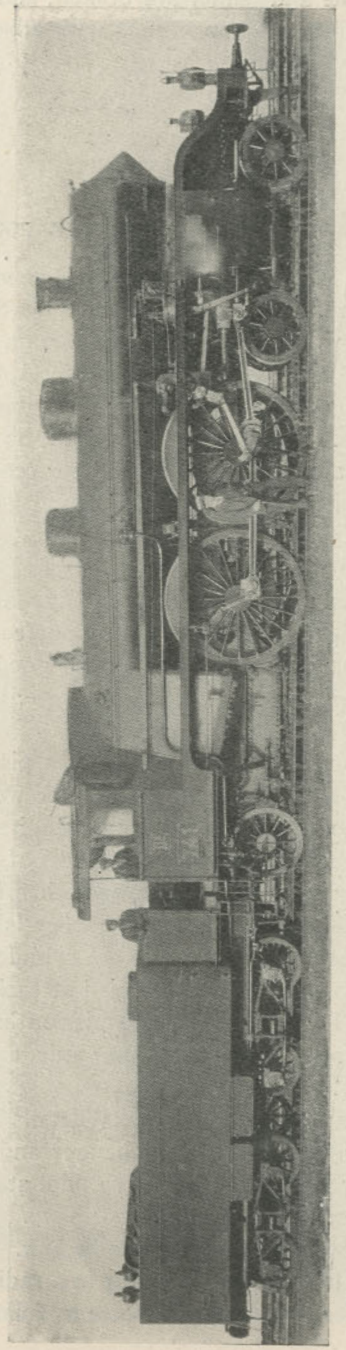
These engines were built for the Baden State railways. They were designed to haul express trains of 200 tons behind the tender at a speed of from 75 miles per hour on the level, and at 62 miles per hour on grades of 1 in 300. The cylinders are arranged with the high pressure inside and the low outside. The cylinders are 13.2 and 22.4x24.4 ins. The ratio of cylinder volumes is about 2.9. The cranks on a side are placed at 180 degrees, but are at 90 degrees with reference to the corresponding ones on the other side, so that the balancing is perfect, and the counterweights used are for the rotating parts.

The wheels are 82.7 ins. in diameter. Each side of the engine has only one valve gear placed outside the wheels and that is of the Walshaert type. A rocking shaft moves both valves, that of the high pressure, being piston with inside admission, that of the low, is a balanced side valve. In consequence of the joint arrangement of both valves, the cut off is the same for all four cylinders, and usually amounts to 40 per cent. of the stroke. The carrying wheels have radial axle boxes.

For diminishing resistance, or in order to throw the smoke and steam high in air, the smoke box is fitted with a sharp conical cover. The cab front sheet is composed of two pieces, running together at an angle of 90 degrees, thus forming a kind of prow.

The boiler is straight and contains 279 tubes, 15 ft. 9 ins. long and 2 ins. outside diameter. The working pressure is 228 lbs. per sq. in. The smoke box is of the very extended type, being 8 ft. 2 ins. long. The fire box is of the wide type, made of copper with 42 sq. ft. of grate surface; the total heating surface is 2,550 sq. ft. The safety valves are pops, which is a novelty for Europe.

The tender is carried on two trucks, and has a tank capacity of 5,300 U. S. gallons, and it carries from 6 to 11 tons of coal. All



GERMAN FOUR-CYLINDER ATLANTIC TYPE COMPOUND.

wheels on the engine and tender are braked, and the total weight of the engine in working order is 74 tons with adhesive weight of 31.9 tons.

CONSOLIDATION ENGINE FOR THE ROCK ISLAND.

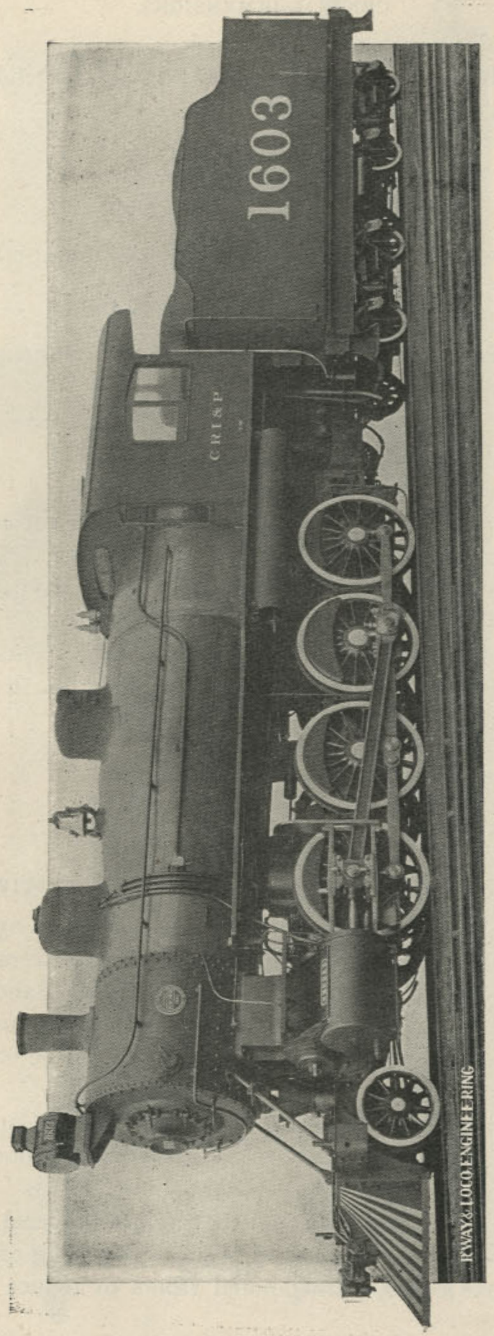
The American Locomotive Company have supplied the Chicago, Rock Island & Pacific with some powerful 2-8-0 engines, built at their Dunkirk shops, one of which is shown on page 653. The engines are probably the heaviest now on the C., R. I. & P., the machine weighing in all 202,500 lbs. The engine is simple and has cylinders 22x30 ins. The driving wheels are 63 ins. in diameter and carry a weight of 182,000 lbs. With 85 per cent. of the boiler pressure, which is 200 lbs., assumed to be the mean effective pressure at slow speed the maximum tractive effort is 39,200 lbs., and the ratio of tractive effort to adhesive weight is therefore 4.6.

The engine has a large boiler which is $72\frac{1}{8}$ ins. at the smoke-box end and a total of 3,264 sq. ft. of heating surface has been provided. This, with the ample fire box, guarantees good steaming qualities. The boiler is of the extended wagon-top type, with plenty of steam room.

The valve gear is direct, and operates a piston valve having inside admission. This arrangement reduces the wear and tear on valve stem packing at both ends, as it is only required to stand the comparatively light and intermittent pressure of the exhaust steam. That prolific steam waster, the clearance, has been very materially reduced in this design. The valve chamber is placed in the direct line of steam passage, and as close to the cylinder as possible, so that the steam spaces to be filled and emptied at each stroke are as small as can be made. The valve-rod transmission bar is slightly curved, in order to work freely over the leading axle, and being a steel casting, is stiffened latterly with webs.

There are many familiar Brooks details about this engine, among others, the band-like spring hanger and the reach rod of 2-in. extra heavy wrought iron pipe. The pilot stays are riveted to the smoke box and pinned to the front foot plate. The headlight frame is below the level of the top of the smoke box. The diameter of the engine-truck wheels is 36 ins., running in a radial swing truck.

Some of the leading dimensions are as follows:



T. S. Lloyd, Supt. Motive Power. ROCK ISLAND CONSOLIDATION ENGINE American Locomotive Company, Builders.

GENERAL DIMENSIONS.

Weight in working order, 202,500 lbs.

Weight on drivers, 182,000 lbs.; weight engine and tender in working order, 347,500 lbs.

Wheel base, driving 17 ft.; total 26 ft.

Wheel base, total, engine and tender, 57 ft. 6 ins.

CYLINDERS.

Cylinders, 22x30 ins.; size of steam ports, 2x29 ins.; exhaust ports, 65 sq. ins.; bridges, $3\frac{3}{8}$ ins.

VALVES.

Kind, improved piston; greatest travel, $5\frac{13}{16}$ ins.; outside lap, 1 in.; lead in full gear, $\frac{3}{32}$ in.

BOILER.

Style, radial stayed extended wagon top.

Outside dia. first ring, $72\frac{1}{4}$ ins.; work, press, 200 lbs.

Fire box, length, 108 ins.; width, 68 ins.; depth, front, $75\frac{1}{2}$ ins.; back, $61\frac{1}{2}$ ins.; plates, thickness, sides, $\frac{3}{8}$ in.; back, $\frac{3}{8}$ in.; crown, $\frac{3}{8}$ in.; tube sheet, $\frac{5}{8}$ in.; water space, 4 in. front, 4 in. sides, 4 in. back.

Tubes, number, 383; dia., 2 ins.; length over tube sheet, 15 ft. 6 ins.

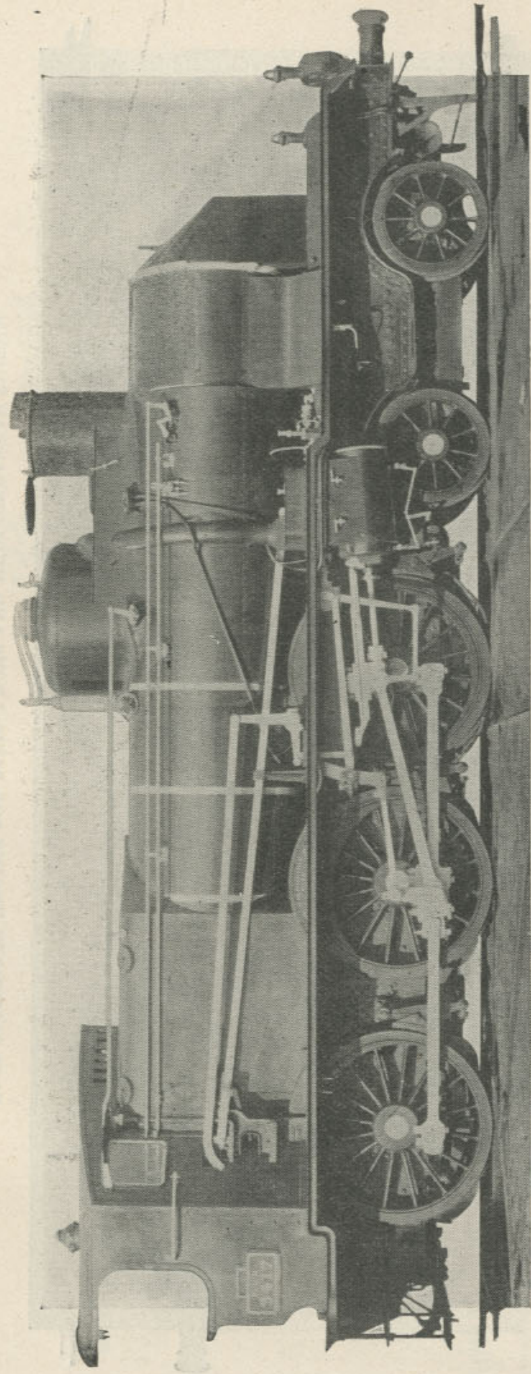
Heating surface, tubes, 3,087 sq. ft.; fire box, 177 sq. ft.; total, 3,264 sq. ft.; grate surface, 50 sq. ft.

PARIS, LYONS & MEDITERRANEAN LOCOMOTIVES.

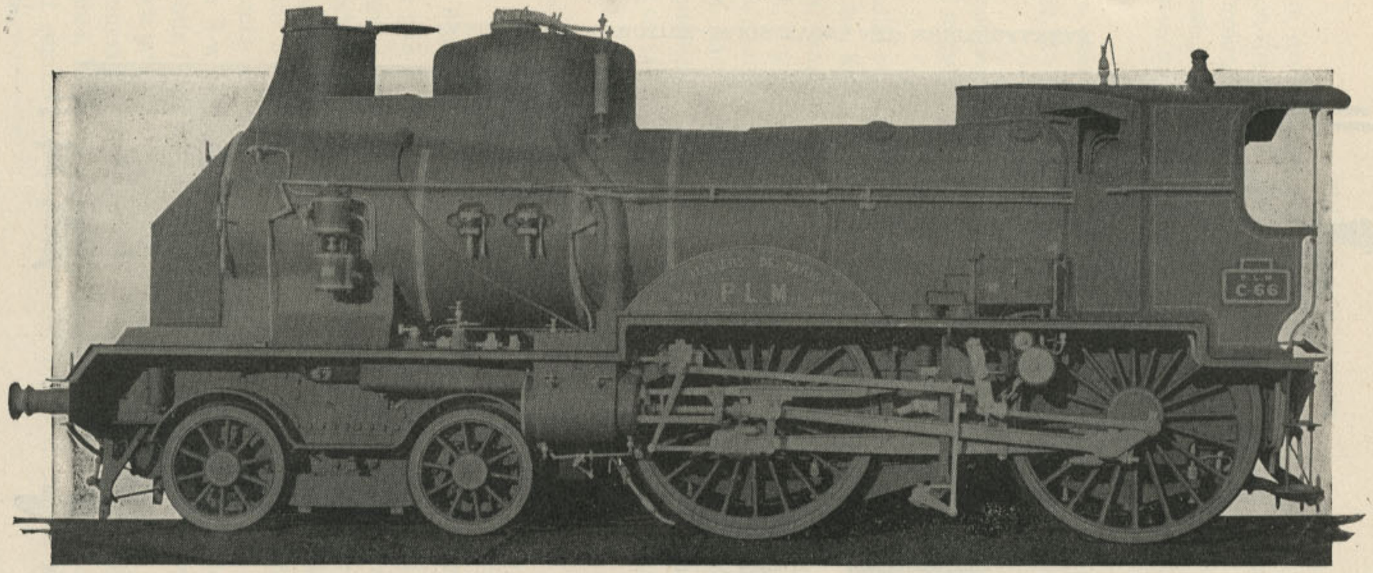
The two French locomotives illustrated on pages 655 to 658 are latest engines designed for the Paris, Lyons & Mediterranean, by the chief mechanical engineer of the system, M. C. W. Baudry. Both of these engines are compounds, with four cylinders, two inside and two outside the frames. Particulars of the designs can be obtained from the line cuts.

The 8-wheel type of engine has proportions adapted to high speed, while the ten wheeler is designed to combine moderate speed with much power.

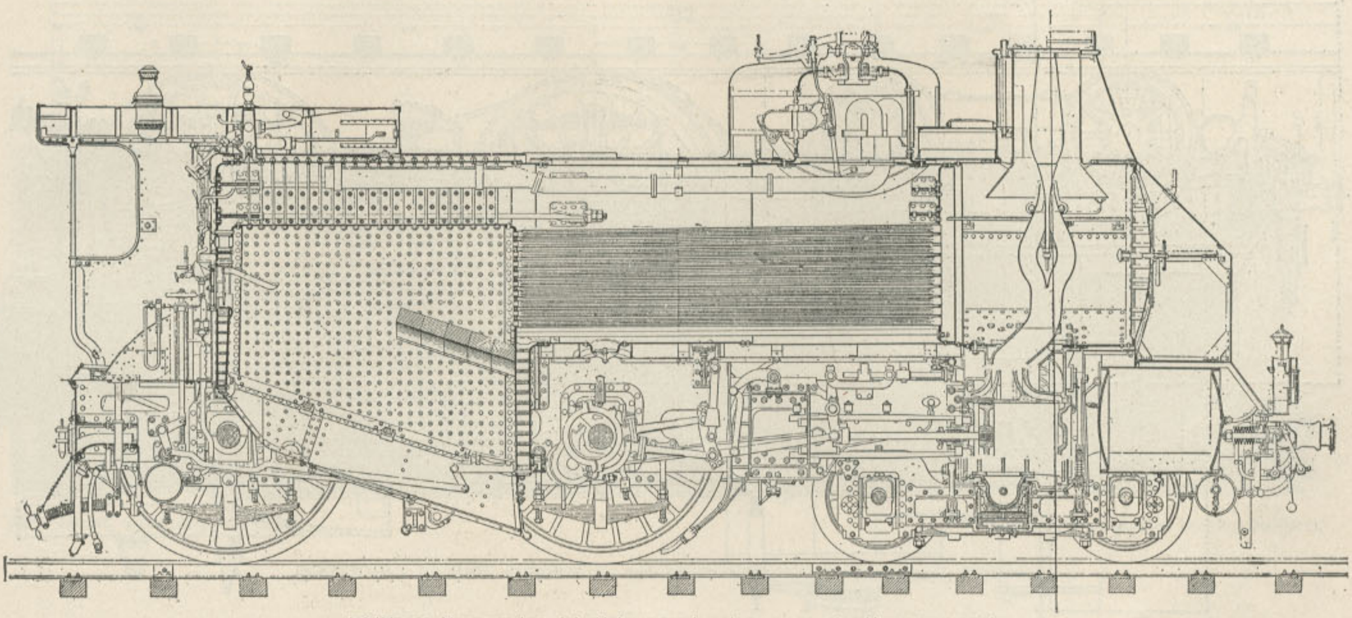
Common characteristics of all the engines are steel boilers with Serve tubes, Belpaire fire boxes, the inside part being of copper, and extended smoke boxes, with pointed fronts to reduce atmospheric resistance.



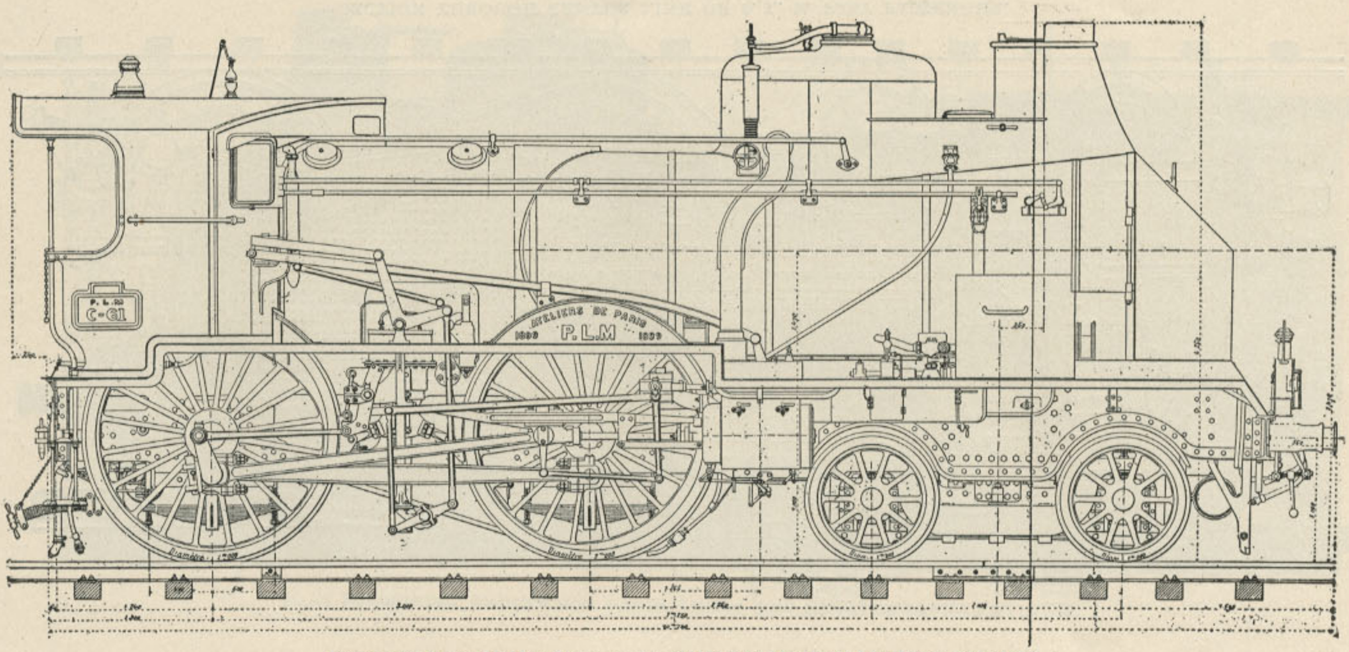
TEN-WHEEL PASSENGER LOCOMOTIVE—PARIS, LYONS AND MEDITERRANEAN.



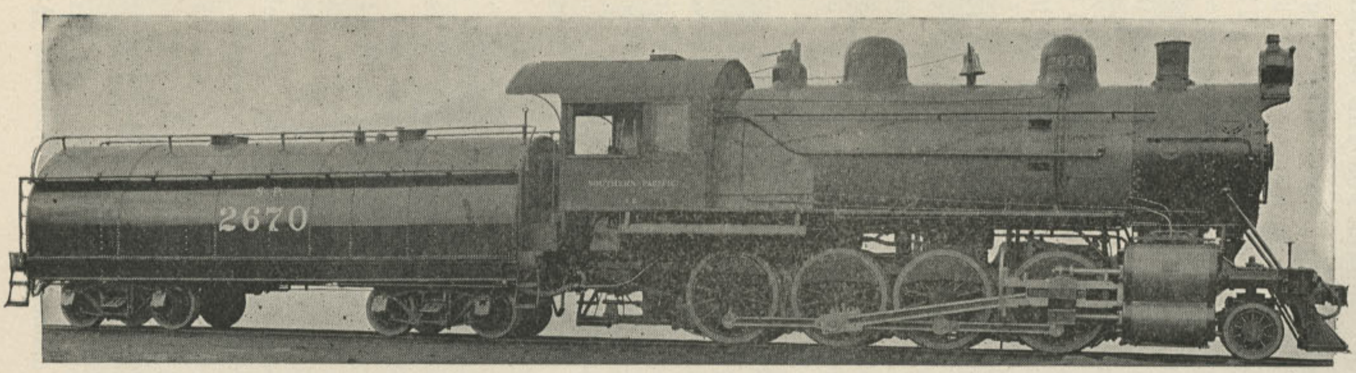
FAST PASSENGER ENGINE FOR PARIS, LYONS AND MEDITERRANEAN SYSTEM.



SECTION THROUGH CENTER LINE OF P. L. M. FAST PASSENGER.



OUTLINE ELEVATION OF P. L. M. FAST PASSENGER 8-WHEEL ENGINE.



H. J. Small, Supt. Motive Power. Baldwin Locomotive Works, Builders.

SOUTHERN PACIFIC COMPOUND OIL-BURNER WITH VANDERBILT TENDER.

COMPOUND OIL BURNER FOR THE SOUTHERN PACIFIC.

A very interesting example of an oil-burning compound consolidation engine is presented on page 659. It was built by the Baldwin Locomotive Works for the Southern Pacific. The cylinders are 17 and 28x30 ins., the high pressure being underneath. The driving wheels are 57 ins. diameter and all are flanged. The two leading wheels are equalized with the front truck, and the two rear drivers are equalized by themselves.

The boiler is of the straight-top variety and radial stayed. It is 76 ins. in diameter at the smoke-box end. The heating surface is in all about 3,604 sq. ft., of which 3,390 sq. ft. are in the tubes. There are 442 tubes, and the grate area is 54½ sq. ft. The weight of engine and tender is 210,130 lbs., and 185,240 lbs. rest on the drivers.

The striking feature about this machine is the Vanderbilt tender, which is, semi-circular in sections and contains 3,300 gallons of fuel oil and 7,300 gallons of water. The tender has a running board and hand rail the full length, with ladder and steps at the back. The tank is carried on a steel channel frame. The tender is longer than usual, being in the neighborhood of 24 ft., which is no doubt the result of the special design which the Southern Pacific have adopted.

Some of the principal dimensions are subjoined:

Cylinder, 17 ins. and 28x30 ins.

Valve, balanced piston.

Boiler, thickness of sheets, $\frac{27}{32}$, $\frac{7}{8}$ and $\frac{29}{32}$; working pressure, 200 lbs.; fuel oil; staying, radial.

Fire box, length, 108 ins.; width, 72½ ins.; front, 75¼ ins.; back, 66¼ ins.; thickness of sheets, sides, ⅜ in.; back, ⅜ in.; crown, ⅜ in.; tube, ⅝ in.; water space, front, 4 ins. to 4½ ins.; sides, 3½ ins. to 6 ins.; back, 3½ ins. to 4½ ins.

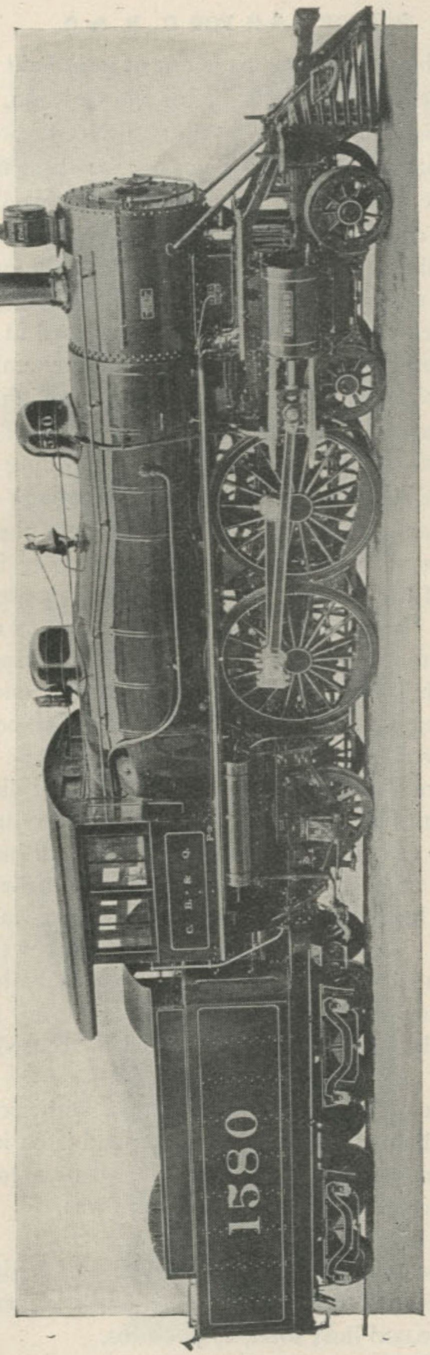
Tubes, number, 442; diameter, 2 ins.; length, 14 ft. 9⅛ ins.; heating surface, fire box, 182.2 sq. ft.; tubes, 3,390.7 sq. ft.; fire brick tubes, 30.9 sq. ft.; total, 3,603.8 sq. ft.; grate area, 54.5 sq. ft.

Driving wheels, diameter outside, 57 ins.; journals, main, 10x12 ins.; others, 9x12 ins.; engine truck wheels, diameter, 30½ ins.; journals, 6x10 ins.; wheel base, driving, 15 ft. 8 ins.; total engine, 24 ft. 4 ins.

Weight, on driving wheels, 185,240 lbs.; on truck, 24,890 lbs.; total engine, 210,130 lbs.

Tank, capacity, oil, 3,300 gals.; water, 7,300 gals.

Tender, wheels, diameter, 33½ ins.; journals, 5½x10 ins.



F. H. Clark, Supt. Motive Power. HEAVY "ATLANTIC" TYPE ENGINE FOR THE C., B. & Q. Rogers Locomotive Works, Builders.

ROGERS 4-4-2 FOR C., B. & Q.

The engine shown on page 661 is one of a lot built by the Rogers Locomotive Works, Paterson, N. J., for the Chicago, Burlington & Quincy. They haul the famous "Burlington No. 1" and other trains of that class, so that work is already cut out for these machines. The engines are simple, with 20x26 in. cylinders, 84½-in. drivers, the adhesive weight is 92,000 pounds and the pressure carried is 210 pounds. The total weight of the engine is 174,000 pounds.

The trailing wheels, which are 54¼ ins. in diameter, have outside journals which are 12x8 ins., and are enclosed in a journal box with dust-guard brass and wedge on the same general lines, though larger, as the regular M. C. B. axle box. The use of this box necessitated a special frame arrangement. The main engine frames terminate in a steel casting which acts as a very solid filling piece between the frames, and the casting extends out far enough to spread the frames for the rear truck so as to pass them over the center of the axle box when in normal position. The box slides in frame jaws similar to those of the driving wheels, but considerable side play has been allowed for. The equalizer for the rear wheels rests upon the top of the box and terminates in a pair of spiral springs at the back and connects with a pivoted equalizer bar which connects with the rear driving-spring hanger. The driving wheels are equalized in the usual way with overhung springs.

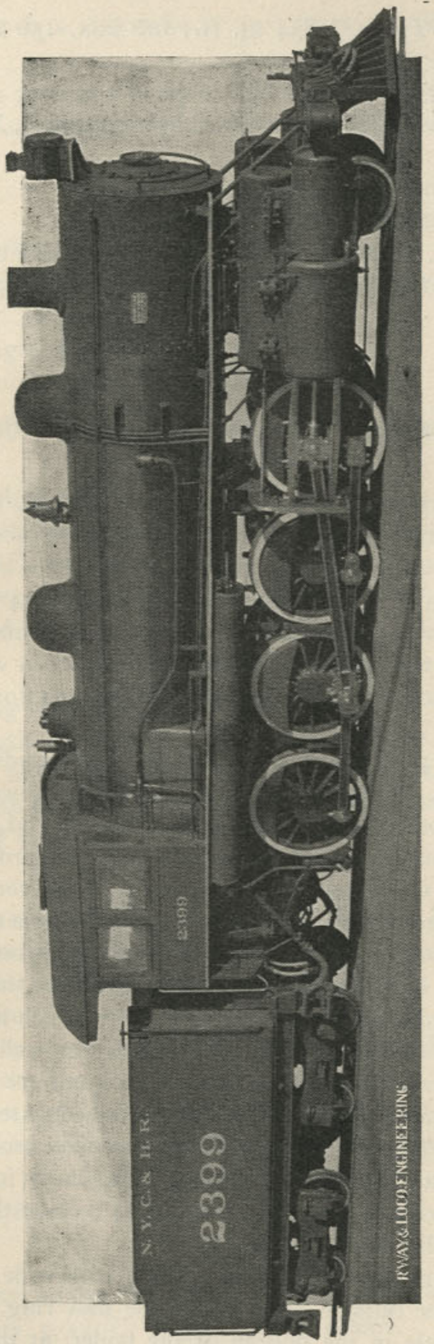
The valves are of the piston type and are placed directly between the top and bottom bar of the frame front, thus giving short direct steam passages to the cylinders. The valves are 12 ins. in diameter, and the packing rings are put in what may be called spoked bull rings, which are held in place at each end by the valve stem with shoulder and nut. The transmission bar passes over the axle of the leading driver and is attached to a rocker with both arms on the same side of the center, thus securing direct action for the valve. The cross head is of the two-guide bar type and is secured to the piston rod by a nut.

The boiler is of the wide fire-box type, with extension-wagon top. The inside diameter at the smoke-box end is 64 ins. The heating surface amounts to 2,990 sq. ft., and the grate area is 44.2 sq. ft. A few of the principal dimensions are as follows:

Cylinders, 20x26 ins.

Driving wheel base, 7 ft. 3 ins.; total wheel base of engine, 27 ft. 7 ins.

Weight on drivers, 92,000 lbs.; weight on truck, 42,000 lbs.; weight on trailers, 40,000 lbs.; total, 174,000 lbs.



TANDEM COMPOUND CONSOLIDATION FOR NEW YORK CENTRAL.

J. F. Deems, Supt. Motive Power. American Locomotive Company, Builders.

Heating surface—Tubes, 2,834 sq. ft.; fire box, 156 sq. ft.; total, 2,990 sq. ft.
Grate area, 44.25.
Tubes, diameter, 2 ins.; length, 16 ft. 6 ins.; thickness, No. 11; number, 330.
Grate, length, 96 ins.; width, 66 ins.
Wheels—Engine truck, diameter, $37\frac{1}{4}$ ins.
Tender—Capacity, 6,000 gals.; frame, wood with steel center beams; trucks, with cast-steel bolster; wheels, diameter, $37\frac{1}{4}$ ins.

NEW YORK CENTRAL TANDEM COMPOUND CONSOLIDATION ENGINE.

The New York Central & Hudson River Railroad have received some heavy tandem compound freight locomotives, shown on page 663. They were built at the Schenectady shops of the American Locomotive Company. The cylinders are 15 and 28x34 ins., and the driving wheels, which are all flanged, are 63 ins. in diameter. The calculated maximum tractive effort of this machine when working compound is about 38,000 lbs., and the ratio of tractive effort to adhesive weight is 4.5.

The tandem principle has advantages and disadvantages like many other things. The most obvious advantages, however, are that the thrust upon the cross head is delivered by one rod, and that the variation of pressures upon both pistons does not produce any injurious strain on cross-head guides or rods. One very easily perceived disadvantage is that economy of space demands that both cylinders be bolted close together, which renders the piston rod packing between cylinders hard to get at or repair; however, this defect is in part remedied by placing the packing in a sleeve which is capable of a certain amount of self-adjustment up and down as well as sideways.

The valves are of the balanced-piston type and are driven by indirect connected valve gear. All the driving wheels are flanged, and the two forward ones are equalized with the pony truck, while the two rear wheels are equalized together. The cross head is of the two-guide type, with upper guide cut out to receive the lip on the upper portion of the cross head.

The boiler is of the straight-top variety, with wide fire box, and measures $72\frac{3}{16}$ ins. outside diameter at the first ring. There is a four-inch hand hole in the bottom of the boiler, at the smoke-box

end, and there is a fifteen-inch mud drum placed near the throat sheet.

The engines present a compact and powerful appearance, and are designed for fast heavy freight. A few of the dimensions are given below:

GENERAL DIMENSIONS.

Weight in working order, 200,000 lbs.
Weight on drivers, 172,500 lbs.; weight engine and tender in working order, 306,400 lbs.
Wheel base, rigid, 17 ft.; total, 26 ft. 3 ins.
Wheel base, total, engine and tender, 54 ft. 3 ins.
Cylinders, 15 and 28x34 ins.

VALVES.

Greatest travel of valves, 6 ins.
Outside lap of slide valves, 1 in.; inside lap, none; H. P. clearance, 0 in.; L. P. clearance, $\frac{1}{4}$ in.
Lead of valves in full gear L. P. line and line; F. & B., H. P., $\frac{1}{4}$ in. lead.

WHEELS, ETC.

Dia. of driving wheels outside of tire, 63 ins.
Dia. and length of driving journals, main, $9\frac{1}{2}$ ins., 1, F. & B. 9x12 ins.; dia. and length of main crank pin journals, $7\frac{1}{2}$x$5\frac{1}{4}$ ins.
Dia. and length of side rod crank pin journals, main, $6\frac{1}{2}$x6 ins., F. & B. $5\frac{1}{2}$x$4\frac{3}{4}$ ins.

BOILER.

Working pressure, 210 lbs.; thickness of plates in barrel and outside of fire box, $\frac{25}{32}$, $\frac{5}{8}$, $\frac{13}{16}$, $\frac{1}{2}$ in.
Fire box plates, thickness, sides, $\frac{5}{16}$ in.; back, $\frac{3}{8}$ in.; crown, $\frac{3}{8}$ in.; tube sheet, $\frac{1}{2}$ in.
Fire box water space, 4 and 5 in. front, $3\frac{1}{2}$ and $5\frac{1}{2}$ in. sides, $3\frac{1}{2}$ and $4\frac{1}{2}$ in. back.
Tubes, number, 396; dia., 2 ins. O. D.; length over tube sheets, 16 ft.
Heating surface, tubes, 3,298.08 sq. ft.; water tubes, 27.09 sq. ft.; fire box, 155.40 sq. ft.; total, 3,480.57 sq. ft.; grate surface 50.32 sq. ft.

TENDER.

Weight, empty, 44,750 lbs.; wheel base, 16 ft. $7\frac{1}{2}$ ins.
Water capacity, 5,000 U. S. gals.; coal, 10 tons.

TEN-WHEEL ENGINES FOR THE CENTRAL OF GEORGIA.

The Central of Georgia received some simple 4-6-0 engines from the Rogers Locomotive Works, of Paterson, N. J., one of which is illustrated on page 667. These engines have cylinders 19x20 ins., and the driving wheels are 69 ins. With a pressure of 200 lbs. to the square inch, the calculated tractive force of these engines is about 23,100 lbs., and as the weight on drivers is 116,000 lbs., it follows that the ratio of adhesive weight to tractive power is about 5. The total weight of the machine is 148,000 lbs. The symmetrical appearance which these engines have is no doubt in part due to the fact that the drivers are all equally spaced and the center line of the boiler is so placed as to add to the general effect. The drivers are equalized together on underhung springs.

The valve motion is indirect connected and the valves are of the ordinary balanced slide-valve type. The cross heads are the two guide-bar style, with the upper part of the top guide slightly overhanging the cross head, which is lipped up into the recess, thus avoiding collecting dirt and grit.

The boiler is $62\frac{1}{2}$ ins. in diameter at the smoke-box end, and is of the extension wagon-top type. There are about 2,123 sq. ft. of heating surface in the boiler and the length of the tubes is 13 ft. 7 ins. The whistle is placed in a somewhat protected position behind the dome, and the pop valves are below the level of the dome casing, which adds to the general appearance of the machine. The headlight, as will be seen in the illustration, is electric, and the beam of light is thrown from a 17-in. reflector.

A few of the leading dimensions are appended for reference:

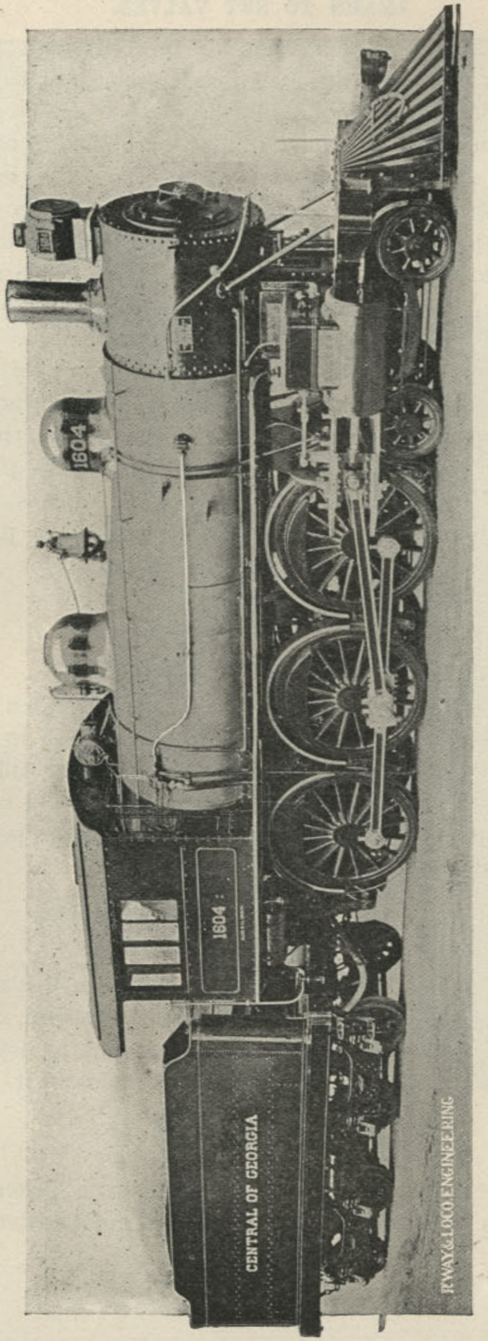
Cylinders, 19x26 ins.

Drivers.—Diameter, 69 ins.; driving journals, 9x12 ins.; driving wheel base, 13 ft.; total wheel base of engine, 23 ft. 5 ins.; weight on drivers, 116,000 lbs.; weight on truck, 32,000 lbs.; total, 148,000 lbs.

Heating surface.—Tubes, 1,955.80 sq. ft.; fire box, 167.57 sq. ft.; total, 2,123.37 sq. ft.; grate area, 30.59 sq. ft.

Tubes.—Diameter, 2 ins. O. D.; length, 13 ft. 7 ins.; thickness, No. 12 gauge; total number, 275.

Boiler.—Working pressure, 200 lbs.; thickness of barrel, $\frac{21}{32}$ in.: thickness of dome course, $\frac{3}{4}$ in.; thickness of crown, $\frac{7}{16}$ in.; thickness of tube, $\frac{6}{16}$ in.; thickness of side, $\frac{3}{8}$ in.



TEN-WHEEL ENGINE FOR THE CENTRAL OF GEORGIA.

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LEARN TO SET VALVES.

Nearly every intelligent man connected with locomotive maintenance or operation desires to understand how to set valves; but very few people have an opportunity to learn how the work is done. By the aid of the valve motion here shown, now handled by the Angus Sinclair Company, any person can learn to set valves just as easily as if he had a real locomotive to experiment with. All the parts that are adjustable in the valve motion or a real engine are adjustable in this model. The eccentrics can be rotated on the shaft to any position, the eccentric rods and the valve stem can be changed in length and the hanger stud of the link being secured to a sliding block, the point of suspension can be changed to adjust the cut-off. That feature and the moveable eccentrics give good opportunity to experiment as to how the valve motion is often out of square. A piston valve can be put in to replace the slide valve when that is desired. It is the best valve-motion model ever offered, at a price within the reach of an ordinary engineman or shopman.

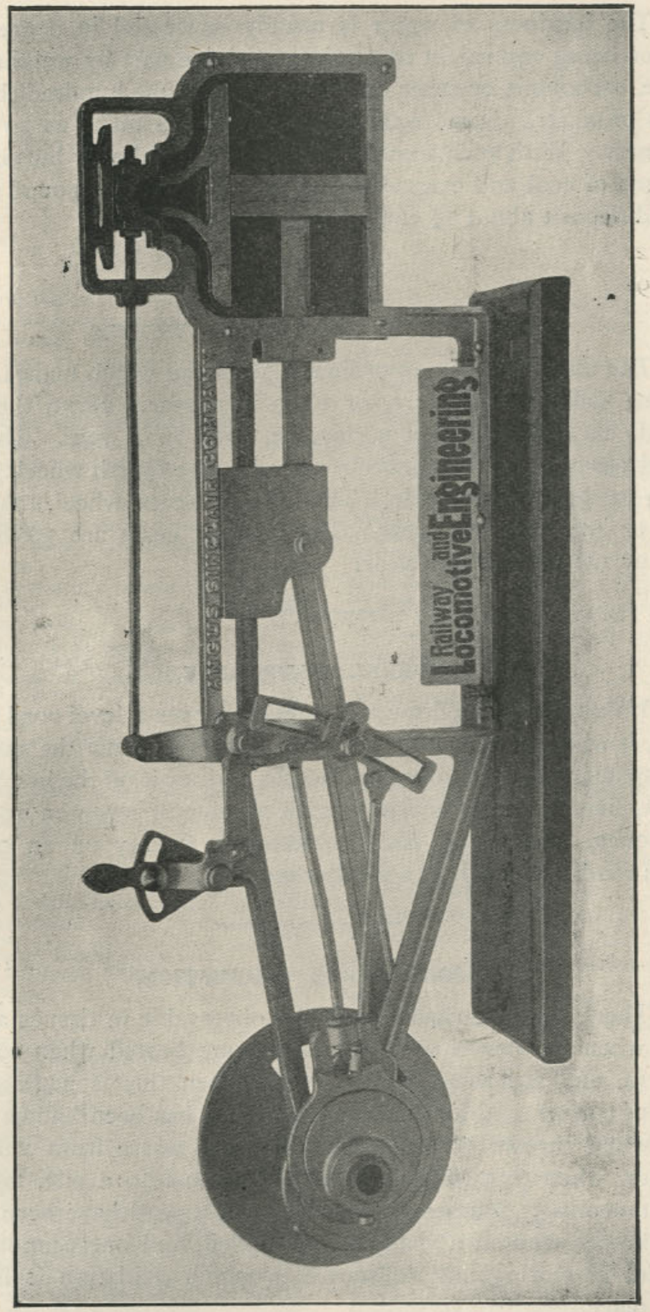
HOW BOILER PLATES ARE TESTED.

This is done by placing a piece of Bessemer steel ten inches long in a testing machine. Gradually the surface scales off in the middle, to become smaller in area, and somewhat elongated, till, at last, it breaks with a sharp snap at a breaking strain of about twenty-eight tons to the square inch, the reduction of area being 51 per cent., and the elongation 23 per cent.

HOW TO MAKE TRACING PAPER.

Take some good thin printing paper, and brush it over on one side with a solution consisting of one part, by measure, of castor oil in two parts of meth. spirit; blot off and hang up to dry. You can trace by pencil or ink on this. I have tried it and done it.

The degrees of a curve, so frequently heard spoken of among railroad men, is found by the angle subtended at its center by a chord of 100 feet.



ANGUS SINCLAIR COMPANY'S VALVE MOTION MODEL.

HARDNESS OF WATER.

The hardness of water is usually expressed in degrees, one degree being equivalent to a solution of one part by weight of sulphate, carbonate, or other hardening salt, in one hundred thousand parts of water. Some well waters contain as much as 30 deg. of hardness. With such a water an ordinary mill boiler burning, say, 25 tons of coal and evaporating 8 lbs. of water per pound of coal, would deposit about 1¼ cwt. of scale per week.

REVOLUTIONS OF DRIVING WHEELS.

The main wheel in an ordinary American watch makes 4 revolutions a day of 24 hours, or 1,460 in a year. Next, the center wheel, 24 revolutions in a day, or 8,760 in a year. The third wheel 192 in a day, or 59,080 in a year. The fourth wheel, 2,440 in a day, or 545,600 in a year. The fifth, or 'scape wheel, 12,960 in a day, or 4,728,200 in a year. The ticks or beats are 388,800 in a day, or 141,882,000 in a year.

WHEEL RESISTANCE.

If one horse can draw a certain load over a level road on iron rails, it will take one and two-thirds horses to draw the same load on asphalt, three and one-third horses to draw it on the best Belgian block, five on the ordinary Belgian pavement, seven on good cobblestones, thirteen on bad cobblestones, twenty on an ordinary earth road, and forty on a sandy road.

SPONTANEOUS COMBUSTION.

There is a remarkable tendency observable in tissues and cotton, when moistened with oil, to become heated when oxidation sets in, and sad results often follow when this is neglected. A wad of cotton used for rubbing a painting has been known to take fire when thrown through the air. The waste from vulcanized rubber, when thrown in a damp condition into a pile, takes fire spontaneously. Masses of coal stored in a yard have been known to take fire without a spark being applied, and one cannot be too careful in storing any substance in which oxidation is liable to take place.

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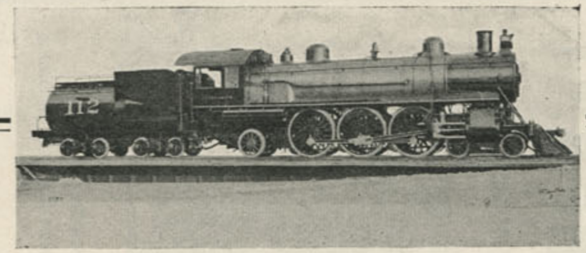

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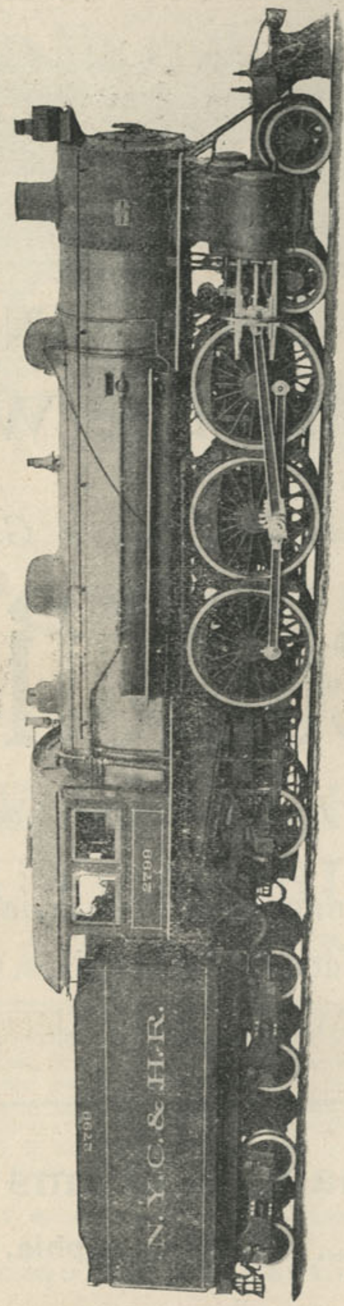

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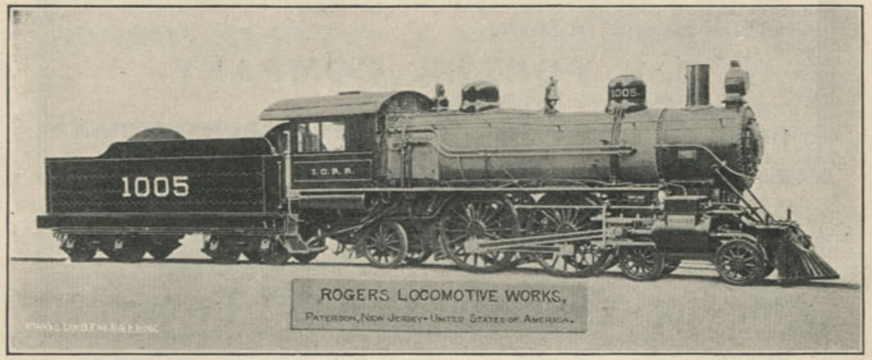

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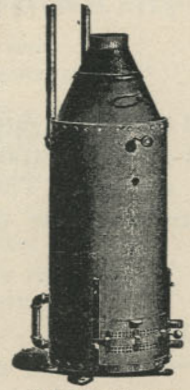

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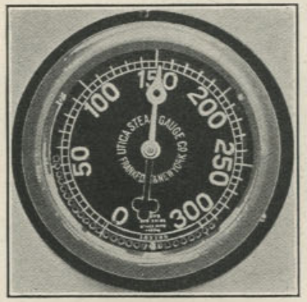

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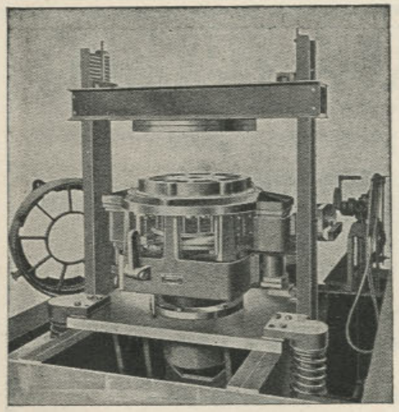

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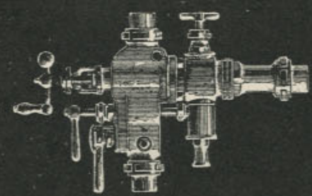

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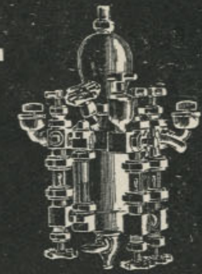

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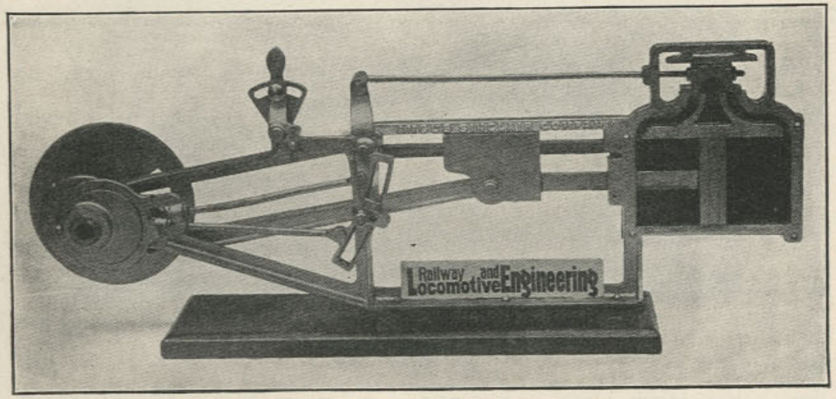

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