LOCOMOTIVE ENGINE BREAKDOWNS AND HOW TO REPAIR THEM

WITH QUESTIONS AND ANSWERS

ILLUSTRATED

WALLACE

Locomotive Breakdown Questions

ANSWERED AND ILLUSTRATED

BY W. G. WALLACE

PAST PRESIDENT TRAVELING ENGINEERS' ASSOCIATION

INDEXED FOR QUICK REFERENCE

CHICAGO

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1907

Locomotive Breakdown Questions

Answered and Illustrated

Being nearly 400 questions that were asked by enginemen during a series of years, answered by Mr. Wallace through the columns of the "Brotherhood of Locomotive Firemen's Magazine." They cover almost every possible "Breakdown" and include many difficult problems, all of which are answered in a clear-cut manner in simple terms easily comprehended by railway men.

Valuable Pointers, Rules, and Tables

With Numerous Engravings

PREFACE

The questions with answers thereto which are here given in compact book form were asked through the "Brotherhood of Locomotive Firemen's Magazine" by members of the brotherhood, and were answered through its columns by Mr. W. G. Wallace.

They have been collected together, carefully revised, and edited by him, for publication in this form.

These questions were the outcome of "snags" met, or problems encountered in the daily work of practical men; they cover a wide range of subjects, and in preparing them in compact form to go between the covers of a book great care was bestowed upon the index. Each question and answer has been given a number, and by reference to the index, which is alphabetically arranged, the questions and their answers may be readily found by their numbers through the system of cross-indexing which has been employed wherever possible.

No expense has been spared in using diagrams and cuts to illustrate answers when a clearer understanding of the subject seemed possible by so doing.

Mr. W. G. Wallace needs no introduction by us to the great army of locomotive enginemen and firemen. For many years he has been a writer for the "Brotherhood of Locomotive Firemen's Magazine" and other technical publications, is author of a valuable treatise on locomotive running, and for over a quarter of a century has been actively engaged in the motive power department of railways. As an acknowledged authority on questions relating to locomotive running he is widely known.

He desires to take this opportunity to express publicly, through us, his thanks to the Editor "Brotherhood of Locomotive Firemen's Magazine" for according him permission to have published in book form the questions and answers which appeared in that publication. He also wishes to express the hope that in this more convenient form they may prove of practical benefit to many who otherwise might never have seen them.

RAILWAY PUBLICATIONS SOCIETY.

AMERICAN LOCOMOTIVE COMPANY

ENGINEERING DEPARTMENT

CLASSIFICATION OF LOCOMOTIVES

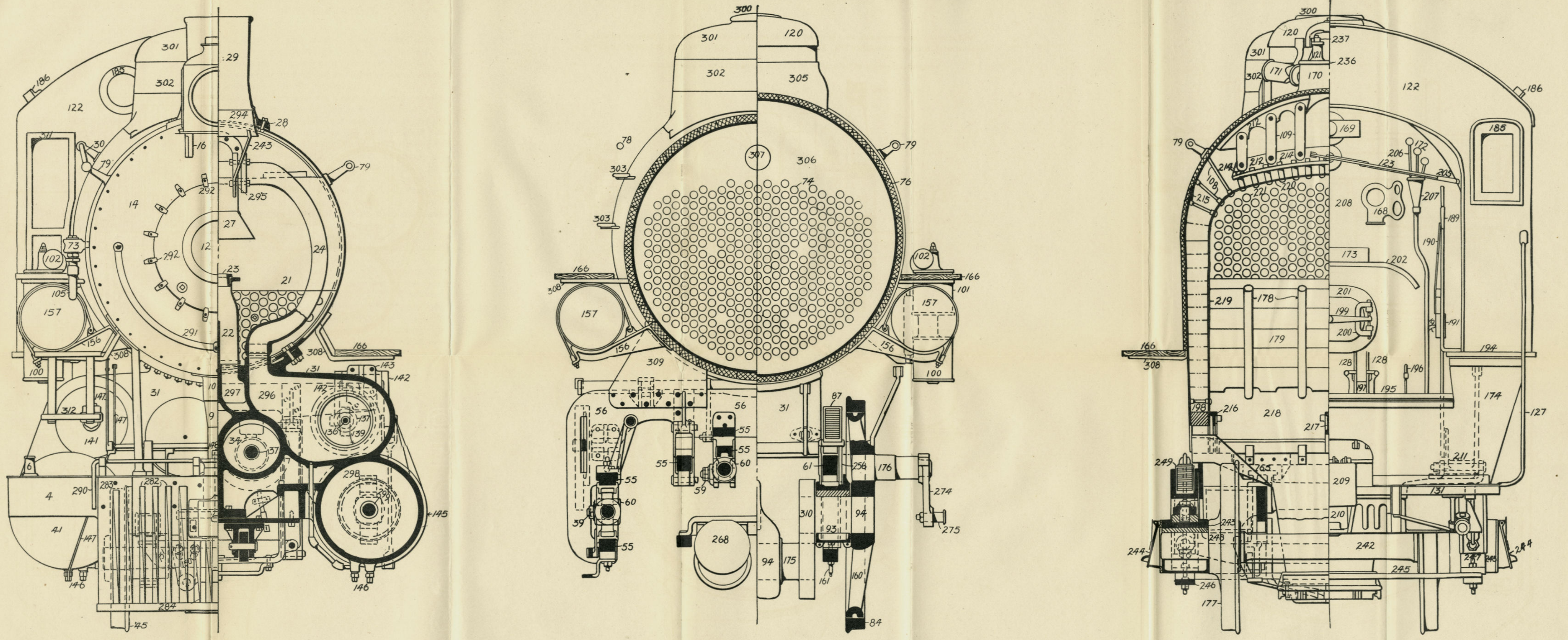
(WHYTE'S SYSTEM)

040	4 WHEEL SWITCHER
060	6 " "
0660	ARTICULATED
080	8 WHEEL SWITCHER
240	4 COUPLED
260	MOGUL
280	CONSOLIDATION
2100	DECAPOD
440	8 WHEEL
460	10 "
480	12 "
042	4 COUPLED & TRAILING
062	6 " "
082	8 " "
044	FORNEY 4 COUPLED
064	" 6 "
046	4 "
066	" 6 "
242	COLUMBIA
262	PRAIRIE
282	8 COUPLED DOUBLE ENDER
2102	10 " " "
244	4 " " "
264	6 " " "
284	8 " " "
246	4 " " "
266	6 " " "
442	ATLANTIC
462	PACIFIC
444	4 COUPLED DOUBLE ENDER
464	6 " " "
446	4 " " "
466	6 " " "

The locomotive classification adopted by the American Locomotive Company is based on the representation by numerals of the number and arrangement of the wheels commencing at the front. Thus 260 means a Mogul and 460 a ten wheel engine, the cipher denoting that no trailing truck is used.

The total weight is expressed in 1,000 of pounds. Thus an Atlantic locomotive weighing 176,000 pounds would be classified as a 442-176 type. If the engine is Compound the letter C should be substituted for the dash thus 442 C 176. If tanks are used in place of a separate tender the letter T should be used in place of the dash. Thus a double end suburban locomotive with two wheeled leading truck, six drivers and six wheeled rear truck, weighing 214,000 pounds, would be a 266 T 214 type.

Supplement to The Art of Railroading.



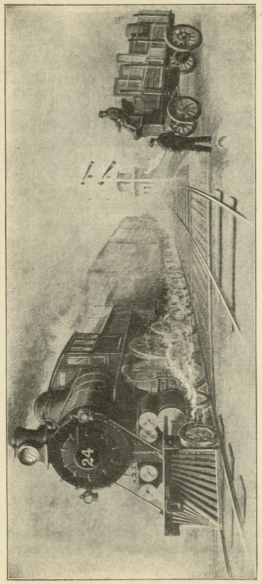
FRONT VIEW.

CROSS-SECTION AT FRONT FLUE-SHEET AND CYLINDRICAL RING OF BOILER UNDER DOME.

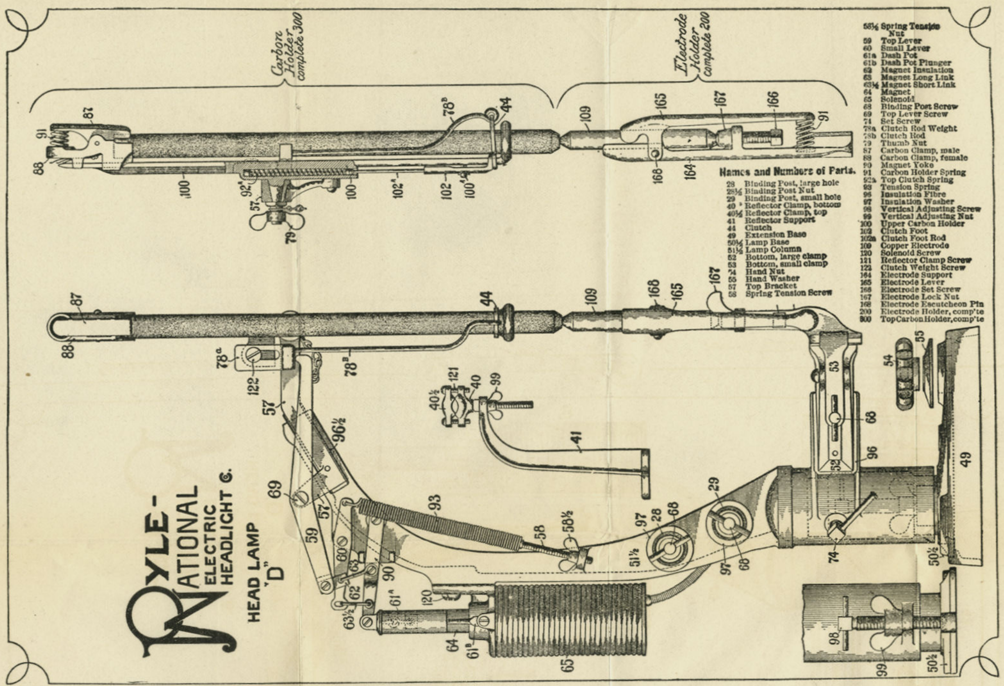
REAR VIEW.

END AND CROSS-SECTIONAL VIEWS OF "PRAIRIE" TYPE, BALANCED-COMPOUND LOCOMOTIVE.

Parts are numbered to correspond exactly with those listed on preceding plate showing side view of same engine.



Twentieth Century Transportation Methods.



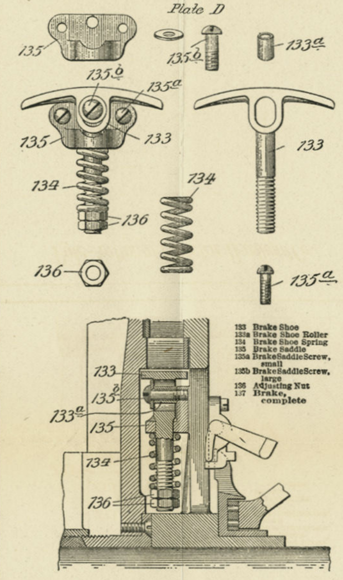
Names and Numbers of Parts.

28 Binding Post, large hole
28½ Binding Post Nut
29 Binding Post, small hole
40 Reflector Clamp, bottom
40½ Reflector Clamp, top
41 Reflector Support
44 Clutch
49 Extension Base
50½ Lamp Base
51½ Lamp Column
52 Bottom, large clamp
53 Bottom, small clamp
54 Hand Nut
55 Hand Washer
57 Top Bracket
58 Spring Tension Screw
58½ Spring Tensjon Nut
59 Top Lever
60 Small Lever
61a Dash Pot
61b Dash Pot Plunger
62 Magnet Insulation
63 Magnet Long Link
63½ Magnet Short Link
64 Magnet
65 Solenoid
68 Binding Post Screw
69 Top Lever Screw
74 Set Screw
78a Clutch Rod Weight
78b Clutch Rod
79 Thumb Nut
87 Carbon Clamp, male
88 Carbon Clamp, female
90 Magnet Yoke
91 Carbon Holder Spring
92a Top Clutch Spring
93 Tension Spring
96 Insulation Fibre
97 Insulation Washer
98 Vertical Adjusting Screw
99 Vertical Adjusting Nut
100 Upper Carbon Holder
102 Clutch Foot
102a Clutch Foot Rod
109 Copper Electrode
120 Solenoid Screw
121 Reflector Clamp Screw
122 Clutch Weight Screw
164 Electrode Support
165 Electrode Lever
166 Electrode Set Screw
167 Electrode Lock Nut
168 Electrode Escutcheon Pin
200 Electrode Holder, comp'te
300 TopCarbonHolder,comp'te

Pyle-National Electric Headlight Co.

Improved Centrifugal Brake

Plate D



133 Brake Shoe
133a Brake Shoe Roller
134 Brake Shoe Spring
135 Brake Saddle
135a BrakeSaddleScrew, small
135b BrakeSaddleScrew, large
136 Adjusting Nut
137 Brake, complete

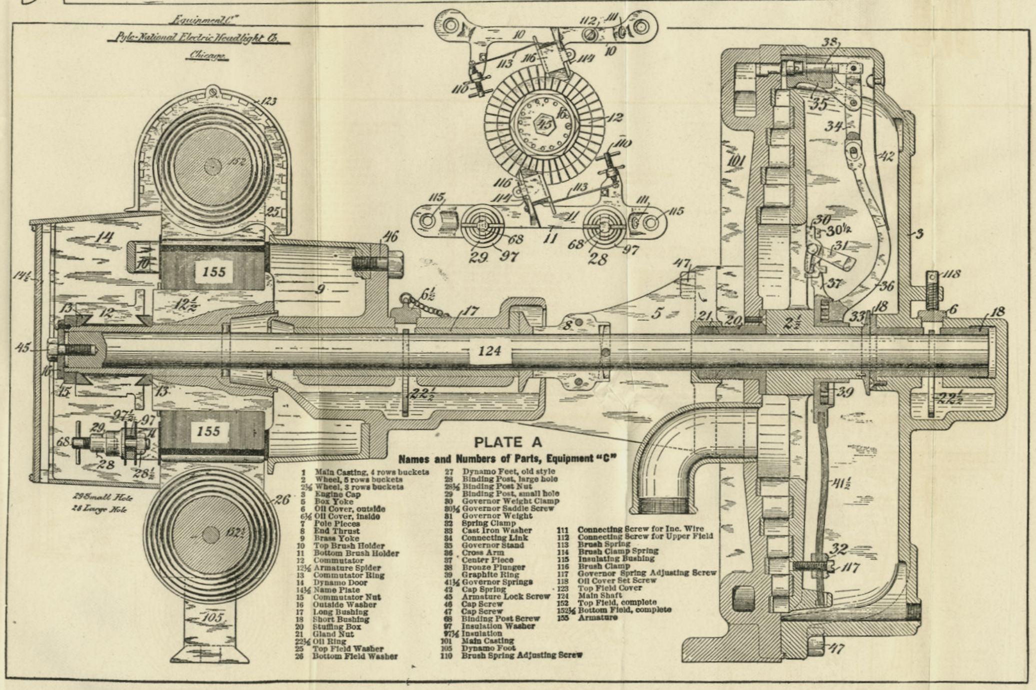


PLATE A

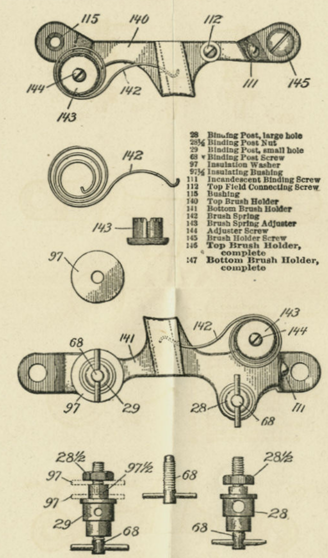
Names and Numbers of Parts, Equipment "C"

1 Main Casting, 4 rows buckets
2 Wheel, 5 rows buckets
2½ Wheel, 3 rows buckets
3 Engine Cap
5 Box Yoke
6 Oil Cover, outside
6½ Oil Cover, inside
7 Pole Pieces
8 End Thrust
9 Brass Yoke
10 Top Brush Holder
11 Bottom Brush Holder
12 Commutator
12½ Armature Spider
13 Commutator Ring
14 Dynamo Door
14½ Name Plate
15 Commutator Nut
16 Outside Washer
17 Long Bushing
18 Short Bushing
20 Stuffing Box
21 Gland Nut
22½ Oil Ring
25 Top Field Washer
26 Bottom Field Washer
27 Dynamo Feet, old style
28 Binding Post, large hole
28½ Binding Post Nut
29 Binding Post, small hole
30 Governor Weight Clamp
30½ Governor Saddle Screw
31 Governor Weight
32 Spring Clamp
33 Cast Iron Washer
34 Connecting Link
35 Governor Stand
36 Cross Arm
37 Center Piece
38 Bronze Plunger
39 Graphite Ring
41½ Governor Springs
42 Cap Spring
45 Armature Lock Screw
46 Cap Screw
47 Cap Screw
68 Binding Post Screw
97 Insulation Washer
97½ Insulation
101 Main Casting
105 Dynamo Foot
110 Brush Spring Adjusting Screw
111 Connecting Screw for Inc. Wire
112 Connecting Screw for Upper Field
113 Brush Spring
114 Brush Clamp Spring
115 Insulating Bushing
116 Brush Clamp
117 Governor Spring Adjusting Screw
118 Oil Cover Set Screw
123 Top Field Cover
124 Main Shaft
152 Top Field, complete
152½ Bottom Field, complete
155 Armature

Pyle-National Electric Headlight Co.

Improved Brush Holders.

Plate C.



28 Binding Post, large hole
28½ Binding Post Nut
29 Binding Post, small hole
68 Binding Post Screw
97 Insulation Washer
97½ Insulating Bushing
111 Incandescent Binding Screw
112 Top Field Connecting Screw
115 Bushing
140 Top Brush Holder
141 Bottom Brush Holder
142 Brush Spring
143 Brush Spring Adjuster
144 Adjuster Screw
145 Brush Holder Screw
146 Top Brush Holder, complete
147 Bottom Brush Holder, complete

LOCOMOTIVE BREAKDOWN QUESTIONS

1. Cross-Feed of Lubricator.—"Is it possible for a lubricator to cross-feed and allow all the oil to go to one steam chest?"

Answer.—It is possible for some lubricators to cross-feed, although it does not happen frequently. With choke or oil pipe stopped up on some lubricators the equalizing tube becomes filled with water, and the oil, instead of being forced through the choke plug by or with the steam from the equalizing tube, rises through the water to the top of the equalizing tube in the condensing chamber and is carried over to the equalizing tube on the opposite side and through the choke plug to the oil pipe on the side that has the equalizing tube open, thereby cross-feeding.

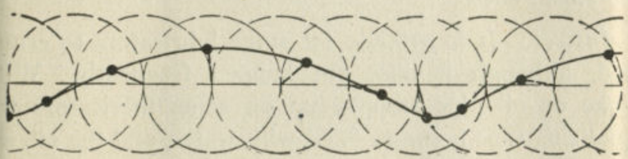
This can usually be detected by the sluggish manner in which the oil rises through the water on the defective side of the lubricator.

2. By-Pass Valve on Lubricators.—"What advantage has the by-pass valve, that is, in speaking of lubricators? Explain how it is operated."

Answer.—The advantage of a by-pass valve on a lubricator is that it takes the place of a hand oiler, and in case the feed valve is stopped up or the glass breaks, the valves and cylinders can be lubricated without shutting off steam. When the by-pass valve is opened the oil will flow directly from the oil reservoir through the by-pass valve to the oil pipe. They can be regulated to feed the same as the feed valves when necessary, but it would not be a sight-feed lubricator when the by-pass valves are being used.

3. Motion of Main Pin.—"Please describe the motion of the main pin on a locomotive as it moves along?"

Answer.—The motion is like this: (See illustration.)



4. Positions of Eccentric Rods in Relation to Link Block.—"What are the positions of the eccentric rods in relation to the link block in full forward and full backward motion?"

Answer.—Nearly opposite the link block in both motions.

5. Front-End Appliances.—"Name what adjustments can be made to the different appliances in the front end of a locomotive and the effect of changing each on the fire.

Answer.—The Master Mechanics' standard front-end arrangement consists of a diaphragm, petticoat pipe, exhaust nozzle, and netting. The adjustments are to raise and lower petticoat pipe and diaphragm, and increase or decrease the diameter of the nozzle. The diaphragm is an apron extending downward from above the top rows of flues and usually forward to or in front of the exhaust pipe, and is for the purpose of equalizing the draft on the fire. Raising the diaphragm causes the fire to burn most in the back end of the box, and lowering it causes the fire to burn most at the front

end of the firebox. If you get it in position to burn the fire evenly on the grate surface and utilize the heating surface of the flues, you have done all you can with it. The petticoat is for the purpose of regulating the draft on the fire; it is usually made in two pieces, the lower part having the flare is called the pipe, and the straight part, or top, is the sleeve. Now, you can see if this pipe and sleeve extended from the base of the stack to the bottom of the smokebox, that there would be very little if any, draft on the fire, but by moving the top part or sleeve down and the bottom part or the pipe up above the top of the nozzle, the draft is increased within certain limits. Therefore, raising the pipe or lowering the sleeve increases the draft, and raising the sleeve and lowering the pipe decreases the draft. The nozzle, petticoat pipe and stack are in the same relation to the front-end arrangement as the tubes and nozzles are in the injector. Both are induced currents, only one is for water and the other for steam and gases. Decreasing the diameter of the nozzle tip will sometimes increase the draft on the fire, but as it also increases the back pressure in the cylinders, nozzles should be bushed or reduced only as a last resort.

6. Radial Stayed Crown Sheets.—"What are the advantages of radial stay crown sheets?"

Answer.—When crown bars are used to support crown sheet, the crown sheet is made more flat than with radial stays, and the crown bars take up water space, and, where muddy water is used, help to collect mud on the crown sheet. When radial stays are used the crown sheet may be given considerable curvature and the stays placed as near right angles as possible. The advantage is that less mud will accumulate on the crown sheet with radial stays than with crown bars, as the wash of the water from the curved surface washes the mud from the crown sheet. Radial stays take up less room and they are much cheaper, give better chance to wash out boiler, and are more favorable for inspection.

7. Manner of Securing Firebox Sheets.—"How are the inside and outside sheets of the firebox secured at the bottom?"

Answer.—The inside and outside sheets are riveted to the mud ring at the bottom of the firebox. This is of wrought iron and shaped to conform to the firebox. Long rivets are used and they pass through the ring and both sheets and are riveted over.

8. Mud in Leg of Firebox.—"What would be the effect if the leg of the firebox became filled with mud?"

Answer.—The water would not come in contact with the inside sheet and it would become burned or overheated. Heat would cause it to bulge and crack and the staybolts would pull through the sheet, necessitating patches or half side sheets on the firebox.

9. Overheating of Firebox Sheets.—"What would be the result if the firebox sheets became overheated?"

Answer.—If the firebox sheets became overheated the metal would become soft and the pressure would force the sheets from the staybolts or pull the flues through the flue sheet. This is an important part of the engineer's duty to keep the crown sheet wet. The results to you will cause you to look for a position elsewhere if you don't.

10. Position of Boiler Checks.—"Why are boiler checks placed so far away from the firebox?"

Answer.—Because it is a convenient place on the boiler to attach them and they are less liable to be knocked off, and introducing the cold feed water as far as possible from the firebox gives the advantage of increasing its temperature before it comes in contact with the heated sheets of the firebox.

11. Cast Steel Wheel Centers.—"Why do they cut cast steel wheel centers on the rim and put in filling pieces?"

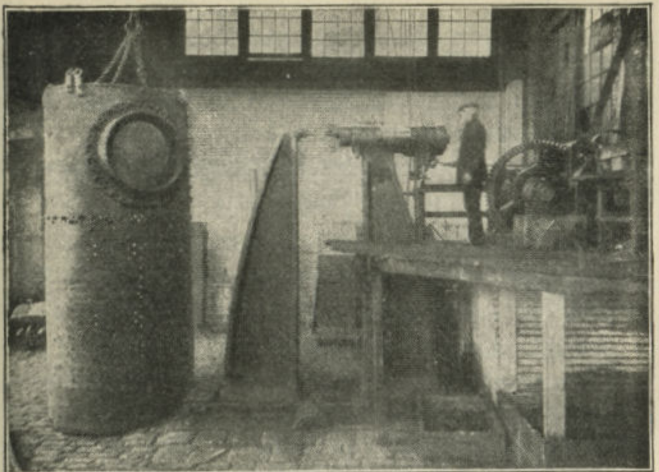
Answer.—To prevent the rim from breaking. The cuts are placed in the rim near the counterbalance and prevent the unequal contraction of the metal from cracking or breaking the rim of wheel. Owing to the large amount of metal in the counterbalance and the pin hub, and the small amount in the rim of the wheel, by using filling pieces the liability of fracture at rim is lessened.

12. Size of Nozzle Tips.—"What size nozzle tip would you recommend to be placed on a passenger engine with 20-inch cylinders and 26-inch stroke, a 'Jack Wilson high pressure' valve, and 200 pounds of steam pressure?"

Answer.—Use as large a nozzle tip as possible consistent with steam making and quality of coal used. Would recommend a nozzle tip 5⅛ inches in diameter, decreasing or increasing the size to meet the requirements.

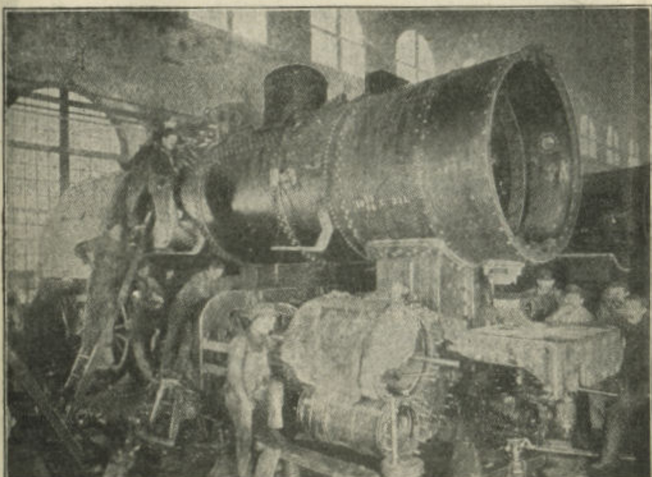
13. Lead and Clearance.—"What lead should the valves have and what inside clearance?"

Answer.—Opinions differ as to lead and clearance. Clearance may be zero or ⅛-inch, and valves may be set according to the ideas of best practice; it depends on the design of valve gear, length of eccentric rods or radius



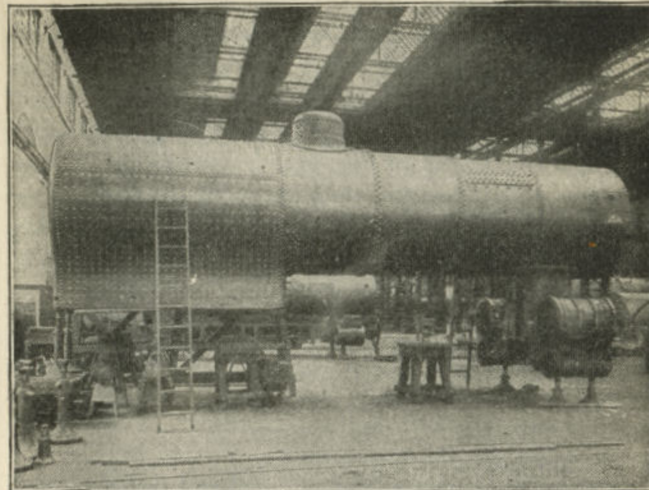
Boiler Riveting Machine

The boiler shell, suspended by chains from overhead travelers, is raised or lowered as required. The sheets pass between the fixed die, which forms rivet head on inside of shell, and the movable die, which finishes other end of rivet by hydraulic power on the outside.



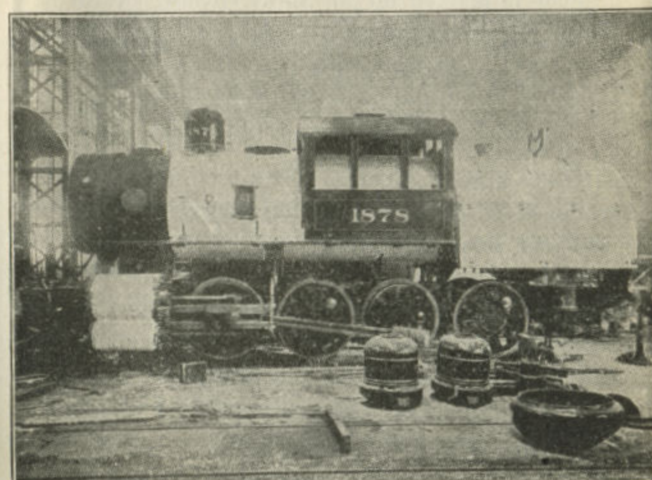
Erecting a Locomotive.

Boiler and cylinders assembled; frames in place; driving wheels in place.



Boiler as Sent to Erecting Shop.

Riveting finished, stay-bolts screwed in, dome mounted, and tube sheets inserted.



Lagging a Boiler.

Strips of magnesia are used for the purpose, fastened by cleats to wire hoops encircling the shell. Cylinders are lagged with cement. Outside the lagging, is fastened a protective sheet-iron jacket.

of link, etc. Valve set 3-32-inch blind in forward motion and line and line, or 1-16-inch blind in back motion, or so valve would have about 3-16-inch or 7-32-inch lead at 5-inch or 6-inch cut-off, will give very satisfactory service. Lead increases as the lever is hooked up towards the center and serves to retard the piston instead of accelerating it. Wait until the piston is past the center, then get the port open and admit steam to push it along. Excessive lead is often too much of a good thing.

14. Effect of Changing Back Motion Eccentric.—"What effect would changing the back motion eccentric so the valve would show 1-16-inch blind instead of line and line, have on the forward motion?"

Answer.—By setting the eccentrics in back motion blind it reduces the amount of lead in the forward motion as the lever is hooked up for short cut-off. With both motions set the same and given lead in full gear, the lead would increase in proportion to the radius of the link as the link block was brought toward the center of the link. Setting the back motion blind reduces the lead when hooked up.

15. Broken Back Motion Eccentric.—"If you were running an engine on a busy piece of track and broke the back motion eccentric, what could you do to facilitate clearing the track for other trains?"

Answer.—The engine can be run in forward motion by securing the bottom of the link stationary and working engine in full gear. Sometimes this is readily accomplished by bolting the back motion eccentric rod to the forward motion eccentric strap, using a long bolt and filling in the space between both rods with a block or large nut. This will hold the bottom of the link slightly

back of its original position when the back motion eccentric rod was coupled to the strap of the back motion eccentric, but it is a convenient and positive fastening. There should be a block placed between the bottom of the link block and the bottom of the link to prevent the engine from being reversed while running under the above conditions.

16. Failure to Observe Proper Precaution with Broken Eccentric.—"In the event of not disconnecting when the back motion eccentric was broken, what would be the effect if the lever was not left at full stroke?"

Answer.—Consequent damage to the valve gear, resulting in trouble for yourself and expense to your employer. If the eccentric was broken it would run hot and break or pound the strap to pieces. Then the back end of the eccentric rod would fall down and strike the ties, and the pressure of the valve would cause the link to tip and slide over the link block, because there would be no fastening for the bottom of the link. Do not take chances on breeding trouble. If the back motion eccentric rod was fastened to the forward motion strap the engine would be slightly lame as you hook lever up toward the center, and if the lever was put in back gear the disabled side would work in forward motion and the good side would be working in back motion. Thus the reason for blocking between the bottom of the link block and the link.

17. Cylinder Packing Rings.—"What keeps the cylinder packing rings steam tight when snap packing rings are used? Why can not steam go through the one joint in the first ring, then go around and go through next joint until it went clear through?"

Answer.—Cylinder packing rings are turned slightly larger in diameter than the cylinder, and when the ring is placed in the piston it has a slip fit in the groove and the steam that enters the joint will go under the ring and balance the pressure on the outside of the ring and usually overcome it if the ring is in fair condition. You have the spring in the ring and the steam pressure that goes through the joint, tending to force the ring outward or against the cylinder walls, and, the cylinder walls being colder than the steam, the steam is condensed and the condensation helps to keep the packing rings tight. Of course, when the ring becomes worn it loses its set or spring, and if the cylinder is worn out of round, or cut, the space between the rings and cylinder walls is so great that the steam will blow through.

18. EXPANSION VS. VALVE WITHOUT OUTSIDE OR INSIDE LAP.—"Would there be any expansion if a valve without any outside or inside lap was used and the reverse lever hooked up to the 6-inch notch, or where the engine cuts off steam at 6 inches with a valve having a lap?"

Answer.—The advantage of lap on a valve is that steam may be used expansively. The lap of the valve closes the port at the point of cut-off and the steam expands in the cylinder until the port is opened for the exhaust. If we used a valve that had no lap the outside and inside edges would register with the edges of the steam ports, and the least movement of the valve would give steam admission at one end of the cylinder and exhaust at the other. You could not use steam expansively with a valve without lap. In this case you would have the eccentric set at right angles to the pin. When lap is

added to the valve and the engines given lead, the eccentric is advanced that amount from right angle.

19.—EXPANSION AND CUT-OFF.—"How is expansion increased as the reverse lever is hooked toward the center, and does the valve travel slower in relation to the piston with a 6-inch cut-off than it would at full stroke?"

Answer.—In speaking of expansion, we mean the work done by the expansive force of steam pushing the piston to near the end of the stroke, if the steam is cut off or the port closed by the valve. If the lever is hooked toward the center the steam is cut off earlier in the stroke. The stroke of the piston is constant and can not be changed, say 26 inches or 28 inches, and when the lever is in full gear steam is admitted to the cylinder nearly its full stroke, but by hooking the reverse lever up the travel of the valve is shortened and the port is closed, cutting off the steam when the piston has made only a portion of its stroke. Therefore, the shorter the cut-off the greater the expansion, as the steam confined in the cylinder will expand until the piston reaches the part of its stroke where the port is opened for steam to escape, or what is known as the opening of exhaust. The valve must travel over its seat at full stroke twice the lap and twice the width at port opening. At six inches cut-off it would travel twice the lap and port opening, but as the port would not be full open it would not travel as far or as fast as it would at full stroke. When at full gear the link block would be nearly opposite the eccentric rod and the rod would control its movement, but at short cut-off it receives its motion from near the center of the link and both eccentric rods. Look this over when you are under an engine, and have the lever moved from full gear to 6-inch notch; it will help you to understand it.

20. Equalizing Tubes of Lubricators.—"Please explain the use of the equalizing tubes in a lubricator, and if all lubricators are supplied with them. Some lubricators do not seem to have any on the outside."

Answer.—The use of the equalizing tube in a lubricator is to equalize the pressure of steam on the water in the sight-feed glass. The steam enters the condensing chamber and condenses, forming water, and the oil is floated on the water in the oil reservoir of the lubricator and fills the oil pipes leading to the sight-feed glasses with oil. When the feed valves are open, we have the pressure of the steam and the weight of the water to force the oil through the nipple in the sight-feed glass. When you have an equalizing tube that is stopped up or an enlarged choke plug, you have this condition, and when the throttle is closed the oil is forced through the feed valve nipple in a stream. The equalizing tube is connected to the cavity above the sight-feed glass and steam exerts a pressure on top of the water in the glass. This, therefore, equalizes the pressure in the lubricator, and we have the weight of the water in height in the condensing chamber to force the oil out of the nipple, and the buoyancy of the oil causes it to rise to the surface of the water in the sight-feed glass, when it is carried into the oil pipe by the steam that came in on top of the water from the equalizing tube, which forces a small jet of steam and the oil through the choke plug. On some lubricators the equalizing tubes are inside of the condensing chamber, and on others they are on the outside.

21. Changing Length of Eccentric Rod.—"What effect would be produced upon the lap and lead by changing the length of eccentric rod?"

Answer.—None. As lap is the amount of valve that extends over the outside edges of the steam ports when the valve is in the center of its seat, changing the length of the eccentric rods would not affect the lap. Lead is the amount of opening of the steam port when the piston is at the beginning of its stroke. An engine is given lead by advancing the eccentric toward the pin, and changing the length of the eccentric rod would not change the lead. Changing the length of the eccentric rods would only cause the valve to travel a greater or less distance on either side of a line drawn through the center of the valve and the center of its seat.

22. Valve Motion for Outside and Inside Admission Valves.—"What is the difference in valve motion for outside and inside admission valves?"

Answer.—No difference in the valve gear, only in the position of the eccentrics in relation to main pin. In an engine with an indirect rocker (one with a valve arm above the rocker box and the link arm below the rocker box) and outside admission, the eccentrics are set at right angles to the pin and advance towards the pin the amount of lap and lead. Now, if you change the cylinders on this engine and use an inside admission valve, you would only need to change the position of the eccentrics. You would set the eccentric at right angles to the pin, and instead of advancing them towards the pin the amount of lap and lead, you would advance them away from the pin that amount. In case it is desired to employ a direct rocker (one with the valve arm and the link arm both below the rocker box), then the eccentric would be at right angles to the pin and advance the amount of lap and lead towards the pin in the same position as they were for outside admission valve with an indirect rocker.

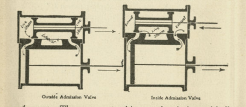
23. DIRECT MOTION VALVE GEAR.—"What is direct motion valve gear?"

Answer.—Usually termed in locomotive practice "direct motion," when the valve rod moves in the same direction as the eccentric rod. When the valve rod mov[illegible] in the opposite direction to that of the eccentric rod, we have "indirect" valve motion.

24. POSITION OF ECCENTRIC WITH DIRECT AND INDIRECT VALVE GEAR.—"Why do eccentrics occupy the position that they do with either direct or indirect valve gear?"

Answer.—To admit and exhaust steam to and fr[illegible] the cylinders at the proper time and exert a pressure [illegible] the piston which is transmitted to the pin, causing it [illegible] give a rotative force on the wheel when the crank pin is above or below the center.

25. RELATIVE MOTION OF MAIN PISTON AND VALVE FOR INSIDE AND OUTSIDE ADMISSION VALVE.—"What is relative motion of main piston and v[illegible]lve for inside admission valve and outside admission valve?"

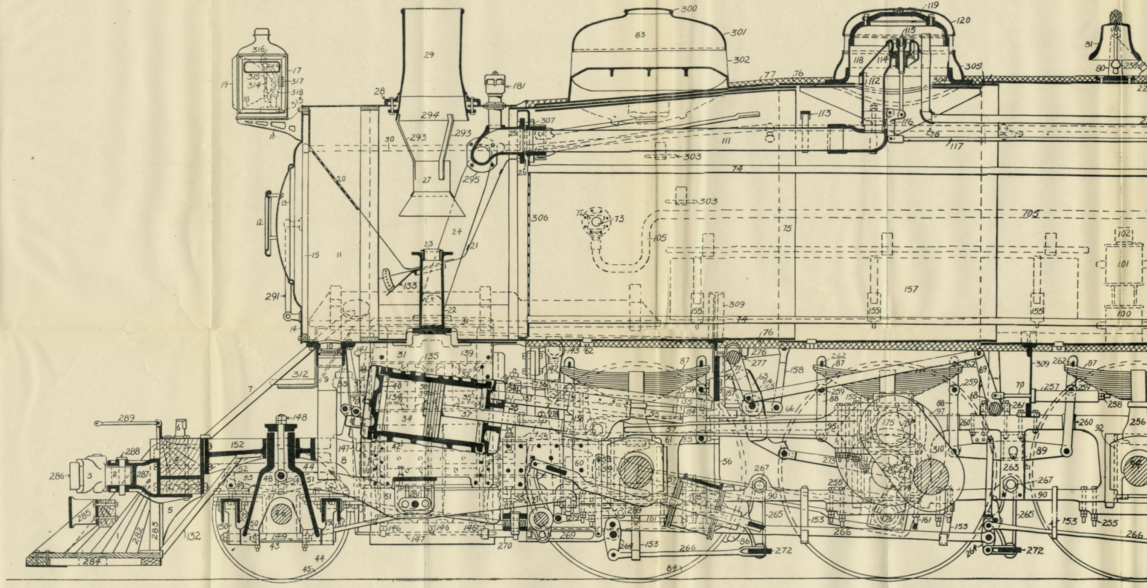


Outside Admission Valve   Inside Admission Valve

Answer.—The answer to this question is herewith illustrated. The arrows indicate the motion of valve and

Supplement to The Art of Railroading.

1. Pilot.
2. Pilot Coupler Shank.
3. Coupler.
4. Buffer Beam.
5. Pilot Bracket.
6. Flagstaff.
7. Arch Brace.
8. Front Frame.
9. Cinder Chute.
10. Cinder Shute Slide.
11. Extension Front.
12. Number Plate.
13. Smoke Arch Door.
14. Smoke Arch Front.
15. Smoke Arch Ring.
16. Headlight Bracket.
17. Headlight Case.
18. Headlight Reflector.
19. Headlight.
20. Netting.
21. Deflector Plate.
22. Nozzle Stand.
23. Nozzle Tip.
24. Steam Pipe.
25. T or Nigger Head.
26. Dry Pipe Joint.
27. Petticoat or Draft Pipe.
28. Stack Base.
29. Smokestack.
30. Arch Hand Rail.
31. Cylinder Saddle.
32. Steam Chest.
33. Relief Valve.
34. Cylinder, High-Pressure.
35. Back Cylinder-Head, High-Pressure.
36. Piston Packing, High-Pressure.
37. Piston Rod, High-Pressure.
38. Piston Head, High-Pressure.
39. Piston Packing Rings, High-Pressure.
40. Front Cylinder-Head, High-Pressure.
41. Cylinder-Head Casing, High-Pressure.
42. Cylinder Lagging, High-Pressure.
43. Engine Truck.
44. Engine Truck Wheel.
45. Engine Truck Tire.
46. Engine Truck Axle.
47. Engine Truck Box.
48. Engine Truck Pedestal.
49. Engine Truck Frame.
50. Engine Truck Pedestal Brace.
51. Engine Truck Equalizer.
52. Engine Truck Spring-Hanger.
53. Engine Truck Spring.
54. Engine Truck Spring Band.
55. Guides.
56. Guide Yoke.
57. Main Rod.
58. Main Rod Front Strap.
59. Crosshead Pin.
60. Crosshead.
61. Front Frame.
62. Wash-out Plugs.
63. Link.
64. Suspension Stud.
65. Link Block Pin.
66. Link Block.
67. Tumbling Shaft Arm.
68. Tumbling Shaft.
69. Tumbling Shaft Lever.
70. Counterbalance Spring and Rig.
71. Rocker.
72. Check Valve Case.
73. Check Valve.
74. Flues.
75. Circumferential Seam.
76. Boiler Lagging.
77. Boiler Jacket.
78. Hand Rail.
79. Hand Rail Brackets.
80. Bell Stand.
81. Bell.
82. Air Bell Ringer.
83. Sand Box.
84. Driving Wheel Tire.
85. Ashpan.
86. Driver Brakes.
87. Driver Springs.
88. Driver Spring Hangers.
89. Driver Spring Equalizers.
90. Lower Rail of Frame.
91. Driving Box Shoe.
92. Driving Box Wedge.
93. Driving Box.
94. Driving Axle.
95. Main Rod Connection.
96. Main Frame.
97. Go-Ahead Eccentric.
98. Main Rod Valve Gear.
99. Rocking Grates.
100. Air-Cylinder Brake Pump.
101. Steam-Cylinder Brake Pump.
102. Pump Valve Case.
103. Injector.
104. Water Pipe.
105. Branch Pipe.
106. Firebox.
107. Tube Sheet.
108. Radial Stay Bolts.
109. Sling Stay.
110. Stay Bolts.
111. Dry Pipe.
112. Stand Pipe.
113. Dry Pipe Hangers.
114. Throttle Pipe.
115. Throttle Valve.
116. Throttle Bell Crank.
117. Throttle Stem.
118. Dome.
119. Dome Cap.
120. Dome Casing.
121. Safety Valves.
122. Cab.
123. Throttle Lever.
124. Reverse Lever.
125. Quadrant.
126. Fire Door.
127. Hand Hold.
128. Shake Lever Stub.
129. Ashpan Damper Rod.
130. Feed Pipe.
131. Tailpiece of Frame.
132. Pilot Brace.
133. Adjustable Diaphragm Plate.
134. Piston Valve.
135. Valve Packing Rings.
136. Valve Stem.
137. Valve Stem Gland.
138. Valve Stem Support.
139. Valve Bushing.
140. Valve Chamber Head.
141. Valve Head Casing.
142. Rocker Arm.
143. Rocker Box.
144. Truck Center Casting.
145. Cylinder Casing.
146. Cylinder Cocks.
147. Cylinder Cock Rigging.
148. Truck Center Pin.
149. Truck Pedestal Bolt.
150. Three Point Hangers.
151. Truck Cross Braces.
152. Front Frame Casting.
153. Safety Hanger.
154. Guide Block.
155. Main Rod Key.
156. Air-Drum Bracket.
157. Valve Radius Bar.
158. Link Sifter.
159. Reach Rod.
160. Driving Wheel Center.
161. Wedge Bolts.
162. Frame Splice.
163. Grate Shaker Levers.
164. Grate Shaker Rods.
165. Expansion Pad.
166. Running Board.
167. Cab Ventilator.
168. Steam Gauge Bracket.
169. Steam Fountain.
170. Auxiliary Dome.
171. Steam Whistle.
172. Gauge Cocks.
173. Oil-Can Shelf.
174. Cab Wind Sheet.
175. Inside Crank Pin.
176. Outside Crank Pin.
177. Trailing Wheels.
178. Arch Tubes.
179. Brick Arch.
180. Steam Turbine.
181. Relief Valve for Dry Pipe.
182. Cab Ventilator Lever.
183. Fulcrum Ventilator Lever.
184. Cab Overhang.
185. Cab Window Sash.
186. Rain Trough.
187. Cushion, Engineer's Seat.
188. Engineer's Seat.
189. Reverse Lever Handle.
190. Reverse Lever Latch Rod.
191. Reverse Lever Latch.
192. Reverse Lever Latch Box.



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MODERN "PRAIRIE" TYPE LOCOMOTIVE.

2-6-2 Balance-Compound. Showing latest improvements in arrangement of high-pressure cylinders and cranks, counterbalance weights, and Walschaert valve gear. Numbers indicate parts named as listed. Cross-sectional and end views, similarly numbered, also details at large scale of electric headlight, will be found on other plates in this volume.

193. Quadrant Anchor.
194. Cab Foot-Board.
195. Firing Plate.
196. Ashpan Damper Handle.
197. Ashpan Lever Fulcrum.
198. Mud Ring.
199. Firedoor Latch.
200. Firedoor Hinge.
201. Firebox Door Casting.
202. Firedoor Shield.
203. Main Throttle Quadrant.
204. Throttle Quadrant.
205. Throttle Lever Handle.
206. Gauge-Cock Drain Pipes.
207. Gauge-Cock Drain Funnel.
208. Boiler Head.
209. Chafing Iron.
210. Draw Bar Pocket.
211. Reverse Lever Fulcrum.
212. Sling Stays Support.
213. Sling Stay Thimbles.
214. Sling Stay Bolts.
215. Horizontal Seam.
216. Grate Side Bars.
217. Grate Center Bar.
218. Throat Sheet.
219. Firebox Side Sheet.
220. Firebox Crown Sheet.
221. Flue Beads.
222. Back Sheet Braces.
223. Boiler Brace Tee Irons.
224. Boiler Brace Anchors.
225. Boiler Wagon Top.
226. Fountain Dry Pipe.
227. Blow-off Cock Rod.
228. Blow-off Cock Bell-Crank.
229. Blow-off Cock Stem.
230. Blow-off Cock Packing Nut.
231. Blow-off Cock.
232. Blow-off Cock Nipple.
233. Blow-off Pipe.
234. Wash-out Plug Hole.
235. Exhaust Pipe for Turbine.
236. Auxiliary Dome Casing.
237. Safety Valve Adjusting Nuts.
238. Bell Clapper.
239. Cylinder Cock Lever.
240. Main Fountain Valve.
241. Deck Casting.
242. Trailing Wheel Axle.
243. Trailing Wheel Box.
244. Trailing Wheel Box Lid.
245. Trailing Truck Cross Brace.
246. Trailing Truck Pedestal.
247. Trailing Truck Box Support.
248. Trailing Truck Brass.
249. Trailing Truck Spring.
250. Trailing Truck Spring Hanger.
251. Trailing Truck Hanger.
252. Trailing Truck Hanger Pin.
253. Trailing Truck Equalizer.
254. Trailing Truck Equalizer Hanger.
255. Main Pedestal Bolts.
256. Driving Spring Saddle.
257. Counterbalance Spring Casing.
258. Counterbalance Spring Adjusting Nut.
259. Driving Spring Hanger Knuckle-Joint.
260. Frame Protection Gib (or Key).
261. Tumbling Shaft Box.
262. Driving Spring Hanger Gib.
263. Equalizer Fulcrum.
264. Driver Brake Equalizer.
265. Driver Brake Shoe Hanger.
266. Driver Brake Rod.
267. Driver Brake Hanger Support.
268. Driver Brake Cylinder.
269. Driver Brake Adjusting Jaw.
270. Driver Brake Adjusting Screw.
271. Driver Brake Fulcrum.
272. Driver Brake Beams.
273. Eccentric Rod.
274. Eccentric Crank.
275. Eccentric Crank Pin.
276. Lifting Arm.
277. Reverse Shaft.
278. Combination Lever, Valve Motion.
279. Union Link, Valve Motion.
280. Crosshead Arm, Valve Motion.
281. Engine Truck, Equalizer Fulcrum.
282. Pilot Slats.
283. Pilot Needle Board.
284. Pilot A Frame.
285. Pilot Buffer Block.
286. Pilot Coupler Knuckle.
287. Pilot Coupler Casting.
288. Pilot Coupler Swing Pin.
289. Pilot Coupler Pin Lifter Arm.
290. Pilot Coupler Pin Lifter Handle.
291. Smoke Arch Door Hand Rail.
292. Smoke Arch Door Clips.
293. Petticoat Pipe Braces.
294. Stack Extension.
295. Nigger Head Flange.
296. Steam Passage to High-Pressure Cylinder.
297. Exhaust Steam Passage.
298. Cylinder, Low-Pressure.
299. Piston Rod, Low-Pressure.
300. Sand-Box Cover.
301. Sand-Box Cap.
302. Sand-Box Casing.
303. Enginemen's Foot Step.
304. Steam Dome Base.
305. Dome Casing Stand.
306. Front Flue Sheet.
307. Hole for Dry Pipe.
308. Running Board Brackets.
309. Boiler Belly Brace.
310. Cheek of Crank Axle.
311. Front Cab Door.
312. Front Running Board Step.
313. Extension Base.
314. Copper Electrode.
315. Carbon.
316. Carbon Holder.
317. Solenoid.
318. Lamp Column.

piston in each case. Note that with the outside admission the valve moves in the same direction as the piston while opening the port for admission, and with the inside admission the valve moves in the opposite direction to the piston while opening the port for admission.

26. BALANCE SLIDE VALVE.—"What is a balance slide valve, how is it balanced and why?"

Answer.—A balance slide valve is a valve provided with strips or rings that surround a portion of the area of the back of the valve to relieve it of pressure, and these strips or rings form a steam tight joint between the part of the valve and the underside of the steam-chest cover. Note the plain "D" slide valve in sketch, Fig. 1. You have steam-chest pressure forcing the valve

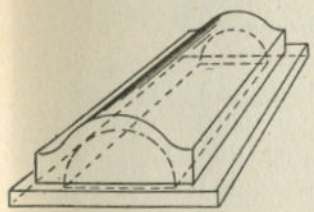


Fig. 1. Plain "D" Slide Valve

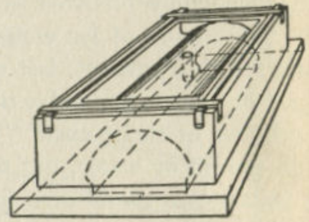


Fig. 2. Balance Valve.

to its seat at all times when the throttle is open, and the exhaust steam and the steam pressure in the cylinder when the valve has just closed the steam port or cut-off the steam forcing it up from its seat. The area of the valve being the same on both top and bottom of the valve and the steam-chest pressure being the greater, friction is produced that absorbs power. To reduce the friction and lessen the power required to move the valve back and forth over its seat for the admission and exhaust of the steam to and from the cylinder, strips or rings are employed to keep the pressure from a certain portion of the back of the valve, as shown in sketch, Fig. 2, and a hole or holes are made in the back of the valve to allow any leakage of steam past the strips or rings to escape to the exhaust cavity, thus relieving this part of the valve from steam-chest pressure. The valves are balanced to increase the efficiency of the engine, reduce the cost of lubrication, and to make the engine easy to handle.

27. Kerosene for Cleaning Cylinders and Valves.—"Is it good to give an engine kerosene into the relief valves when drifting, for cleaning out cylinders and valves?"

Answer.—If balance strips are stuck in the valve, or a packing ring gummed up in the piston, a slushing of kerosene oil will sometimes loosen them up, but it should be immediately followed by a liberal allowance of valve oil. A solution of lye would do equally as well as kerosene for this purpose, but would not recommend either. Good dry steam and valve oil are the best things to put in a cylinder or steam chest. If graphite is used, feed it in with the oil or water, but do not use a low grade of oil in your steam-chests or cylinders, as it burns and causes trouble and does not lubricate at high temperature. Keeping the throttle cracked sufficiently open to hold the relief valve shut when drifting, and the use of dry steam and valve oil, will obviate the necessity of using anything else in the steam-chests and cylinders.

28. Piston Valve.—What is a piston valve?"

Answer.—A piston valve is a valve composed of two pistons connected together, properly fitted with rings that form the edge of the valve for the opening and closing of the steam and exhaust ports.

29. Lifting and Nonlifting Injectors.—"What is

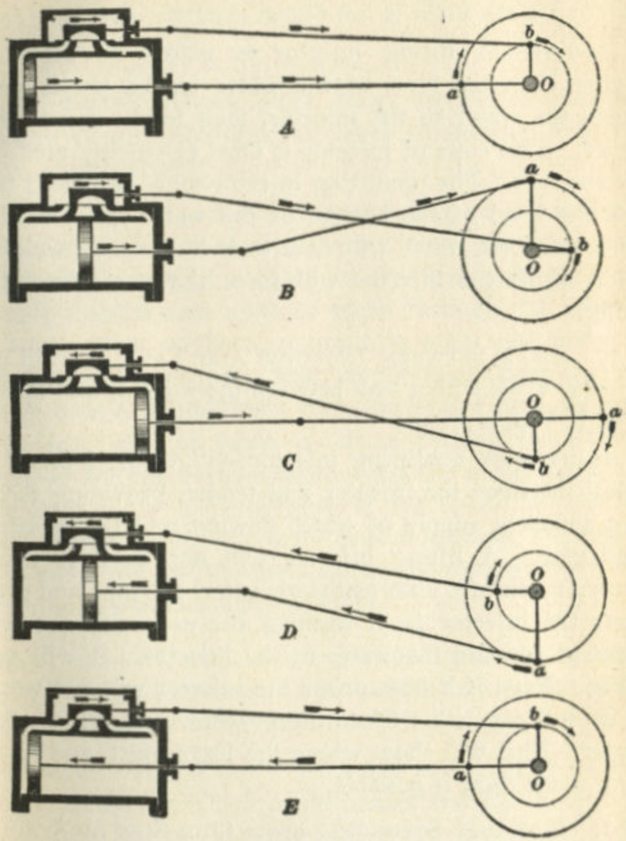


Diagram of Slide-Valve Engine.

Showing positions of piston, valve, piston-crank (Oa), and valve-crank (Ob) at each quarter-turn during one complete revolution of driver. At the start (A), port at left is about to admit steam, port at right about to be connected with exhaust, and piston about to begin outward stroke. All parts move in direction of arrows and have returned to original position in E.

the difference between a lifting and a nonlifting injector?"

Answer.—A lifting injector is placed as high or higher than the level of the water in the tender and raises the water to the injector, then forces it into the boiler. This class of injector is most commonly used on locomotives. The nonlifting injector must be placed below the level of the bottom of the water space in the tender so that water will flow to it by its own weight, after which the injector will force the water into the boiler.

30. LEAK BETWEEN INJECTOR AND TANK.—"Will an injector work with a leak between the injector and tank? Why? Will it prime?"

Answer.—A nonlifting injector will work if there is a leak between the injector and tender, providing there is a sufficient supply of water flowing into the injector feed pipe. A lifting injector will not work if there is very much of a leak, as the air enters the pipe and prevents the injector from forming the necessary vacuum required to raise the water to the injector. It will not prime. Even if it does prime the injector will not work to its full capacity. Close the overflow and put on the heater. This will show where the leaks exist, and have them made tight if possible.

31. EXHAUST STRONGEST FROM ONE SIDE OF STACK.—"What does it indicate when the exhaust issues strongest from one side of the stack?"

Answer.—If the engine has been in service and the exhaust has filled it evenly, the indications are that the petticoat pipe is loose or tipped, directing the exhaust to one side of the stack. If the engine has recently

passed through the shops, it may be that either the petticoat pipe, exhaust pipe, nozzle tip, or stack are not in line with one another.

32. LEAKY STEAM PIPE JOINT INSIDE OF SMOKEBOX.—"What is the effect of leaky steam pipe joint inside of smokebox?"

Answer.—The exhaust steam passing up through the stack expels the smoke and gases from the front end, producing a partial vacuum in the front end. Air to supply this vacuum must be taken through the ashpan, grates, hollow staybolts, combustion tubes, and firedoor. If the steam-pipe joints leak, or the joint under the exhaust pipe, or if the steam from the blower pipe, exhaust pipe from the air pump or steam turbine for electric lighting are not directed up through the stack, but strike the flare of the petticoat pipe, or are tipped so that the leak or steam will destroy the partial vacuum, the engine will not steam and the fire will not burn brightly but will burn with a smoky dull red color.

33. LEAKY CHECK AND INJECTOR THROTTLE VALVES.—"Will injector prime if checks leak bad or are stuck up, or if throttle valve leaks bad?"

Answer.—If the check leaks bad and there is no line check in the branch pipe, the steam and hot water will flow back into the injector and prevent a vacuum being formed to raise the water to the injector. If the throttle leaks bad you will have the same trouble. Sometimes injectors have been started when throttle or checks were leaking, by throwing cold water on the check or injectors, thus condensing the steam so that they would prime and bring water up to the injector.

34. Leaky Primer Valves.—"Will the injector prime if the primer valves leak? Will this prevent its working?"

Answer.—No. The primer valve leaking will only cause the injector to prime when not wanted, but would not interfere with the working of the injector when steam was turned on to force water into the boiler. To prevent waste of water, close water valve or tank valve.

35. Operation of Sight-Feed Lubricator.—Describe the manner in which a sight-feed lubricator operates?"

Answer.—Steam is condensed into water and flows down into the reservoir. As the water is heavier than the oil, the oil rises and flows into the pipe leading to the feed valves of the lubricator. The water in the condensing chamber being higher than the oil in the oil cup gives the oil below the condensing chamber the pressure equal to the height of the water above the cup. Steam pressure is also on top of the water tending to force the oil out of the feed valve nipples when feeds are open. Steam also passes through the equalizing tubes to the chambers above the sight-feed glasses and is held back by the chokers, thus equalizing the pressure on the top of the water in the sight-feed glass and the oil in the cup. Therefore, when the feed valves are opened, the pressure of the height of the water in the condenser and the buoyancy of the oil are all that forces the drop of oil up through the sight-feed glass. When the oil reaches the surface of the water in the chamber above the sight-feed glass it is opposite the hole in the choke plug and it is carried into the oil pipe leading to the steam chest by the steam that flows through the choke plug. This is why the oil will feed so fast when the hole in the choke plug is worn too large or the equalizing pipe is stopped up.

36. Effect of Draft on Working of Lubricator.—"Does the draft from an open cab window affect the working of the lubricator? Why?"

Answer.—The cold air striking the lubricator will cool it and chill the oil, which retards its flow. If the feed valves are open to feed the proper number of drops, then closing the window allowing the lubricator to get warm, the oil will feed faster, thus causing an irregularity of feed.

37. Irregularity of Feed of Lubricator.—"What else might cause irregularity of feed?"

Answer.—Dirt in the lubricator, choke plugs worn too large, equalizing tubes stopped up, or insufficient area of steam pipe to supply steam to the lubricator. Sometimes this occurs when pipes are tapped to a fountain that is too small in its main opening to supply the boiler attachments, such as injectors, air pumps, blower, smoke consumers, etc.

38. Cleaning Chokers of Lubricators.—"How would you clean out chokers?"

Answers.—Disconnect the oil pipe and run a small wire through them, or by draining the lubricator and opening feed valves and drain cock and then opening the throttle the steam will flow from the steam chest to the lubricator and may blow the obstruction into the sight-feed glass. It may be necessary to remove the choker and clean it out, but care should be exercised not to enlarge the hole in it.

39. CLEANING SIGHT-FEEDS OF LUBRICATOR.—"If sight-feeds get stopped up, how would you clean them out?"

Answer.—You can clean the sight-feeds out by removing the regulating valve and blowing steam through the nozzle or nipple, or by running a fine wire or broom-straw through it, or by draining the oil out of the cup, closing the water valve that regulates the opening between the condenser and the oil cup. Leave the drain cock at the bottom of the oil cup open. Open feed valves and steam valve, and the steam will flow down through the equalizing tubes into the sight-feed glasses, forcing the water and obstructions into the oil cup and out at the drain cock. Close the drain cock, shut the feed valves until the glasses become filled with water and the feed will work all right. Sometimes a small piece of soap put into the lubricator with the oil and then blowing the lubricator out in the above manner will improve its working.

40. CLOSING LUBRICATOR WHEN WAITING ON SIDING.—"Which is the better practice, to close the feed valves or water valve on a lubricator when waiting on a siding?"

Answer.—The feed valves always. The water valve may not be tight. It is always best to leave the water valve open except when filling the lubricator.

41. FILLING LUBRICATOR WITH COLD OIL.—"Will any bad results ensue from filling a lubricator full with cold oil?"

Answer.—The answer to this question is usually "Yes, for when the oil is heated it expands and may cause the lubricator to bulge or burst." This is not correct, as the lubricators are all tested before they leave the factory under a pressure of 500 or 600 pounds, and there is also a partition extending down from the top of the cup that will trap a small amount of air, thus providing an expansion chamber for the oil when it becomes heated. You see many lubricators filled until they overflow and no bad results come from it. Therefore, would say that no bad results would come from filling the cup too full.

42. INCREASING POWER OF AN ENGINE.—"Is there any possible way of getting more power out of an engine than that at which she is rated?"

Answer.—Increase the pressure or increase the number of revolutions per minute, or allow a longer cut-off. Any and all of the above will increase the horse-power of the engine.

43. CYLINDER CLEARANCE AND BLOCKING.—"With the kind of a guide yoke which bolts on top of the top guide and under the lower guide, there is nothing at the back end to prevent the piston coming so far back as to allow the packing rings to get caught in the counterbore. How would you block to prevent the piston coming too far back?"

Answer.—An engine that would allow the packing rings to get caught in the counterbore of the cylinder would have excessive cylinder clearance. All the room there is between the piston and the cylinder head when the piston is at the end of the stroke is called "cylinder clearance." In blocking the crosshead at either end of the stroke you would have the thickness of the piston or follower up the groove for the packing ring, and then have almost the width of the ring additional to move back or ahead before the ring would get caught in the counterbore, which rarely, if ever, occurs. Even if it should, no damage would result, as it would be discovered when repairs were being made. So block her clear back and get ready to go in on one side.

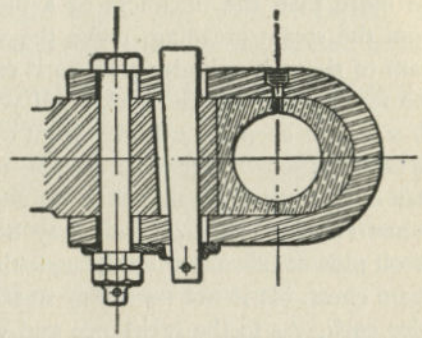
44. HANDLING HEAVY MAIN RODS IN BREAKDOWNS.—"It puzzles me how I could handle a main rod on our largest locomotives in case it was necessary to take one down on the road. In some breakdowns, such as broken guides or crossheads, how would it be to let it down on the ground then pick it up and put it on the pilot. It would be so heavy that a man could not lift it."

Answer.—Get the train crew to help you handle the rod; call on the section men if you need them. There is always a way to bring in the broken parts, and they are necessary sometimes in order to get the engine in service. You would tie up the engine if you brought her in without the main rod; you can always get help.

45. KEYING UP A DRAW STRAP.—"They say you have to loosen the strap bolts before you key up a draw strap. Please explain how I may know if it is the draw strap by looking at it, and if it is correct to loosen the bolt. Do they use drawstraps on the back end of the main rod, or just on the front end?"

Answer.—A draw strap is used on the forward end of main rods on some classes of engines, and the key goes through the main rod and strap instead of being placed between the end of the rod and the brass. The bolt is a good slip fit in the rod, but the bolt-hole in the strap is slotted and you have to loosen the bolt before you can drive the key. With this arrangement in keying the front end of the rod it is shortened instead of lengthened.

Observe the construction in sketch. Men have reported front end rod brasses filed when this kind of strap is used, because they were not familiar with it and did not loosen the bolt before trying to drive the key.



Draw-Strap for Forward End of Main Rod.

46. CLAMPING VALVE, WITH MAIN ROD AND PISTON WORKING.—"When clamping a valve with one port slightly open to lubricate cylinder in case where the main rod is left up and piston allowed to move in the cylinder, would you advise taking out cylinder cock in opposite end from the end where port is left open, or in other words, would you advise both cylinder cocks taken out? I have seen instructions to take out cylinder cock in the end that the port is left open, but it seems to me that when the piston moves towards the open port it would go against atmospheric and steam pressure and the partial vacuum at the other end of the cylinder causing a great resistance. Wherever both cocks were removed the vacuum would be less. How much would you leave the port open, judging from the flow of steam from the cylinder cock? How much resistance would the piston work against, and is there any danger of cutting the

cylinder? Would you feed oil any faster on the disabled side?"

Answer.—Take out the cylinder cock at the end of the cyclinder that you left the port open. The port opening need not be more than the thickness of a piece of tin. Judging from the steam escaping, move the valve until you get steam to show at cylinder cock so it can be seen two or three feet away from the cock. All you want is just enough steam to keep the cylinder from cutting and to carry the oil into the cylinder. To do this, feed the oil a little faster on the disabled side than on the working side, and when running, shut off; oil may be admitted through the oil pipe at lubricator or through the air inlet valve on steam chest. It is not necessary to take out the other cylinder cock. As to the resistance and vacuum on each side of the piston, it would all depend on the speed and condition of the cylinder packing rings. There is no danger of cutting cylinder if engine is properly handled. However, you will be responsible for consequential damage, but if you follow instructions you will be safe in handling the engine in the above manner.

47. Keying Siderods on Six-Wheel Connected Engine.—"Keying up siderods on a six-wheel connected engine and two keys for front and back pin, would you drive both keys for each pin or just one, and if so which one would you drive?"

Answer.—Before keying siderods see that the wedges are properly set up. Then place the engine on a straight track on dead center on the side to be keyed. Key main pin or middle connection brass first. If necessary to slack off all other keys in the siderods, do so. When you get the main pin or middle connection brasses keyed,

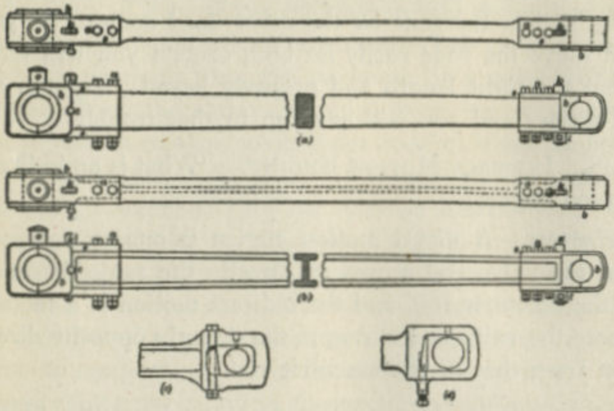
then key the back end brasses first, then the front end brasses last. Use both keys to get rods the proper length, then try rods on the other dead center. If you can move the rods easily on both centers you will have them the right length and properly keyed. Tighten up set-screws and you will have no further trouble.

48. Indirect Motion Engine.—"What is an indirect motion engine?"

Answer.—A direct motion engine is one so designed that the valve rod moves in directly the same direction as the eccentric rod, and the indirect motion is a motion where the valve rod moves in the directly opposite direction from that of the eccentric rod.

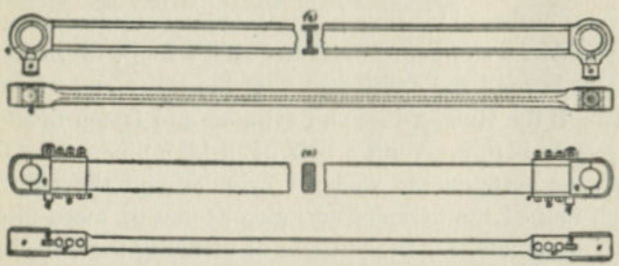
49. Lining Up a Stationary Engine.—"How would you proceed to line up a stationary engine?"

Answer.—Remove the cylinder head, piston and rod, stuffing-box gland, cross-head and connecting rod, and turn the crank to the lower quarter. First place a level on the shaft and level it, if need be, by raising or lowering the outboard bearing, as the case may require. Fasten one end of a stout cord or, better still, a fine wire to some object beyond the crank and pass the other end of wire through the stuffing-box and cylinder and fasten to some object as before. With a pair of inside calipers take the distance between the walls of cylinder and the wire at each end of the cylinder and also at one or more intermediate points, for the purpose of bringing the wire into the exact center of the cylinder. When the wire occupies a perfectly central position throughout the length of the cylinder, turn the crank around until the crank pin just touches the under side of the wire. When the pin occupies this position the distance from the wire to



TYPES OF MAIN RODS.

(a)-Rectangular cross-section type; (b)-I-cross-section type; bb, Brasses; ss, Straps; kk, Keys for adjusting brasses; cc, Set screws—and ll, Guards—securing keys in position; oo, Oil-cups.



TYPES OF SIDE RODS.

(a)-Rectangular cross-section type, with strap ends; (d)-I-cross-section type, with solid ends; kk, Keys for taking up wear of brasses in strap-end type; no provision made for this in solid-end type, but worn brasses must be replaced by new ones.

the inside of the shoulder or collar on pin should be the same on both sides of the wire. If it is not, equalize the distance by moving the outboard bearing slightly, as the case may require. Now turn crank around and bring pin up to the wire at the opposite center; again measure the distance from the wire to the inside of the collar or shoulder as before, which should be the same as at opposite end. If engine is fitted with locomotive guide bars, or a single bar-guide, the distance from the wire to the guide should be taken with the calipers at each end of the stroke, equalizing the distance of bar from wire by slightly moving the guides as the case may require. Should shaft be much out of line, requiring considerable movement of outboard bearing, it would be advisable to remove the quarter boxes and scrape them to an even bearing, otherwise the shaft in its new position will be liable to bear very heavily at the ends of the quarter boxes only and cause excessive heating. Replace all the parts removed and make the necessary adjustments with the crank on the dead center. Turn engine to opposite dead center and make sure that the crank passes the dead center easily.

50. FUNCTION OF BALL VALVE WITH MICHIGAN LUBRICATOR.—"What is the function of the ball valve in the oil pipe next to the steam chest on a Michigan lubricator, and where is its station when the throttle is open?"

Answer.—The Michigan lubricator is equipped with a steam-chest plug and ball valve. If the ball is perfectly round you will notice that near the seat for the ball there is a small hole the size of the ordinary choke plug. The position of the ball when the throttle is closed is on its seat, then the small hole serves as a choker and answers the same purpose as it did in the lubricator. Just as soon as the throttle is opened, and the steam chest pressure is greater than the oil pipe pressure, the ball leaves its seat and allows the full size opening of the oil pipe or plug for communication between the steam chest and lubricator, *i. e.*, removes the choke plug feature when the steam chest pressure is greatest and restores the choker when the lubricator pressure is the greater (throttle closed).

51. STEAM GAUGE WITH TWO POINTERS.—"We have some locomotives equipped with the Crosby steam gauge, which has two hands or pointers. What is the object of the larger one?"

Answer.—These gauges have an opening in the dial for the large figures so that the longer pointer may be in a vertical position on the dial and the figures shown through the opening denote the pressure which the boiler is permitted to carry in service, expressed distinctly and without reference to the other figures on the dial. The pressure is always easier determined by the position of the long pointer. The dial also has a circle of small figures denoting the pressures to which the gauge is adjusted, the same as on an ordinary dial. The large and small figures have respectively a large and small index; one is a check upon the other, as each should always indicate the same pressure, and the large figures shown at the top and the long index make it a very desirable feature, especially at night.

52. BROKEN-OFF CHECK VALVE.—"Can a broken-off check valve be repaired and engine brought in under steam? Explain in detail."

Answer.—That depends on the style of check valve used and its position in line with the highest point of

crown sheet. With a check valve that had a check inside of the boiler shell, it would be easy, but with the ordinary check, screwed or flanged to boiler, it would be more difficult. However, if you could keep water enough on the crown sheet to fire up with, or fill the boiler from a hose or water supply, or by being towed after plugging the check, or if flanged the check could be removed and a blind gasket inserted between the check and the boiler, you might be able to accomplish results when check valve was broken off an engine. But usually in a case of this kind the engine is damaged to such an extent that it would not always be advisable to consume the time necessary to put her in shape to bring her in under her own steam. If the line is busy, get the engine towed to the shops and have the repairs made without delaying other trains.

53. PROPER REGISTER OF STEAM GAUGE.—"How can you tell if the steam gauge is registering properly?"

Answer.—By comparing it with the test gauge or with the pop valve when it opens; also by the working of the engine, the sound of the exhaust and the whistle; the steam escaping from the open gauge cock, or the pressure shown on the air gauge. If the air-pump cylinders are same size, steam and air end, you can not get more air than you had steam, but would get less the amount of friction of piston in air pump and weight of same. If your steam gauge was fast, or indicated more pressure than you had on the boiler, you would notice it by the engine not handling her train properly. If the gauge was slow and did not show as much steam as was being carried on the boiler, and pop valves did not open at the maximum pressure, the engine would be more slippery.

54. Temperature of Firebox vs. Steam Pressure. —"What is the temperature of the firebox when the steam gauge registers 200 pounds."

Answer.—Steam at 200 pounds is at a temperature of 387.8 degrees Fahr., and if a boiler was allowed 220 pounds of steam the fire could be drawn and the boiler have 200 pounds of steam with a very much lower firebox temperature. Recent tests on a testing plant at St. Louis gave firebox temperature, ranging from 1,427 to 2,112 degrees Fahr. and smokebox temperatures from 561 to 726 degrees Fahr. Firing light and often and closing the door after each shovelful of coal has been placed in the firebox when the engine is working, will maintain a more uniform temperature. Leaving the door open while you put in four or five shovelfuls of coal will reduce the temperature possibly below the above figures. Try and keep the door shut as much as you can; it saves coal and flues.

55. Position of Saddle Pin.—"Why is the saddle pin placed back of the center of the link, instead of in the center?"

Answer.—This is to equalize the cut-off. Please note that if you place the engine at mid, or half stroke, and use a tram equal to the length of the main rod, or the distance from the center of the crosshead pin to the wheel center, and describe an arc to that radius on wheel and tire, you would find that the tram point would mark the tire forward of a perpendicular line drawn through the center of the axle, and the shorter the main rod the farther away from the perpendicular line the tram point would be, showing that the difference would increase with a short main rod and decrease with a long main rod. Now, if you move the engine from half stroke to forward center and back to half stroke, you would not move half the circumference of the wheel, but only the difference measured on the tire between the two marks made by the tram, and while you move the engine from half stroke to back center and to half stroke again, the engine would move a greater distance than on the first half of the stroke. This is due to the angularity of the main rod. Therefore, it is necessary to locate a position for the saddle pin so that equal portions of steam may be admitted alternately into the cylinder, and the cut-off be equal when the crank pin is at half stroke. This is usually accomplished by locating the point of suspension of the link back of the center, and is for the purpose of securing equality of cut-off and overcoming the angularity of the main rod and the inequality in the motion of the piston at half stroke.

56. Wide vs. Narrow Firebox.—"How does the wide firebox type of boiler, with wide firebox projecting out each side behind the wheels, differ from the narrow firebox sitting between the wheels, and what advantage has the wide firebox over the narrow firebox?"

Answer.—The wide firebox differs from the narrow firebox in height, width and length, necessarily shallow on account of being placed above instead of between the frames, and permits a larger ratio of grate area to heating surface of boiler, with a corresponding decrease in rate of combustion or coal burned per hour per square foot of grate surface, and admits of a larger water space between the inside and outside sheets of the firebox.

57. Broken Tire or Axle on Four-Wheel Switch Engine.—"How would you block up for a broken tire or axle on a four-wheel switch engine?"

Answer.—If back tire or axle, block it same as for back tire on consolidated, and block on top of driving box of good wheel on disabled side, chaining across to tender frame. If front tire or axle breaks, block up on top of back boxes, raise wheel or axle of broken tire and chain across to car to hold good flange against the rail. If necessary, a car or truck may be used to support front end of engine to get her to the shop.

58. INDIRECT MOTION ENGINE.—"With an indirect motion engine, doesn't the back-up eccentric always lead the pin a quarter of a turn less the lap and lead?"

Answer.—With an indirect motion the back motion eccentric leads the pin when the engine is running ahead, and follows the pin when backing up. It is proper to say, with this motion, that either eccentric follows the pin in either direction that the engine is running. (See Fig. 1.)

59. DIRECT MOTION ENGINE.—"With a direct motion valve gear, doesn't the go-ahead eccentric lead the main pin about a quarter of a turn?"

Answer.—A direct motion gear, inside admission valve, the eccentrics are set the same as in Fig. 1. Note Fig. 3, which shows the arrangement with the inside admission valve and direct rocker.

Fig. 5 shows the position of eccentrics if an outside admission valve were used with a direct rocker.

Fig. 7 brings you back to the starting point, only with a piston instead of a slide valve.

60. BROKEN AXLE OR BACK TIRE ON CONSOLIDATED ENGINE.—"How would you block up for a broken axle or back tire on a consolidated engine?"

Answer.—When the back driving axle breaks, if no other damage is done, remove both sections of side rods,

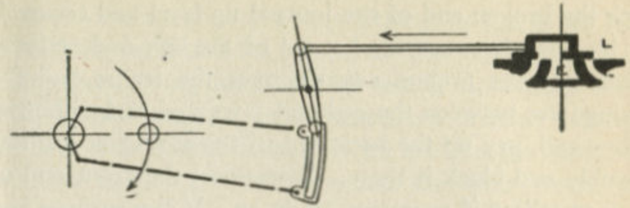


Fig. 1

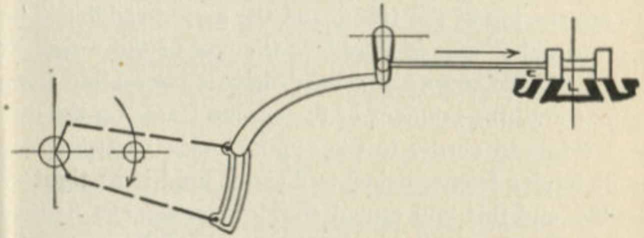


Fig. 3

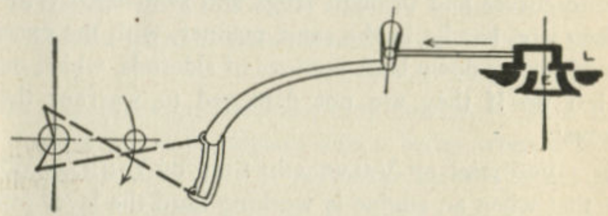


Fig. 5

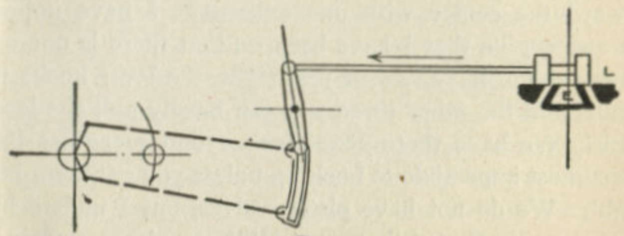


Fig. 7

Direct and Indirect Valve Motion. Illustrating Questions 58 and 59.

jack the broken end of the journal up level and secure it by blocking between the bottom of the box and pedestal brace. If the firebox extends over the frame and the springs are between the pedestal jaws and under the top frame rail, pry up the back end of the spring as high as possible and block it there. Disconnect the front end of back equalizer if necessary to do so. If the springs and equalizers are above the frame, the block should be placed between the top of the frame and the spring saddle. The object in either case is to relieve the box of the weight it carries. If the second and third drivers have blind tires, chain around the tailpiece of the engine frame on the disabled side and across to the opposite side to front corner of tender frame, using wedges to hold it as tight as possible, and this will crowd engine over against flanged driver. Cut out the driver brake, run carefully, especially around curves and through frogs and switches. With a broken tire, handle in the same manner, with the exception of taking down back sections of siderods, which may be left up if they are not damaged to warrant their removal.

61. Friction of Valve and Slip of Link.—"Why is it that when an engine is working hard the lever pulls toward the corner of the quadrant for three exhausts and toward the center with one exhaust? I have noticed on any engine that I have been on that there is one exhaust which, if you catch just right, the lever hooks up easily, and the other three you can hardly pull the lever back. We have three 20x26-inch cylinder engines that are almost impossible to hook up unless you get them just right. We do not have piston valves, but I understand they are not affected that way. Will you please explain?"

Answer.—The reason that the lever pulls forward for three exhausts and back on one exhaust is due to the friction of the valve and the slip of the link on the link block. The valve moving hard over its seat at slow speed and a well opened throttle cause increased friction between the link and the link block. If the pull on the lever was constant in the forward direction the lever would not rattle when the valves got dry. As it is, the pull is forward while making three-quarters of a revolution, or for three exhausts, and backward for one exhaust. Get out on the running board and note that the tumbling shaft arms lift up when left side is passing back center running ahead, and pulling forward while passing top quarter forward center and bottom quarter left side. Tightening up or placing more tension on the counterbalance spring and more efficient lubrication on valves will partially overcome this trouble. The reason that this is not as noticeable on piston-valve engines is due to the fact that a piston valve is more perfectly balanced than a slide valve.

62. Lubricator Siphons into Boiler.—"How does oil from a lubricator siphon into a boiler when a boiler is allowed to cool and the lubricator throttle is not shut off? What is cause?"

Answer.—When a boiler is in service it contains water and steam at a temperature in proporttion to the pressure. The steam and water occupy space. When allowed to cool the steam is condensed, and the water, losing its heat, also occupies less space. When this occurs a vacuum is formed in the boiler. Atmospheric pressure surrounding the boiler trying to get in and destroy the vacuum is the cause of the oil siphoning out of the lubricator, and this occurs only when the lubricator is not perfectly tight in all joints. A very slight leak at filling plug, around the gaskets of the oil glass, or packing nut on the feed valve, will admit air enough to destroy the vacuum and allow atmospheric pressure on top of the oil in the cup. The vacuum in the boiler will tend to draw the oil up through the steam pipe above water valve when it is open, and as this passage or pipe extends nearly to the bottom of the oil cup it affords an easy passage for the oil to siphon into the boiler. If the oil cup was absolutely airtight, oil would not siphon out. This is why it only takes place occasionally on certain engines when the lubricators are not absolutely tight.

63. TRACTIVE FORCE OR DRAWBAR PULL.—"Give a formula for figuring the tractive force or drawbar pull of any class of engine?"

Answer.—The tractive power or drawbar pull of a locomotive at slow speed may be ascertained by assuming that 85 per cent of the boiler pressure will equal the cylinder pressure, or, as it is termed, M. E. P. (mean effective pressure), and using the formula $\frac{C^2 \times S \times P}{D} = T$. C^2 means that the diameter of the cylinder should be multiplied by itself, or squared. S represents the stroke of the piston in inches, and P the mean effective pressure in pounds per square inch in the cylinder, which is usually figured at 85 per cent of the boiler pressure. D equals the diameter of the driving wheel in inches, and placed under the line means that when the diameter of the cylinder is multiplied by itself, or squared, then multiplied by the number of inches of the stroke of piston, and then by the number of pounds mean effective pressure in the cylinder, and divided by D, or the diameter of the

driving wheel in inches, this will give T = tractive power or drawbar pull of the engine, and is worked out in the following manner:

Example: A locomotive with 20x26-inch cylinders; diameter of driving wheel, 56 inches; boiler pressure, 200 pounds.

$$
\begin{array}{r}
C^2 = 20 \times 20 \\
20 \\
\hline
400 \\
S = \quad 26 \\
\hline
2400 \\
800 \\
\hline
10400
\end{array}
$$

85% of boiler pressure $= P$.

$$
\begin{array}{r}
200 \\
.85 \\
\hline
1000 \\
1600 \\
\hline
170\,00
\end{array}
$$

Now we have a pressure of 170 pounds for P.

$$
\begin{array}{r}
10400 \\
170 \\
\hline
728000 \\
10400 \\
\hline
\end{array}
$$

Diam. of driver 56)1768000(31571
168
———

88
56
———
320
280
———
400
392
———
80
56
——
4

Tractive force or drawbar pull = 31,571 pounds.

For a two-cylinder compound take two-thirds of the boiler pressure and consider the high-pressure cylinder only. Use this formula: $\frac{C^2 \times S \times 2\text{-}3\, P}{D} = T.$

For a four-cylinder compound use this formula:

$$\frac{C^2 \times S \times 2\text{-}3\, P}{D} + \frac{C^2 \times S \times 1\text{-}4\, P}{D} = \text{T, or drawbar pull.}$$

High pressure cylinders. Low pressure cylinders.

Work out for high and low pressure cylinders the same as you did for the simple engine and add the quotients.

64. Inside or Outside Admission Valve.—"How can you tell by looking at a piston valve engine whether it is inside or outside admission?"

Answer.—By the position of the rocker arm. For instance, if you had a piston valve engine on forward center, with the lever either in forward or full backward motion, if it was inside admission the valve and rod would have to move forward to open the front steam port, and if it was outside admission the valve would have to move back to open the port to admit steam to the cylinder. After you have given this a few minutes' study a glance will enable you to determine which are the inside and outside admission valves.

65. Headlight Oil in Lubricator.—"B claims that by putting headlight oil in the lubricator it benefits the lubrication of the valves. A can not see in what way it does, and B says that the engine handles better when the valve oil is mixed with a certain per cent of headlight oil and fed through the lubricator."

Answer.—Valve oil will stand a temperature of about 650 degrees of heat, headlight oil only about 300 degrees before burning. Therefore, the kerosene oil should not be mixed with valve oil and used for lubricating valves or cylinders, as it may burn and cause the strips and rings to gum. Mixing valve oil with kerosene reduces the consistency of the valve oil, and it is not advisable to use it for valves and cylinders.

66. Tractive Power of a Locomotive.—"Would there be any difference in the power of an engine by increasing the length of the stroke one inch, thereby increasing the leverage and diminishing the cylinder diameter a corresponding amount so as to leave the number of cubic inches in the cylinder the same, or vice versa? The cylinder dimensions are 22x26 inches, driving wheels 76 inches in diameter, and M. E. P. 175 pounds."

Answer.—The formula $\frac{C^2 \times S \times P}{D} = T$ is usually employed to determine the tractive power of a locomotive, and the object of this department is to furnish information if possible that will enable the readers to solve problems of this nature. Would suggest that you figure this out. The practice will be beneficial.

67. Length of Main Rod.—"What is the correct way to determine the length of a main rod?"

Answer.—If guides and cross-head are up and main driving box set properly in jaw, place the cross-head in exact center of guides and use a square, measuring from center of main driving box. When adjusting a main rod to the proper length you should always notice whether the key in the back end is in front of or behind the crank pin. When in front, you lengthen the rod as the brass wears and the key is driven down, and when behind the crank pin the rod is shortened. Divide your clearance accordingly and always consider the space occupied by the piston rod in the back end of the cylinder, which should have 1-32-inch more clearance than the front end to equalize the exhaust. Therefore to get the correct length of a main rod, place the cross-head 1-32-inch ahead of center of travel and measure to center of the axle and you have it.

68. Engine Drifting with Reverse Lever in Center of Quadrant.—"While engine is drifting with reverse lever in the center notch of the quadrant, do the rocker arms stand perfectly still, or do they move forward and back a small amount? Explain in detail."

Answer.—You understand that the lead is increased as the lever is hooked up toward the center of the quadrant. Lead is the opening of the steam port when the piston is at the beginning of its stroke. Now, in order to get any

opening of the steam port, the valve must first travel a distance equal to the lap. Therefore the valve and rocker arm would have to travel a distance of twice the lap plus twice the lead with lever in center notch while drifting.

69. Right Go-Ahead Eccentric Slipped.—"If the go-ahead eccentric on the right side is slipped, by following these directions will it be properly set? By placing the engine on top quarter and putting the reverse lever in extreme forward corner, then take out bolt on top of link clevis, put reverse lever in back corner, and drive eccentric back so as to put in bolt?"

Answer.—This method is not accurate enough to recommend your wasting any time trying to prove it. Why not place engine on forward center with lever in full gear forward and move eccentric until steam shows at front cylinder cock? This will require less time and there is no chance for a mistake. In case you want to set the eccentric by the position of the link, place engine on forward center, hook reverse lever in the center notch, then tie a nut to a piece of string and fasten it to the eccentric-rod bolt at the top of the link, and move the eccentric on the axle until the string is plumb with both the eccentric-rod bolts. This will be more satisfactory than the directions given in the question.

70. Piston Travel.—"Is the distance from the center of the rod pin to the center of the axle half of the piston travel?"

Answer.—Correct—always.

71. Cross-head Travel and Main Rod Angularity.—"Does the cross-head travel farther when the main pin travels from one center to the quarter, than it does

when the pin travels from that quarter to the opposite center?"

Answer.—If you will take a compass and make a circle to represent the crankpin circle, then draw a straight line through its center, extending the horizontal line a sufficient distance to represent the length of the main rod, then extend the compass points in proportion to the length of the main rod and describe an arc through the center of the crank-pin circle, you will find that the arc thus described will intersect the crank-pin circle in front of a vertical line drawn through the center of the crank-pin circle. The shorter the main rod the greater the distance will be from the vertical line. Now, if you mean when the main pin is on the quarter, that is, with the center of main pin and center of axle in a vertical line, the cross-head will travel farther from that quarter to forward center and back to the same vertical position than it would if the pin moved from the quarter to the back center and back to quarter. Look up the angularity of the main rod and it will help to make this clear to you.

72. Principle of the Injector.—"Describe as plainly as possible the principle upon which an injector works."

Answer.—The principle upon which an injector works is a principle of induced currents. A current of any kind has a tendency to induce a movement in the same direction of any body with which it may come in contact. A blower or any steam jet acts on the same principle. With a non-lifting injector the steam does not raise the water to the injector, as the water flows to it and is forced into the boiler by the steam imparting a portion

of its heat and velocity to the water and giving it a sufficient momentum to force it into the boiler. The steam entering the injector at a high temperature with great velocity strikes the cold water and is condensed, but imparts a large portion of the velocity to the water, sufficient for it to raise check valves and enter boiler at a high pressure. A lifting injector, so called because the injector is usually set above the level of the water in the supply tank, must raise the water to the injector, as well as force it into the boiler. When the steam valve is open slightly on a lever injector, or the lifting valve, if the injector is of that type, the steam is permitted to flow out of the nozzle, directing it to pass out of the overflow pipe to the atmosphere, carrying with it the air from the supply pipe, thus creating a partial vacuum in the pipe between the injector and the water. Then the atmospheric pressure on the surface of the water in the tank forces it into the supply pipe and out of the overflow pipe, thus priming the injector. Then when the steam valve is open, steam enters the injector in a much larger volume and, coming in contact with the water that is flowing through the injector, increases the velocity of the water which is forced into the condensing tube and out of the injector at the delivery nozzle with sufficient force to enter the branch pipe, lift the check, and enter the boiler. The steam and water flow through the injector and pipe at a high speed, forming a vacuum in the injector supply pipe and connections. Hence the importance of keeping them tight and free from leaks.

73. Circulation of Water in Boiler.—"What is meant by the circulation of water in a boiler?"

Answer.—A free movement of the water so that it may come in contact with the heating surface, and after being converted into steam be immediately replaced by a fresh supply. Proper circulation of the water is essential to the efficient operation of a boiler, as it tends to keep all its parts at a nearly uniform temperature and prevents overheating, as is the case when the boiler is filled with mud or scale. The mud does not circulate and can not carry away the heat and the sheets are burned. When a boiler is filled with cold water the water is dense, and there is little, if any, circulation, but as soon as a fire is built in the firebox or furnace, the sheets become heated and the heat is immediately absorbed by the water coming in contact with them. As the water rises in temperature it becomes lighter and rises to the surface, and the cooler water, being heavier, flows down in the space, between the flues and boiler shell, promoting the circulation. The rapidity with which heat may be absorbed from the heating surface depends on the effectiveness of the circulation in the boiler. A poor circulation will result in a poor steamer.

74. Operation of Sight-Feed Lubricator.—"Describe as plainly and completely as possible the operation of the sight-feed lubricator."

Answer.—We will assume that we have an ordinary sight-feed lubricator with a condensing chamber on top of the oil reservoir, a partition between the condensing chamber and the oil reservoir, a pipe or passage leading from the base of the condensing chamber to near the bottom of the oil reservoir, a pipe or passage for oil extending from or near the underside of the partition downward to near the bottom of the oil cup and branching out to the feed valves under the sight-feed glasses. When the cup is filled with oil and the valves opened, steam enters

the condensing chamber and condenses. The water flows down the pipe and, being heavier than the oil, the oil is floated to the top of the oil reservoir and fills the passage to the sight-feed valves with oil. Now we have a pressure on the oil equal to the pressure of steam in the cup and the weight of the water in the pipe and condensing chamber, forcing the oil through or to the sight-feed nipples. (This would occur if the equalizing tube on a lubricator was stopped up and the glass was broken.) It does not matter whether the equalizing tubes are inside of the condensing chamber or outside, the principle is the same; the equalizing tubes extend from near the top of the condensing chamber to the top of the chamber above the sight-feed glass and exert a pressure downward on the water in the glass; hence are called equalizing tubes, because they equalize the pressure in the lubricator. The choke plug is a small opening which only allows a small amount of steam to escape into the oil pipe leading to the steam chest, but it carries any water that may accumulate above the level of the choke plug into the oil pipe. Now you will readily understand why they are called equalizing tubes; when the feed valve is open a drop of oil will form in the nipple of the sight-feed glass and, on account of its being lighter than the water, it rises to the top of the water in the chamber above the sight-feed glass and is carried through the choke plug, forced into the oil pipe and to the steam chest by the steam from the equalizing tube when the pressure at the lubricator end of the pipe is greater than the pressure at the steam chest end of the pipe.

75. Blows in Main Valve and Cylinder Packing.—"How can a blow in the main valve be located and how can a blow in cylinder packing be determined?"

Answer.—Place the engine on the center, on the side you wish to test. Plumb the rocker arm and this will place the valve central on its seat. Open cylinder cocks and throttle. If steam blows out of one or both cylinder cocks when the valve is covering the ports, it indicates that the valve is blowing. In case you find that the valve is tight and you want to test the cylinder packing, place the lever in full gear, either forward or back. This will open either the front or back port leading to the cylinder; close the cylinder cocks and block open the cylinder cock at the end of the cylinder opposite to the end where the port is open, set the brake and pen the throttle, and if steam blows out of the open cylinder cock, the cylinder packing on that side will, as a rule, be found to be leaking. The sound of the steam escaping through the exhaust nozzle and stack will also assist in locating a cylinder packing blow. Taking off the front cylinder head and admitting steam to the back of the cylinder is a dead sure way to locate a cylinder packing blow.

76. Slipped Eccentric.—"How would you detect a slipped eccentric?"

Answer.—By the irregular sound of the exhaust. When an eccentric is slipped its position is changed on the shaft and if it slips toward the pin admission occurs too early, and if away from the pin admission will be delayed. When you slip an eccentric you will have no trouble in detecting it.

77. Purpose of the Link.—"What is the purpose of the link?

Answer.—The purpose of the link is for reversing the engine and varying the rate of expansion or cut-off.

The amount of travel communicated to the valve depends on the distance the link block is from the center of the link. By moving the link up or down on the link block, the travel of the valve will either be increased or decreased. On account of the ease with which it may be handled on engines, which of necessity have to run backward or forward, it is considered the most desirable for an engine requiring a reversing gear.

78. Height of Smoke-stack.—"Why is it that on our small locomotives they have such long smoke-stacks and on the large ones so short a stack? I claim that on our small locomotives, having a long exhaust pipe, the steam from the exhaust would not expand and fill the smoke-stack if it was only from 24 to 26 inches long, and on the large locomotives we have short exhaust pipes and short smoke-stacks. I claim that the reason for this is due to the large boiler and that the steam from the exhaust pipe exhausts into a petticoat pipe and expands, and thence to the smoke-stack."

Answer.—The reason for the small engine having a long stack and a large engine having a small stack is that the height of stack is governed by the limit of tunnels, bridges, roundhouses, etc. Experiments have shown that there is nothing to compensate for length of stack in promoting efficiency of the front end, consequently as long a stack as can be used is desirable. The arrangement of the front end is usually based on formulæ on which the diameter of front end is a factor, so that the larger the boiler the higher the nozzle. The short stack on large engines is so made only to give proper clearance and is compensated for as much as possible by use of petticoat pipes.

79. WORKING STEAM EXPANSIVELY.—"What is meant by working steam expansively?"

Answer.—Working steam expansively is the work done by the expansive force of the steam; after the valve has closed the port at a certain part of the stroke, then the steam thus confined in the cylinder forces the piston to the end of the stroke by its expansive force. Expanding in volume the pressure becomes less. To make it clear to you, there are four terms used in speaking of the action of steam in the cylinder. When the valve closes the port it is known as "cut-off," and the cut-off is regulated by the position of the reverse lever. Then the expansion of the steam thus confined in the cylinder forces the piston to the end of its stroke. This is called "expansion." When the valve opens the port for the escape of steam, this is called "exhaust," and the steam that does not get out of the exhaust port while the valve is open is confined in the cylinder and compressed by the piston on its return stroke. There you have admission, expansion, exhaust, and compression.

80. BALANCE SLIDE VALVE—"What is the balance slide valve, how is it balanced, and why? For what reason is a hole drilled through the top of the valve?"

Answer.—A balance slide valve is balanced by strips or rings placed in the back of the valve that fit to the balance plate. The area of the valve inside of the rings or strips is not subject to pressure for the reason that the rings or strips make a steam-tight fit and prevent the steam from exerting a downward pressure from that part of the valve. They are balanced to reduce the friction of the valve on its seat and lessen the wear on the valve gear and increase the efficiency of the engine. The hole drilled in the top of the valve is for the escape of any steam that might leak past the strips or rings. If the hole was not there for the escape of this steam and the strips or rings should leak, a pressure would be accumulated on the back of the valve and the balance feature would be lost.

81. INSIDE AND OUTSIDE ADMISSION VALVE.—What is meant by inside and outside admission valve?"

Answer.—A valve that is surrounded by steam, the outside edges of the valve uncovering the ports for admission, is known as an outside admission valve. Where the admission valve is usually made hollow in the center or in the form of a spool, and the inside edges of the valve uncover the ports for admission, then it is termed an inside admission valve.

82. RELATIVE MOTION OF PISTON AND VALVE.—"What is the relative motion of main piston and valve for inside admission valve and for outside admission valve?"

Answer.—The motion is just reversed for the reason that with an outside admission valve, to open the front port, the valve and rod would have to move back to uncover the port, where if it was an inside admission the valve would have to be moved forward to uncover the port.

83. VALVE MOTION FOR OUTSIDE AND INSIDE ADMISSION VALVES.—"What is the difference in the valve motion for an outside admission valve and an inside admission valve?"

Answer.—There need be no difference other than instead of advancing the eccentrics toward the pin, as is the case with an outside admission valve, they should be advanced away from the pin to the same angle where the indirect rocker is employed. The motion can be arranged either in the application of a direct rocker or changing the position of the eccentrics on the shaft.

84. DIRECT AND INDIRECT VALVE MOTION GEAR.—"What is a direct motion valve gear and what is an indirect motion valve gear?"

Answer.—A direct motion valve as applied to a locomotive is one where the valve rod will travel in the same direction as the eccentric rod, or both moving forward at the same time. Both arms of the rocker shaft turned either down or up. An indirect motion valve gear is a gear where the valve rod travels in the opposite direction from that of the eccentric rod.

85. INJECTOR AND LUBRICATOR QUESTIONS.—If it is necessary to take down the tank hose, how can the water be prevented from flowing out of the tank that has the siphon connection instead of the old style tank valve?"

Answer.—Put the heater on and force the water out of the siphon pipe, if they are not equipped with vent cocks or plugs for this purpose. Usually there is a plug in the siphon that should be removed to prevent water running out when hose is taken down, or there is a cock there that should be turned open. This will admit air to the pipe and prevent the water from siphoning out of the tank.

"A. If the lubricator feeds faster when the throttle is closed than open, where is the trouble?"

Answer.—Choke plugs worn too large or equalizing pipe stopped up.

"B. What is the use of an equalizing pipe in the lubricator?"

Answer.—The equalizing tube in a lubricator is for the purpose of placing a pressure on top of the water in the sight feed glass and chamber. The oil rising through the water by reason of its buoyancy does not rise very fast on account of the equalizing tube holding the pressure equal. When the tube is stopped up the pressure of steam and water in the body of the cup would force the oil through the nipple and sight feed glass into the chamber at the top of the glass, and there would be no pressure from the equalizing tube to force the oil through the choker and into the oil pipe to the steam chest.

"C. What would be the effect if the equalizing pipe became loose or broken?"

Answer.—If pipes were loose or broken, the benefit of the condensing chamber would be lost.

"D. Can you explain why, when an engine is worked slowly, with full throttle, the valves become dry, when the lubricator is apparently feeding properly?"

Answer.—Sometimes the valve on steam pipe to lubricator is not opened fully; steam pipe to lubricator too small, or if tapped from steam turret on boiler head the area of main valve on opening may be less than the combined area of the valves for the other attachments, which would prevent sufficient pressure at lubricator to work it properly at all times. When the throttle is wide open, and engine working slow, the steam chest pressure being the greatest, oil is often held in suspension in the pipes until the throttle is closed and steam chest pressure reduced. Avoid pockets and abrupt bends in oil pipes.

"E. What should you do in such a case?"

Answer.—Have the defect remedied at the shop if possible. To get in, would partly close throttle at frequent intervals and let the oil into the chests and cylinders. By partly closing the throttle and dropping the lever down for a revolution or two, the oil held in suspension in the pipes will readily go to the valve seats and cylinders.

"F. What should be done in case the combining tube of an injector became obstructed?"

Answer.—Close the main valve on boilerhead and take the steam valve or throttle out of the injector and use a wire to remove the obstruction. In most cases this can be done very quickly.

86. POINT OF CUT-OFF.—"Lap of valve is 1 inch, travel of valve is 5 inches, no lead, stroke of piston is 24 inches; at what part of stroke will the steam be cut off?"

Answer.—This depends entirely on the position of the reverse lever. Place the engine so that the piston is at any desired part of the stroke and move the reverse lever to bring the valve in position to just close the port or cut off the admission of steam to the cylinders, and you will get the part of the stroke at which steam will be cut off with the lever in that position. For instance, in case you desired to make your quadrant at a certain notch, say 5 inches, you would move the crosshead back 5 inches from the end of the stroke, then move the lever so the port would be closed for admission, this would give you a 5-inch cut-off with the lever in that position, and the position for the lever to obtain other cut-offs at different parts of the stroke could be determined in the same manner.

87. TRACTIVE POWER AND HORSEPOWER.—"When the tractive power is known on a simple engine, can the horsepower be found by using the same rule as with a compound?"

Answer.—Yes. Multiply the tractive power by the speed in miles per hour and divide by 375.

88. BACK-SET OF ROCKER ARM.—"Why is a standard rocker arm back-set?"

Answer.—A straight line engine is so called by reason of the wheel center and cylinder center being on a horizontal line, which is called the center line of motion, and a straight rocker is used for a rocker arm with no back-set. If the center of lower rocker arm is below a line drawn through the center of the axle and the center of the cylinder, there must be back-set in the rocker so that it will travel an equal distance each side of a vertical line drawn at right angles to the line of motion. Plumb the top arm of the rocker, then draw a line from center of axle to center of lower rocker arm and give it back-set enough to bring center line of lower rocker arm at right angles to the line of motion.

89. AUTOMATIC DRAIN VALVE.—"How does the automatic drain valve in the Moran steam heat or flexible joint operate?"

Answer.—The automatic drain in this joint consists of a small steel ball which is held from its seat by a spring with a tension sufficient to resist a pressure of about 15 pounds per square inch. When the steam pressure exceeds this amount the ball is forced to its seat and prevents the escape of steam or water. When the steam is shut off or the pressure falls below the resistance of the spring, the ball is forced upward from its seat and all condensation escapes, thus preventing freezing or bursting of joints if the pipe is properly located, viz.: at the lowest point in the piping system.

90. Engine Out of Tram.—"What is meant by engine out of tram?"

Answer.—When the distance between any two wheel centers on one side of the engine is not equal to the distance between the wheel centers of the corresponding wheels on the other side, or when the axles are not square with a line drawn through the center of the cylinders.

91. By-Pass Valve.—"What is a by-pass valve?"

Answer.—A by-pass valve is used on a simple piston valve engine, and is for the purpose of relieving the compression when it becomes higher than the initial pressure. It is located in a cage that extends over the port leading to the cylinder and leads to the steam chamber between the heads of the piston valve. The by-pass valve is held to its seat by the pressure in the steam chamber forcing it to closed position. Now, if from any cause, the pressure in the cylinder should be increased above that in the steam chamber, the by-pass valve would be forced from its seat and the steam would be forced back into the steam chamber, thus relieving the cylinder head and piston from an excessive pressure that would cause the cylinder head or piston to break. The piston valve working in a bushing can not lift to relieve excessive compression the same as a slide valve. Hence the necessity of the by-pass valve or relief valves in cylinder heads of piston valve engines.

92. Steam Heat Reducing Valve.—"How does the steam heat reducing valve control the pressure?"

Answer.—Similarly in manner to the operation of the air-pump governor. The valve controlling the opening in the regulating or reducing valve is forced from its seat and held in open position by the pressure put on it by a spring above the diaphragm. The more tension put on the spring the higher the pressure will be in the trainline before closing. When the steam pressure on the other side of the diaphragm exceeds the strength of the spring it is forced upward, thus preventing further flow of steam from the boiler to the heating system until the pressure is reduced. Ascertain the kind of valve used on the line where you are employed, and if you are unable to get one to take apart so you can trace the steam through it, write to the manufacturers for a descriptive circular, which will be gladly furnished. They want you to know how to handle their appliances and always grant requests for information.

93. Disconnecting for Broken Steam Chest.—"How would you disconnect for a broken steam chest?"

Answer.—This all depends on the style of chest and the extent of breakage. If the walls of the chest were broken so they could be drawn together, would slack off nuts on steam chest studs and drive wedges or nails between the studs or chest to bring the parts together. Then tighten nuts on studs and proceed. If this could not be done, would disconnect valve rod and remove chest, blocking over the steam ports leading to the steam chest and put the cover on blocks, bolting it down hard on the wooden blocks by tightening the nuts on the steam chest studs. Would not take down main rod, as lubricant could be introduced through the admission ports to the cylinder. If studs were all gone and the cover broken, would prepare to be towed in. Do not try to put in blind gasket in steam pipe joint, as it is impracticable to do so out on the road.

94. LEAKY THROTTLE OR DRY PIPE.—"How can you distinguish between a leaky throttle and dry pipe?"

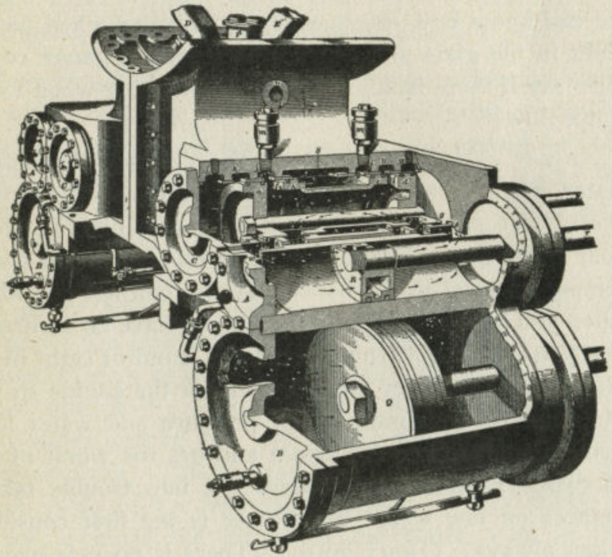
Answer.—A leaky throttle or dry pipe will be indicated by steam escaping from the cylinder cocks when the throttle is closed. If steam escapes you should be sure that the steam valve to the lubricator is closed before deciding that the throttle is leaking. If the throttle is leaking there will be a constant flow of dry steam from the cylinder cocks, and if the dry pipe is leaking more or less water will be mixed with the steam. Much depends on the position of the dry pipe in the boiler. If it should be up near the boiler shell and the leak on the upper side of the pipe, the boiler should be well filled with water before the wet steam would show at the cylinder cocks. Test for the leaky throttle first with the steam valve of the lubricator closed. If dry steam is shown, increase the height of the water level in the boiler until the dry pipe is covered with water, and if dry steam still appears report throttle; if wet, report dry pipe. If dry pipe is not submerged, the location of leak can not be determined.

95. PRIMING AND FOAMING.—"What is the difference between priming and foaming in a boiler?"

Answer.—Priming is caused by filling the boiler too full of water (think of priming a pump). Foaming is caused by the impurities of the water or by foreign substances, such as oil, soap, or anything that will cause water to foam.

96. TEST FOR LOW WATER.—"Kindly answer if the test for low water is safe, when water comes in water glass if you close top water cock, bottom one remaining open. Explain fully why we close top cock and how we can know how much water is in boiler when out of sight in the glass and can not be found in gauge cocks. Also say if there is any safe way of knowing when water is too low?"

Answer.—Much depends on the distance the bottom water glass is above the highest point of the crown sheet. Would not recommend it as safe practice to let your water get so low as to require this method of ascertaining its level in the boiler. If you can not get water when you have one or two gauges you have no assurance that you will be able to get it after it is out of sight in the glass, and it is better practice to work the engine so you can maintain maximum boiler pressure and water level than to trade water for steam and get the worst of the bargain. Engineers sometimes get into trouble taking chances on low water, and safety is the first consideration, always. (Don't do it.) There is no safe way of knowing where the water is if you can not determine the level by the gauge cock or water glass. The reason that water shows in the glass when top cock is closed is, because at the time the top cock is closed the glass is full of steam at a temperature corresponding to the pressure in the boiler. Closing the cock shuts off communication with the boiler at the top end of the glass, and the pressure of the steam in the boiler will force water into the bottom water glass cock providing the water is above the opening; the steam in the water glass is condensing, due to its exposure to a lower temperature, and the water is forced up into the glass.



CYLINDERS AND SADDLE OF A VAUCLAIN COMPOUND LOCOMOTIVE.

A–High-pressure cylinder; B–Low-pressure cylinder; C–Valve chamber; V–Piston valve; R–High-pressure piston; Q–Low-pressure piston; E–Steam pipe for left side of engine, branches in saddle, ending in chambers *g l*, surrounding valve bush; *kh* and *ji*–Steam-chest ends of passages *wx* and *ji* leading respectively to front and back ends of high and low-pressure cylinders; S–Passage leading to exhaust pipe P. Steam enters through *g* and *l*, filling both ends of steam chest; passes through *k* or *h* to high-pressure cylinder. and through *j* and *i* to low-pressure cylinder; thence through exhaust passage S.

97. BROKEN SIDE ROD ON BALDWIN BALANCE COMPOUND LOCOMOTIVE.—"We have a few of the Baldwin Balance Compound Locomotives; they are the four-wheel connected. The high pressure rods are connected to the front drivers and the low pressure rods are connected to the back drivers, the eccentrics are on the back axle. Now if we were to break a side rod, what are we to do to get the engine in? This question has come up and there is considerable discussion on the matter."

Answer.—The Baldwin Locomotive Company recommend that in a case of this kind, where the high pressure cylinders are connected to the front axle and the low pressure cylinders to the second driving axle, the eccentrics being on the second axle, if the side rod breaks on an engine of this type the high pressure pistons should be removed and the engine run in with the low pressure cylinders. Under these conditions she will run as a single expansion engine; the high pressure cylinders merely serve as steam chests for the low pressure cylinders.

98. RELATION BETWEEN VALVE AND LINK.—"Will you kindly explain the relation between the valve and the link? Does the valve travel as far when the lever is hooked up as in full stroke? How is the supply of steam cut off? Some claim it is cut off in the exhaust cavity."

Answer.—The forward motion eccentric is connected to the top of the link and the back motion eccentric to the bottom of the link, and the eccentrics are set on the axle in position to admit steam to the cylinders and cause the engine to move in either direction. The link block being connected to the lower rocker arm remains stationary in respect to the rocker, but the link can be raised or lowered by the reverse lever, tumbling shaft, link hangers, etc. Now, when the lever is in full gear, either in forward or back motion, the eccentric rod is opposite the link block and moves with the eccentric rod. The movement given the rocker is transmitted to the valve. This gives full travel of the valve with the lever in full gear, and steam is admitted during the stroke of the piston. The travel of the valve to open the steam port fully cannot be less than twice the width of the steam ports and twice the lap of the valve. If we had an engine with steam ports $1\frac{5}{8}$ inches and lap on the valve of $\frac{7}{8}$ inch, to get full port opening we would have to give the valve a travel of $(1\frac{5}{8}+\frac{7}{8})\times 2 = 5$ inches, but most locomotives have a slight overtravel. The supply of steam is cut off by the valve closing the port when the piston is at a certain portion of its stroke. In that event the port is not fully opened. We will say that steam was cut off by the valve closing the port when the piston had moved 7 inches of the stroke and we would have a maximum port opening of $\frac{1}{4}$ inch; of course the lever would be hooked up to give this cut-off and we would have a valve travel of port opening plus the lap of the valve $\times 2 = 2\frac{1}{4}$ inches. When the lever was hooked up it raised the link on the link block nearer the center of the link, and instead of the forward motion eccentric imparting its motion to the rocker arm it received its motion from both eccentrics or a compound motion which decreased the travel of the valve. The outside edge of the steam ports and the edge of the valve cut off the admission, but the inside edge of the steam port and the edge of the exhaust cavity of the valve cut off the exhaust. Possibly this is what brought up the discussion.

99. Angularity of Main Rod.—Please explain what is meant by the term 'angularity of the main rod.'"

Answer.—The reader understands that when the crank pin is on the forward center the crosshead has reached its extreme travel forward, and when the pin is on the back center the crosshead has reached its extreme back travel. If you place the crosshead in mid-stroke, the distance from the center of the wrist pin in the crosshead to the center of the axle is the length of the main rod. Now, if you would draw a circle around the axle representing the crank pin circle, and with a radius equal to the length of the main rod describe an arc, you would find that it would pass through the center of the axle and intersect the crank pin circle in front of a line drawn vertically through the center of the axle. This also applies to the outside diameter of the wheel, and measuring the distance that the wheel travels from the middle position of the crosshead to forward center and back to middle position, we find that it is much less than from middle position to back center and forward to middle position, due to the angularity of the main rod. This angularity increases with a short and decreases with a long main rod, hence the term, "angularity of the main rod."

100. Determining Size of Exhaust Nozzle.—"Will you please state how the size of the exhaust nozzle is determined? What would be the proper size nozzle for a 17x24 inch cylinder locomotive?"

Answer.—Practically determined by running as large a nozzle tip as is consistent with steam making with the quality of fuel used. We do not know of any rule that would be applicable to all engines and classes of service, but you can usually figure that the nozzle tip should contain as many square inches of area as the cylinder is in diameter, and the alterations will be slight if the engine is properly drafted and boiler in good condition. Do not bush the nozzle until you have failed to get steam by all other means. A locomotive having cylinders 17 inches in diameter should run a nozzle tip with an area of

17 inches = 4⅝ inches diameter
18 inches = 4⅞ inches diameter
19 inches = 5 inches diameter
20 inches = 5⅛ inches diameter
21 inches = 5¼ inches diameter
22 inches = 5 5-16 inches diameter

With fairly good coal and liberal heating surface of boiler.

101. HEATING SURFACE OF A BOILER.—"Will you please publish the rule showing how to find the square inches or feet of a fire-box and door and the flues of a locomotive?"

Answer.—We presume you mean the heating surface of a boiler. This is intended to include the surfaces in the boiler and firebox that are exposed to the heat of the fire and generated gases on one side and have water on the other. The total heating surface in a locomotive boiler is the crown sheet, side sheets, flue sheet and back or door sheet. The area of the front flue sheet is usually neglected in figuring the heating surface. Multiply the length of the sides and ends of the firebox by the height in inches and multiply the length of the crown sheet by its width in inches. Add the product together and subtract the combined area of the fire-door and the area of the flues in the flue sheet and divide by

144. This will give you the area in square feet of direct heating surface of the firebox. The heating surface of the flues is called the "indirect" heating surface. Multiply the circumference of one tube in inches by its length in inches and multiply that product by the total number of flues, and divide the product by 144, which will give you the heating surface in square feet of the flues. This, added to the heating surface of the firebox, will give the total heating surface. A flue 2 inches in diameter will have a circumference of 2 multiplied by 3.1416 equals 6.2832 inches. If 16 feet long, 16 feet equals 192 inches. Then 6.2832 multiplied by 192 equals 1,206.3744 square inches, the heating surface of one flue. Now multiply this by the number of flues and divide by 144 and you have the square feet of heating surface of flues. Always figure the outside diameter of flues, as that is the area that is exposed to the water, and it should be assumed that the grate is on the level with the bottom of the firebox. If the grate is above the lower edge of the firebox this height should be deducted from the heating surface.

102. FILLING BOILER OF DEAD ENGINE.—"How would you fill a boiler if a live engine was near at hand, and plenty of water was in tender of dead engine?"

Answer.—If the engine was equipped with a pump the proper thing to do would be to tow the dead engine up and down the track until the water was pumped into the boiler. If the engine had no pump, would either get her to a hose connection with water tank or city pressure and fill the boiler through the blow-off pipe on the dome, or if you could get the live engine on an adjacent track, so that the branch pipe could be disconnected from the check on dead engine and the branch pipe from live engine be coupled up to check of the dead one, working the injector would fill the boiler of the dead engine.

Having heard how to fill the boiler of a dead engine by towing her, we took a 21x26-inch piston-valve engine and a 17x24-inch slide-valve engine and plugged up cylinder cocks, relief or air valves, overflow pipes to injectors and the whistle valve, then opened injector throttle and engine throttle and placed the lever in direction that engine was moving, but with the tanks full of water we could not obtain sufficient vacuum to pull the water from the tender through the feed, injector, and branch pipes to the boiler, therefore, could not recommend even giving it a trial. Better get ready to be towed to a terminal than to waste time on theories, unless you know they will work out a successful termination of your difficulty.

When experimenting with these two engines, on account of the speed limit in the yard, we could not make more than eight or ten miles per hour, which was the possible cause of failure to fill the boiler. Boilers have been filled in this manner when a speed of from twelve to twenty-five miles per hour was attainable in distances of from six to ten miles. The delays to traffic, trains and engine crews, and the expense incurred, would more than offset the advantage unless it was an isolated case.

103. Disconnecting Engine.—"What else could be done on one of the most important passenger trains while ascending a grade about 75 miles out on a trip? I first broke piston valve, and before I could make a stop broke both the eccentric straps, blades and link hanger on that side, and knocked off the MacIntosh blow-off cock; the boiler was so full of mud that the blow-off cock did not leak. When the broken eccentrics were removed

I could not move the valve, and the back port was open, so took down the main rod and blocked the cross-head forward. Took the train 108 miles on one side, and made eight stops for stations and railway crossings, arriving 240 minutes late at terminal. Something happened so that the back cylinder head was broken when I got in. I thought that I did fine, but the 'Old Man' can not see it that way. Will you please give me all the information you can on this?"

Answer.—Not being on the engine at time of the failure, but judging from the above, it would appear that the eccentric strap or link hanger broke first, which allowed the valve to move beyond its full travel, and the valve got stuck in the bushing or a broken ring got into the port, which would prevent its being moved back. Then with the back port open the main rod certainly had to be taken down. This is often a difficult piece of work on the track with the tool equipment usually found on locomotives at the present time, and much depends upon the condition of the rod bolts. Cases of this kind have come under, the observation of the writer, where, with the help of the section gang and train crew, more than an hour was consumed, and, he has seen the bolt sheared so that it required drilling out when the engine arrived at shop.

After you were ready to go on one side time could not be made, and in starting the train minutes were lost that could not be made up. While the time consumed taking down the rod, size of engine, weight of train and schedule of same are not given, we are of the opinion that the work performed by the engine crew in this case is more creditable than otherwise. Master mechanics sometimes escape being placed in embarrassing positions by not being on the ground and having a finger in the pie in a serious delay like this.

The proper thing to have done would have been to furnish another engine, but if none was available it was no fault of the crew. That you did as well as stated shows that you met the emergency when it came up the best you could with conditions against you, and we cannot criticise your work.

The reason that the MacIntosh blow-off cock did not leak was not on account of mud, but because the check valve there for that purpose found its seat and prevented the water from escaping from the boiler, when the part of the blow-off cock outside the boiler shell was broken off. The back cylinder head being broken could not have shown much of a leak until after you arrived at the terminal, and it is not an uncommon thing to find cylinder heads cracked on inspection in roundhouse.

104. POUND FROM LOOSE PEDESTAL BRACE.—" A book by MacBain states that a loose pedestal brace will pound on one center only, but gives no explanation. We created the cause and watched for effects, and believe the pound is in the back center. Will you say if this is right and the reason that the pound is only on one center?"

Answer.—An engine with a loose pedestal bolt will pound most when passing the forward center. When the engine is running ahead and the main pin is passing the back center, the pound due to the driving box taking up the lost motion is minimized to almost nothing, on account of the jaw or shoe that the box is to come in contact with moving away from it, or in the same direction as the box when it takes up the lost motion; and the pound or blow that the box strikes the shoe and which is transmitted to jaw and frame is not as intense as

when the pin is passing the forward center. With the driving box moving in the opposite direction from the wedge, the difference in the pound on front and back centers is similar to the difference between a head-end collision with two trains running in opposite directions and a rear-end collision with two trains running in the same direction at different speeds, or just as it is easier to row a boat with the current than against it.

105. DEFECTIVE LUBRICATOR.—"I filled the lubricator and turned the steam on and opened the condensing valve. The oil ran to the top of the condensing chamber and leaked out at the joint that connects the steam pipe to the chamber, also at the union and globe valve between the lubricator and the steam box on the boiler head. All of these joints were leaking. Please say what was the trouble with the lubricator."

Answer.—As no particular make of lubricator is given, we will assume that it is a Nathan lubricator or one of similar construction. Such being the case it is evident that the partition separating the oil reservoir from the condensing chamber had a crack or a sand hole in it or the plug was loose or leaked; or the pipe leading from the opening of the water valve that extends down to near the bottom of the oil cup was split. Either of the above defects would allow the oil to rise to the top of the condensing chamber, and, if the leakage was greater than could escape through the choke plugs, the oil would naturally rise to the top of the condensing chamber and leak out at the joints as stated.

106. VALVE TRAVEL AND THROW OF ECCENTRIC.—"Is not the travel of the valve on a locomotive the same as the throw of the eccentric?"

Answer.—When the upper and lower rocker arms are of equal length, or if a direct motion engine, with the valve arm and link arm the same length, the valve travel will equal the throw of the eccentric when in full gear. It is the practice to increase or decrease the travel of the valve, by having the valve arm longer than the link arm to increase the travel, and the valve arm shorter than the link arm to decrease it. The difference between the travel of the valve and throw of the eccentric will be in proportion to their lengths.

107. LENGTH OF CYLINDER.—"I noticed that when the bushing was removed from the cylinder of a 20x26-inch engine, the bushing was 34 inches long. Now, I would like to know why this engine was called a 20x26-inch cylinder engine, when the cylinder is 34 inches long?"

Answer.—The length of the cylinder is usually stated as the stroke of the piston, although the real length of the cylinder is the distance between the cylinder heads. This engine having a 26-inch stroke, possibly had a piston head 5 or 5¼ inches thick, with at least ¼-inch clearance at each end of the stroke, or a total clearance of ½ inch, and the front and back heads extend into the cylinder, to take up the balance of the space between the ends of the bushing. It is correct to term this engine as a 20x26-inch cylinder.

The writer was recently very much interested to observe several enginemen trying to determine the length of the cylinder on some heavy engines that were going over the road, by taking measurements outside of the cylinder casings; the proper method would have been to measure the distance from the center of the axle to the center of the crank pin and multiply this by two, which would have given the correct length of stroke.

108. TESTING STEAM PIPE JOINTS.—"What is the most accurate method of testing steam pipe joints for leaks when an engine fails for steam and you have reason to think that they are leaking?"

Answer.—A leaking steam pipe is usually indicated by the pressure running up to the blow-off point as soon as the throttle is closed, and instead of having a bright fire when the engine is working it will burn a dull red or smoky fire, with the pointer going over to the fireman's side of the cab. A very good way to make this test is to remove the petticoat or draft pipe if the front end is so equipped. Place a board and a piece of sheet rubber over the nozzle tip with the rubber between the board and the nozzle to insure a tight joint, set a jack on this and place a bar lengthwise in the smokebox under the stack and tighten the jack until sufficient pressure is put on the board to hold water. Then connect the boiler to the water system in the roundhouse, open the throttle, fill the boiler with water and put on pressure on the pipes, thereby obtaining the desired water pressure on the pipes and joints, as well as the joint at the base of the exhaust pipe. If leaks exist the joint or pipe will be detected by the water running out of the leak. A sure thing when done right.

109. LEAKY STEAM PIPE JOINTS.—"Am firing a switch engine that is giving all kinds of trouble with leaky steam pipe joints. The engine has been taken in and joints reground, but they will not stay tight. Will you please say why?"

Answer.—If the joints are ground to a fit and properly tightened they should remain tight. Road engines in double header service when subjected to rough usage frequently give trouble of this nature, due to the stress and shocks caused by the leading engine tending to loosen the frames from the cylinders or the cylinders from the smokebox. A switch engine doing most or all of the work from the front end is subject to the same conditions as the second engine in the double-header service. A loose cylinder of a cylinder saddle that is not securely bolted to the smokebox will soon work the joints loose. If such is the case, remove the cause by reaming out the holes and applying new bolts that will fit and hold the parts rigid. A boiler that is fast or stuck in the expansion buckles or plates is also liable to give trouble. If the mud ring is on top of the frames, a few drops of oil occasionally on the expansion plates or knees may relieve it and prevent the mud ring from leaking.

110. Keying Rods.—"In posting for a mechanical examination one of our firemen had in his possession a clipping from a railway publication, which stated that a rod should never be keyed up on the center, even with a pin perfectly round, because, unless the valve has no lead, there will be a pressure one way or the other on the pin and the engineer is pretty sure to either key too much or too little, according to whether the pressure is with or against the key. Too much means a hot bearing, and too little a pound; this, of course, on the supposition that the rod is keyed up when the engine is hot. With the pin on the quarter and ports covered, the conditions are always the same, even for a new pin and for a worn pin, there is no question as to the quarter being the proper position. I failed to agree with the brother and we decided to refer the question to you for a reply."

Answer.—Would say in reply to the above that the throttle should be ground in, but, if it was desired to key up the rod, the engine should be placed on the center on that side to key all brasses except the front end of the main rod. Relieve the pressure in the cylinder, by opening cylinder cocks or placing a packing hook or iron under the air valve, raising it from its seat to allow the pressure to escape, then drive the keys to bring brass to brass, if the rod can be shaken on the pin; if not, drive the key up until you can shake the rod and the pin will run cool if the brass is filed square and it is properly lubricated. The least wear on the pin is when the engine is on the center, therefore, its largest diameter; and, if the brass will not pinch the pin at its largest diameter it will not pound or run hot when the brass is pushing or pulling on the small diameter.

The correct answer to the question is: To key the rod on the largest diameter of the pin, but care should be taken to observe that tightening the set screws on the key does not pull the key down. If the brasses are filed open, see that the brass is loose on the pin before you get up in the cab.

111. Obstructed Flow of Steam to Injector Throttles.—"I am firing a ten-wheel engine, cylinders 21x26 inches. Everything goes all right until it is necessary to put the second injector at work to keep water in the boiler. Then trouble begins; neither one will work satisfactorily and both throw water on the ground, but one injector will work at a time on either side. Injectors have been changed and repaired, with the same results. The main steam valve to the turret or combination valve is wide open and the other boiler attachments such as

blower, lubricator, and air-pump work all right. What is the trouble?"

Answer.—It is evident that the trouble is not in the injectors, as they will work all right when only one is used at a time. The reason for this is that they do not get a sufficient quantity of steam to force the water into the boiler. This may be caused by some obstruction in

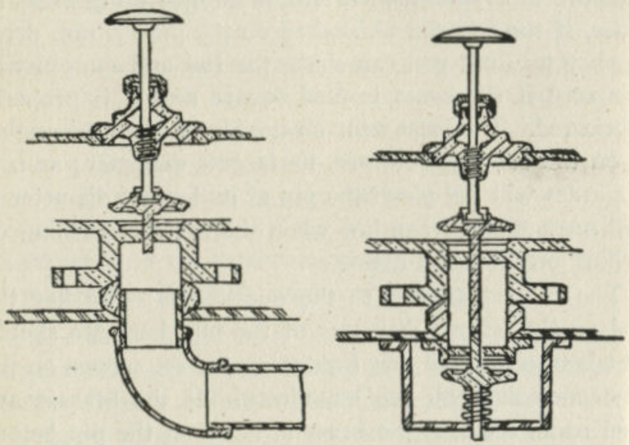


Fig. 1. Fig. 2.

Obstructed Flow of Steam to Injector Throttle.

the steam pipe leading from the dome to the combination valve or turret. A rivet, stud, or nut may have been dropped into the steam pipe, which would obstruct the flow of the steam from the boiler to the injector throttles, or the area of the opening leading from the boiler to the main valve is not large enough to equal the combined area of the valves for the other boiler attachments. This trouble sometimes occurs from the use of a combination valve that was designed for safety in case of accident. The two illustrations show valves of the same exterior

appearance. Note the one with the single valve, Fig. 1, which is fast to the stem, and can be opened wide open by raising it ¼ inch from its seat for every inch of diameter, and if then given a turn or two will do no harm. But the other, Fig. 2, with the double valve, should only be opened to about middle position, as shown in the cut. Should this valve be opened the same as the other it is obvious that the spring under the lower valve would force it to its seat and reduce the flow of the steam, if it did not shut it off entirely, so that both injectors would not work at the same time, because there would not be enough steam to do the business. The effect of the restriction would not be as apparent on the action of the blower, air-pump, and lubricator, although if they get a liberal supply of steam to the turret they will work much better.

112. Sound Waves.—"What makes the sound from the bell?"

Answer.—The sound of the bell is caused by the heavy iron clapper striking the rim of the bell near its mouth, setting the molecules of the bell metal vibrating as a mass. This mass vibration is transmitted to the ear by the vibrations of the air, as they leave the bell in waves of sound similar to the waves of water, caused by dropping a stone or other substance into a body of water that is perfectly still. The wave is produced by the force with which the object strikes the water and its displacement sending the water waves out from where they were first formed or vibrated. As they expand they become less and less until the wave is lost or is imperceptible. Figure the sound waves from the bell being carried by the vibrations of the air in the same manner until they are lost.

113. LOCOMOTIVE WHISTLES.—"What makes the whistle on a locomotive sound? Is it the steam cutting on the edge of the whistle bell or not?"

Answer.—Yes, the bell of the whistle should come directly over the circular opening in the cup so that the steam escaping through the circular opening will strike the thin edges of the bell. This gives the bell of the whistle a vibrating motion and generates a deep sound, the tone being dependent on the length of the bell or barrel of the whistle. If a long barrel is used on the whistle the vibrations will be longer, and it will be termed a coarse, or bull whistle. By placing a block inside the barrel, or reducing its length, the whistle will be more shrill or ear splitting as the vibrations are shorter. The chime whistle consists of a bell with three compartments of different lengths which produce three distinct tones pitched to the first, third and fifth tones of the musical scale, which gives an agreeable musical chord by the vibrations of each blending together.

114. EQUALIZING VALVE TRAVEL.—"In running over the slide valves on a locomotive in full gear to get the full travel of the valve, say, the travel of the valve should be 5 inches, and it showed up in the forward gear 4¾ inches travel and in the back gear 5¼ inches, how would you adjust the eccentric blades to make it show up 5 inches in both gears? Suppose the valve travel lines would not be equal distance from the port opening lines, how should they be adjusted to make it equal on both ends?"

Answer.—The question is just a little mixed. If the valve travel in forward motion should be 5 inches and the back motion gave the valve ¼ inch less travel, would look for the trouble in the back motion eccentric as not having the same throw as the forward motion eccentric. If this question is correct the back motion eccentric on that side of the engine was not bored out properly. Measure the least distance between the bore and the outside face and the greatest distance between the bore and the outside face of the eccentric. The difference will be the throw of the eccentric and equal to the travel of the valve if the rocker arms are same length. Measure them and see if all the eccentrics have the same throw. If not, change them, and the travel of the valve will be the same in both motions. Now with the eccentrics all the same throw and advanced toward the pin the amount of lap of the valve plus the lead, the eccentrics are all right. We will now assume that the conditions are as above stated, and in running the valves over we find that valve closes the steam port or cuts off the admission of steam in the forward end of the cylinder when the piston has moved back 4¾ inches, and cuts off or closes the steam port leading to the back end of the cylinder when the piston has moved ahead 5¼ inches in the forward motion, and we desire to have the valve cut off the steam at 5 inches in each end of the cylinder. Move the engine until the piston has moved back from the center 5 inches, then adjust the eccentric blade to bring the valve line and line with the edge of the steam port. This should give you a 5-inch cut-off at each end of the cylinder. Remember that the eccentric is to give the valve the travel, and the eccentric rods or blades are made adjustable to equalize the travel of the valve to the same distance each side of a line drawn through the center of its seat. Lengthen or shorten them as the case may require, to give equal travel each side of the center line.

115. LINING WEDGES.—"When it becomes necessary to line down a wedge, why is the liner put behind the wedge and nothing put behind the shoe? Should not both shoe and wedge be lined up and wheels trammed? Does the shoe not wear as fast as the wedge, and if not, why not?"

Answer.—The reason for lining down a wedge is usually because it is pushed up so far that it strikes the frame and can not be set up any further to keep the box from pounding, and by making it thicker, placing a lining on the back of the wedge, it fills up the space between the box and jaw, and can again be adjusted to take up the wear. Wheels are trammed only for the purpose of keeping each pair of wheels square with the frame after the engine has left the shop. It is not necessary to tram all wheels when the wedge is lined up, if the engine is running true. If the liners were put in between the shoe and jaw it would be necessary to tram the wheels to insure a good job. As a rule, where the engine is running ahead, or doing the greatest amount of work in the forward motion, the shoe will wear faster than the wedge.

116. WATER SPLITTING IN A BOILER.—"What caused this? Several years ago I was firing one of the old Roger engines on the P., F. W. & C. We were running down a slight grade, using some steam, lever in second notch from center. Engineer was pumping her up, getting ready for the big hill ahead of us. We had three gauge cocks, but no water glass. On trying the lower cock he found dry steam, and, without closing it, he opened the upper gauge cock and found solid water. He called my attention to it, and while we were talking the conditions were reversed, viz., water at the lower, and dry steam at the upper cock. Neither of us had ever heard of such a thing before. It changed three times while we were looking at it. Then he closed them and nothing happened. We tried it repeatedly afterwards at same place, but never saw it again. The boiler had been washed out only a couple of days before and we had good water. Please explain."

Answer.—This might come under the head of what is termed "water splitting in a boiler." The writer has heard of water being so light in some instances that the steam would get under it and hold it in suspension, but it is only in rare cases. There is no better way to determine the water level in a boiler than with the ordinary gauge cock with a free opening to the inside of the boiler, although sometimes they are located behind a crowfoot or a brace that interferes with their proper working. If such was the case and a hole drilled through the brace in the boiler, it might become stopped up opposite the gauge cock and the steam would leak down between the boiler head and the brace on the inside, which would perhaps cause a flutter of steam and water to show at the gauge cock when open. In a bad-water locality, on account of bubbles in the water, we might get a condition of this kind occasionally, but where good water is used we are unable to explain it. If we could give you a good, clear explanation of this case it would be difficult to determine at any time if the crown sheet was scorched on account of low water.

117. TEMPERATURE AND POUNDS PRESSURE.—"Will the temperature of steam be greater at 200 pounds than at 100 pounds pressure?"

Answer.—The temperature of saturated steam, or steam that is in contact with the water from which it is generated, at atmospheric pressure is 212° Fahrenheit.

At 100 pounds pressure per square inch the temperature is 337.8°, at 200 pounds pressure per square inch it is 387.8°. Steam in a locomotive boiler is saturated steam, and the temperature depends on the pressure.

118. FRONT HEAD OF CYLINDER.—"Please inform me which is the front head of a cylinder, or in what quarter would a locomotive be standing if the piston rod was all the way out of the cylinder on the right side?"

Answer.—The front cylinder head on a locomotive is the head nearest the pilot, and the back head is the one next the crank pin. To avoid mistakes they could be specified as the front cylinder head and the crank cylinder head. This term is used at times in stationary practice, and they are called back cylinder head and crank cylinder head; but on locomotives they are known as front and back heads. Thus, when the piston is all the way out of the back cylinder head on the right side, the engine would be on the right back center, as the right side leads the left one-quarter of a turn or revolution. The left side would be on the lower quarter, with the piston on the right side on the back center.

119. MAXIMUM TEMPERATURE OF WATER.—"Will the maximum temperature of water exceed 212° Fahrenheit? For instance, will the temperature be greater at 200 pounds steam pressure than at 100 pounds pressure?"

Answer.—Yes. When water is placed in an open vessel over a flame or fire, the molecules of the water that are in contact with the parts of the vessel absorb the heat, and as they are heated they become lighter and rise to the surface and the air contained in the water is driven off. Continued application of the heat causes the molecules to rise more rapidly through the body of water,

overcoming the pressure on its surface and escaping in the form of gas or steam. At sea level the pressure of the atmosphere is 14.7 pounds per square inch, and water will begin to boil at a temperature of 212° Fahrenheit. If the pressure on the surface of the water is increased, it will require a higher temperature to reach the boiling point, and if the pressure is decreased, water will boil at a lower temperature. If you could get up high enough on a mountain where the atmospheric pressure is light, potatoes will not cook in an open vessel. The rule is: All increase of pressure on the surface of a liquid raises the temperature at which it boils, and a decrease of pressure lowers the temperature at which it boils.

120. BACK MOTION ECCENTRIC STRAP BROKEN.—"If the back motion eccentric strap was broken and the blade was coupled to the forward motion blade with a long bolt, could the engine be run backwards with its own steam, and vice versa? Explain what action this trouble has on the valve."

Answer.—If the back motion eccentric strap was broken and the blade was connected to the forward motion strap by a long bolt, as you state, if the blade was the same length and the engine was reversed, or the lever put in the back motion, the disabled side would be working steam in the forward motion while the other side would be working it in the back motion. In order to get the engine to back under these conditions, it would be necessary to slip the forward motion eccentric around to the position opposite that of the back-up. That would be the only way you could work steam in both motions in both directions, using both sides of the engine.

121. TEMPERATURE OF SHEETS VS. TEMPERATURE OF

WATER AGAINST THEM.—"Will the temperature of the sheets exceed the temperature of the water constantly against them? If so, how much?"

Answer.—The temperature of steam or water in a boiler at 200 pounds pressure is 387.8° Fahrenheit, while the temperature of the firebox, when the engine is working, is from 2,500° to 3,500°. It is admitted that the water does not come in contact with the sheets at all times, but as the heat is absorbed by the water a thin layer of steam prevents the water from coming in contact with them at times, and the result is cracked and burned firebox sheets. The water does not carry the heat away fast enough and the sheets will not absorb it without damage, hence the reason for larger bridges in flue sheets, and wider water space around fireboxes on high-pressure engines.

122. BY-PASS VALVE ON L. P. SIDE OF SCHENECTADY COMPOUND BROKEN.—"How would you locate a broken by-pass valve on low-pressure side of a Schenectady compound, and how remedy it?"

Answer.—To locate a defective by-pass valve on the low-pressure side of a Schenectady two-cylinder compound, place engine on upper quarter on low-pressure side, reverse the lever in forward motion. Close separate exhaust valve by placing three-way cock in compound position and admit steam to cylinder. If blow occurs from exhaust, defect would be in forward by-pass valve. If blow occurs with lever in back motion, engine in same position, defect would be in back by-pass valve.

123. BY-PASS VALVE ON H. P. SIDE OF SCHENECTADY COMPOUND BROKEN.—"How would you locate a broken by-pass valve on high-pressure side of a Schenectady compound, and how remedy it?"

Answer.—To locate a defective by-pass valve on high-pressure side, follow the same course as with low-pressure side, except that in this case open the separate exhaust valve by placing the three-way cock in simple position. A blow from a broken by-pass valve can be easily distinguished from other blows on account of its being a very strong one and only occurring during one stroke of the piston. For example: If the blow occurs during the forward stroke, the defect would be in the forward valve. The best way to remedy it is to remove the by-pass valve casing from the side of the cylinder and cover both openings with a thin copper or sheet-iron gasket and replace the casing.

124. BY-PASS AND MAIN PISTON VALVES.—"How would you tell a broken by-pass valve from the main piston valve?"

Answer.—To distinguish between broken piston valve and defective by-pass valve, would place engine on quarter on defective side, and if by moving reverse lever steam could be prevented from blowing into exhaust port, would conclude that there was nothing wrong with the valve. In this case the reverse lever would be at or very near center of quadrant, this depending upon whether or not the valve had exhaust clearance.

125. ECCENTRIC STRAPS BROKEN OFF OF FLANGES—"What could be done if forward or back motion eccentric strap should break off of the flange on both sides?"

Answer.—This is rather an unusual occurrence, and the safest thing to do in a case of that kind would be to take the engine down on that side or handle it the same as you would a broken strap, although if it was the eccentric strap next to the box that was broken and in your judgment you could bring your train into the terminal without further delay or consequential damage, it would be exercising good judgment on your part to do so; but to give an answer to this question the only safe thing to do would be to take her down on that side.

126. Course of Steam from Boiler to Stack.—"Will you trace the steam in the locomotive from the dome to the stack and give me the exact names of all the pipes and passages the steam goes through?"

Answer.—Steam is generated by the water absorbing the heat from the flues and firebox sheets, rises through the water to the dome, and while the throttle is opened enters the throttle box or steam pipe and is carried through the dry pipe to the "nigger-head" where it branches into the steam pipes leading to each steam chest, through a passage known as the live steam passage, to the steam chest, surrounding the valve if an outside admission, or filling the chamber between the ends of the piston valve if an inside admission. When the port is opened by the valve it enters the steam port leading to the cylinder, exerting a pressure on the piston to the end of its stroke. When the valve uncovers the port for exhaust, the steam in the cylinder escapes through the port which it entered and into the exhaust cavity, thence through the exhaust passages into the exhaust pipe, through the nozzle tip and up through the stack to the atmosphere.

127. Position of Saddle Pin Relative to Link.—"Why is a link block not put in the center of a link? As I understand, it is not."

Answer.—We presume that you refer to the saddle pin which is set back of the center of the link. You understand that the length of the main rod is the distance from the center of the axle to the center of the crosshead pin when the crosshead is in the middle of its stroke. Then with a radius equal to the length of the main rod, if you describe an arc, it will intersect the tire or circumference of the wheel forward of a vertical line drawn through the center of the axle, indicating that the wheel travels farther while the crosshead travels from the half stroke to back center and to half stroke, than it does from half stroke to forward center and back to half stroke. This is due to the angularity of the main rod, and increases as the length of the main rod decreases, *i. e.*, the difference is greater with a short main rod than a long one.. The imperfections thus introduced by the main rod are imparted to the valve motion. To overcome it and obtain an equality of cut-off for both ends of the cylinder, the saddle pin is set back of the center of the link. The amount is usually determined by the result of experiment on the different motions.

128. Changing Eccentric of Direct Motion Engine.—"Will a direct motion stationary engine with a valve having lap and lead run if the eccentric has moved exactly half way around on the shaft?" In your answer to this question you claim that the engine will not run. I claim that an engine, with the valve having a very small amount of lap and lead, will run if the eccentric has moved just half way around on the shaft, although the valve will be badly out of square and the engine will be working against herself to a certain extent, but if the engine is helped off the center and once given a start

she will run the same as an engine will run with a valve having a larger amount of lead. I have experimented with a small engine in the way described and know that the engine will run with the valve having a small amount of lap and lead.

Answer.—The eccentric is advanced away from the pin the amount of lap and lead. This gives the lead opening on the valve having lap and lead, and by turning the eccentric half way around the shaft the back of the steam port is open and steam would be admitted behind the piston and the engine would not run, but if the eccentric was changed, advancing away from the pin, the amount of lap and lead, the engine would run in the opposite direction. The following rule generally applies: When the valvé rod and eccentric rod move in the same direction, the eccentric is set ahead of the pin and the angle between the pin and the eccentric is 90 degrees plus the angle of advance, which would be the lap and lead. This rule holds good for the engine to run in either direction. You do not state how much lap and lead this engine had when you made the experiment, and if any we are inclined to think that the engine running at all was due to the momentum of the fly-wheel after you had started the engine and caused her to work, as you mentioned, against herself.

129. NUMBER OF STEAM ADMISSIONS PER REVOLUTION.—"I was asking two engineers the other day how many times steam was admitted to the cylinder at one revolution of the wheels (one side), and they argued me that steam was admitted four times. Now, I say twice. The valve opens just before the beginning of the stroke and admits steam to the piston and drives it over to the other end, and while doing so the arch of the valve opens the exhaust from the other end of the cylinder. Now, the crank is about its forward center and the body of the eccentric has moved the strap, rod, link, rocker-arms and valve stem to their forward radius, which has again opened the admission to the cylinder and drives the piston back to back center. Are not the eccentrics attached to the axle? Then how are they going to admit steam four times on one revolution of the wheels?"

Answer.—Steam is admitted to the cylinder at each end of its stroke or twice to each revolution of the wheel. The eccentric attached to the axle makes one revolution when the wheel makes a revolution, and through the rocker-arm connections the eccentric rod moves the valve forward and back from the center of the valve seat, admitting steam to the front and back port leading to the cylinder. When the steam has followed the piston to the end of its stroke the valve opens the port to allow it to escape through the exhaust cavity and pipe to the atmosphere. Therefore, you are right.

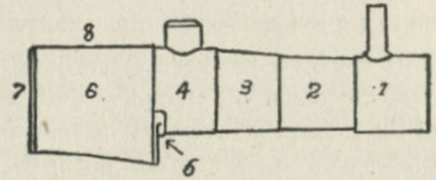
130. DISCONNECTING A CONSOLIDATED ENGINE.—"An engineer running a consolidated engine with eccentrics not on the same axle as the wheels with the main pin, broke the main pin on the left side. He disconnected the valve stem on that side and took down all the side rods on both sides and succeeded in taking the engine 20 miles to the terminal. When the hostler took the engine to put her in the house she was further damaged. In your opinion did the engineer disconnect her properly, and should the engineer or hostler be held responsible for the consequent damage?"

Answer.—It is our opinion that the engine was not properly disconnected by the engineer. By taking down all the side rods it left the wheels and axle that controlled the valve gear for the admission and exhaust of steam to the cylinders independent of the position of the piston or the main wheels. The reason for taking down side rods on opposite sides is that if one side was on the quarter the other side would be on the center, and the wheel connected by one side rod only would be liable to break the pin or start to revolve in the opposite direction. But in this case, where the engine was only working steam on one side, if all the side rods on that side were left up, should she stop on the center she would have to be pinched or moved until all the pins were above or below the axle a sufficient distance to insure their revolving in the right direction. Therefore, there would be no danger from leaving the rods up on that side to come in. It looks to us that the engineer was not only in big luck to reach the terminal under the above conditions but put the company to additional expense and set a trap that caught the hostler.

131. Boiler Sheets.—"Will you kindly illustrate the outside sheets of a boiler and show which sheet is called the throat sheet?"

In the illustration herewith, *1* represents the smokebox and extension front; *2* the first ring of the boiler; *3* the second ring, or slope sheet if on an incline forming a wagon top; *4* is the third ring or dome sheet. These parts form the barrel of the boiler. Sheet *5* is the sheet that connects the underside of the barrel of the boiler to the outside shell of the fire box and is usually termed the throat sheet; *6* is the outside sheet of the firebox; *7* is the back boiler sheet, or head; and *8* is the roof sheet.

The firebox consists of a back sheet, flue sheet, two side sheets and a crown sheet. The front flue sheet is next to the smokebox. The lower edges of the inside and out-



side shells of the firebox are riveted to an iron ring called the "mud ring."

132. A Pound in the Trailer.—"On several of our E2A class engines equipped with trailers we found a pound or kick in the trailer. I contend that there can not be any lost motion in the trailer box that would cause a pound of this kind, while some of the men say it is the frame thumping on the trailer box, due to weak springs. Others claim it is the right back driving box, and three of the four engines that I have in mind all pound on the right side."

Answer.—The only pound that could come from the trailer would be, as you say, the box striking the frame or pedestal brace or the pedestal striking the spring, due to the spring not being heavy enough to carry the weight. The writer has in mind several engines that had to receive new springs to overcome this trouble on a similar class of engine. It would be well to make an examination and ascertain just where the striking occurs. The marks will be shown where the parts strike and a remedy will be suggested.

133. Grease Lubrication.—"On the latest type of engine we had for pin lubricant the grease in cup instead of oil. Some of the engineers contend that two or

three turns of the compression plug is sufficient. Others say to screw down on them until you see the grease show up around the collar of the pin. I would like to hear from you on this question."

Answer.—If the brass has been taken down it is good practice to screw down on the plug until the grease shows up at the collar, that you may be sure that the pin is properly lubricated in starting out, but if the brass has not been reduced or taken down the pressure exerted by one or two turns of the plug is sufficient to lubricate the pin for 100 or 200 miles, and less grease will be wasted and the cup will not requre filling so often. Best results are obtained when the plugs are screwed down just before leaving a terminal, as the stored-up energy will feed the grease to the pin and a turn of the plug will force out a piece of the grease through a ¼ or ⅜-inch hole about 6 or 8 inches long. If the plugs are screwed down several hours before starting on the trip the energy of the grease in the cup is expanded before it is needed. One or two turns of the plug before leaving will give you better service.

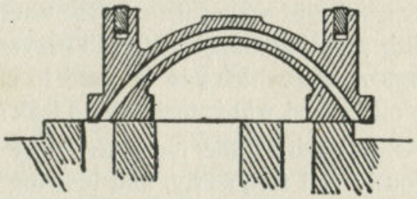
134. TRANSMISSION BAR VS. LONG VALVE STEM.—"We have a class of engine on our division with short eccentric rods in connection with the transmission bar. The division that we terminate with have a Pacific type of locomotive and are equipped with short eccentric rods and long valve stems. I have listened to many arguments on the speed of the two different types of engines. A says that an engine with a long valve stem can acquire the same speed that an engine with the transmission bar can, and B says that she can't. Now, who is right?"

Answer.—If the valve gear, valves, size of steam ports

and passages, length of eccentric rods, etc., are identically the same, and the only difference is that one engine has a transmission bar and the other has not, with valves set the same on both engines and the same distribution of steam, it is our opinion that one would run equally as fast as the other. The valve gear simply gives the valve its movement for the admission and exhaust of steam to and from the cylinders, and on like engines the only difference would be the friction of the gear in this case.

135. THE ALLEN PORTED VALVE.—"Describe an Allen ported valve and the advantage claimed for same."

Answer.—An Allen ported valve is similar to the plain "D" valve, but it has a supplementary steam port or passage above the exhaust cavity; see illustration. Its ad-



vantages are to admit steam to the same cylinder steam port from both sides of the valve at the same time which will permit a smaller amount of lead opening than by the "D" valve. The Allen valve will give twice as much opening for the admission of steam at a short cut-off as the ordinary valve, and is very desirable for high speed service. It opens the steam port at admission and closes it at exhaust at twice the rate of the "D" valve.

136. THE BY-PASS VALVE.—"What is a by-pass valve and what are its uses?"

Answer.—A by-pass valve is used on a simple engine having piston valves, is used to prevent excessive pressure in cylinders due to compression or other causes, and is constructed so that the valve is between the steam cavity and the cylinder steam port. When the throttle is opened the steam in the chamber holds the by-pass valve to its seat, but when the steam or pressure in the cylinder is greater than that in the steam chamber, the excessive pressure unseats the valve and establishes communication between the cylinder and the steam chamber, relieving the pressure and preventing damage to cylinder heads. They are used on piston-valve engines because the piston valve can not lift from its seat as the slide valve does under like conditions.

137. FORMATION OF SCALE ON FLUES.—"We are using water from an artesian well in a stationary boiler but a large quantity of scale forms on the flues. Will you please publish a preparation which will prevent the flues from scaling, or one which can be used to clean them? If kerosene oil is used will it make them leak?"

Answer.—Soda-ash is the most universal "cure-all;" used judiciously and frequently, and blowing out of the boiler, may prevent the formation of scale on flues. If you are unable to obtain treated water for boiler use, an analysis of the water should be made, then a compound can be prepared to prevent the formation of scale. Kerosene should not cause flues to leak.

138. KEYING SIDE RODS ON SIX-WHEEL CONNECTED ENGINE.—"Why should the side rods of a six-wheel connected engine be keyed up from the main connection first?"

Answer.—To insure free movement of the brasses on the pins and the main connection being keyed properly. If the front and back ends of side rods were keyed

up first and the main connection last, there would be more liability of putting strain on either front or back section of rods. Should you attempt to key the main connection up, brass to brass, and to have brasses free on pins, you would have to go over them again. Solid end rods are displacing straps and keys on modern engines.

139. BROKEN STEM OF INTERCEPTING VALVE.—"If you break the stem off the intercepting valve on a two-cylinder Schenectady compound, what would you do?"

Answer.—A break in the intercepting valve means running the engine simple, after valve has been blocked to allow this. This can easily be done by clamping the stem or rod, but if not, remove the head and insert a block to hold the valve in place and replace the head.

140. BROKEN DRIVING SPRING OR HANGER ON SCHENECTADY COMPOUND.—"If you break a driving spring hanger or a spring on a Schenectady compound, what would you do?"

Answer.—The boiler, frames, truck, and driving wheels are the same on a compound as on a simple engine, the only difference being in the arrangement of the cylinders, pistons, crossheads and valves. A breakdown of this nature should be handled in a similar manner. In order to answer this question correctly would require description of spring rigging, and type of engine.

141. BROKEN ENGINE TRUCK EQUALIZER ON CONSOLIDATED ENGINE.—" If you broke the long equalizer of engine truck on a consolidated engine what would you do?"

Answer.—Remove loose or broken pieces and block between driving box and frame, both sides, so as to carry the frame rigidly on the front boxes.

142. Broken Hanger at Back End of Long Equalizer.—"If you broke hanger at back end of long equalizer what would you do"

Answer.—Remove the broken hanger and chain back end of long truck equalizer to cross-equalizer.

143. Broken Tire on Consolidated Engine.—"If you broke a tire on same class engine how would you fix it up to bring engine in?"

Answer.—If it was a front tire, would run broken wheel up on a wedge to bring it to about its normal position, remove the oil cellar and fit a block in its place, using a piece of a tie, leaving it about flush with the bottom of the driving box, and then fill in the space between the bottom of the driving box and block and pedestal brace, with another block. Put some well oiled packing in space around the journal to lubricate it, then put an iron block between the top of the frame and the spring saddle so as to take the weight off the box; then cut out the driver brake. If a main tire, would block up in same manner, but if found that the spring would not carry the load would block ends of equalizers next to the broken wheel instead of blocking between the frame and the spring saddle.

144. Broken Eccentric Strap, Forward Gear.—"If you break an eccentric strap, the forward gear, how would you disconnect?"

Answer.—If going to back up to terminal, would use long bolt to secure back end of forward motion eccentric rod to the back motion strap and use both sides. Would block link to prevent a possibility of reversing the engine while under these conditions. If was going ahead would remove broken strap and rod, also link hanger

and let link ride on link block. Would disconnect valve stem and clamp it, leaving one port open sufficient to let enough steam into cylinder to prevent damage, and proceed in the usual manner without taking down main rod.

145. Wilson High Pressure Balanced Valve.—"We have a class of engine here called the 'E.2.A' that are equipped with the Wilson valve instead of the Richardson, and they have a sharp, quick exhaust, not like the other locomotives, caused by the valve having a separate exhaust cavity. Would like to hear from you on this."

Answer.—The sharp, quick sound of the exhaust in this case is caused by the double exhaust port in the valve letting the steam out at two port openings instead of one.

146. Leaky Check and Injector Steam Valves.—"How may it be determined whether the check valves or steam valve are leaking on an injector?"

Answer.—If the steam valve leaks it will show steam only at the overflow or wastepipe of the injector, but if the check valve is stuck open or is leaking, water will come out with the steam, indicating that the leak is in the check. Open the frost cock on the branch pipe and the temperature will indicate that it is the check that is giving the trouble. Steam valves are located above the water level and the check valves below the water level in a boiler.

147. Freezing of Injector Waste Pipe.—"Explain how you would prevent the waste-pipe from freezing either while the injector was working or shut off."

Answer.—Open the overflow valve occasionally to prevent the pipe from freezing. This will allow steam to go through it and keep it warm.

148. Number of Exhausts During a Revolution.—"How often does the ordinary locomotive exhaust steam during a revolution of the driving wheels, and at what points does the exhaust take place?"

Answer.—A locomotive takes steam at each end of each cylinder once every revolution of its drivers, and therefore has four exhausts, which take place when the piston is nearly at the end of its stroke. The two exhausts for the right side take place when the crosshead is near the front and back centers, and the two exhausts on the left side take place when the crosshead on the right side is at near half or quarter stroke.

149. Position of Eccentric Relative to Crank Pin.—"What position on the shaft should the eccentric be relative to the crank pin with a direct motion engine and with an indirect motion?"

Answer.—With a direct motion engine, inside admission, eccentrics are set at right angles to the pin, and advance toward the pin the amount of lap and lead of the valve. Direct motion with outside admission eccentrics are set at right angles to the pin and advance away from the pin the amount of lap and lead of the valve. With an indirect motion engine, outside admission, eccentrics are set at right angles to the pin and advance toward the pin the amount of lap and lead of the valve. Indirect motion, inside admission, eccentrics are set at right angles to the pin and advance away from the pin the amount of lap and lead of the valve.

150. Miles Run to a Pint of Oil.—"How many miles should an engine run to one pint of valve oil; engine oil; and how would you oil an engine to effect the greatest economy?"

Answer.—Just how many miles an engine should run to a pint of valve oil or engine oil depends on the class of engine and the class of service, and how many of the bearings are lubricated with oil, and if the driving boxes are equipped with grease cellars and grease used on the pins.

The proper way to determine a fair amount of oil to use in your service would be to check up the performance sheet and strive to keep above the average. By doing so you will, as a rule, have sufficient oil to keep the bearings cool. To oil an engine with economy it is necessary to first provide yourself with suitable oilers and large cans to hold the supply for the trip. Keep them clean and free from leaks, see that you get the amount of oil you are charged with, and if the engine is of a type that you can oil without moving, place the engine so that the crossheads are opposite each other—as near the back cylinder heads as possible. This will usually enable you to reach the shoes, wedges, driving boxes, eccentrics, etc., on both sides. If you can not do this, oil one side at a time. Place engine on forward center right side and hook lever clear back. Commence at the right back driving box, oiling shoe and wedge, also the main oil pocket in the driving box. Get the oil well over toward the inside of the box, but do not disturb the sponging on top of the driving box. This to insure oil getting to the part of the driving journal that is most exposed to dirt and ashes at the ash pit. The hub of the wheel protects the outside of the box, and the bearing gets dry on the inside first. Then go forward to the next and oil in the same manner. Oil eccentrics, link motion, rocker boxes and back end of valve stem. Open feeders on guides, but do not fill guide cups so full that they will run over.

Oil swabs on pistons and valve stems; oil engine truck, and go to the left side, oiling back to the driving boxes. Then move engine to forward center on left side, leaving lever in full forward gear. This will give you a chance to oil back motion eccentric rod where it connects to the bottom of the link if you were unable to reach it before, and when you oil back to the back wedge on the left side you are through. Then fill the lubricator and feed the oil to air pump, valves and cylinders to get the best results, keeping the water at its proper level in the boiler all the time, and the throttle slightly cracked open to prevent vacuum being formed in the cylinders while drifting. This will insure a good oil record to those who practice it. Shut off all feeders on guide cups, valve and piston rods on arrival at terminal.

151. Effect of Temperature on Lubricating Qualities of Oil.—"At what temperature does engine oil lose its lubricating qualities? Valve oil?"

Answer.—When its temperature is increased above the flashing or burning point, and the nearer the temperature the oil is to the burning point the less are its lubricating qualities. Engine oil usually burns at a temperature of 380 to 400 degrees F. and valve oil at 680 to 700 degrees F.

152. Miles Run per Ton of Coal, and Pounds of Coal per 100-Ton Mile.—"On monthly coal report what is meant by miles run per ton of coal, and what by pounds of coal used per 100-ton mile?"

Answer.—The monthly coal report made up in this form is for the purpose of showing the amount of coal used by each engine and the miles run per month and per ton of coal. By dividing the number of miles made by

the number of tons of coal used you get the miles run per ton. Thus: If the engine made 3,000 miles and consumed 150 tons of coal, 3,000 divided by 150 would equal 20 miles per ton of coal. This would not be a fair comparison, as the engine making the largest number of miles per ton of coal would possibly have the lighter train, and, consequently, would be earning less revenue for the company than an engine with a heavier train and a very much heavier coal consumption. Hence the ton mile basis in which each engine is given credit for the number of tons hauled one mile or 100-ton mile. Where this system is used engines are, or should be, grouped that are in similar service; passenger trains on opposite runs; freight trains on opposite runs, such as time freight, stock, locals, and rounds or miscellaneous service. This makes all engines in the same group and class of service comparable with each other, and also the enginemen. In making a comparison between engines or men the time or speed should not be overlooked. While one engine or crew may show up poorly on the performance sheet, they may have made up more time than the engine holding a better record. A slow train crew may cause an increased coal consumption per 100-ton mile, and a fast crew would decrease it.

To find the pounds of coal used per 100-ton mile, multiply the coal in pounds by 100 and divide by the tons multiplied by the number of miles hauled. Example: A 600-ton train is hauled over a 200-mile division, and 12 tons of coal are used. To find the number of pounds of coal used per 100-ton mile: 12 tons = 24,000 pounds; 24,000 pounds x 100-ton mile = 2,400,000; 600 tons x 200 miles = 120,000.

120,000)2,400,000(20 pounds of coal used per 100-ton
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153. General Form of Locomotive Boiler.—"Describe the general form of a locomotive boiler and explain the use of the cylindrical part of the boiler?"

Answer.—A locomotive boiler is cylindrical in form, with a rectangular shaped firebox at the back end and the smokebox at the other end, with flues through the cylindrical part which are surrounded by water. The cylindrical part is used for the smokebox, the front flue sheet, and to secure the throat or slope sheet or wagon top to the firebox end, and to provide a place for the dry pipe and flues.

154. Engine Supports.—"At what point is an engine supported in working order?"

Answer.—Supported on the rails first. The frame and the boiler resting upon it is supported at the engine truck center in front and at the fulcrums of the equalizers, and from these points of suspension the weight is transferred through the equalizers and springs to the spring saddles which rest directly on the driving boxes.

155. Setting a Slipped Eccentric.—"How would you set a slipped eccentric?"

Answer.—If the forward motion eccentric was slipped, would place engine on forward center on that side, put the lever in full gear back motion and make a mark on the valve stem even with the gland, then put the lever in full gear forward and move forward motion eccentric until the mark on the valve stem showed in same position as when it was made. This is simply setting the slipped

eccentric by the good eccentric. You can obtain quite good results by placing the engine on forward center, lever in full gear forward, open the cylinder cocks and move the eccentric until steam shows at the forward cylinder cock. This will get you in and is much quicker. The same method can be employed in setting a back motion eccentric that has slipped.

156. Number of Exhausts to a Revolution.—"How often does the ordinary locomotive exhaust steam during a revolution of the driving wheels, and at what point does the exhaust take place?"

Answer.—Each cylinder has steam admitted at each end to push the piston from one end of the cylinder to the other and back in order to complete one revolution of the drivers. Therefore, there will be two strokes of the piston and two exhausts from each cylinder for each revolution of the drivers, or four exhausts in all. Exhaust taking place when the piston is nearly at the end of its stroke, frequently the exhaust port opens for the release of steam at from 75 to 85 per cent of the stroke of the piston, depending on the exhaust edges of the valve. If the valve has inside clearance the exhaust will be earlier, and if inside lap the exhaust will be later. Have a talk with the valve setter and ask him to show you the valve motion card showing the opening and closing of the exhaust on the class of engine you desire to know about. If the valve is line and line inside, locate a center on the valve stem between the port marks, and by using a tram to the center mark you will find the point of stroke the exhaust opens at, also when the mark comes back to the tram point it will indicate the point at which the exhaust closes. When the valve is line and line inside and placed central on its seat the exhaust ports are closed, and the mark made in the center between the port marks will show the position the valve is in and just when the port opens if a tram is used.

157. VALVE GEAR.—"Name the different parts of the engine that operate and control the valve motion?"

Answer.—Briefly, the parts are the eccentrics, eccentric straps, eccentric rods, link, link saddle, link hanger, tumbling shaft with link arms and reach-rod arm, reach rod, reverse lever, link block, rocker-link arm and valve arm of rocker, and valve rod.

158. CARS NOT PROPERLY HEATED, WHILE GAUGE SHOWS REQUIRED PRESSURE.—"If the steam heat gauge showed the required pressure and the cars were not being heated properly, how would you proceed to locate the trouble?

Answer.—Close the shut-off valve on train line and uncouple steam heat hose between engine and train, then open the shut-off valve and pressure regulating valve, and in this manner determine that the steam was being furnished back of the engine. Would then couple up steam heat hose and open all valves through to rear end of train. This will show that the steam is or is not obstructed in the main steam heat pipe. Next close valve on rear end of last car, but not tightly, leaving it open sufficiently to take care of the condensation. Then open all valves to radiators in the coaches and the drip valves to let out the condensed steam or water, thereby getting a circulation through the heating pipes or coils. If this will not heat the cars the chances are that there is not radiation enough in the pipes to raise the temperature. It's not the pressure shown on the gauge on the engine that keeps the cars comfortable, but the circulation of the steam in the pipes, and when cars are not provided with automatic drips, trainmen sometimes allow the pipes to fill with water and the cars get cold. When the engine piping is under the tender there is little or no trouble with it, but if it is on top of tender there is danger of the tender being flushed at water stations, or an accumulation of snow melting and surrounding the pipe with water, which will condense the steam very rapidly. Keep the back of the tank clean and the steam pipe dry.

159. STEAM HEAT VALVE INOPERATIVE.—"In the event of the steam heat reducing valve being out of order, how would you heat the train until repairs could be made?"

Answer.—If you have a Mason regulating valve and it becomes inoperative, the cause is probably dirt or grit around the piston *D* in or above the dash pot. For quick repair remove the dash pot and clean the piston, replacing same. Then if steam does not get to train pipe after this treatment, take out the piston and place a small block in it of sufficient thickness to raise the steam valve from its seat when the dash pot casing is screwed into place. This will raise the steam valve from its seat and allow the steam to flow directly through the valve to the train pipe. Of course, when the valve is removed the pressure must be regulated by the globe valve next to the boiler attachment. If the engine is equipped with a Gold pressure regulating valve and it should fail to allow steam to go through into the train pipe, take out the bottom plug or cap, remove the spring and valve and steam will flow through the regulator the same as it did with the Mason valve. In each of the above types of valve it would be proper to relax the tension of the regulating valve spring. If the valves are kept clean they will give very little trouble. Do not pound the side of a regulating valve, as it often springs the case and prevents proper operation and repair. You have failed to mention the kind of valve that gave you the trouble, but in any case make repair quickly if you can, and if unable to repair get the valve out and the steam back into the train. Keep the cars comfortable and get in on time. Report the valve for repairs at the terminal.

Allowing the train to get cold, sometimes makes the passengers "hot," and frozen pipes are expensive.

160. Changing Diameter of Eccentrics.—"If the outside diameter of an eccentric was turned down ¼ inch, or made ¼ inch smaller, what difference would it make in the motion and valves of the engine?"

Answer.—In case a new eccentric strap was applied that was bored out to fit the eccentric cam or sheave thus reduced in diameter ¼ inch, it would make no difference to the valve motion. It is the throw of the eccentric, or the distance its center is from the center of the axle that governs the travel of the valve, and not the outside diameter. Just figure the throw of the eccentric the same as you would a crank on any axle, and take a case where the center of the eccentric would be bored out 2½ inches from the center of the axle or the true center of the eccentric cam or sheave. This distance is called the radius of the eccentric, and the throw of the eccentric would equal twice this distance of the radius, or 5 inches regardless of the outside diameter of the eccentric.

161. Types of Locomotives.—"Will you kindly give me the names of the decapod engine with a trailer? The A., T. & S. F. road has such engines; five pairs of drivers, two-wheel truck and one pair of trailers. Also the new engines of the B. & O. with six pairs of drivers and two sets of cylinders. Three pairs of drivers connect with each set of cylinders. One pair of cylinders is in the usual place and the other pair is between the third and fourth pair of drivers."

Answer.—The first mentioned engine is designated as Compound Santa Fé type, and was built for heavy freight service by the Baldwin Locomotive Works and is listed in their class as "14, 32-58—¼—F. 70." The number "14" indicates the total number of wheels under the locomotive. Thirty-two divided by 2 equals 16, and 16 plus 3 equals 19; 58 divided by 2 equals 29, and 29 plus 3 equals 32, which indicates the diameter of the high and low pressure cylinders; the addition of the fraction ¼ indicates that there is a truck placed at each end of the locomotive. The letter "F" indicates the number of driving wheels; that is, "B" means the engine has one pair of drivers; "C" two pairs, "D" three pairs, "E" four pairs, and "F" five pairs. The letter "A" is used for a special class of engine with one pair of drivers, and the No. "70" indicates that this is the seventieth engine of its class that has been built. The B. & O. engine referred to is a Mallet type articulated compound; the rear six drivers are driven by the high-pressure cylinders; the low-pressure cylinders are in front of the forward drivers. The front cylinders and drivers are constructed on the principle of a truck, and the frame is jointed between the front and back drivers, which allows the forward part of the frame to slide either to the right or left under the front end of the boiler. The steam from the high pressure cylinders is conducted to the steam chests of the low-pressure cylinders by means of a pipe with flexible joints.

162. POSITION OF REVERSE LEVER AND POINT OF CUT-OFF.—"A simple Baldwin 10-wheel engine when in proper condition had no back-set in the tumbling shaft, and the link-hanger pin was set in the center of the link saddle. Engine was doing good work but met with hard usage and the tumbling shaft was sprung so that it had at least an inch or more back-set, so that when the reverse lever was on the center she had about two or three notches in the forward motion. Now, instead of squaring the tumbling shaft, the shopman shortened the reach rod enough to cause the reverse lever to stand in the center of the quadrant when the link block was in the center of the link. Please say what effect that had on the valve motion. She became loggy after that time and would not run. What was the cause of it?"

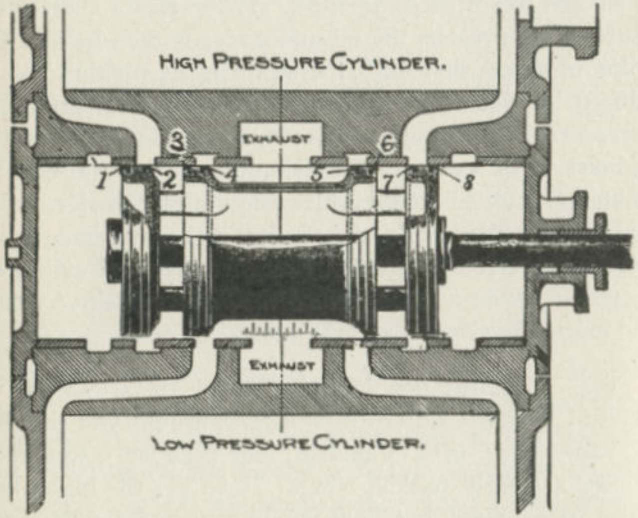
Answer.—As the position of the link block in the link would regulate the cut-off, and the purpose of the tumbling shaft is to raise or lower the links on the block to cut off steam at the desired point of stroke, we do not think that this was the cause of the engine getting loggy. Perhaps this was due to a choked nozzle. The position of the reverse lever should not affect the working of the engine providing the cut-off was the same.

163. THE LUBRICATOR.—"Does the lubricator feed oil to the cylinders of the locomotive, and does it also feed a small amount of the steam with the oil? Will it feed oil to the cylinders at all times? With an engine descending a heavy grade with lever in back motion, will the lubricator feed oil to the cylinders to prevent excessive wear."

Answer.—When a drop of oil rises through the water in the sight feed glass and reaches the top of the water, it is carried through the choke plug with the steam that comes down through the equalizing tube and is mixed with the oil, forming oil and water in the oil pipe leading to the steam chest when the lubricator pressure is greater than the steam chest pressure. If the steam chest pressure is the greater, the oil and water is then held in the pipe in suspension until the steam chest pressure is reduced by closing the throttle or by the fluctuations of pressure, caused by the valve opening the ports for the admission of steam to the cylinders. Then the oil and water is carried to the valve seats and cylinder walls, lubricating them. In descending a heavy grade with engine reversed to prevent excessive wear of cylinders, a water jet or what is termed the "water brake," would be more effective than a lubricator.

164. TESTING FOR VALVE BLOWS IN A VAUCLAIN FOUR-CYLINDER COMPOUND.—"How would you test for a valve blow in a Vauclain four-cylinder compound? There are eight packing rings; I can get the high-pressure valve rings, but how would you test for the low-pressure packing rings?"

Answer.—It is very difficult to distinguish the difference in blows, as there are several different defects about the Vauclain compound that will produce the same effect on the valve motion or the sound of the exhaust, and care should be taken not to mistake two light exhausts on one side for two heavy exhausts on the other. One loud exhaust with the Vauclain compound may be caused by either rings *Nos. 1, 2, 3, 6, 7* or *8* being broken. Rings *Nos. 1* or *8* broken, gives more port opening at the end of the high-pressure cylinder that the ring is broken on. This goes to the opposite end of the low-pressure cylinder and produces a heavy exhaust. If rings *Nos. 3* or *6* are broken, the volume of steam admitted to the low-pressure cylinder is increased with the same effect. Rings *Nos. 2* or *7* being broken will give



Testing for Valve Blows in a Vauclain Four-Cylinder Compound.

one heavy exhaust on that side of the engine, as the steam will blow past 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 there is a heavy exhaust from the front end on the right side it may be caused by rings *Nos. 8* or *2* being broken, thus increasing the pressure in the low-pressure cylinder, and you get a heavy exhaust. The illustration and method of making standing tests, taken from their report is as follows: Place engine on bottom quarter on side to be

tested; block the drivers or set brakes, and remove both indicator plugs on high-pressure cylinder. If engine is not equipped with plugs, remove pops or water relief valves on the cylinder heads; give the engine steam and be sure that the throttle is open sufficiently to set packing rings out against bushing. If ports can be covered, this shows rings *1* and *8* are in good order. In testing for high-pressure packing blow, put the reverse lever in forward motion, which will open front port to the high-pressure cylinder; close the starting valve and have the indicator plug or pop out at the back end of the high-pressure cylinder. When steam blows out of the indicator plug, the high-pressure packing may be blowing or ring *No. 7* 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; 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 indicator plugs in except the one in the 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 low-pressure packing blows, you will note it at the back of the indicator plug. In this same position, if rings *Nos. 3* and *4* or *5* and *6* are broken, steam will blow through the stack. The blow will be light in either case, as the steam, to produce it, must come through the starting valve.

165. DISCONNECTING A VAUCLAIN COMPOUND OR TANDEM.—"How would you cover ports and hold valve in position when disconnecting a Vauclain compound, and how with a tandem?"

Answer.—Cover ports same as with a simple engine, by placing the valve in the center of its seat and clamp securely. Employ the same method with a tandem.

166. BLOCKING CROSS-HEAD.—"At which end of the guides would you block cross-head, and why?"

Answer.—Back end, as less damage would result in case it got loose. The front head would be the only one knocked out, and is less expensive to replace.

167. BROKEN HIGH-PRESSURE CYLINDER HEAD.—"Is it practical to try to clamp a board over the high-pressure cylinder head, using live steam in the low-pressure cylinder on a Vauclain compound?"

Answer.—No. In case of a broken high-pressure cylinder head, block the valve central on that side, cover the ports, disconnect the main rod and block the cross-head, same as with a simple engine. Run in with the other side.

168. CENTERS OF CYLINDERS AND CENTERS OF DRIVING AXLES.—"Should the centers of the cylinders and the centers of the driving axles be on a line. If not, why not?"

Answer.—When possible, yes. An engine with centers of cylinders and centers of axles on a horizontal line is called a straight-line engine, and a straight rocker arm can be used (one with no back-set). When the center of the cylinder is above the center of the axle, it produces irregularities that require more care in putting up main rods the correct length, finding travel point to get pin on dead center, position of eccentrics on shaft, etc.

169. BLOCKING LINKS.—"I have a book where it says that in the event of a tumbling shaft arm broken

you should block up one link by putting block above link block, and if necessary to back up you must reverse the block to lower end of the link. I am satisfied that the information in regard to blocking for the reverse motion is incorrect and that you should simply substitute a longer block between the top of the link and the link block. Please advise which is correct."

Answer.—When the link is blocked on account of a broken reach-rod, link hanger or saddle pin, there should be a block placed between the top of the link and the link block, in position to insure the handling of the train in forward motion, and a block between the link block and the bottom of the link, allowing enough space between the blocks for the slip of the link on the link block. Then when it is desired to block the link for the back motion the blocks should be reversed, placing the long block on top of the link block and the short one at the bottom of the link. This is, very likely, what was intended to be understood by reversing the block in the book referred to, and is correct.

170. TYPES OF PISTON VALVES.—"Explain the principal difference in the two radically different types of piston valves."

Answer.—There are several kinds of piston valves used on simple engines. One is the solid valve without rings, and with outside admission, as in Fig. 1, and the other is the hollow piston valve with rings in the ends of the spool, as shown in Fig. 2, and internal admission. Note that the internal admission valve admits steam from the inside of the spool, and the outside admission valve admits steam from the outside ends of the valve when port is opened.

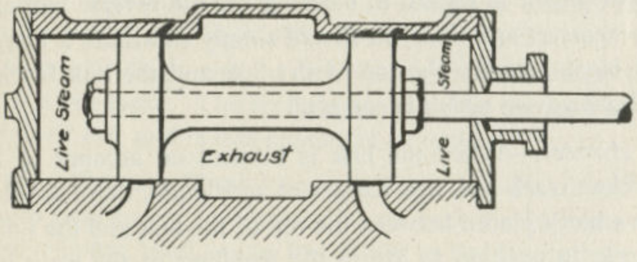


Fig. 1. Solid Piston Valve without rings, and outside admission

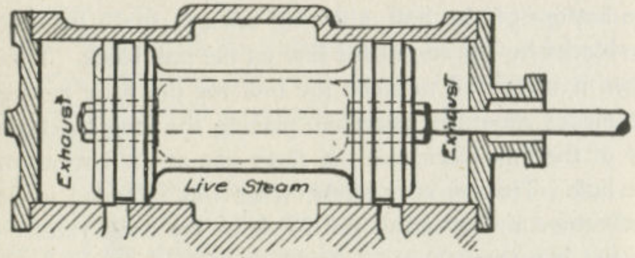


Fig. 2. Hollow Piston Valve, with rings in ends of spool, and internal admission

171. Precautions Necessary When Valves are Faced, etc.—"What precautions should be taken if any work or repairs have been done, such as valves faced, rod brasses filed, etc?"

Answer.—When the valves have been faced it is advisable to run the engine a short distance with lever in full gear and lubricator feeding freely, before coupling onto train. If the opportunity presents itself, also a little graphite introduced to the steam chests or valve seats will help to form a skin on the valves and seats and prevent cutting on the start. Use oil enough and as long a cut-

off or valve travel as is possible for the first few miles. If there are no stops or drifting places, close the throttle for an instant and drop lever in full gear occasionally. This will allow oil that may be held in the oil pipes to get down into the steam chests and onto the valve seats. After the seats are smoothed up, cut the lubricator feeds down to regular supply. Use dry steam always to get best results. If brasses have been filed on main rods, see that they are properly keyed and the set-screws are tight, back ends free on pins when on center, and front ends free when on quarter. If side rods, have them free when passing centers. Keep bearings properly lubricated and no trouble should be experienced.

172. Broken Eccentric Strap.—"Will you kindly explain the following: I fire a passenger run and on one of our outgoing trips something let go just as we shut off. Drifting to our next stop we got down and found the right forward motion eccentric strap broken, leaving the eccentric and front part of the strap riding on the shaft. We took the broken strap and rod off, and as we were getting ready to go on one side another engine came and took our train, and we were ordered back to the shop. The engineer intended to back in, using both sides in back motion. I said it was impossible and risky, so he took my advice, which was to disconnect valve stem and leave the good eccentric up and block the link on top of the link block. Some of the boys have criticised the method and wanted to know why I blocked the link and what prevented it from turning over, and why I disconnected the valve stem. I thought the block in the link would make a positive fulcrum point on the link block. I could not explain the why or the action.

What kept the link from turning over, or would it turn over?"

Answer.—Your advice to the engineer was bad. Had he disconnected the broken strap from the eccentric rod and removed one of the bolts that hold the backward motion eccentric in the strap and substituted a longer one, and bolted the back end of the forward motion eccentric rod to the backward motion strap, he could have put the lever in the back notch and backed up to the shop. The back motion eccentric rod would be almost in line with the link block, and the forward motion eccentric rod being bolted to the back-up strap would hold the top of the link in position and prevent it from turning over. It is advisable to block the link on disabled side under above circumstances, to prevent the engineer from reversing the engine in case an emergency should arise, and he might forget and try to reverse the engine. This would have been quicker and much easier. When you disconnected the valve rod and took off the forward motion eccentric strap and rod, the weight of the back-up eccentric held the bottom of the link down and prevented it from turning over, so that there was only the work of moving the rocker arm required of it when the valve stem was disconnected. If the valve stem had remained connected to the valve yoke, the friction of the valve would have been greater and overcome the weight of the back motion eccentric which held the bottom of the link down with the valve stem disconnected, but would have caused the link to turn over if the valve rod was not disconnected.

173. Cost of Locomotives.—"Would you please give me the cost of locomotives, commencing with the small standard and up to the heavy modern engine?"

Answer.—Much depends on the specifications, and the following figures are only approximate. It's similar to the cost of a suit of clothes. Material and workmanship must be considered, as well as the appliances of equipment, such as air brakes, number of pumps, etc.:

Standard 8-wheel, 17-in. cylinder	$ 8,000 and up
Light switching	8,000 and up
Heavy switching	11,000 and up
10-wheel	14,000 and up
Consolidated	16,000 and up
Atlantic type, wide firebox	17,000 and up
Compounds, heavy	18,000 and up

174. Loss of Heat in Working Injector.—"Is there any heat lost in the steam used to work an injector?"

Answer.—There is no transmission of power without some loss. Heat being the power to generate the steam to work the injector, there is loss due to radiation from the pipes and from the friction of the steam and water passing through them at high velocity. The heat is used to lift and force the water into the boiler, and the amount of steam that is condensed by the water or heat imparted to the water which raises its temperature is the useful energy. The balance is the loss.

175. Broken Eccentric.—"Would it work, if the back-up eccentric broke while running ahead, to take one bolt out of the good eccentric blade and bolt the eccentric blade of the broken eccentric to it, and proceed without disconnecting, or vice versa?"

Answer.—Yes. That is all right for forward motion, but the link should be blocked, so that there would be no possibility of reversing the engine. In case you were backing up and broke the forward motion eccentric the same thing could be done with the forward motion blade, but not if you were running ahead. In either of the above breakdowns, when the back end of the blade is bolted to the strap of the good eccentric, the blade only serves to hold the link in position and prevent it tipping or turning over, but the link should be blocked to prevent reversing, and the good eccentric would govern the movement of the valve while in that position. If the forward motion eccentric would break while running ahead and the back one on that side could not be substituted, and the eccentric could be moved on the shaft, the back motion eccentric could be moved to correspond with the position of the forward motion eccentric, and by disconnecting the link hanger and blocking the link the train could be taken in in forward motion.

176. PROPORTIONATE AREA OF SAFETY VALVE TO GRATE AREA.—"Will you please work out in full the following examples. With 1 square inch of valve area to 3 square feet of grate area, what size safety valves should be used on a boiler having a firebox 116 inches long and 89 inches wide?"

Answer.—A firebox 116x89 inches would have a grate area of 89 times 116=10,324 square inches, or 71.69 square feet. One square foot contains 144 square inches, and 3 square feet=3×144, or 432 square inches. Dividing 10,324 by 432 gives 23.9 square inches of safety valve area. Therefore, with 1 square inch of valve area to 3 square feet of grate area we would require safety valves that would give an opening of 23.9 square inches. A 3¼-inch safety valve would have an area of 8.2958 square inches, and three 3¼-inch safety valves would be ample, as per the above question. It is customary to

base the area of the safety valve opening on the evaporation of water per hour or minute, rather than on the size of the grate area.

177. FINDING STROKE OF PISTON.—"What stroke of piston should be given to a locomotive with a cylinder diameter of 17 inches; weight o1 drivers, 85,000 pounds; diameter of drivers, 56 inches; and a boiler pressure of 180 pounds per square inch?"

Answer.—The tractive power not being given, we will base it on the tractive weight. Allowing a ratio of 4.5 to 1, or, 85,000 pounds, the weight on drivers, divided by 4.5=18,880, or 18,880 pounds tractive power. Then from the formula for getting the tractive power, which is

$$T=\frac{C^2\times S\times P}{D},$$

to get the stroke of the piston we will work the example the other way, or deduce the following formula obtained from the above:

Taking size of cylinder and driver with same pressure, which is 85 per cent of boiler pressure, we have,

$$S=\frac{56\times 18{,}880}{17^2\times 85\%\text{ of }180}$$

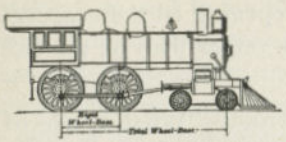
$56\times 18{,}880=1{,}057{,}280.$

$17^2=289.$

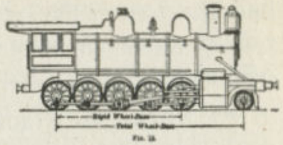
85% of $180=153.$

Then $153\times 289=44{,}217$, and $1{,}057{,}280\div 44{,}217=23.9+$, or 24-inch stroke of piston for above engine.

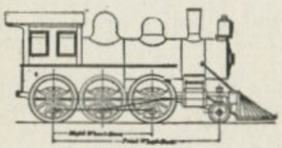
178. STRESS ON STAYBOLTS.—"What stress per square inch of section will be put upon the staybolts of a firebox working under a pressure of 175 pounds steam per square



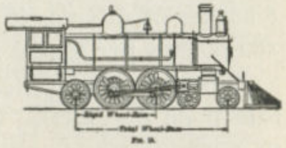
American, or Eight-Wheeled.



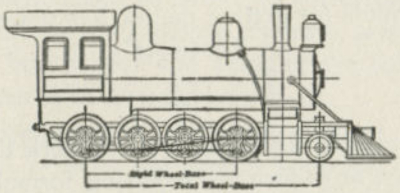
Decapod.



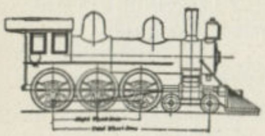
Mogul.



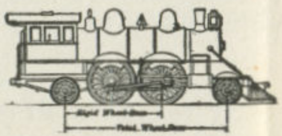
Atlantic.



Consolidation.

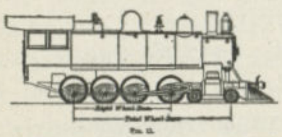


Ten-Wheeled.

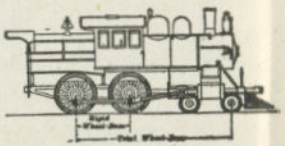


Columbia.

38 STEAM, CYLINDERS, AND VALVE GEARS



Twelve-Wheeled.



Wide Firebox.

SOME COMMON TYPES OF LOCOMOTIVES.

inch. The staybolts to be 1 inch in diameter and spaced 4½ inches from center to center.

Answer.—Each staybolt will have a stress of 175 pounds per square inch of sheet in proportion to the spacing of bolts, or the distance between centers. To find the stress per square inch on staybolt, use the formula $\frac{4.5^2 \times 175}{.7854}$. Taking the staybolt to be 1 inch at the root of the thread and neglecting the area of the bolt where screwed into the sheet:

```
          4.5
          4.5
         ----
         22 5
        180
       ------
        20.25
         1 75
       ------
        101 25
       1417 5
       2025
      --------
.7854)3543.7500(4,512 pounds=Answer.
       3141 6
       ------
        402 15
        392 70
        ------
          9 450
          7 854
         ------
          1 5960
          1 5708
         -------
```

A staybolt 1 inch in diameter has a cross section of .7854 square inches. Now, by dividing 3,543.75 by .7854 we have the answer, 4,512 pounds.

179. CLASSIFICATION OF LOCOMOTIVES.—"I have read a short paper by Mr. Louis Hurtubise, C. E. of the C. P. R. He names type 2 of the third series the Atlantic type. In this type the main rods are connected to the rear drivers. We have some of this type running out of Tucson, and some with the main rods connected to the front drivers, like the American type, which I believe are known as Pacific type. Am I right in my belief?"

Answer.—The classification list by Mr. Hurtubise, shown in the Locomotive Firemen's Magazine, is no doubt suitable for the C. P. R., in designating the various types of engines on that line, but does not mention the Pacific type you speak of. A Pacific type engine consists of an engine with a four-wheel truck, six drivers and one pair of trailers under the firebox, and is frequently designated as a 4-6-2 type. The one you saw is no doubt a Baldwin balanced compound, called the Atlantic type, with the main rod connected to the pin on front driver. The manner of designating the type of engine by the number of wheels is meeting with general favor, calling an American engine a 4-4-0, a ten-wheeler a 4-6-0, a Mogul a 2-6-0, an Atlantic type a 4-4-2, and the Pacific Type a 4-6-2 type, etc.

NOTE:—See "Four Cylinder Balanced Compounds," a pamphlet issued by Railway Publications Society, Chicago. Price, 15c, postpaid.

180. BURNED OR BROKEN GRATE.—"How would you manage with a burned or broken grate? How if entirely gone, with deep ashpan?"

Answer.—If a grate was broken you might be able to block up under it so as to bring in your train. But it is usually better with a grate burned, broken or entirely gone, to place angle bars across the space to keep coal from falling through into the ashpan. Keep the ashpan clean and you will be reasonably free from grate troubles.

181. GREASE CELLARS ON DRIVING BOXES.—"With an engine equipped with grease cellars on driving boxes, how would you know there was sufficient grease in the cellar to make the trip, and if it needed packing out on the road, how would you proceed to pack it?"

Answer.—If you will observe closely you will find that there are two indicators that are attached to the follower plate and extend through the bottom of the cellar, and are for the purpose of indicating the amount of lubricant in the lubricator or grease cellar, and also to show that the grease is being fed to the journal, front and back. When the top part of the ring on the indicator is flush with the bottom of the cellar, it is then time to have it repacked. Examine this before you leave the terminal, but do not get uneasy, as they only have to be repacked every 30,000 to 50,000 miles. If you need to pack a cellar out on the road you can easily accomplish it by removing the end plate on the cellar, which is held in place by two small bolts. Then insert hooks in the eyes of the indicators and pull them down as far as you can; secure them in that position and you will find that the follower plate will be flush with the lower edge of the opening in the end of the cellar. A cake of lubricant or grease should be about one inch thick and two and one-half or three inches wide, and cut in length to fit inside of cellar. Place the first cake to one side of the cellar on top of the follower plate, and the second to the opposite side, then fill the space in the middle with a third piece, put on the end plate, release the indicators and the spring will force the grease up to the journal and you are ready to go.

If you anticipate a job of this kind, have the cakes of lubricant ready, firmly packed, of the right size and free from dirt.

182. TESTING FOR BROKEN BY-PASS VALVE.—"If a by-pass valve was broken, how would you test for it?"

Answer.—The piston valve can not raise from its seat to relieve the pressure in the cylinder when the valve has covered the port, hence the necessity of a means of relieving the pressure. The by-pass valve is placed between the live-steam chamber and the admission port, and located in a case that is bolted to the cylinder casting. When steam is admitted into the steam chamber between the pistons of a piston valve, if inside admission type, the by-pass valve is held to its seat by the pressure in the steam chamber. But when the pressure in the cylinder is greater than that in the steam chamber, the by-pass valve is raised from its seat and permits the steam to flow from the cylinder into the steam chamber, relieving the pressure in the cylinder in this manner instead of allowing it to escape to the atmosphere, as it would if a relief valve was used on the cylinder head.

To test for a broken by-pass valve, place the rocker arm plumb. This should cover the ports. Then open the cylinder cocks and the throttle. Steam will flow past the broken valve and out of the cylinder cock at the end of the cylinder the broken by-pass valve is on. If blow will prevent your handling train properly to terminal, take off by-pass valve case and insert blind gasket between by-pass valve case and cylinder casting. In some cases you may be able to block the valve in position by removing cap.

183. BROKEN DRIVER OR TRAILER SPRING, HANGER OR EQUALIZER.—"How would you proceed to block up for a broken driver spring, spring hanger or equalizer on a class D engine; how for a broken trailer spring or hanger? The class D is a Northwestern type."

Answer.—For a broken front driving spring, run front driver up on a wedge, then pry up the front end of the equalizer nearest to the broken spring until it is in about normal position and place a block either between the front end of the equalizer and the lower bar of the frame, or between the back end of the equalizer and the top rail of frame. This gives the use of the main driver and trailer springs. Now run the front driver off the wedge and the back driver up on the wedge, and block between the top of the front driving box and the frame so the front driver will carry its load, remove or secure broken parts.

If equalizer broke between the front and back drivers, raise up engine with jacks or in any other manner, and block between lower hanger pins and the bottom of the top rail of the frame.

When a trailer spring breaks it allows the end of the cross equalizer nearest the end of the broken spring to drop into the safety hanger. First jack up the end of the cross equalizer into position and place a block in the U-shaped safety hanger to hold it until you are ready to remove it. Now raise the back end of the engine frame so she will ride level, remove the broken spring and take a tie or a piece of rail and place it over the trailer box and chain front end to the cross equalizer, and the back end to the frame and hanger pin, remove the block from the safety hanger under the cross equalizer and let the usual load come on the trailer box.

If a front hanger on a trailer spring should break, raise the back end of the engine on the disabled side so as to relieve the trailer spring, then jack up the end of the cross equalizer next to the broken hanger, pry down the front end of the trailer spring and securely chain the end of the spring to the end of the cross equalizer.

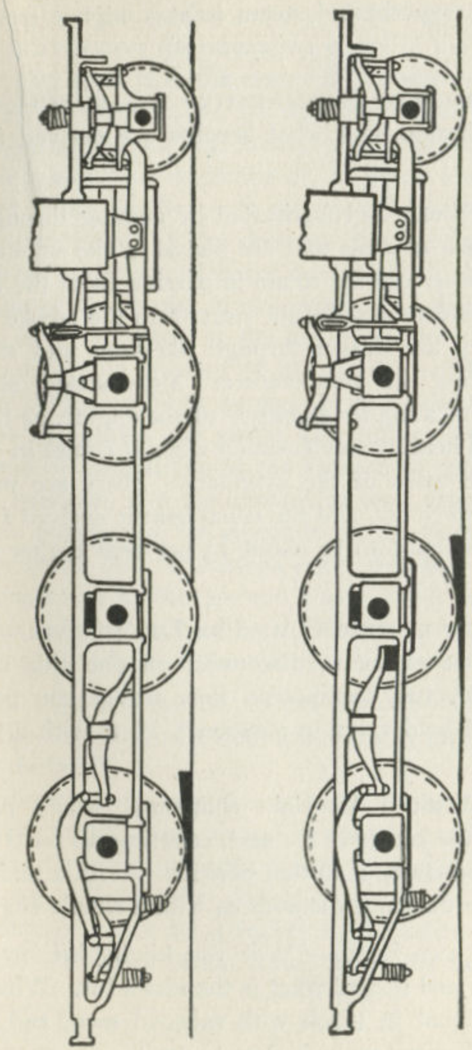
If a back hanger on trailer spring is broken, raise the back end of the engine and also jack up the end of the cross equalizer to relieve the spring, then pry the back end of the spring down and chain it so it will not work off the hanger pin.

184. Guides and Cross-head Not in Line—"What would be the result if guides and cross-head were not in line?"

Answer.—Excessive wear on sides of cross-head and guides, unequal wear in cylinders and cylinder packing rings, difficulty in keeping piston rod packing from blowing and wearing out rapidly, and trouble with main rod brasses, especially in the front end of main rod.

185. Superheated Steam.—"What is superheated steam?"

Answer.—Superheated steam is steam heated to a temperature above that due to its pressure. The temperature of steam in contact with water depends on the pressure under which it is generated, as shown in steam



Method of Blocking for Broken Spring, Spring Hanger, or Equalizer.

First raise frame by running wheel up on wedge, and block as indicated by upper figure. Next raise second driver on wedge as indicated by lower figure, which will release tension so that block can be placed under spring as indicated.

tables, while superheated steam is at a higher temperature.

186. Method of Superheating Steam.—"How is steam superheated, and what benefits are derived from it?"

Answer.—Steam is superheated by passing through a system of pipes or coils that are placed in the smokebox for this purpose, and the steam in passing from the boiler to the cylinders absorbs the heat from the smoke and gases as they are drawn through the flues and stack, thus increasing its temperature. Superheated steam therefore gives a higher efficiency of the engine, as there is less loss of heat by condensation when it comes in contact with the walls of the cylinders. There are many types of superheaters, and the usual benefit derived from their use is claimed to be about 13 per cent higher efficiency.

187. Disconnecting Compound Locomotives.—"In case it was necessary to disconnect on one side of a Vauclain compound locomotive, how would you cover the ports and hold valve in position? How with a tandem?"

Answer.—With a Vauclain compound would place the valve in the center of its seat, covering all ports for admission, and clamp it in that position. With a tandem would employ the same methods as with a simple engine.

188. Lap and Lead.—"Will you kindly inform me what lap and lead is, and what is the idea of it. What is it for? I am not in touch with railroad men, and the book I have does not make it clear to me."

Answer.—Lap is the amount of the edge of the valve that extends over the admission edges of the steam ports when the valve is in the center of its seat or mid travel, and is for the purpose of working steam expansively. If a valve had no lap, steam would follow the piston the full length of its stroke or, in other words, the cylinders would be filled with steam at chest pressure twice every revolution of the drivers. By having lap on the valve the admission of steam can be cut off at any desired portion of the stroke of the piston, and the object of it is to effect economy in the use of steam. Lead is the amount of port opening of the valve when the piston is at the beginning of its stroke, or on the dead center, and serves to cushion the piston and reciprocating parts at the end of each stroke in the absence of compression or back pressure, and the amount of lead depends entirely on the position of the eccentric on the shaft in relation to the crank pin. It hastens every function of the valve in proportion to the amount given, while lap can only be increased or reduced by substituting a wider valve or planing the edges of the old one to reduce its width.

189. Deflection of a Coil Spring.—"How do you find the deflection of a steel coil spring 1 inch by 4 inches by 8 inches?"

Answer.—In asking this question the number of coils or turns in the spring should be specified rather than the height of spring, in order to get the deflection. Therefore, we will take the spring shown in the illustration, measuring 1 inch by 4 inches by 8 inches and having 6 coils. We have (from Kent) W as the safe or working load for the spring $= .3927 \dfrac{S\,d^3}{D}$

S = ultimate tensile strength per square inch of material. In this case we will take it at 60,000 pounds.

d=diameter of bar in inches, which is 1 inch.

D = diameter of spring from center to center of bar.

Now the strength, or working load, is obtained by using the formula. Thus,

$$W = .3927 \times \frac{60{,}000 \times 1}{3} = 7{,}854$$

pounds.

This load would apply to a spring of the above dimensions with any number of coils.

Now to get the deflection (from Kent).

$$E = \text{deflection for one coil or turn} = \frac{D^3 \times W}{d^4 \times C}$$

D = diameter of spring from center to center of bar.

W = imposed load.

d = diameter of bar in sixteenths of an inch.

C = a constant whose value is 30 for round steel.

Substituting, we now have:

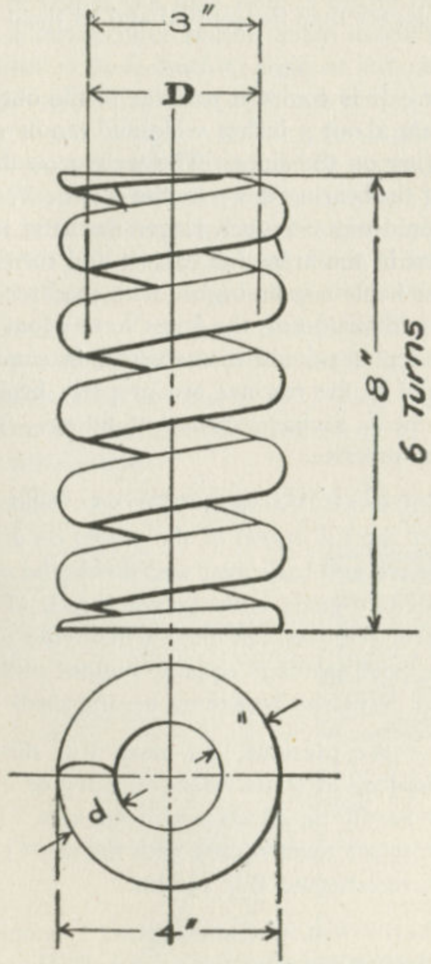
$$\frac{3^3 \times 7{,}854}{16^4 \times 30} = .108 \text{ inch.}$$

This is the deflection for one coil, and as there are six coils shown in this spring, .108 x 6 gives us a deflection of .648 inch with a load of 7,854 pounds.

190. Radius Bar.—"Will you give me the proper name for what I call the tongue of an engine truck to a consolidated locomotive?"

Answer.—This class of engine has what is called a pony or Bissell truck, and the tongue you refer to is a V-shaped frame. Its proper name is a radius bar.

191. Fitting Driving Boxes.—"How would you fit a driving box on an engine weighing 200,000 pounds?



Deflection of Coil Spring.

Our superintendent of motive power claims to bore them 1-64-inch larger than the journal and let them go without fitting."

Answer.—It is common practice to file out the crown of the brass about 3 inches wide and file or scrape to a good bearing on the sides. The weight on the box will soon bring the bearing down on the crown. We have seen brasses bored out 1-64-inch larger than the journal and holes bored in the brass for babbitt and then bored out, leaving the babbitt spots higher than the brass, and they run good without fitting the brass to the Journal. Your superintendent no doubt is successful in employing this method, and if the engines are properly broken in and run good he is saving expense of fitting. This is not the general practice.

192. SQUARING VALVES.—"Do you think it proper to run over the full travel of the valves on a locomotive in the forward and back gear and divide the valve travel between the two gears with the reach rod. Then adjust the eccentric rods so that they will divide up on each side of the port openings equally without putting up the main rod. Will she be square on the dead center?"

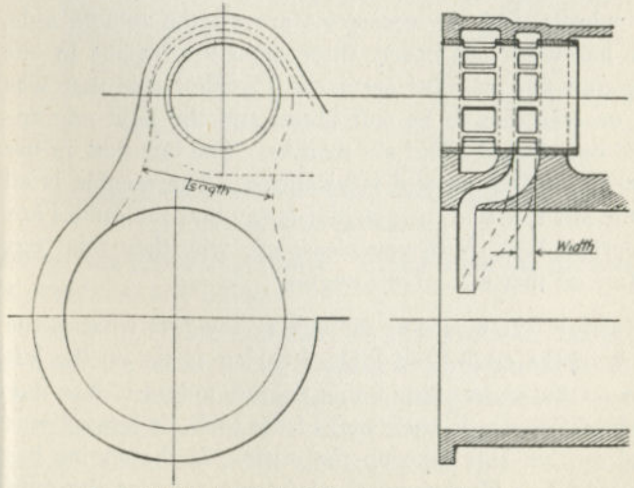
Answer.—We presume you mean will she be square when hooked up at short travel of valve or cut-off, and would say hardly on all classes of engines. It's usually close work to get them square with the main rod up, and would not recommend this system.

193. PISTON-VALVE CHAMBER.—"I would like to know the proper name for the valve cylinder on a piston-valve engine. All I have ever heard it called was a steam chest. Is this proper?"

Answer.—Hardly. The proper name is piston-valve chamber. It would not look well to report steam chest leaking on a piston-valve engine, but it would be correct to report front or back head on right or left piston-valve chamber leaking. Therefore it is not customary to call it the steam chest. If it was a slide-valve engine and the chest was broken a new chest could be applied. With a piston-valve engine, and the valve-chamber broken, it would have to be patched or a new casting made, which usually consists of a cylinder and valve chamber with ports for the admission and exhaust of steam. The valve chamber is bored out large enough to insert a bushing, which is called a valve-chamber bushing.

194. DIMENSIONS OF PORTS IN PISTON-VALVE ENGINES.—"How do you get the dimensions of the ports in a piston-valve engine?"

Answer.—The accompanying sketch shows an end



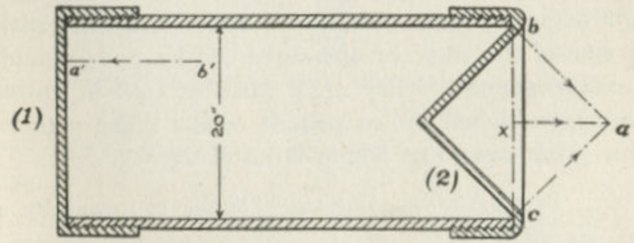
End and partial side view of Piston-Valve Chamber, Bushing and Cylinder and part of a side view of a piston-valve chamber, bushing and cylinder. In speaking of the width of the ports they are measured for width the same as in the slide-valve engine. Taking the width of the full lines shown in the bushing as the width, the dotted lines show where the chamber is cored out to allow the steam to flow into the port leading to the cylinder. The bridges in the bushing are to keep the rings in the piston valve from entering the ports when the valve passes over them and the width of the port openings in the bushings. To get the length of the port, measure the shortest distance between the valve chamber and the cylinder, as shown in the sketch. This will give the width and length of ports.

195. Wear of Cross-head Gibbs.—"There is a Brooks six-wheel connected piston-valve engine in switching service that has come under my observation. She has double guides, main pins are on the back driving wheels, and the eccentrics are on the middle axle. She has worn out nearly three cross-head gibbs in one year and five months' service. The first one that was put on was said to be soft brass, and the next one applied only lasted about six months. The one now in use is nearly worn out and is babbitted. The trouble is all on the left side and the machinists say that the guides are in perfect line. Will you please say why they wear out so fast on that side of the engine?"

Answer.—It would be difficult to say just what is the cause of the cross-head gibbs wearing faster on the left than on the right side of this engine, unless it was due to the difference in the metal of the gibb, or less oil was used on that side than on the other. If the engine has the sand box filled from the left side daily or the sand

box is leaking, allowing sand to get down on the guides and between the wearing surfaces, that would cause excessive wear on that side. Cultivate the art of seeing things and you may locate it. We are unable to say why there should be a great difference in the wearing of the gibbs if they are of equal bearing surface and properly lubricated.

196. Pressure on Flat and Cone-shaped Surfaces.—"If I take a piece of pipe, any length or size, and screw an ordinary cap on each end, my argument with a friend was that if one of them was a flat surface inside and the other was cone-shaped, as per sketch, the pressure would be considerably less on the cone-shaped end with any given pressure inside the pipe than it would on the other end, which had a flat surface inside. I claim that the pressure will follow the angularity of



Pipe with Flat and Cone-shaped Caps

the surface given to pressure. Please state the difference in pressures, and oblige?"

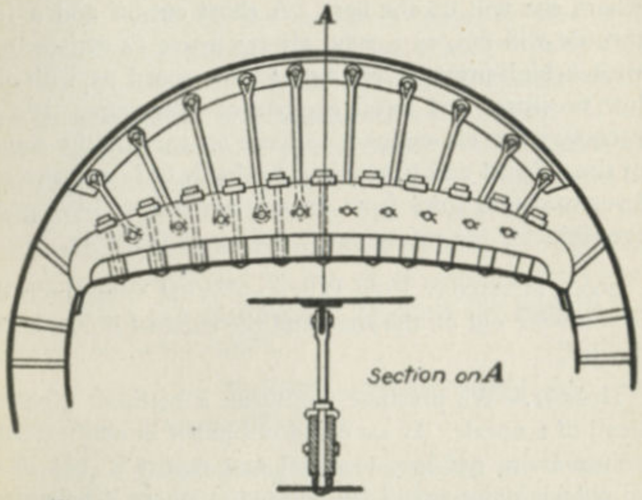
Answer.—There would be no difference in the pressure exerted on each cap, tending to force them from the pipe or to strip the threads, as the pressure is equal.

This brings to mind a valve that was made with a back to it like the angle shown by the fine lines at the cone-shaped cap, in order to reduce the pressure on the back of the valve, but it was found that the pressure on the valve seat was the same as on the valve with the flat back. Theoretically, we will take the above cut for an example and let the diameter of the cylinder or pipe be 20 inches, drawn to a scale of 1 inch equals 1 foot. Let the interval pressure be 14.15 pounds per square inch tending to force the caps from the pipe or cylinder, represented by a line *a b* drawn to a scale of 12 pounds to the inch, or 1 pound per inch of scale of the drawing. Then the pressure on cap (1) equals the area of a 20-inch circle multiplied by 14.15, which equals 4.445 pounds. Let cap (2) be a 45° cone. Then the area of the cone will equal 444.5 square inches. Now the effective pressure on this area tending to remove the cap must be one-half the resultant of two forces, each equal to *a b*, acting perpendicular to the surface of the cone, or at right angles to each other, as *a b* and *a c*, which equals the sine of the angle of 45° multiplied by 14.15 pounds equals 10 pounds. Then 444.5 (area of cone in square inches) multiplied by 10 pounds equals 4.445 pounds, same as on cap (1). There is no difference.

197. Sling-Stayed Boiler.—"What is meant by a sling-stayed boiler?"

Answer.—A boiler that is built with crown bars, as shown in sketch. Note that the ends of the crown bars rest on the side sheets, and that the bars are also supported between the ends by sling stays that are fastened to the crown bars and dome, or roof sheet of the boiler, which in turn hold the crown bolts that pass through the crown sheet and are riveted over. This is a sling-stay and crown-bar boiler. If the bolts were severed

and riveted into the crown sheet and dome sheet it would not be necessary to use the crown bar, and the boiler would then be called a radial-stayed boiler.



Sling-stay and Crown-bar Boiler. Illustrating Question No. 197.

198. Leaky Mud Rings in Winter and Summer.—"Why do mud rings leak worse in winter than in summer?"

Answer.—On account of the greater differences in temperature, causing greater expansion and contraction. If a wide firebox, it is often due to lack of proper lubrication of the expansion pads or braces, and the unequal expansion of the frame and boiler, producing a strain on the mud ring and throat sheets when the expansion pads are dry or not properly oiled.

199. Throttle and Cut-off.—"What would you advise for best results in pulling a train, a certain stroke and a full throttle, or a little more stroke and less throt-

tle? I find I can keep them hot the easier with more stroke and less throttle."

Answer.—Would advise that the engine be worked where she will do the best. A short cut-off and a full throttle will not, as a rule, always prove as satisfactory with a high-pressure engine at slow speed as with the low pressures and small engines of years ago. It's as necessary for an engineer to have an ear for the sound of the exhaust and to manipulate the throttle and reverse lever to obtain work from the engine, as it to have good eye-sight for the safety and handling of the train.

200. PETTICOAT PIPE DOWN.—"What would you do if you were out on the road and the exhaust nozzle came down?"

Answer.—We presume you mean a petticoat pipe instead of a nozzle. If we could not put it in place, would reduce train, get into terminal and report it, but if at an outside point would try and put it where it belonged, after the fire was drawn. It's almost impossible to adjust a pipe in the front end of an engine with a fire in the box, unless the adjustment can be made from the outside.

201. FRICTION—"Upon what does the amount of friction depend?"

Answer.—Friction is the resistance that a body meets with from the surface on which it moves, and depends on the pressure between the surfaces and the condition of same. A body moving over a smooth surface will produce less friction than when moving over a rough surface, and friction is greater between soft bodies than hard ones. It is proportional to the perpendicular pressure between two surfaces in contact.

202. OIL AND FRICTIONAL SURFACES.—"What is the effect of introducing oil between frictional surfaces?"

Answer.—Reduction of friction, less wear on the bearings, and separating the metals of same by placing a film of oil between them. If we had a heavy box to slide on a platform and could not move it, the reason would be that the friction was greater than the power. If we had a layer of grease or film of oil between the surfaces in contact it could be moved more easily. This would be sliding friction. Then if we put rollers under it we could roll it easier than we could slide it. This would be rolling friction, and the film of oil introduced between two bearings acts as rollers in reducing the friction and keeping the metals apart.

203. ABUSE OF ENGINES.—"What would you consider abuse of engines?"

Answer.—Slipping engine when taking her from the roundhouse track without opening the cylinder cocks to let the water out of the cylinders; slipping her at any time and catching her on sand at any time without closing the throttle; reversing engine with brake set; sliding drivers and flattening tires; poor pumping, knocking the steam pressure down by too much injector, and pulling out of stations without having fire in proper condition; working engine harder than necessary to handle train and make time; working water and wet steam through valves and cylinders; imperfect lubrication; firing engine without getting coal on forward section of grates, causing flues to leak; failure to tighten a nut or drive a key where needed, and not reporting necessary work on arrival at terminals, all go toward the abuse of an engine.

204. HORSE POWER OF ENGINE.—"What is the horse

power of a 17x24-inch cylinder? Will you please give the answer worked out?"

Answer.—The formula is $\frac{PALN}{33{,}000}$ = horse power.

As the pressure or number of strokes are not given we will assume them to be as follows, and proceed with the example:

P=Mean effective pressure per square inch on the piston, 100 pounds.

A=Area of the piston in square inches.

L=Length of stroke in feet, 2 feet.

N=Number of revolutions per minute, 200.

```
     17
     17
    ---
    119
     17
    ---
    289
  .7854
 ------
   1156
  1445
 2312
2023
-------
226.9806
     100
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22698.0600 = { Area of piston multiplied by pounds pressure.
----------
         4 = { Length of stroke in feet for every revolution.
----------
```



```
                 90792.2400
Divided                 200
  by—          ------------
33000)18158448.0000(550.256 = horse power.
      165000
      ------

       165844
       165000
       ------ 
         84480
         66000
        ------
        184800
        165000
        ------
         198000
         198000
         ------
              0
```

This for a 17x24-inch cylinder, or one engine. If you are figuring for a locomotive the horse power would be 2 times 550.25 H. P., or 1,100.50 horse power, as per the above example.

205. Direct vs. Indirect Valve Motion.—"There is a great difference of opinion as to whether a certain class of our engines are direct or indirect valve motion. They have inside admission piston valves with a transmission bar, and the go-ahead eccentrics following the pins, same as in ordinary indirect engines. Please advise what they are, direct or indirect engines."

Answer.—Fig. 1 shows an inside admission piston valve with an indirect rocker. You will observe that the position of the eccentrics on the shaft or axle is directly opposite to the position that they would be in if this was an outside admission valve. Instead of being advanced toward the pin the amount of lap and lead, they are advanced away from the pin. The internal or external ad-

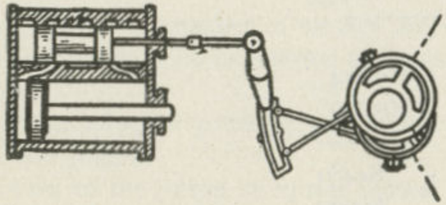


Fig. 1

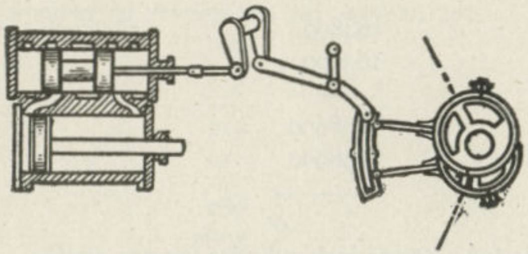


Fig. 2

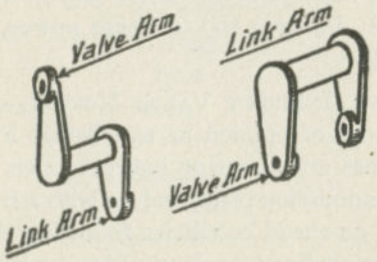


Fig. 3

mission valves make this change of position of the eccentrics necessary with an indirect rocker. This illustration is a view of an indirect motion or rocker, because

the valve is traveling in one direction and the eccentric is traveling in the opposite direction. Fig. 2 shows the same kind of a valve with inside admission, but with a direct motion or rocker, and the eccentric and valve both move in the same direction. In this illustration the eccentrics are placed on the shaft in the same position as if you had an indirect rocker with an outside admission valve.

The front steam port must be opened to admit steam to the cylinder in both illustrations. If your engine is put up as shown in Fig. 2 you have a direct motion engine. Fig. 3 shows an indirect rocker on the left and a direct rocker on the right, or a rocker with a link arm and the valve arm opposite each other is a direct rocker.

206. TROUBLESOME BOILER CHECKS.—"I am firing an eight-wheel wagon-top boiler engine equipped with No. 8 Monitor injectors on both sides. The boiler checks are in the barrel of the boiler and set about level with the center of same. The injectors are on a level with the top of the tank and they work in good shape until the tank is one-half empty and less. Then every time the injector on either side is shut off the boiler checks stick up, and they give no trouble at any other time when the tank is over half full of water. Both checks have been ground in, examined and pronounced all right and give no sign of leaking when injectors are not in use. What is the trouble?"

Answer.—From the description given of the action of the checks, it is the opinion of experts that the trouble is from sediment deposited on the valve and interior of the cage and passage to boiler through check, and that the check valve may be fitted too close to allow any deposit without interfering with the free action of the check. The height of water in the tank would in no way influence the boiler check if in proper condition. possibly the valve and seat may be battered sufficiently to cause too tight a fit for free action of the valve. This case would require a personal examination in order to render a definite conclusion, and we would recommend that the check be made sufficiently loose so that the valve would find its seat readily at all times when the injector was shut off.

207. Injector Worked by Air Pressure.—"Can an injector be worked on a boiler with air pressure on it instead of steam? If not, why not? I have consulted several different engineers about it and they vary in opinion."

Answer.—No, it can not. The injector is an instrument that will force water into a boiler against a pressure equal to that of the steam that is used in its operation. Steam in forcing water through the injector and into a boiler gives up heat and imparts a velocity to the water, and starts it with a momentum sufficient to overcome a pressure even higher than the original pressure of steam. A great deal of the velocity of the steam is given up to the water, and gives the water sufficient energy to open the check valve and enter the boiler. As the steam condenses in imparting its heat and velocity to the water the pipe is solid full of water. When the water will not condense the steam or is too high a temperature (too hot) the injector will not work. Therefore, the reason that the injector will not work with air pressure is that the mixture of air and water would make bubbles and it would not be a solid body of water to absorb the velocity or mix with the air, as you could not have air and water occupying the same space at the same time. Our experience has been when reversing an engine and

opening the throttle to prevent striking the rear end of a preceding train, that the injector always broke on account of the air mixing with the steam.

208. Per Cent of Heat Used.—"Will you kindly give me the per cent of heat used and the per cent of heat that escapes from the stack of a locomotive while working?"

Answer.—In order to make this clear we will have to take an example and work out the answer. Conditions vary so much that the answer will only be approximately correct for this specific case.

We will assume that we have an engine with 22x27-inch cylinders; driving wheels 56 inches in diameter, with a boiler pressure of 175 pounds, and running at a speed of 12 miles per hour. Allowing a mean effective pressure in the cylinders of 78 per cent of the boiler pressure we would obtain a tractive power of 33,000 pounds, or the locomotive would develop one horse-miles per ton of coal at 12 miles per hour, she be equal to 1,056 horse-power. If the engine run 15 miles per ton of coal at 12 miles per hour she would burn twenty-six and six-tenths (26.6) pounds of coal per minute. Now all the energy that we are to get from the engine is stored in the coal, and is called heat units. The mechanical equivalent of a heat unit, expressed British thermal unit (B. T. U.), when changed to work is equal to 778 foot-pounds of work. Then, figuring that one pound of coal contains 11,660 B. T. U., or heat units, we would have stored in twenty-six and six-tenths (26.6) pounds of coal 7,320 horse-power if all the heat units could be converted into work. But as they can not we will have the difference between the energy taken from or liberated from the coal by combustion and the energy delivered to the drawbar to overcome the train resistance, which would be 7,320 and 1,056 horsepower, respectively, or about fourteen and four-tenths (14.4) per cent of the heat in the coal used.

209. TEMPERATURE.—"How was the degree of temperature first found and determined?"

Answer.—Dr. Joule, of England, found by tests and a series of careful experiments that a British thermal heat unit was equal to 778 foot-pounds of work. A British thermal heat unit is a quantity of heat that will raise the temperature of one pound of water one degree, or from 62 degrees to 63 degrees Fahrenheit. The Fahrenheit thermometer is the kind generally used in this country, and is an instrument used for measuring temperature. It consists of a thin glass tube, at one end of which there is a bulb filled with mercury. Upon being heated, the mercury expands in proportion to its temperature. The Fahrenheit thermometer is graduated to show the degrees of heat, as follows:

Take the glass tube and surround it with melting ice at a temperature of 32° and mark the tube at the height of the mercury. Then surround the tube with a temperature of boiling water at sea level, which is 212°, the mercury expanding in the tube and rising higher than when it was at the temperature of melting ice. Now mark the tube where the mercury stands at the temperature of boiling water and divide the distance into 180 parts called degrees, as shown by the height of the mercury in the tube on a Fahrenheit thermometer.

210. BROKEN PISTON VALVE.—"I wish to ask how to get at it to bring in a piston-valve engine with a piston valve on one side broken and nothing to do it with, only the tool equipment that is necessary to get an engine over the road."

Answer.—First get the good side on the eighth or quarter so you can start engine when you get ready to go. Then disconnect valve rod from rocker arm, and if you can place the valve in position desired over the ports and secure it there, handle the case the same as you would a broken slide-valve engine, leaving the back port slightly open about the thickness of a piece of tin, and remove the valve from the back cylinder cock; this to prevent taking down the main rod. If you can clamp the valve rod in this position and it will hold the valve in place, steam will be admitted to the cylinder and will take oil with it to lubricate the cylinder while running in with main rod up, and if you at any time get stuck on the center on the good side, by replacing the valve in the cylinder cock steam will be admitted to the back end of the cylinder on the disabled side to move engine off the center on the good side and save pinching. If the valve is broken so that you can not do this you will have to take off the valve-chamber head and place the broken pieces so they will cover the ports, block them securely and replace the head. If the valve is so badly broken that this can not be done, the only way out of the difficulty will be to remove the broken valve entirely from the valve chamber and cut a piece of post or telegraph pole to fit the valve chamber, blocking the admission of steam to the cylinder and preventing it from escaping through the exhaust ports to the stack. Get into the section house if you can not get the saw and axe out of the caboose, or borrow the tools from a farmer if near one.

211. By-Pass Valve.—"What is a by-pass valve and what are its uses?"

Answer.—A by-pass valve is a valve used to relieve compression or excessive pressure in the cylinders. When the valve closes the port at the time of exhaust closure the steam that did not get out while the port was open is compressed by the piston as it completes its stroke and is called compression. The piston moving toward the cylinder head compresses the steam into the clearance space and often at a higher pressure than that in the steam chest with a slide valve. When the compression is great enough to lift the valve from its seat the pressure is relieved, but with a piston valve the valve can not lift from its seat and the by-pass valve is used to relieve the pressure and prevent breaking the cylinder heads.

There are many kinds, but they are all used for the same purpose and usually connect the steam ports to the cylinder with the steam chamber between the pistons of the piston valve, the valve being held to its seat by the pressure of steam in the chamber, and when the compression exceeds this the valve is forced from its seat and the steam escapes back into the steam chamber. This also prevents the waste of the steam as would be the case if it was allowed to escape to the atmosphere through a pop or compression valve in the cylinder head.

212. Lap and Lead.—"What effect would be produced upon the lap and lead of an engine by changing the length of the eccentric blades?"

Answer.—Lap is the amount of valve that extends over the outside edges of the steam ports when the valve is in the center of its seat. If the valve edges extended over the edges of the ports one inch the valve would be termed as having one inch lap. Lead is the amount of opening of the steam port when the piston is at the beginning of its stroke, and is governed by the position of the eccentric in relation to the pin. Advancing the eccentric toward the pin increases the lead of the valve, outside admission and indirect rocker. Now, changing the length of the eccentric blade would not change the lap or lead of the valve. The distance that the valve would travel over its seat would remain the same, but shortening the blade would cause it to travel too far forward or work too much steam in the back end of the cylinder, and lengthening the blade would cause it to travel too far back or work too much steam in the forward end of the cylinder, but would have no effect on the lap or lead.

213. Keying Brasses.—"What is the necessity for keeping brasses keyed up properly?"

Answer.—To prevent them from pounding when passing centers, and prevent excessive wear on pins and brasses and to keep them from getting loose in the rod straps. A brass that needs keying will often pound itself hot and make trouble for the engineer and work for the machinist, where if it was properly keyed it would run cool. Here is where an ounce of prevention is worth a pound of cure.

214. Using Water on a Hot Pin.—"What is the objection to using water on a hot pin where grease is used?"

Answer.—There is no real objection to using water on a pin if the grease is of a soft nature, that is, fed to the pin with a plunger in the grease cup, but if a hard grease is used and is forced through the hole in the strap and brass by pressure produced by screwing down the plug, the water will wash off the grease from around the collar of the pin and the grease will not stay between the brass and pin as well when water is used. This grease is similar to a bar of yellow soap, and is made of caustic soda or lye, valve oil and tallow. When the pin is run in water, grease is washed off or made into a suds that has not sufficient consistency to keep the metals apart. You will notice that on a trip in a hard rainstorm the grease will work out faster and the pin run hotter than when the weather is dry.

215. BROKEN SAFETY VALVE SPRING.—"What could be done if a safety valve spring should break?"

Answer.—Remove the cap, if there is one, on the pop and screw down the adjusting screw as far as it will go. If the jamb nut prevents the screw from going down far enough, split the nut and screw it down far enough to hold the valve solid to its seat. This broken pop valve spring will render the valve inoperative, but the others will relieve the pressure until you arrive at a terminal. This is one reason why two or more valves are used.

216. STUCK WEDGE.—"If a wedge was stuck, in what manner would you proceed to get it down?"

Answer.—Loosen the jamb nut on the wedge bolt on top of the pedestal or binder brace and pull down on the wedge bolt. If the driving box was hot, would cool it off first. If the wedge did not come down easily would run driver over a good sized nut. By cooling off the box and putting a tension on the wedge bolt and oiling the wedge good, the box will often get loose in running to the next stop. There is no such thing as a stuck wedge. It's the box that sticks on account of the

wedge being set up too tight. Lack of oil between the box and the face of the wedge, or the expansion of the box from heating causes the box to stick.

217. EFFECT OF LAP AND LEAD ON POSITION OF ECCENTRIC.—"How do the lap and lead of the valve affect the position of the eccentric?'

Answer.—When a valve is used that has no lap or lead the position of the eccentric is at right angles to the pin, or 90 degrees. Now, assuming that the top and bottom rocker arms are of equal length, and you add one inch to the edge of the valve, giving the valve one inch lap, if your engine stood on the forward center with the valve that had no lap and the eccentric set at right angles to the pin, when you put in the valve that had one inch lap you would have to move the eccentric toward the pin the amount of lap of the valve to bring it to its former position, and if you gave the valve lead, also advance it the amount of lead as well. This would push the lower rocker arm forward and bring the top arm back, which would bring the valve in position to open the steam port the amount of lead. Hence, the rule, "set the eccentrics at right angles to the pin and then advance them toward the pin the amount of lap and lead."

218. LENGTH OF SMOKEBOX.—"What should the length of a locomotive smokebox be? This is one of the questions in the list for promotion."

Answer.—We are unable to give you formula for length of smokebox in proportion to diameter of boiler shell. There are two general types, the short smokebox and the extended front end. Herewith are given the length of front ends or smokeboxes and diameter of boiler shell on some of the locomotive boilers of recent design:

Diameter of Shell	Length of Smokebox
70 inches	69 inches
82 inches	73 inches
77 inches	66 inches
70 inches	101 inches
60 inches	54 inches
74 inches	52 inches

Much depends on the size of the boiler and the class of engine. In order to keep the length of smokebox within reasonable limits, flues have been increased in length.

This question would apply more to boiler design than to promotion of a fireman to the position of engineer.

219. COURSE OF STEAM FROM BOILER TO STACK—"Answer to Question 7 (Examination Questions for Promotion and Their Answers) is not quite clear to me. If steam comes, or exhausts, through the cylinder saddle it certainly has to go through the cylinder saddle before doing its work. A blue print I have says, 'Steam passes through the throttle, stand pipe, dry pipe, steam pipe, cylinder saddle, and admission ports to the cylinder.' The answer to Question 7 reads: 'Steam passes through the dome, by the throttle valve, through the dry pipe and steam pipes, and into the steam chest.' Why not say, 'Steam pipes, cylinder saddle, steam chest, and admission ports,' or vice versa, 'thence to the cylinder?'

"How many openings in cylinder saddle? Name and give use of each."

Answer.—The answer to a question does not always give every detail sufficiently clear to a student to enable him to understand it without further effort or study on his part. We will try to explain this more fully, and

would suggest that you examine a locomotive that is in the shop for repairs, with flues out of boiler and covers of steam chests and cylinder heads removed.

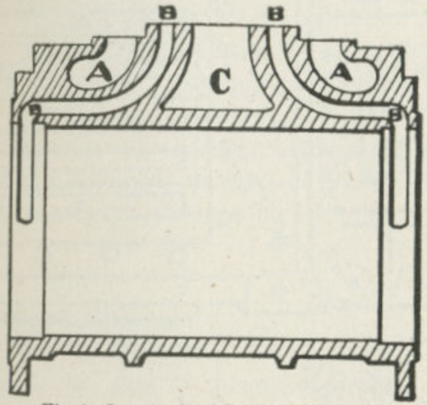


Fig. 1. Longitudinal Section of Cylinder.

Steam is generated at or near the heating surfaces of the boiler and rises into the dome. When the throttle valve is open steam enters the stand pipe, and follows, through it, to the dry pipe to the "nigger head," or tee, in the smokebox. It then enters the steam pipes and is conducted to the cylinder saddle, thence through the passage *A A* (see illustration) to the steam chest. If the valve is now in the center of its seat it can go no farther, but when the port is uncovered by the valve, steam is admitted to the end of the cylinder nearest the opened admission port, shown as *B B,* and exerts a pressure on the piston nearly equal to that of the steam chest pressure while the port is open. This pressure is exerted on the piston and transmitted to the piston rod and connecting rod to the crank pin, and produces a rotative effect on the wheel in proportion to the pressure and the position of the crank pin above or below a line drawn through

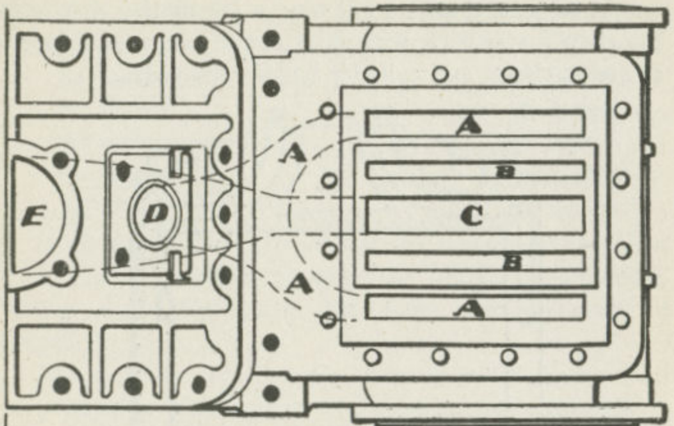


Fig 2. Valve Seat and Cylinder Saddle. Top View.

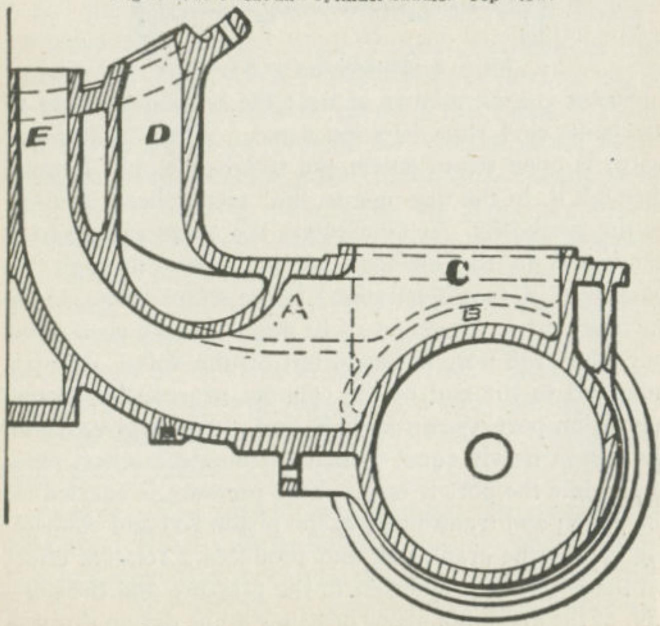


Fig. 3. Cross-Section of Cylinder and Saddle.

the center of the main driving axle and cylinder. If the steam is cut off before the piston has reached the end of its stroke, the valve having closed the port, the steam confined in the cylinder forces the piston to the completion of its stroke by its expansive force acting like a spring. This is the expansion of the steam in the cylinder. When it has pushed the piston to the end of its stroke, it escapes through the admission port which it entered, passes under the valve, over the bridge, and into the exhaust passage *C*, through the cylinder saddle again, into the exhaust pipe and out through the nozzle tip, through the petticoat or draft pipe and out of the stack.

There are usually five openings in the cylinder saddle to the steam chest, as shown in the illustrations. Fig. 1 shows a sectional view if the cylinder was cut in two and lengthwise through its center. Fig. 2 is a view looking down on the valve seat and cylinder saddle. Fig. 3 is an end view showing its construction, and the dotted lines represent lines that can not be seen. Ports *A A* are to admit steam to the steam chest when the throttle is open. Ports *B B* admit steam to the cylinders alternately when they are uncovered by the valve. Ports *B B* and *C* exhaust the steam from the cylinder when the exhaust cavity of the valve extends over the bridge between ports *B* and *C*. Opening *D* in the cylinder saddle is to connect with the steam pipes to the steam passage for the purpose of supplying steam to the steam chest, and opening *E* is to allow the steam to escape from the cylinder through ports *B* and *C* to the exhaust.

220. Difference in Amount of Water Used by Engines of Same Class.—"In two engines having same size boilers, doing the same work, carrying same steam pressure and run by the same engineer, one of these

boilers used two-thirds more water than the other boilers on all of the same class of engines. Can you enlighten me in regard to cause?"

Answer.—Can not give you the real cause of this engine using two-thirds more water than the others of the same class, and think that your figure is a little high. The class of service is not stated. Assuming that all boilers of engines of this class are in the same condition and free from coarse mud or scale, and that the water is evaporated into steam; that the valve and cylinder packing are in the same comparable condition, it may be that the nozzle or exhaust passages are restricted, causing back pressure in the cylinders and the engine is worked harder to handle the same tonnage and make the time. There may have been a change in the cylinder heads or pistons when the engine went through the shop for repairs. If the cylinder heads are of different pattern they may be thinner and increase the cylinder clearance, thereby using more steam. The same increase in cylinder clearance would occur if the pistons were substituted by others that were not so clear. Measure the distance between the front of the follower and the back of the spider, and compare it with other engines of the same class. If the engine is in service where she is worked at short cut-off, the increased clearance would give you an increased water and coal consumption. Then, again, the exhaust cavity of the valve may have been cut out or enlarged, giving the engine or valve exhaust clearance which would allow the steam to escape from the cylinder too soon and before it had expanded in the cylinder to the proper portion of its stroke, thereby losing on the expansion and compression. It is hard to tell just what is

the trouble in this case, but some one in the locomotive department should "get busy."

221. Temperatures of Steam at Different Pressures.—"What is the rule for figuring the temperature of steam in a locomotive boiler when it is at different pressures?"

Answer.—There are several formulas or rules to determine the temperature of steam at various pressures, when a steam table, giving temperatures and pressures, is not available. One of these is given worked out below, and gives an error of less than 1½ degrees in nearly all cases for pressures of over 100 pounds.

t = temperature in degrees Fahr.

p = gauge pressure in pounds per square inch.

$$\text{then } t = 14 \times \sqrt{p} + 198 \text{ minus } \frac{(p-100)}{11}$$

Taking 200 pounds we have $p = 200$.

The square root of 200 is 14.15; this multiplied by 14 = 198.1, and 198.1 plus 198 = 396.1; pressure minus 100, divided by 11 = 9.1 (or 200 minus 100 = 100, which divided by 11 = 9.1); then 396.1 minus 9.1 = 387 degrees, the temperature of steam at 200 pounds pressure.

222. Circulation in a Boiler.—"What is meant by circulation in a boiler"?

Answer.—The free movement of the water so that it may come in contact with the heating surface, and after being converted into steam a fresh supply taking the place of that evaporated. As the water absorbs the heat it becomes lighter and rises to the surface, the cold water, being heavier, taking its place. The circulation depends on the condition of the boiler, which should be free from scale or mud and the flues should be spaced to allow free movement of the water.

223. Blocking for Broken Reverse Lever or Reach Rod.—"In blocking a broken reverse lever or reach rod is it good practice to block on top of both links, or to simply block one link at a cut-off where engine will handle train? If both links were blocked would not the slip of the link-block cause the wooden blocks to be pounded to pieces and possibly damage the link motion?"

Answer.—In a case of broken reverse lever or reach rod it may be possible to block the tumbling shaft arm in the running board, if not, sometimes it may be advisable to place a bar of iron or wood across the top of the frame under the link arms to hold the links in position to give the required cut-off, but the blocking and arms should be securely fastened. When blocking the links to hold them in position it is better to block only one link. Even if working in full gear a small block should be placed between link block and top of link to prevent damage by an increased travel of the valve. Blocking one link will answer the purpose. If both links were blocked solid there would be no chance for the link to slip on the link block and damage would result to the link motion.

224. Effect of Changing Length of Eccentric Rods.—"I notice in your answer to Question: 'What effect would changing the length of the eccentric rods have on the lap and lead of the valve?' you say that lead would be affected by changing the length of these rods, but the lap would not be changed. Now, we read in many of our mechanical books that lead is the amount of port opening at the beginning of the stroke, and is brought about only by the angular advance of the eccentric on the shaft; that lap is the part of the valve that extends over the steam port when the valve is in middle position; that it delays admission and enables us to secure an early cut-off. Now, your answer admits that lead is secured not only by the angular advance, but also by the changing of length of the eccentric rods, a point with which I fully agree, but it is not clear to me why the lap is not also changed, as is not admission delayed and cut-off hastened at one end? For an example: Suppose the go-ahead eccentric rod on an indirect valve motion outside admission was lengthened, this would shorten the forward travel of the valve and lengthen the backward travel, measuring from a line drawn through the center of the exhaust port, and now the center line of travel has been moved back an amount equal to the change of the length of the eccentric rod, both rocker arms being same length, and such change would cause steam to appear too early at the front end of the cylinder and too late at the back end, and the cut-off would be late at the front end and early at the back end. Now, would this not be virtually increasing the lead at one end and the lap at the other?"

Answer.—According to the answer to Question, you are correct in stating that the lap is changed as well as the lead when the eccentric rod is lengthened or shortened, or that lead would be increased on one end and lap at the other. The answer states that the lap of the valve is a fixed amount and never varies, and changing the length of the eccentric rod would have no effect on it; that is true. Now, the lead is obtained by advancing the eccentric toward the pin from an angle of 90 degrees, the amount of lap and the amount of lead. Therefore, the lead being given by the advance of the eccentric when the eccentric is keyed to the axle is as fixed a quantity as the lap of the valve (neglecting the wear on the valve gear), and, generally speaking of lead, it means the lead opening at each end of the stroke in the motion which the engine is moving, and by lengthening or shortening the eccentric rod you would not change the lead any more than you would change the lap of the valve, although, as you state, you would have too much opening at one end of the valve and not enough at the other. The same results would be obtained by lengthening or shortening the valve rod if it was made adjustable, but you could not increase the lead on the engine by changing the length of the eccentric or valve rod. We would say that changing the length of the eccentric rod does not affect the lap or lead of the valve.

225. WAGON-TOP BOILER.—"Describe a wagon-top boiler."

Answer.—A wagon-top boiler has a shell over the crown sheet much larger than the cylindrical part of the boiler, with the dome located over the firebox and crown sheet supported by crown bars. The large part tapers off to the boiler shell ahead of the throat sheet. An extended wagon-top boiler has the high part or wagon-top extended farther forward, usually to the first ring of the boiler shell, and the dome is placed ahead of the crown sheet. The extended wagon-top type gives increased steam space in the boiler.

226. PART OF BOILER UNDER GREATEST PRESSURE.—"What part of a locomotive boiler has the greatest pressure?"

Answer.—The bottom part; steam is expansive and exerts the pressure evenly in all directions; the bottom part, having to support the weight of the water as well as the steam, has the greatest pressure.

227. FORM OF LOCOMOTIVE BOILER.—"Describe the general form of a locomotive boiler."

Answer.—A locomotive boiler is cylindrical in form, with a smokebox at one end and a firebox at the other. The firebox consists of a flue-sheet, side sheets, crown sheet and back sheet. The side sheets, flue and back sheets are secured to the boiler shell by a mud ring and stay-bolts. The crown sheet is supported by crown bars or radial stays. Flues or tubes run through this cylindrical part and are secured to the front and back flue sheets. These parts are surrounded by water from which steam is generated. Boilers are provided with steam domes to insure dry steam being used as much as possible, and also to provide a place for throttle valve, pop valves, whistle, etc. There are several kinds of locomotive boilers: the straight boiler, Bellpaire, wagon-top, extended wagon-top and wide firebox types.

228. PULL ON FIRE-DOOR.—"What causes a pull on the fire-door?"

Answer.—Dampers closed, ashpan full of cinders, grates without sufficient openings for admission of air, too heavy a fire and badly clinkered fire, or insufficient opening of dampers in ashpan, all tend to produce a pull on the firebox door. The exhaust steam passing up through the stack expelling the smoke and gases from the smokebox creates a partial vacuum in front end to stack. The air supply should come up through the grates and fire. When the supply is insufficient the pull on the door results.

229. SATURATED STEAM.—"What is meant by saturated steam?"

Answer.—Steam in contact with the water from which it is generated is called saturated steam. Locomotives use saturated steam unless they are equipped with a "superheater," which is an appliance for heating steam on its way to the cylinders to a higher temperature than it had while confined in the boiler with the water from which it was generated.

230. BROKEN CYLINDER HEAD ON SCHENECTADY COMPOUND.—"If you blew out high-pressure cylinder head on a Schenectady compound how would you disconnect? If a low-pressure cylinder head, how would you disconnect?"

Answer.—The instructions of the American Locomotive Company are: "Should the high-pressure side become disabled, disconnect, block, cover the ports and open separate exhaust valve same as when running simple. Should the low-pressure side become disabled, 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 used, inserted in the valve cylinder by removal of the head and the head again replaced over the block.

231. BROKEN BY-PASS VALVE.—"If you broke a by-pass valve on a high-pressure cylinder what would you do? What if on a low-pressure side?"

Answer.—Take off the valve body and insert a blind gasket between it and the cylinder.

232. BLOCKING CROSSHEAD IN DISCONNECTING.—"Why is it necessary to block the crosshead in disconnecting? Why couldn't you, and wouldn't it be easier to, leave one port open a little and let a little steam in one end to hold piston to end of cylinder?"

Answer.—The reason a crosshead is blocked is to prevent further damage to the engine, and, if the style of engine will permit, it should always be blocked at the back end of the guides, although some engines require that they be blocked forward so that the crank pin will clear crosshead. It is much more up to date not to disconnect the main rod, but to leave it up wherever possible. First, get the engine on the quarter on the good side so you can start when ready. Then disconnect the valve rod on the disabled side and move the valve until a very little steam is seen escaping from the front cylinder cock. Clamp valve rod, take out front cylinder cock valve and open the feed on the lubricator on disabled side so it will feed a little faster than on the working side, and you are ready to go. The opening of the port need not be any more than the thickness of tin or Russia iron, and in case you stop in the center on the good side you can move the valve on the disabled side to admit steam to get the engine off the center. If you have to run a long distance shut off, oil may be admitted to the cylinder through the oil pipe at lubricator, or through air inlet valves on the steam chest.

233. TAKING OFF OPPOSITE SIDE RODS IN DISCONNECTING.—"Why do you have to remove the opposite side rods to disconnect, and what harm does it do the boxes if you do not take the opposite rods off?"

Answer.—If an engine is using steam in both cylinders and one side rod is bent, broken or for any cause is removed, the opposite rod on the other side should come down, for the reason that with both main rods, by using steam on both sides, when one side is on the center the other side is on the quarter. Now imagine a ten-wheel engine with the back section of side rod removed on the right side and engine standing on the quarter on the right side. The left side is on the center and all rods in a straight line with the center of the axle. When the throttle is opened steam is admitted to the cylinders. The right side being on the quarter, it will exert the greatest rotative force on that side and turn the wheels in the direction of the motion. The back wheel on the left side having the side rod up, and pulling on a straight line, may be undecided which way to go, whether in the direction of the others or in the opposite direction. The rod on the left side is liable to be bent or broken, or the pin broken or pulled out from the wheel center. This is the reason for taking down the opposite side rod when working steam on both sides of the engine. In case a main pin should break, or any other failure should occur which would require all side rods and main rod on that side to be taken down, you can safely leave up all side rods on the working side of the engine without causing further damage, for the reason that the power is applied to that side of the engine only, and the pin must be either above or below the center to enable the engine to move, and they will all be sure to move in one direction. No harm will result to the driving boxes and the wheels will trail all right on the dead side. This may be a little deviation from general practice, but it will work and save taking down all the side rods, and gives you three wheels instead of one to bring engine to shop.

234. Engine Pounding When Shut Off.—"If an engine pounded when shut off and did not when working

steam, what would you do to avoid damage to the engine, and what would you report?"

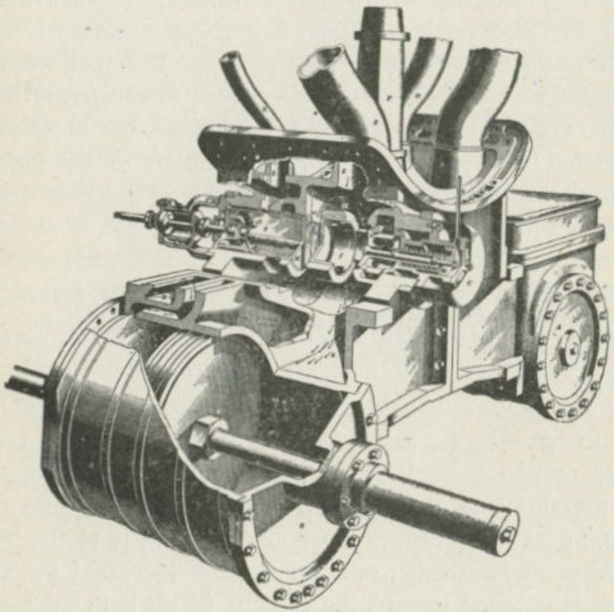
Answer.—Work a little steam to form a cushion and prevent pounding until stopped. Then examine travel of cross-head on guides and see if the length of the main rod had been changed in the shop. If it had, would change liners in rod brasses to lengthen or shorten as the case required. Main rods get longer as the keys are driven. If we found the main rod to be of the right length would take off cylinder head and possibly find broken follower bolt or loose spider. If not, look for a sprung piston rod, and if piston rod was sprung would take down on that side to prevent damage to the cylinder.

235. Covering Ports When Engine Having Lead is on Center.—"Can the ports of an engine having lead be covered by the valve when the engine is on center?"

Answer.—If the valves are set with lead in both forward and back motions the ports could not be covered on the side that is on center, as lead is the amount of opening of the steam port when the piston is at the beginning of its stroke, and the lead is increased as the lever is notched toward the center. With both motions set with lead it would be impossible to cover the ports when on center, as the lead would be the same with lever in either forward or back motion and would increase as the lever was drawn to the center of the quadrant.

236. Broken Steam Chest on Two-Cylinder Schenectady Compound.—"What should be done if right-hand steam chest breaks on one of the two-cylinder Schenectady compounds?"

Answer.—In case a low-pressure steam chest is broken use the high-pressure side as a simple engine. To



VALVE ARRANGEMENT OF SCHENECTADY COMPOUND LOCOMOTIVE.

M-Intercepting valve controlling passage *mn* leading from chamber I to chamber G; N-Emergency exhaust valve controlling opening from I to emergency exhaust passage *e*; O-Reducing valve admitting live steam to G and regulating its pressure there; E-Small steam pipe leading to chamber L ending in passage surrounding one end of bushing of M; *e*-Chamber also surrounding intercepting valve bushing and opening into G; G Chamber dividing into R and S leading respectively to back and front ends of low-pressure steam chest; F-Exhaust passage leading below G and behind I to exhaust pipe P; 6-Small pipe leading to operating valve in cab.

do this you will have to take out the intercepting valve and block the reducing valve in closed position, so that when the intercepting valve is replaced no steam can get to the low-pressure side when intercepting valve is in simple position.

237. BROKEN STEAM AND EXHAUST RINGS WITH INSIDE ADMISSION PISTON VALVES.—"On engines having inside admission piston valves, what would be the effect if a piece of the steam ring on one end should break out? What would be the effect if an exhaust ring on one end should break?"

Answer.—With a piston valve the inside and outside edges of the valve rings are considered the same as the steam and exhaust edges of the slide valve. If the steam or inside ring of an inside admission piston valve was broken steam would be admitted to the port at that end of the cylinder too soon and would flow into that end of the cylinder during a longer period of the stroke, i. e., the broken ring in that end of the valve would not cut off the steam or close the port as soon as it should if the ring is all right. Therefore, it would admit the steam too soon and cut it off too late. The effect would be that too much steam would be admitted to that end of the cylinder. If the exhaust ring in the piston valve was broken steam from that end of the cylinder would escape to the exhaust port too soon, and in each of these cases the engine would sound lame. If the inside or admission rings are broken you can easily locate it by placing the valve central and opening the throttle and cylinder cocks. If an exhaust ring, note that the exhaust takes place too early. Many a piston-valve engine has had her valves run over when reported lame and the marks indicated that the valve gear and eccentrics were all right, and the trouble afterwards was found to be in broken rings in the piston valve. Try to locate the broken ring. Better take a chance on having the rings examined than to report "Run the valves over" when the valve gear indicates no spring, broken or slipped parts.

238. LEVER IN CENTER OF QUADRANT AND ENGINE DRIFTING.—"Will the valves of an engine move if the lever is in center of the quadrant and engine is drifting? If so, how much?"

Answer.—As you hook the lever towards the center of the quadrant the lead is increased in proportion to the radius of the link. The valve will travel the distance equal to twice the lead and twice the lap of the valve if at mid-gear when the engine is drifting.

239. SECTIONAL ECCENTRIC SLIPPED.—If a sectional eccentric is slipped and you cannot move it on the axle to get it back in position, what should be done?

Answer.—The section bolts should be slacked up enough so it can be moved easily, and, after it is in proper position, and before the set screws are set up, the section bolts should be drawn up tight again.

240. CARRYING WATER IN BOILER.—"Why is it bad practice to carry water too high in a boiler?"

Answer.—Wet steam is less effective than dry steam. when the water is too high in the boiler it is carried into the dry pipe and to the valves and cylinders when throttle is open. More water is used, more fuel consumed and the efficiency of the engine is decreased. The wet steam or water carried over into the steam chests and cylinders destroys the lubrication and increases the friction on the valves and cylinders. Keep your crown sheet wet, but

use steam as dry as possible to make time or pull tonnage always.

241. VALVES BECOME DRY.—"When valves get dry when using steam and lubricator is working all right, what would you do to relieve conditions and how may you know that the valves are dry?"

Answer.—You will know that the valves are dry when the engine begins to lag with the train by the sound of the exhaust and the rattle or pull on the reverse lever. If the lubricator is working all right it is evident that the oil is not reaching the steam chests but is held up in the oil pipe, due to the steam chest pressure being greater than the pressure at the lubricator end of the pipe. This is called the hold-up of oil in the oil pipe. To relieve conditions, close or partly close the throttle for a revolution or two and place the lever at full stroke. If you can not shut off for this length of time partly close the throttle and drop lever into full gear. This will reduce the steam-chest pressure so that the pressure in the lubricator will be the greater and the oil will be forced to the valves and cylinders.

242. ENGINE OR SIGNAL OIL FOR VALVES OR CYLINDERS.—"Why should engine or signal oil not be used in valves or cylinders, and at what temperature does engine and valve oil lose their lubricating qualities?"

Answer.—Because engine and signal oils will burn at a lower temperature and are not made for lubricating hot surfaces. When low test oils are used they burn and gum the strips on valves and rings and serve to choke the nozzle. Use the oils to lubricate the parts they were intended for. Engine oil will lubricate up to about 300 degrees, and valve oil will stand a temperature of about 500 degrees without losing its lubricating properties.

243. ADJUSTMENT OF DOPE CUPS.—"How do you adjust dope cups on rods, and is it usual for pins to run warmer when using dope?"

Answer.—There is no adjusting on grease cups where a hard grease is used on rods, other than to slack jamb nut and screw down the plug, usually a turn or a turn and a half of the plug will force enough grease to the pin for a run of from 100 to 150 miles on main pins, and proportionately less for siderods. This should be one of the last things done before leaving a terminal. If in a heavy rain-storm the rain will wash the grease from around the collars and they may need more frequent attention. It is usual for pins to run at a little higher temperature when using grease than when using oil as the friction is greater, due to the sticky layers of grease on the pin and brass.

244. EFFECT OF TOO MUCH PRESSURE IN GREASE CUPS.—"What effect does too much pressure in grease cups produce?"

Answer.—Pins will run warmer and grease will be forced out around collars and pins and wasted. More work for an engineer if he is required to fill the cups and increased cost of lubrication.

245. USING OIL WITH DOPE.—"Is it necessary to use oil with dope on crank-pins?"

Answer.—No. Oil or water should not be used with grease.

246. LAP OF VALVES.—"Why are locomotives given lap?"

Answer.—To enable them to work steam expansively. If the valve had no lap, as soon as one end was opened

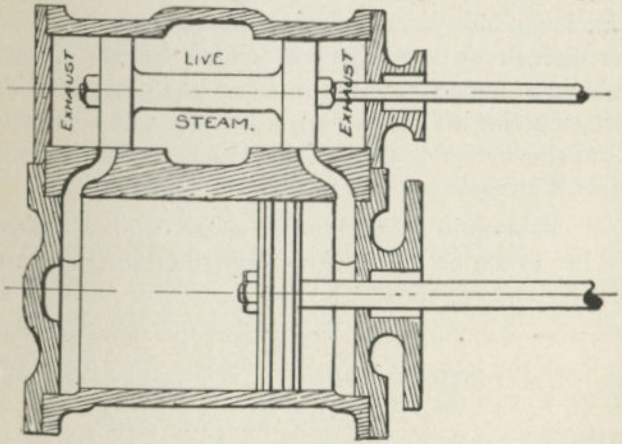
for admission the other end would be open for exhaust and steam would flow from the boiler into the cylinder during the entire length of stroke."

247. INSIDE LAP AND INSIDE CLEARANCE.—"What is inside lap and inside clearance?"

Answer.—Inside lap is the amount that the inside edges of the valve overlap the inside edges of the steam ports when the valve is in the center of its seat, and its purpose is to delay the exhaust or release of steam from the cylinder.

248. PISTON VS. SLIDE VALVES.—"How do they differ on piston valves with inside admission from others?"

Answer.—With a plain slide valve the two outside edges of the valve are the steam edges and the two in-



Piston Valve with Inside Admission.

side edges are the exhaust edges. With a piston valve with outside admission, the edge of the packing ring represents the edge of the valve and the lead and lap are measured in the same manner as with a slide valve. In a piston valve with inside admission the lap would be the amount of valve measuring from the edge of the rings that extend over the inside edges of the steam ports when the piston valve is in the center of its seat. Exhaust lap, or what is termed inside lap, would be the amount of valve that extended over the outside edges of the steam port when the valve was in the center of its seat or in mid-position. See cut.

249. TESTING FOR BLOWS IN COMPOUNDS.—"How would you test for a valve blow in a Vauclain compound? How with a tandem? How for high and low pressure cylinder packing, each type, and several others, regarding compounds?"

Answer.—The detection and location of blows in any engine is not always an easy thing to do at all times and more difficult on a compound, and mechanical officers should not expect too much from enginemen. For details covering full answers see "The Art of Railroading" (Prior Series). Published by Railway Publications Society, Chicago.

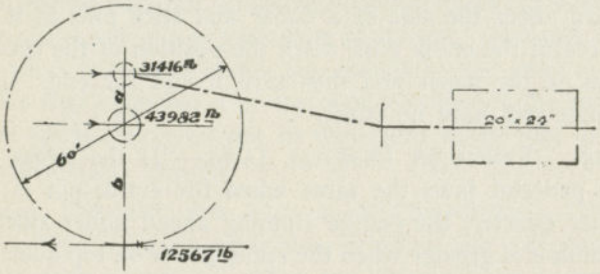
250. EFFECT OF CHANGING DRIVING WHEELS. —"What would be the effect of changing the main pair of drivers end for end?"

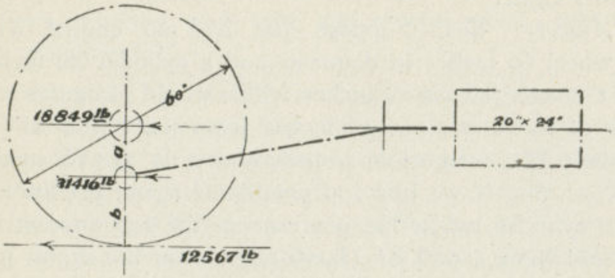
Answer.—On American locomotives the right-side engine leads the left-side engine one-quarter of a turn, or, in other words, the crank pins are set at an angle of 90 degrees to each other, and when the right side is on forward center the left side would be on the top quarter, eccentrics set at right angles to the pins and advanced toward the pins the amount of lap and lead. If you could take the main wheels, axle and eccentrics out and turn them end for end and give them one-quarter of a turn forward, the main pins and eccentrics would be in identically the same position as before. Take a piece of cardboard about the size of a dollar and stick pins in it to represent the crank pins, mark the position of the eccentrics on the paper and then turn it end for end. The change will have no effect.

251. STRESS ON PEDESTAL JAWS.—"Is the stress on the pedestal jaws the same when the crank pin is on either quarter, the engine running ahead under steam? I think it is greater when the crank pin is on top quarter. Am I right?"

Answer. Yes. Suppose you had an engine with a wheel 60 inches in diameter and a cylinder 20 inches in diameter, stroke 24 inches. This would place the center of the crank pin 12 inches from the center of the axle. The area of a 20-inch piston is 314.16 square inches, and if we had 100 pounds of steam pressure in the cylinder, when the pin was on the top quarter we would have a pull of 31,416 pounds on the crank pin. Now, looking at the wheel as we would look at a lever, we have the point in contact with the rail as the fulcrum. The main axle is the load or weight to be moved and the pin is the power. This gives us a lever of the second class, in which $a = 12$ inches and $b = 30$ inches; power applied at $p = P \times \frac{(b+a)}{b} = W$, or the stress put on the pedestal when in this position, which is 43,982 pounds.

With the pin on the bottom quarter we have a lever of the third class; $a' = 12$ inches and $b' = 18$ inches; we have $\frac{P \times b'}{a' + b'} = W$, or the stress on the pedestal when crank pin is on the bottom quarter, which is 18,849 pounds when in this position. Please note illustration.





Stress on Pedestal Jaws.

252. Horse-Power of Vauclain Compound Locomotive.—"What is the horse-power of a Vauclain compound locomotive, cylinders 19 and 32 inches by 32 inches, speed 30 miles per hour, M. E. P. 225 pounds, and wheels 57 inches in diameter?"

Answer.—We infer that the boiler pressure is 225 pounds, and that you may wish to use this information on other sizes. The following formula is used to find the tractive power for a Vauclain 4-cylinder compound locomotive for different speeds:

$$\frac{C^2 \times S \times 2\text{-}3\,P}{D} + \frac{c^2 \times S \times \frac{1}{4}P}{D} = T.$$

C = Diameter of high pressure cylinder in inches.
c = Diameter of low pressure cylinder in inches.
S = Stroke of piston in inches.
P = Boiler pressure in pounds.
D = Diameter of driving wheels in inches.
T = Tractive power.

The tractive power multiplied by the speed in miles per hour divided by 375, gives the horse-power.

253. Slip of Link Block.—"What is the exact cause of the slip of the link block, and does it increase the travel of the valve?"

Answer.—The exact cause of the link slipping on the link block is due to the link block being securely fastened to the bottom of the rocker arm. Therefore, the block must move in an arc traversed by the rocker arm, and the action of the eccentric rods on the link forces it to move in a vertical motion at certain parts of the stroke, which causes the link to slip on the block. When one eccentric is traveling forward and the other backward the link must move, but the block does not, hence the slip. The longer the cut-off the greater the slip.

254. Broken Aleck Bolt on Mogul Engine.—"What should be done in case an aleck bolt broke on a mogul?"

Answer.—Block up between truck axle and front end of long equalizer, place a truck brass on the axle and allow the end of equalizer to rest on it. Oil the brass well, and you can get in without trouble.

255. Wear of Guide Bars.—"When an engine is running forward and working steam, what part of the guides, top or bottom, does the cross-head bear against, and why does the bottom guide wear so much faster than the top one on all road engines?"

Answer.—When the engine is running forward the top guide will wear more than the bottom guide, because when the piston is at the forward end of the cylinder steam is admitted, and as the pin passes the center the steam is pushing the piston back, exerting a pressure on the forward end of the main rod. The back end of the main rod being below the center the cross-head is forced upward or against the bottom of the top guide.

When the piston leaves the back end of the cylinder the steam in the cylinder is pulling the rod forward and on an angle after the pin leaves the center. The pull on the pin lifts the cross-head and causes it to wear on the bottom of the top guide. It is always pushing and pulling on the rod, and as the back end of the rod follows the crank pin circle it is always on an angle except when passing the centers, thus holding the cross-head up while working steam running forward, and pushing it down when running backward. If your engine is wearing most on the bottom guides when running ahead it is due to improper lubrication of bottom guides and cross-head, or else the guides are not in line. Road engines running ahead do not wear the bottom guides most.

256. Indicator Cards.—"What are the four principal points of an indicator when indicating an engine?"

Answer.—If you mean the four principal points of an indicator card, they are the admission, cut-off, expansion and release or exhaust. If the pencil of the indicator is held to the paper on the indicator drum when communication between the cylinder and indicator is shut off, both sides of the indicator piston are exposed to the atmosphere and a line is made on the paper that has no connection with the conditions existing in the cylinder. This forms the line from which all other pressures are determined. Now before taking the card it is well to allow the piston in the indicator to make a few strokes before applying the pencil to the paper, this to warm up the pipe leading to, and the cylinder of the indicator. Then when the pencil is applied it will indicate the admission line, which will show the pressure in the cylinder until the pencil begins to fall, or the valve has closed the port for admission of steam. This is the point of cut-off, and shows that the valve has closed the port for admission. As the steam expands in volume the pressure decreases, and the drop of the pencil, showing the drop or decrease in pressure indicates the expansion of steam in the cylinder until the port is opened for the release or exhaust, and then the pencil falls until the cylinder piston reaches the end of its stroke, and as the piston now moves forward, if the steam did not all get out of the cylinder the piston will push it out, and the line made by the pencil will indicate the pressure on the exhaust side of the piston, which is called the back pressure, and is measured by its distance above line the first made on the card. This line continues until the valve closes the exhaust, when the line will curve upwards, showing that the steam did not all get out of the cylinder, and what failed to escape through the exhaust port was compressed in the cylinder. Therefore, we have a card showing admission, cut-off, expansion, release, and compression—five important points. For fuller information on Indicator practice see The Art of Railroading, Vol. 2, published by Railway Publications Society, Chicago.

257. Engine Traveling Under or Over.—"What is meant by an engine traveling under or over?"

Answer.—The direction in which the engine runs. When you say a locomotive is running ahead or back it is readily understood that the forward or back motion eccentrics are controlling the valve, but in stationary practice you would not get a very definite idea as to which direction the engine was running corresponding to the eccentric.

Place the crank on the dead center nearest the cylinder, and when the engine starts if the pin starts downward or under the axle first the engine is running under, but if it starts in the opposite direction and goes over the axle first it runs over. When a locomotive is running ahead it is running under, and when backing up it is running over.

258. Effect of Decreased Valve Travel.—"What is the effect on an engine if the travel of valve is decreased?"

Answer.—The effect of shortening the travel of the valve is to increase the lead, both steam and exhaust, and decrease the port opening for the admission of steam to the cylinder, which produces an earlier cut-off and increases the expansion. This causes a reduction in the port opening for the exhaust steam to escape from the cylinder and increases the compression.

259. Long and Short Connected Engines.—"What is the difference between a long or a short connected engine?"

Answer.—The difference in the length of the connecting or main rods, the rods that communicate the pressure on the pistons to the crank pins of the driving wheels or the cranks on the axles.

260. Uptake of Boiler.—"What is meant by the uptake of a boiler?"

Answer.—This applies to what is known as the area

of uptake and funnel. In determining the size of funnel conditions must be considered, and this question refers to marine practice, rather than locomotive, and means the area of funnel to that of the grate and is determined by results based on best practice. The area is usually one-fifth to one-eighth that of the grate, or one-fifth to one-sixth the grate area when the top of the funnel is about forty feet above the grate.

261. A Jet of Steam.—"What is a jet of steam?"

Answer.—A volume of steam escaping through a nozzle or pipe which, while escaping, is projected through a passage, funnel, or opening to mix with air, gases or liquids, thereby inducing current. A blower on a locomotive is a jet of steam that induces a current of gases and air through a stack, causing a draft on the fire.

262. Travel of Valve When Steam Lap and Port Opening is Known.—"When the steam lap and port opening are known, what must be the travel of the valve?"

Answer.—If the valve is to open the steam port its full width, the travel of the valve must be twice the width of the steam port and the lap of the valve.

Example: Width of steam port, 1¼ inches; lap of valve, 1 inch. $1\frac{1}{4} + 1 = 2\frac{1}{4}$ inches, and $2\frac{1}{4} \times 2 = 4\frac{1}{2}$ inches. Answer, 4½ inches.

If the valve has over-travel—that is, if it travels over the edge of the bridge—you can take one-half the width of the bridge multiplied by 2 and add to the above. You will then have a valve travel equal to the width of the steam port plus the lap plus one-half the width of the bridge multiplied by 2.

263. Setting Out Packing Rings—"How should the packing rings be set out?"

Answer.—If engine is equipped with spring cylinder packing remove cylinder head and follower. Use calipers, or a stick if you do not have them, to keep piston central in cylinder, loosen jam-nuts and put tension on the springs to hold packing rings out against the cylinder walls. After adjusting, caliper or measure again and know that the piston is in the center of cylinder before or when the jam-nuts are tightened. Proper adjustment depends entirely on your judgment. If the packing is set out too tight it will absorb the power of the engine and may ruin both the packing ring and the cylinder. On the other hand, the packing should be tight enough to prevent the escape of steam past the packing rings, which would result in a waste of steam and loss of power. If snap rings are used they should be turned from a ring about three-sixteenths of an inch larger than the diameter of the cylinder when applied, but if worn they may be peined out with a hammer to fit the cylinder. When applying new rings the sharp corners should be rounded off to prevent the sharp edge from cutting cylinder walls.

264. Action of Injector.—"What makes an injector lift water?"

Answer.—With a lifting injector, the injector does not really lift the water. The steam jet or primer allows the steam to flow into the overflow pipe and this forces the air out of the pipe and injector, producing a partial vacuum in the injector. This is one reason that all connections should be kept tight. When the air is forced out of the injector the atmospheric pressure on top of the water in the tank then forces the water up into feed pipe

and into the injector. This also explains why injectors will work better at sea level than on mountains or at high altitudes, where the air is light and there is less atmospheric pressure to force the water up to the injector.

265. Broken Pony Truck Center Pin or Long Equalizer.—"In case of a broken pony truck center pin or long equalizer on any engine with a two-wheel forward truck what would you do?"

Answer.—Aleck bolt or long truck equalizer broken, raise the front end of the engine above its normal position. This will take the tension off the front driving box spring. Now jack up the front end of equalizer and place a block of hard wood or a truck brass on top of truck axle and allow the end of the equalizer to rest on it. If kept well oiled where the brass rides the axle, it will give no trouble. Should the equalizer break between the fulcrum and the end so you could not use brass on journal, jack up and place a tie or short piece of rail across top of frames in front of cylinders and chain broken equalizer to it. This will hold the front end of equalizer solid and will give the use of the front driving spring. Run carefully with an engine blocked in this manner.

266. Working Steam Expansively.—"After getting train started, why should you hook your reverse lever towards the center?"

Answer.—That you may work the engine with more economy. By hooking the lever towards the center the steam port will remain open during a portion of the stroke only, and when the valve closes the port the steam thus confined in the cylinder forces the piston to the completion of its stroke by its expansive force or energy. This is termed "working steam expansively," and less steam is required from the boiler to fill the cylinder at a short cut-off than when the port remains open during the full length of the stroke of the piston. If you can do the work with less steam you will use less coal.

267. Lead of Valve.—"What is meant by the lead of a valve?"

Answer.—The opening of the steam port when the piston is at the beginning of its stroke.

268. Angularity of Main Rod.—"In talking about the angularity of the main rod, 'A' says it was overcome by the slip of the link. 'B' says it was overcome by the link saddle pin being set back of the center of the block. If the link saddle pin being placed back of the center overcomes it, how, and if the slip of the link does, please state whether they both have something to do with it, and if only one, which one?"

Answer.—The link block is securely fastened to the bottom of the rocker arm and must move in the arc traversed by the arm. Now the action of the eccentric rods on the link forces it to move in a slightly vertical motion at certain parts of the stroke, which causes the link to slip on the link block. The slip of the link on the block is greatest in full gear and diminishes as the block is moved toward the center of the link. Back setting the link saddle pin or point of suspension also has the effect equal to lengthening the eccentric rod during a portion of the stroke, thereby equalizing the valve travel, and has more influence on the equalization of admission and cut-off and overcoming the angularity of the main rod than the slip of the link on the block. It will require a little

study to understand the motion of the link at each end, as it moves in the motion of a pendulum from its point of suspension (the saddle pin), and the motion of the link on the link block. If you can trust yourself to ride on a brake beam while a careful man handles the engine for a few revolutions it will assist in making this clear to you.

269. Position of Eccentric.—"What should be the position of the eccentric with direct motion and piston valve inside admission?"

Answer.—With valve arm and link arm of same length, eccentrics should be set at right angles to the pin and advanced toward the pin the amount of lap and lead of the valve. The eccentrics should be in the same position as if indirect motion and outside admission valves were used.

270. Direct or Indirect Engines.—"I wish to ask about some Erie engines that are run into our terminal. What are these engines, direct or indirect? I will describe them: The eccentrics are placed on the axle in direct position, viz., forward motion eccentrics lead the pin 90 degrees plus the angle of advance. Other eccentrics have relative position to make engine direct, but a top and bottom rocker arm is used and piston valve is situated outside of frame; and have inside admission valves. The valve stem and main piston move together almost entire stroke, thus indicating a direct engine. What are these engines, direct or indirect?"

Answer.—You are evidently mistaken when you say that these engines have inside admission. The valve moving in the same direction as the piston from the beginning of the stroke would indicate that they are outside admission valves, and with the top and bottom rocker arm they would be indirect motion, as the valve would move in the opposite direction to that of the eccentric rod. Therefore, the eccentrics should be set at right angles to the pin and advanced toward the pin the amount of lap and lead the same as if a plain slide valve was used.

271. Crosshead Gib on Top of Single Bar Guide.—"Please explain why the gib in the crosshead on top of the single bar guide of a mogul engine is left loose, or what effect it would have if made tight in crosshead?"

Answer.—The gib in the crosshead can be made to fit tight, providing that it will permit a free movement on the guide bar. When they are not tight it is usually due to wear. With this type of crosshead it is difficult to keep them tight, and they wear rapidly, on account of the horizontal and vertical motion of the crosshead.

272. Friction.—"What reduces friction and what is the result of excessive friction?"

Answer.—Friction is the resistance that a body meets with from the surface on which it moves, and is reduced by polishing, smoothing, or lubricating the surfaces. The result of excessive friction is heat, which expands the journal and increases the pressure between the journal and its bearing, which further increases the friction and gives you trouble from hot pins, journals, and burned brasses, etc.

273. Lubrication.—"What is lubrication and its object?"

Answer.—Lubrication is a method of introducing a lubricant, either liquid or solid, between the journal and its bearing, or between any two wearing surfaces, and the object is to keep the surfaces of the two metals or bearings

apart by separating them with a film of lubricant, thereby reducing the amount of friction.

274. Caring for Hot Bearings on the Road.—"In what manner would you care for hot bearings on the road, and what kind of oil should be used on hot bearings?"

Answer.—When a bearing gets hot, increase the oil supply, if possible, and be sure the oil reaches the bearing. If an engine truck, tender or driving journal, would examine it at first stop, if time would allow, and pack it if necessary. If driving box was hot, due to wedge being too tight, would pull wedge down. If eccentric was hot, would keep lever hooked up as near center as possible and use valve oil in the strap. If the strap was too tight on the eccentric, would loosen bolts and put in a liner at first stop. If the forward motion eccentric is heating, by having the lever well up in the quadrant a good share of the work is taken on the back motion eccentric. It is not good practice to drop the lever well forward when a forward motion eccentric is running hot, as it increases the work on the forward motion. Care and attention to the bearings will prevent a great deal of trouble due to hot bearings. This is where an ounce of prevention is worth a pound of cure. Use engine oil on all bearings, but if the bearing is very hot, valve oil should be used, and when the box is reported at the terminal to be repacked the sponging that has been saturated with valve oil should be removed and the oil holes cleaned out, especially in cold weather.

275. Duties at Completion of Trip.—"At completion of trip, what is necessary?"

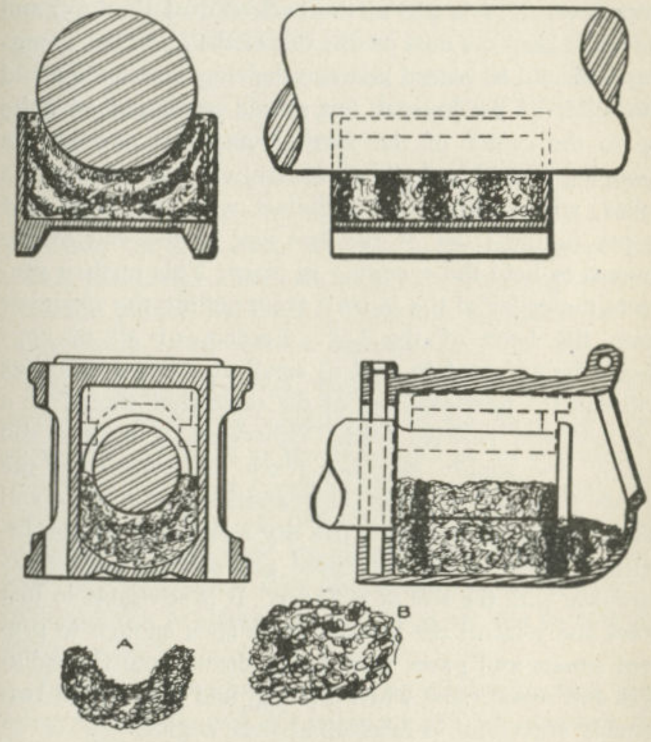
Answer.—A thorough inspection of the locomotive.

The fire should be well burned down and sufficient water in the boiler to avoid the necessity of hostler working injector while on the pit or in the house. Look at the fire-box, crown-sheet and flues, then begin your inspection when you strike the ground, and examine all parts of the engine and tender, going completely around. Look for loose nuts, wedge bolts, cracked leaves in springs, defects in spring hangers and in spring rigging; note the temperature of all journals and bearings, look for broken or lost cellar bolts in driving and engine truck boxes. Examine flanges of wheels, see if pilot is too low. Uncoupling levers, grab irons, etc., should receive inspection. Shut off feeds on guide cups, see that all cotter pins are in place, and figure that the inspector or any one else can not find any defect that you have not located. Then write a report of the necessary work, so that the roundhouse men can readily locate and make needed repairs.

276. Successful Lubrication.—"What examination should be made by the engineer to insure successful lubrication, and how should feeders of oil cups be adjusted?"

Answer.—To successfully lubricate bearings on a locomotive, all the examination necessary is to see that the oil holes are opened and a sufficient amount of oil is given the bearing, just enough to properly lubricate them and prevent cutting. The sponging in the driving box cellars, tender truck boxes and engine truck cellars should be saturated with oil and have enough elasticity to remain in contact with the journals. The top of the driving and engine truck boxes should be packed with a good quality of cotton waste, well saturated with oil, and this packing should not be disturbed except when absolutely neces-

sary, and in case of its removal from the top of the boxes, care should be exercised to prevent the dirt from entering the oil holes and getting on the bearing. It is advisable to have the ends of the packing or sponging



Method of Packing Driving and Engine Truck Cellars.
Fig. 1-Upper figure. Fig. 2-Lower figure.

turned down at the edge of the cellars in driving and engine truck boxes, to prevent the waste from working in between the journal and the brass, forming what is known as "waste grabs." Keep the packing from becoming glazed or hardened in the cellars, and there should be no trouble. Driving and engine truck cellars are often packed as shown in Fig. 1 and give very satisfactory results. Tender truck boxes are run most successfully when packed as shown in Fig. 2. The loose ring of saturated waste *A* is put at the back end of the box, and serves to keep the dust or dirt out of the oil. The sponging *B* should be placed between the ring first applied and the collar of the journal, but should never extend quite up to the center of the journal, and this part of the sponging should be built up square with the edge of the collar, without any thread contact with the waste that is put in the front of the box and at the end of the journal to hold the sponging in place. This method prevents the collar of the journal from pulling the sponging from the back of the box. Feeders of all oil cups should be adjusted to feed as small an amount of oil as will run the pins cool, but at the same time should be a constant and positive feed. Otherwise, if gauged too closely, the supply may not reach the bearing at the proper time and in sufficient quantities, and trouble will result. For the cylinders, use dry steam and set the lubricator feeds to suit the speed and service, and in accordance with the size of cylinder. It is advisable to just crack the joint of the throttle valve open enough to prevent smoke and gases from being drawn into the cylinders and steam chest when drifting, and you will be reasonably successful in lubricating your engine.

277. Effect of Heat on Engine Oil.—"Why is it bad practice to keep engine oil too close to boiler-head in warm weather?"

Answer.—Because the increase in temperature of the oil will make it very much thinner, and it will not lubricate the bearings as well as when it is at its normal temperature. It will also run through the sponging more rapidly, leaving the waste on the top of the box dry.

278. Effect of Changing Position of Link on Indirect Motion Engine.—"What effect would it have on a valve of the indirect type if the eccentrics were connected to the axle in front of the links instead of behind them; in other words, with the eccentrics in the same position in relation to the pin, only with the link behind the eccentrics instead of ahead?"

Answer.—The motion of the valve would be the same, with this exception—as the lever was hooked toward the center the lead would decrease in the same proportion that it would increase if the eccentrics were connected to the axle behind the links. Otherwise the effect on the valve would be the same in each case.

279. Regulating the Draft in Front End of Engine.—"I wish you would inform me how the draft should be regulated in the front end of an engine with only a petticoat-pipe sleeve and hangers in the front end, and how the sleeve and petticoat-pipe should be handled to increase draft near the flues, or to increase draft near the firebox door. Can you regulate the draft with the petticoat-pipe or sleeve, and must you use one or both for this purpose?"

Answer.—If the front end has no diaphragm in it, lowering the sleeve will give more top draft through the flues. This will reach farther back and cause the fire to burn better or increase the draft at the back end of the firebox near the door. Raising the pipe will increase the draft through the bottom flues and cause the fire to burn more near the flue sheet. Lowering the pipe will decrease the draft near the flue sheet. After you get the fire burning evenly on the grate, if the draft is not strong enough to burn the fire so the engine will steam freely, the draft may be increased by moving the pipe up and the sleeve down. When increasing the draft after you get the fire burning evenly, both the sleeve and pipe should be used. If only one is moved you will get the fire burning evenly on the grate surface again. The more you raise the pipe and lower the sleeve the stronger will be the draft, and the more you lower the pipe and raise the sleeve the lighter will be the draft on the fire.

280. Difference in Engines of Same Type.—"I am firing an engine called the Moncton rebuild. We have two of them on this division of the same type, and put up in the same way, same size cylinder, with same amount heating surface, grate and front end arrangement. One of these engines steams fine and is light on coal, while the other steams poor and is heavy on coal. Where will I look for the trouble?"

Answer.—Ascertain if the flues and boiler are clean, flues open and the boiler free from mud and scale. If they check favorably with each other, examine steam pipes and exhaust pipes for leaky joints. Should you find them to be all right, see that the joints on smokebox are tight, stack is in line and filled equally on all sides when engine is working. Note the valve motion and find if valves are set the same, with the same lap, and if they have the same inside clearance or lap. Sometimes valves are given inside clearance to such an extent that steam is permitted to exhaust too early and before it has performed the work it should in the cylinder. In case you do not find the trouble in the valves, examine the pistons and ascertain if they are the same thickness as on the good engine; also cylinder heads, so that you will know

the cylinder clearance is the same on both engines. If this does not locate the trouble you will need an indicator to help you find the defect. You will probably find some one of the above mentioned causes responsible for the difference in the two engines.

281. Calculating the Horse-Power of an Engine.—"In the study of steam engineering I find two different methods of calculating the horse-power of an engine which, according to my figures, do not give anywhere near the same results, and I would be pleased to have your opinion as to which is correct. The rule given by Hawkins in his study of the steam engine is as follows: 'Multiply the area of the piston in square inches by the average force of steam in pounds and by the velocity of the piston in feet per minute and divide the product by 33,000 pounds. Seven-tenths of the quotient equals the effective power.' The other rule is: 'Multiply the mean effective pressure on the piston by the length of its stroke in feet. Multiply this product by the area of the piston in square inches, and multiply again by the number of strokes per minute, dividing the last product by 33,000 pounds,' or, in other words, the P L A N method. Your example:

P = 82 pounds steam pressure during length of stroke.
L = 3.5 feet, length of stroke.
A = 907.922 square inches, area of piston.
N = 45 strokes per minute.

In this example:

$$\frac{PLAN}{33{,}000} = \frac{82 \times 3.5 \times 907.922 \times 45}{33{,}000} = 355.3 \text{ H. P.''}$$

Answer.—The rule given by Hawkins is identical with the above. Therefore both rules are correct. This is termed the indicated horse-power, and designates the work done by the steam. In taking seven-tenths of the quotient in either case you have 248.71 horse-power, which expresses the total available power of the engine, thus allowing three-tenths to overcome the friction of the engine, as the available horse-power is less than the indicated horse-power the amount that is absorbed in overcoming the resistance and friction of the engine. In one formula you made allowance for this and in the other you did not, which accounts for the difference.

282. FINDING DIAMETER OF CIRCLE FOR A GIVEN AREA.—"Give a rule to find the diameter of a circle when the square inches of its surface only are known."

Answer.—Suppose you desired an area of 12 square inches and wished to determine the diameter of a circle that would contain 12 inches area: 12 inches divided by $.7854 = 15.278$, and the square root of $15.278 = 3.908$ inches, the diameter of a circle that will contain 12 square inches of area. Written thus:

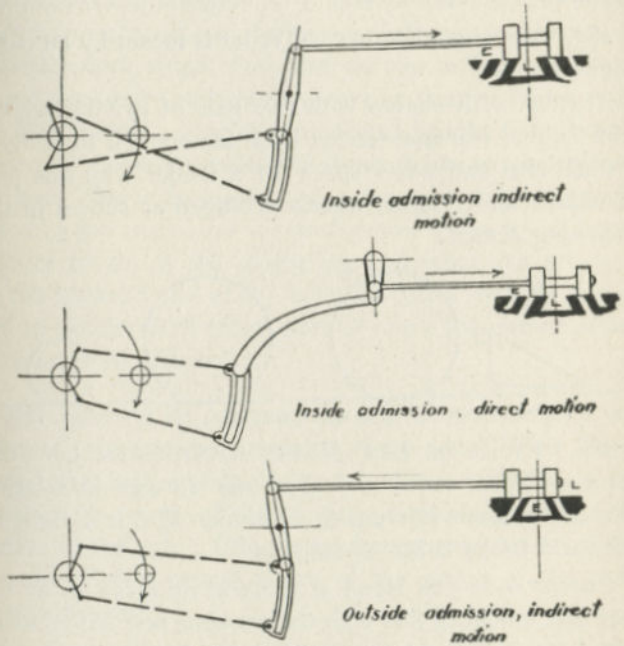
$$\sqrt{\frac{\text{Area}}{.7854}} = \text{diameter of circle.}$$

283. POSITION OF ECCENTRICS FOR DIFFERENT MOTIONS.—"Please give position of eccentrics of an inside indirect, an inside direct, and an outside admission indirect motion engine."

Answer.—See diagram, page 199.

284. ECCENTRIC MOST LIKELY TO SLIP.—"Which eccentric is most liable to slip, the go ahead or the back up, and why? Which way will it slip?"

Answer.—The forward motion eccentric when running forward and the back motion eccentric when running backward, because they are more nearly in line with the link block in either motion and, therefore, controlling the valve. You can readily understand that when the



Illustrating Different Motions

engine is in full gear forward, the forward motion eccentric rod is nearly in line with the link block, and the work of moving the valve is done by the forward motion eccentric, and this proportion of work will hold good in relation to the position of the link block in the link. The back motion eccentric is only holding the bottom of the link, and the work done by the back motion eccentric is very light when the lever is in this position, and when they slip on the axle they usually slip back, or away from the work, just the same as a man walking forward and pulling a load would slip backward, or if walking backward under the same conditions and would slip, he must slip forward.

285. AN 0-4-2 ENGINE.—"What is meant by an 0-4-2 engine?"

Answer.—An engine with two pair of driving wheels with engine frame extended back far enough to provide a small coal and water space for a tender with one pair of wheels under same, wheels arranged as shown in the following sketch:

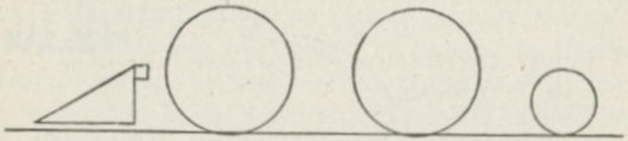


Diagram of an 0-4-2 Engine

286. RIGHT OR LEFT-HAND BRAKE BEAM OR FULCRUM.—"What position does a man assume in relation to a brake beam fulcrum to determine if it is a right or left-hand brake beam or fulcrum?"

Answer.—If you stand at the end of a car or at the rear of a tender in line with the drawbar and face toward the engine, and the brake beam is hung outside the wheels, and the fulcrum for the lever on the brake beam is at an angle that causes the top of the lever to lean toward the right side of the engine, the beam would be a right-hand brake beam; and if the top of the lever leaned toward the left it would be a left-hand brake beam. Some of the manufacturers have a letter cast on the fulcrum for the brake lever, designating them R. and L. for right and left.

287. SETTING AN ECCENTRIC ON THE ROAD.—"What is the best and quickest way to set an eccentric on the road?"

Answer.—Place engine on forward center on side that the eccentric is slipped. If it is a forward motion eccentric that is slipped, put the lever in full gear forward, open cylinder cock, crack the joint on the throttle open and move eccentric until steam shows at front cylinder cock. If back motion eccentric has slipped, put the lever in back gear and move eccentric until steam shows at front cylinder cock. This is the quickest way to get in with your train. Placing the engine on forward center gives you a better chance to get at the eccentrics, and when the piston is at the forward end of the cylinder steam must be admitted to the forward steam port to move the engine either backward or forward.

288. ANGULAR ADVANCE OF AN ECCENTRIC.—"I am told in answer to my question 'Valves and Their Troubles:' that the angular advance of an eccentric is the amount the center of the eccentric is placed ahead of the center of the axle. I do not understand the center of the eccentric being placed ahead of the center of the axle. Please answer."

Answer.—If you place an engine on the forward center and draw a vertical line through the center of the axle, and place the center of both eccentrics in line with this line first drawn through the axle, there would be no angular or any kind of advance, and the eccentrics in this case would be set at right angles to the pin. When the valve has lap the eccentric must be advanced toward the pin. If the rocker arms are of equal length and lead is given, the angular advance must be equal to the lap and lead of the valve. A line drawn ahead of the vertical line first drawn, a distance equal to the lap and the lead, and the centers of the eccentrics advanced to this line, would be the angular advance. You will find this more fully explained in "The Art of Railroading," published by Railway Publications Society, Chicago.

289. MAIN EQUALIZER FULCRUM.—"What is the proper name for the inverted T-shaped mechanism that is bolted to the frame and runs through the middle of the main equalizer, between the drivers on an eight-wheel engine?"

Answer.—Main equalizer fulcrum is the proper name for this; sometimes it is called equalizer post, or equalizer standard.

290. DIFFERENCE IN PRESSURE ON DIFFERENT PARTS OF BOILER.—"When a boiler under ordinary conditions is under steam pressure of say 100 pounds, are all the parts of the boiler under equal pressure, or is there any more pressure on some parts of the boiler than on others?"

Answer.—Yes. The bottom part has the most pressure. Steam being elastic exerts its pressure evenly in all directions, and the bottom part of the boiler supporting the weight of the water as well as the steam has the most pressure upon it.

291. EXPANSION OF AIR AND STEAM.—"How much difference is there in the expansion of air and the expansion of steam?"

Answer.—The difference due to the steam condensing when it comes in contact with the cold walls of the cylinder being much greater than the condensation of air; the difference depends on the temperature of the steam and the walls of the cylinder.

292. LEAD.—"If you give a simple engine lead and place her on forward center on left side, and then place lever in center of quadrant, do you cover front steam port? I claim that as you pull lever toward center of quadrant when the engine is on center that you keep opening the port wider until the center of the quadrant is reached, and that the port is open wider than when the lever is in the corner."

Answer.—"You are right. Hooking the lever toward the center increases the lead opening in proportion to the radius of the link. The increase is greater with short eccentric rods and less with long eccentric rods.

293. BLOW IN LOW-PRESSURE CYLINDER OF SCHENECTADY CROSS COMPOUND.—"How would you test for a blow in the low-pressure cylinder of a Schenectady cross compound?"

Answer.—Make test for blow in low-pressure cylinder by moving the handle of the operating valve to simple position, and test in the usual manner as for simple engine.

294. PORTS NOT COVERED BY VALVE.—"Can the ports of an engine having lead be covered with the valve when the engine is on dead center?"

Answer.—Lead is the amount of opening of the steam port when the piston is at the beginning of its stroke. Lap is the amount of the valve that extends over the outside edges of the steam ports when the valve is in the center of its seat. If your engine had neither lap nor lead, the eccentrics would be set at right angles to the pin, but as you have both you advance the eccentric toward the pin to pull the valve back the amount of lap, then advance it still farther to give the lead opening desired. Looking at the side of the engine that is on the dead forward center it can be readily seen that if the engine has lead when the lever is in full gear forward, pulling the lever back on the quadrant will push the lower end of the rocker arm ahead and the upper rocker arm back in proportion to the radius of the link or, in other words, increase the lead as you hook the lever back until midgear when it decreases as the lever is moved from mid-gear to full back motion and if the engine has lead in both motions, forward and back, the ports could not be covered on that side without disconnecting the valve rod. However, if the valves were set with lead in one motion and blind in the other, the ports could be covered by the lever in the motion that was set blind but not in the motion that had lead. Place the engine on the right forward dead center, mark the valve stem with the lever in full gear forward, then have the lever moved from full forward to full back motion and watch the marks on the stem as the lever is being moved. If set with the same lead for both motions you can see that it would be impossible to cover the ports. Try it.

295. Effect of Lowering Diaphragm.—"What would be the effect of lowering the diaphragm on a locomotive? That is, will it make a stronger draft on the fire or will it just cause the draft to be stronger in one place, that is, next to the flue sheet? Some claim that by lowering the diaphragm it contracts the opening and consequently the air passes through the grates and flues at a higher velocity and therefore burns the fire more fiercely.

Answer.—The diaphragm is for the purpose of regulating the burning of the fire. Raising it causes a stronger draft in the back end of the firebox and through the upper flues, and lowering it causes a stronger draft in the front end of the firebox and the lower flues. In order to obtain the benefit of the heating surface of the flues and the firebox the diaphragm should be adjusted to burn the fire nearly even on the grate surface and cause an even draft through the flues. As water always boils upward it is sometimes an advantage to have the draft slightly stronger through the lower flues. After the diaphragm is adjusted to obtain the above result it should be kept in that position. If the engine does not steam and we desire to increase the draft through the grates and all the flues it should be done by the adjustment of the petticoat pipe and sleeve. Although lowering the diaphragm would contract the opening and increase the velocity of the gases through the lower flues and front end of the box, it would be a detriment to the steaming qualities of the engine as we would loose the heating surface of the upper flues. Raising the bottom part of the pipe above the nozzle tip or lowering the top part or sleeve

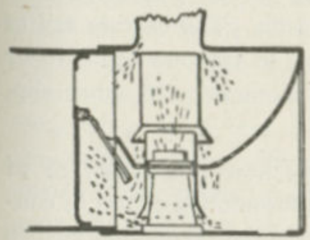


Fig 1.

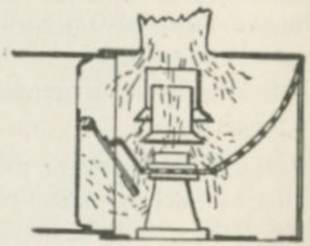


Fig. 2.

from the base of the stack will increase the draft; raising the sleeve and lowering the pipe will decrease it. Observe Fig. 1 with a pipe and sleeve that extends from the base of the stack to the base of the exhaust pipe, the dotted and broken lines representing the steam passing to the stack. This is not a very large opening for the exhaust steam to expel the smoke and gases from the front end; as they are not thrown out, the vacuum is not formed and the air is not drawn through the grates to fill the vacuum in the front end. In Fig. 2 we have the pipe raised above the nozzle tip and the sleeve lowered from the base of the stack so that the exhaust steam will expel the gases from the front end and a greater volume of air will flow through the grates and fire, promoting combustion. Consider that the nozzle, petticoat pipe, sleeve, and stack should do business in the front end the same as the tubes and the nozzle of the injector, and adjustments can be obtained that will be satisfactory. If the draft cannot be made strong enough in this manner then the nozzle should be bushed, but on account of the effect of the back pressure in the cylinders this should only be done when changing the pipe or sleeve will not produce it.

296. WHICH WHEEL SLIPS?—"The wheels of a locomotive are fixed fast on the axle. The outside rail of a curve being the longest, how do the outer and inner wheels keep even in rounding a curve? If either slip, how much?"

Answer.—If we were to ask how much surface of the tire of a driving wheel of a locomotive comes in contact with the rail, the answers from the various enginemen would vary. Some would claim that ½-inch and others 2 inches comes in contact with the rail. Occasionally we would be informed that there was only a fine line or point of contact, which is correct. In order to get more

than a point it would be necessary to have a flat spot on the tire equal to the surface of the tire in contact with the rail. Therefore, when the tire is round we have only a small point of contact. Locomotive tires are turned slightly conical from the flange to the edge of the tire, usually ¼-inch, that is, the small diameter of the tire would be ¼-inch less than the large diameter. If the point of contact between the tires on a pair of wheels and the rails were the same distance from each flange the diameter would be the same, the wheels would roll in a straight line. Then when the wheels strike a curve the flanges of the outside wheels are brought close to or against the ball of the rail, making the point of contact at the largest diameter of the tread, and the point of contact of the tire and the rail is on the smallest diameter of the inside wheel and the flange is farther away from the rail. For an example we will take a pair of wheels with tires 60 inches in diameter on the larger diameter of the tread and 59¾ inches in the smaller diameter, and we have the wheel with the flange near the rail moving a distance of 188.496 inches each revolution and the wheel on the inside of the curve, or with the point of contact on its smaller diameter, with the flange away from the rail will move a distance of 187.7106 inches or .7854 of an inch less distance each revolution of the wheel, due to the difference in the diameters of the wheels at the points of contact with the rails. As there are 5,280 feet in a mile and the 60-inch wheel would make 336 revolutions per mile there would be a difference of 22 feet between the distance covered by the inside and outside driving wheels, providing the wheels came in contact with the rails as described above. The lateral motion or side play between the face of the hubs and the driving boxes will permit the flange on the outside of the curve to roll toward the rail where the diameter is larger.

297. UNDERHUNG SPRINGS AND A BROKEN TIRE.—"How should a standard eight-wheel American engine with underhung springs be handled in case of a broken tire? Spring saddle extends into the bottom of the driving box and is held in position by a pin?"

Answer.—This is a poor design of a driving box for a case of this kind, as the cellar is raised in the center to clear the steel pin that supports the spring saddle, this pin extending through the box is held in place by the face of the shoe and wedge. When the tire breaks, if it still remains on the wheel, it is necessary to keep it from the rail, and if it is broken so that it comes off the wheel, the wheel center must be raised to keep it from being damaged. We will take for example the forward tire broken. We will insert a block between the top of the back box and under the top rail of the frame, take out the cellar and see if we have space enough between the spring saddle and the journal to put in a block that will hold the broken tire from the rail. If not, it will be necessary to remove the pedestal or thimble bolt. Then run the back driver up on a wedge to raise the lower end of the pedestal jaws or legs of the frame above the pin. Take out the pin, remove the spring and saddle, and cut a block from the end of a timber or tie that will fill the space between the pedestal bolt and the journal when the wheel will clear the rail. Have it thick enough to allow for wear and settling. Chain the end of the equalizer to the frame and run the back wheel off the wedge. Then put the pedestal bolt back in place and tighten the nuts. Now put the wedge under the wheel with the broken tire

and run the wheel on it until you can insert the block between the pedestal bolt and the journal. Run the wheel off the wedge and you are ready to proceed. If the back spring is heavy enough to carry the load the blocks may be removed from the top of the back box and the back spring utilized.

298. ENGINE SLIPPING WITH HEAVY TRAIN.—"If an eight-wheel engine was down on her back boxes would it have a tendency to make the engine slip with a heavy train?"

Answer.—An eight-wheel engine usually has about one-third of its weight supported by the engine truck and the other two-thirds supported on the drivers through the medium of equalizers and springs. The truck supporting the weight at the front end is one point and the fulcrums for the equalizers on each side of the engine form the other two points, thus forming a tripod to distribute the weight equally on uneven track. The two back points of the support place the weight on the fulcrums of the equalizers and it is transmitted to the springs, saddles, and hangers for the purpose of lessening the shock and equalizing the load on rough track. It is evident that each end of the equalizer must support one-half of the load or weight at the fulcrum and when one end of the equalizer moves down the other end will move up an equal distance and the weight on the support is the same as if the equalizer was in a horizontal position. Therefore, an engine slightly low behind or down on her back boxes would not lose her adhesion or be more liable to slip providing the points of support were the same and the equalizer free to move on the fulcrum. If the load intended to be carried on the drivers was transferred to the back boxes on account of their being blocked between the top of the box and the frame, the equalizing feature would be destroyed and the forward wheels would support little of the weight, if any. More weight would be carried by the truck and the result would be less weight on the drivers, which would reduce the adhesion and cause the engine to slip.

299. THE SIGHT-FEED LUBRICATOR.—"Does the oil fed through a sight-feed lubricator go from the lubricator to the valve by gravity, or is it forced down by a current of steam?"

Answer.—Oil that is fed through a sight-feed glass of a lubricator rises to the top of the water in the glass by reason of the oil being the lighter, and the pressure of the weight of the water in the condensing chamber whose level is higher than the level of the water in the chamber above the sight-feed glass. The steam that flows through the equalizing tube forces water from condensation through the hole in the choke plug, keeping the water at a level with the opening. As the oil rises to the top of the water, the water and oil above this level are forced through the choker into the oil pipe leading to the steam chest. When the pressure at the lubricator end of the oil pipe is the greater the oil is carried to the steam chest by the current of steam pressure. Oil being heavier than steam it would flow to the chest by gravity without the pressure of steam, but the movement would be slow. When the pressure at the steam chest end of the oil pipe exceeds the pressure of the lubricator end the oil pipe is sometimes filled with water, forming what is termed a "pocket" for the oil and preventing the flow of the oil to the chest until the pressure is reduced at that end of the pipe. Oil does not flow through the pipe as it appears in the glass. When the drop of oil rises opposite the hole in the choke plug the steam and water atomizes it and it is mixed in proportion to the amount of oil and water that pass through the choker. The valves and cylinders get oil and water. A sample of this can be easily obtained by disconnecting the oil pipe, starting the lubricator and placing a bucket under the end of the pipe. Various kinds of circulating valves and devices are used to insure a positive circulation through the oil pipes from the lubricator to the chest and maintain lubrication under the varying conditions.

300. BRIDGING EXHAUST NOZZLES.—"What difference does it make whether you put a bridge in an exhaust nozzle crosswise with the flues or parallel with them? A bridge is used here to spread the exhaust steam to fill the stack so the engine will burn her fire."

Answer.—A bridge placed in a single nozzle has the effect of reducing the area and increasing the back pressure in the cylinders. Spreading the steam to fill the stack in this manner would have a tendency to further increase the back pressure, as it has been found that reducing the choke or small diameter of the stack caused back pressure the same as reducing the nozzle. If the stack is out of line to one side or the other, placing the bridge parallel with the flues would cause the steam to fill the stack and produce a greater vacuum than if the stack was not filled by the exhaust. Should the stack be out of line, either forward or back of the nozzle, then it would be more beneficial to place the bridge crosswise of the flues, but it would be better to have the nozzle and stack put in line so that the expansion of the exhaust steam would fill it evenly. Bridging a nozzle is usually creating one defect to remedy the other.

301. WHAT IS THE DEFECT—"Please explain what defect, if any, and about what percentage of power is lost in the following: Long piston, cylinder is 18x24, 135 pounds of steam, and 55-inch driving wheel. Piston just clears the front end 1-64 of an inch, clearance on other engines of the same make is 5/8 of an inch divided. This engine does not give satisfaction and the trouble cannot be located anywhere except a long piston. If this affects the lead or pulling power, please advise."

Answer.—If this engine is still in service the clearance should be attended to at once, as it is not sufficient to allow for the keying of the main rod to take up the wear on the brasses, and there is danger of knocking out the front cylinder head. We will presume that this engine originally had 5-16 of an inch clearance at each end of the cylinder and the clearance on the front end was reduced on account increasing the length of the main rod by driving the keys. That being the case, we have 1-64 of an inch clearance on the front end and 39-64 of an inch on the back end. Neglecting the space between the circumference of the cylinder and the valve face, we would have a volume of clearance in the front end of about 4 cubic inches and a clearance volume in the back end of about 130 cubic inches. The position of the eccentric in relation to the pin is not changed, therefore, the lead of the valve would be the same, and if cutting off the steam at 5 inches of the stroke, or when the piston had moved 5 inches from the end of its travel, we would have a volume of steam in the front end of the cylinder equal to 1,276.5 cubic inches to force the piston back by its expansive force. In the back end of the cylinder we would have a volume of steam equal to 1,402.5 cubic inches to push the piston ahead, which would give a higher mean effective pressure in the back end than in the front end of the cylinder. This increased volume of steam confined in the cylinder when the valve is closed the admission port may cause the exhaust from the back ends of the cylinders to sound heavy. Would have the clearance divided for each end of the cylinder and take up the dome cover and see if the throttle valve opened enough to admit steam to the dry pipe in sufficient quantity to develop the required power in the cylinders. The throttle valve should lift 1/4 of an inch for each inch of its diameter to get the full opening.

302. ENGINE DOESN'T STEAM.—"Will you kindly give me your advice and the benefit of your experience on the following? The engine came here new last August with a brick arch and up to some time ago did first rate. She has not been doing so well lately and have reported work as follows: 'New brick arch, bore out flues, clean out nozzle, etc.' She had been steaming pretty well before this work was done, but tore the fire all to pieces, especially after being cleaned, knocking it through to the pan. They had no new brick to put in, so took the remains of the one out entirely. They found the nozzle coated about 1/4 of an inch and cleaned that out. Now she does not steam nearly so well and burns all the coal you can pile on. Should the diaphragm be altered, and if so, higher or lower?"

Answer.—An engine out of the shop six months should be in good condition if running in a locality where there is good water used, providing that the flues and firebox do not leak and the boiler is free from mud and scale. You have the same amount of heating surface, and with the valves and cylinder packing tight the engine ought to do good work. Although the brick arch is considered as an aid to combustion, the engine can be made to steam well without one, but it is usually necessary to lower the diaphragm about 3 inches when the arch is removed, providing that the front end was properly adjusted to steam with one. Lower the diaphragm to increase the draft in the forward end of the firebox and through the lower flues and raise it to increase the draft in the back of the firebox and through the upper flues. Change it until you get the fire to burn evenly on the grates. Would suggest that the exhaust pipe be examined and ascertain if it is not choked up below the tip, thereby reducing the area of the exhaust pipe which, with the uneven draft you may have, tears holes in the fire. See that the stack is in line with the nozzle, that the gasket between the exhaust pipe and cylinder saddle is not cracked or blown out, and that the exhaust from the air pump is directed up the stack and not against the pipe or smoke arch, thus destroying the vacuum in the front end. If the fire burns a dull red have the steam pipes examined for leaks. Go right after her and you will make steam.

303. WORKING FULL STROKE AND CUT BACK.—"All other things being equal, with sufficient boiler capacity to furnish the required amount of steam, could a locomotive, such as is run on the fast trains of today, make as fast time by working steam the full stroke of the piston as it will if cut back? If not, please explain why."

Answer.—With sufficient steam supplied to work a locomotive at full stroke, it is the general opinion that the engine would not run as fast if cut back and steam used expansively, regulating the cut-off to meet the requirements of the service. The locomotive as designed would be unable to get rid of the steam fast enough to

prevent back pressure and the engine would be choked with steam. As the back pressure increases the mean effective pressure would be diminished and result in a loss of power and speed.

304. WEIGHT ON DRIVERS AND TRACTIVE EFFORT.—"Does the term 'weight on drivers' mean also the weight of the drivers, journals and pin connections in figuring the tractive effort? If not, why not? Why, in figuring the tractive effort, do you take only one side of the engine instead of both cylinders?"

Answer.—The adhesion of a locomotive is the friction between the driving wheels and rails and depends upon the weight or pressure of the surfaces in contact. Therefore, the weight on the drivers means the weight of the driver and the load resting on it at its point of contact with the rail. The weight on drivers is usually limited by the engineering department and depends on the weight of the rails, condition of the road bed, strength of the bridges, etc. If the weight of the drivers was not included in placing the limit, the engine would be hard on the track and increase the cost of maintenance of roadway and bridges. A pair of drivers will weigh from 6,000 to 9,000 pounds, and as they add to the adhesion, it should be figured from the point of contact with the rail. The use of the dynamometer car is the most accurate method to obtain the drawbar pull or tractive power of a locomotive. This is a car especially fitted with a drawbar connected with calibrated springs that indicate the number of pounds pull on the drawbar. In answer to a similar question we found a tractive power of 22,674 pounds for an 18x26-inch engine with a 60-inch wheel and 190-pound boiler pressure. If we desire to obtain the tractive power by figuring both pistons or both sides of the engine, the following formula should be used instead, which gives nearly the same results. To make the example clear to all we will give the figures. Area of one piston (which = 254.4696 square inches) times the pressure in the cylinders (which = 161.5 pounds) times twice the length of the stroke (which = 4.3333 feet) times 2 (for both pistons or both sides of the engine), divided by the circumference of the wheel, equals tractive power of 22,686 pounds. A slight difference, but either is accurate enough for general application and the one cylinder method is the shortest, therefore most used in calculation. If the weight on the drivers is known, one-fourth of the weight is usually taken as the tractive power. In the above, would expect the weight on the drivers to be about 91,000 pounds.

Should we desire to figure the tractive power with the two-cylinder or both piston method, we would use the following formula: Area of one piston (in this case =254.4696 square inches) times the pressure in the cylinder (which = 161.5 pounds) times twice the length of the stroke (which = 4.3333 feet) times 2 for both sides, divided by the circumference of the wheel (which = 15.7 feet), we have:

```
   254.4696
      161.5 pressure
  ----------
   12723480
   2544696
 15268176
 2544696
 ----------
```



```
   41096.84040
        4.3333   Twice the stroke
  -------------    in feet
    12329052120
   12329052120
  12329052120
 12329052120
16438736160
 -------------
178084.938505320
               2   For both pistons
 -------------
356169.877010640
```

Divided by the circumference of the wheel in feet, we have:

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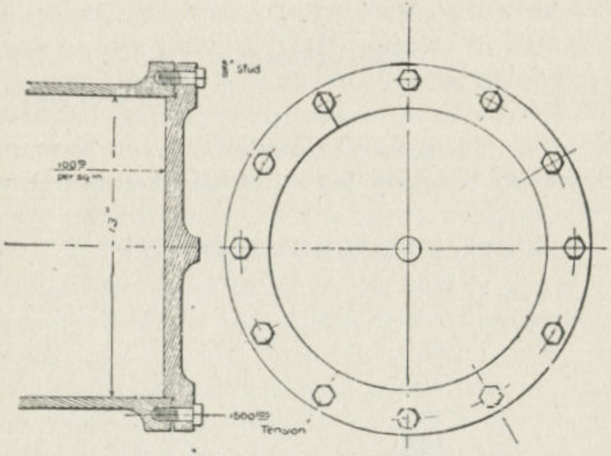
15.7) 356169.877010640 (22685.9+
      314
      ---
       421
       314
       ---
       1076
        942
       ----
        1349
        1256
        ----
          938
          785
          ---
          1537
          1413
          ----
           124
```

305. STRESS ON CYLINDER HEAD STUDS.—"Suppose we tighten the twelve nuts on a 13-inch cylinder head until we have, for instance, 1,500 pound stress on each stud holding the cylinder head to the cylinder, and then we admit steam to the cylinder to the amount of 100 pounds per square inch, is there any additional stress on the studs?"



1,500 x 12=18,000 pounds pressure holding head against cylinder.
Area, 13 inches circumference=132.73 square inches.
132.73 x 100=13,273 pounds steam pressure against head.

Answer.—In this case we would have 12 times 1,500 pounds, which would equal a stress of 18,000 pounds strain holding the head to the cylinder. The area of a 13-inch cylinder is 132.73 inches, and 100 pounds pressure would equal 13,273 pounds, or 4,727 pounds less than the pressure of studs on the head. By dividing 18,000 pounds by the area of the cylinder in inches we find that the pressure on the steam side would have to exceed 135.7 pounds per square inch before there would be additional strain on the studs. (See illustration.)

306. BROKEN FRAMES ON RIGHT LEAD ENGINES.—"Please state reason for so many right locomotive frames breaking on right lead engines."

Answer.—You do not state if the engines are equipped with double or single front rails on the engine frame. There may be many causes—poor design, welds, or material, or water in cylinders. Where the right side leads the engine always pounds harder on the right side than on the left, because when the right crank pin passes the forward center the left cylinder is pulling forward. This helps the right cylinder in pushing the right box back against the jaw of the pedestal, and the same results occur on the back center on the left side. This is usually the cause of more right frames breaking than left on right lead engines, and by having the left engine lead the trouble would only be transferred from one side to the other. One master mechanic reduced the number of broken frames by keeping the thimble bolts tight and wedges set up on the class of engines that were giving trouble. Try it.

307. PISTON VALVE OPENING.—"How would you get the opening on a piston valve when the engine happens not to have any by-pass valves so one could take them off and see to the valve? We have a yard engine at this point and she has not any by-pass valves."

Answer.—The spool of a piston valve is smaller than the steam-chest bushing and the edges of the rings are taken as the valve edges. With an engine equipped as you state there would be no way that we could recommend other than to take off both valve chamber heads and use a strip of tin in the ports, pulling valve in either direction so that the edges of the ring would come up against the strip of tin in the port. However, it is the usual custom to tap into the valve chamber opposite the steam ports so that the edges of the rings can be seen when they are even with the edges of the steam ports to the cylinders, and plugs put in the peepholes similar to the plugs put in the cylinder for indicator connections. Look under the steam chest casing and see if they are not there for that purpose. If not, it would be convenient for valve setting if they were made of suitable size to take in the port opening.

308. PRESSURE AT THE MUDRING.—"Is there more pressure at the mudring than there is at the turret, or location of steam gauge? Some people claim there is steam gauge pressure, plus the weight of the water at the mudring. I claim that the pressure is the same."

Answer.—You are wrong. Steam exerts its pressure evenly in all directions. Therefore, the pressure at the mudring is greatest, as it has the pressure of the steam, plus the weight of the water, upon it. If you had a pail of sand that put a weight of 10 pounds per square inch on the bottom of the pail, and then put a pressure on top of the sand, would not the weight be increased on the bottom of the pail? It is the same with the water in the boiler.

309. TREATING JOURNAL BEARINGS.—"Is it good practice to put sulphur on a hot journal? What would you recommend to bring a driving box down to a bearing after it has been very hot?"

Answer.—Yes; use sulphur with oil, graphite and oil, or powdered mica. They are all good to assist in lubricating an irritated bearing and getting it down to a smooth surface. If the box would not run cool after a fair trial of the above treatment, would recommend that

the wheels be dropped, journals turned, and boxes bored out and refitted.

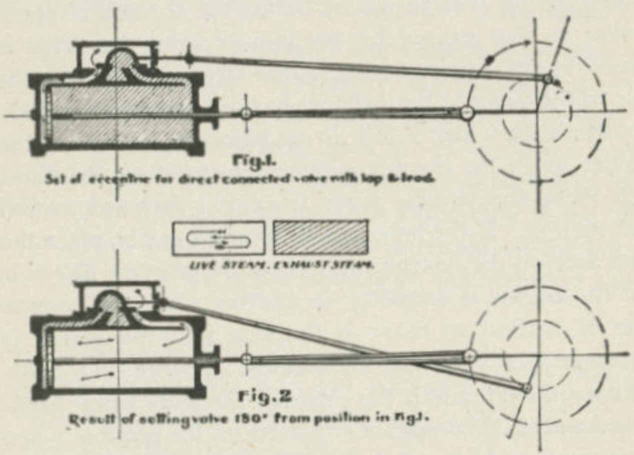
310. LOCATING BROKEN VALVE SPRING.—"In testing for a broken valve spring, how could it be located?"

Answer.—We will presume that you refer to the broken spring that holds the balance strip up to the pressure plate on the steam chest cover, or what is known as a valve strip blow. These springs hold the strips up to the plate and relieve the back of the valve from steam-chest pressure when they are tight. Any leakage past the strip will escape into the exhaust passage through the hole in the back of the valve. The first indication of the broken spring will be a blow when the throttle is open, similar to that caused by the blower being on. This is caused by the steam passing by the strip and through the hole in the valve to the exhaust passage nozzle and stack. To determine which side it is on, place the engine on the quarter, open the throttle sufficient to produce the blow, then move the reverse lever from full forward to full back motion. If the lever can be handled easily, place the other side on the quarter and repeat the above. The side that the engine is standing on quarter when the reverse lever is hardest to move is the side that the spring is broken, as that valve has the greatest pressure on it holding it to its seat, and is the cause of the lever being harder to handle. The engine is placed on the quarter when testing each side to get full travel of the valve when the lever is moved from forward to back motion.

311. CHANGING ECCENTRIC OF DIRECT MOTION ENGINE.—"Will changing the eccentric of a direct motion stationary engine with D slide valve having lap and lead, placing it one-half way around the shaft from its former

position, change the direction of the engine's running, or will the engine run at all?"

Answer.—If the engine had a valve without lap or lead the eccentric would be set at right angles to the pin, or at 90 degrees, and changing the position of the eccentric one-half way around the shaft would reverse the motion and cause the engine to run in the opposite direction. When lap is added to the edges of the valve, and given lead, this is called the angle of advance, and the rule is to set the eccentric ahead of the pin at an angle of 90 degrees, plus the angle of advance. This rule would hold good if it was desired to have the engine run in either direction, and if you changed your eccentric 180



Diagrams Illustrating the Effect of Changing the Eccentric on a Direct Motion Engine.

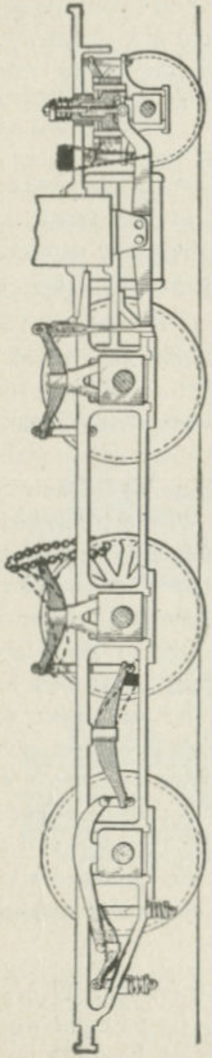
degrees steam would be admitted behind the piston when the engine was on the forward center. Therefore, she would not run at all. See illustration, Figs. 1 and 2, which show the position of the valve with the eccentric

in that position. But if the eccentric was given the same angle of advance in Fig. 2 ahead of the pin, steam would be admitted ahead of the piston, and the engine would run in the opposite direction from that taken when eccentric and valve are as in Fig. 1.

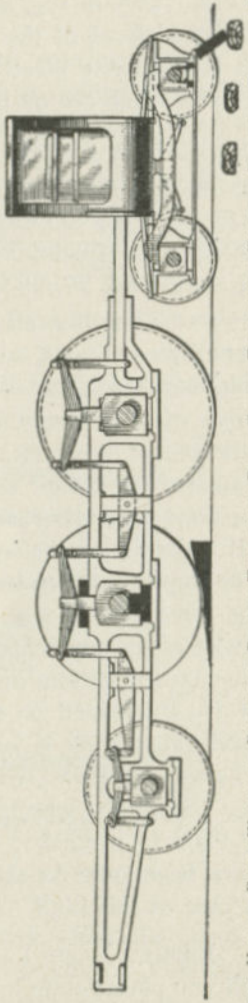
312. BROKEN FRONT TANK WHEEL OR AXLE.—"What should be done in case of broken front tank wheel or axle; if you swing them is there any danger of the second tire leaving the track, especially when the engine is running on curves?"

Answer.—This, like all other breakdowns, should be governed by conditions, such as weight and construction of tank, capacities, etc. Engines with small capacity tanks may often be chained to a tie or piece of rail placed over the top of the tank, and blocking placed between the frame of the tender and the top of the truck boxes on the good pair of wheels, which would support the weight, while the chains would hold the other end of the truck up to prevent derailment. In some cases the apron may be removed and the pieces of rails or ties placed lengthwise of the tender, one end resting on the deck and the other on the bottom of the tank, and the broken end of the truck chained to them. With a six or seven thousand gallon tank it is usually better to get the engine to a side track and send for a truck; this can best be done by sliding the wheels or blocking them up and securing them to a notched tie, when the damaged truck wheels or frame may be skidded into clear; run carefully in any case of this kind.

313. BROKEN BACK TIRE ON EIGHT-WHEEL ENGINE.—"Will you please state how to block up an eight-wheel engine with broken back tire, without blocking over



METHOD OF PULLING A DRIVING SPRING INTO POSITION WITH A CHAIN.
Also indicating how front end of long equalizer can be chained up when Bissel pin is broken.



SHOWING HOW TO RAISE WHEEL TO BLOCK FOR BROKEN TIRE, OR TO RAISE ENGINE TRUCK WITH FULCRUM BLOCK TO REPLACE BRASS IN CASE OF A HOT ENGINE TRUCK BEARING.

main box, as the road that I work on will not allow it to be done?"

Answer.—Run the wheel with broken tire up on a wedge or block, then remove cellar and insert block between the axle and pedestal bolt or brace to hold the broken tire or wheel center off the rail. Also block between drawbar and tail piece, bolted to ends of the frames, so as to relieve the forward or main boxes of as much of the weight as possible. If the side rods are not damaged by fire breaking, leave them up. When you have done this, if the spring over the main box is not strong enough to carry the weight or has lost its set, blocking may have to be used over main driving boxes or engine trucks to keep the pilot high enough to clear crossing planks. In case this should be the back tire on right side and raising the box would bring the spring and hanger so high that it would interfere with the reach rod or reversing lever, it would be necessary to remove the spring and saddle from the box with the broken tire and block the back end of equalizer on the frame.

314. AXLES AND VIBRATION.—To settle a dispute will you please say why a car axle is made with a smaller diameter in center than at the ends near the wheels. Various reasons have been given; one is said to be to save iron; if so, why is not the same practice carried out in the driving and engine truck axles?"

Answer.—The reason that the driving and engine truck axles are of the same diameter their entire length is due to the fact that the bearings carrying the load are inside of the wheels, and the uneven joints in the track, when passed over by the wheel, do not tend to vibrate the axle as they would when the weight is carried on the bearings outside of the wheels as in the case of a truck or trailer axle with outside bearings. When the weight is outside of the wheel, as it passes over uneven track the axle being of a smaller diameter in the center allows vibration to take place in proportion to the force of the blow imparted by the load to the uneven track and the size of the axle. If it was not for this vibration broken journals would be of more frequent occurrence, unless the track was perfect, which condition it would be impossible to obtain, as it would have to be laid with continuous rails without frogs or switches. Figure that the truck axle is smaller in diameter in the center for the same reason that the axe handle is not the same size its full length, and the illustration will be convincing to the person using the axe.

315. TESTING STEAM PIPE JOINTS.—"I have been told to cover the exhaust tip and hold it tight with a jack, and that this will test the joint at the base of the exhaust pipe. Please explain how the water reaches the exhaust passage to give the pressure there to test this joint?"

Answer.—There are very few, if any, valves and cylinder packings that are absolutely water tight, therefore in making the test if one of the ports to the cylinder was open for admission, the other would be open for exhaust and the water under pressure would find its way past the packing rings and fill the cylinder with water on the exhaust side of the piston, and this would allow the water to get into the exhaust passages, even though it did not leak under the valve, or if a piston valve leaks past the rings in the valves. Hence the tight joint at the top of the exhaust pipe tip would prevent the water from coming out and the pressure would be accumulated in the exhaust pipe, as well as in the steam pipes.

If you are fortunate enough to have valves and cylinder packing that will not leak to this extent, moving the lever from forward to back motion will allow the water to get into the exhaust pipe and a test can be made for the leak to a certainty.

316. ANGULARITY OF MAIN ROD.—"I placed the main pin on the top quarter with naked eye and made a mark on the guide bar, then I gave the wheel a half revolution and placed pin on the bottom quarter and marked the guide bar, and I find that it varies almost 2 inches. I have tried this on 18 or 20 engines and have never found one that would come true. Will you please explain this?"

Answer.—Your eye is not accurate enough to measure this correctly and your system is wrong. Engine on the quarter means at half stroke. If you will place the cross-head at half-stroke and mark the guides, then move the engine until the cross-head travels to the end of the stroke and back to the mark again, you will get the engine on the top and bottom quarter, but the pin will be slightly in advance of a perpendicular line through the axle in proportion to the length of the main rod. That is, a short main rod will bring it farther from the line than a long one. Try it this way next time, or use a tram equal to the length of the main rod, and you can not miss it. This is caused by the angularity of the main rod, and also explains the reason that the circumference of the wheel travels farther on the rail from half stroke back to center and to half stroke again, than from half stroke ahead to center and back to half stroke.

317. MOVEMENT OF CROSS-HEAD.—"Will you please explain if it is true that a cross-head moves only one way or direction; I have heard that it does, but do not believe it?"

Answer.—In order to make you believe it we will take a driver with a diameter of 42 inches and a piston with a 2-foot stroke; will use this because it will come out in even figures. To prove to you that the cross-head is always moving in the direction that the engine is going, multiply 42 inches by 3.1416; this will give the circumference of the wheel equal to 131.9472 inches. We will call this 132 inches, which, divided by 12 inches, equals 11 feet; remember that the stroke is 2 feet and the circumference of the wheel is 11 feet. With the cross-head at back center, if you measure 5 feet and 6 inches from the point of contact of the wheel and rail and move the wheel that distance, the engine has moved 5 feet and 6 inches, the cross-head has moved with the engine 5 feet and 6 inches, and in addition has moved in the guides 2 feet, which gives 7 feet and 6 inches that the cross-head has moved while the pin has traveled from back to front center. If the wheel is now moved ahead 5 feet and 6 inches farther, the pin and cross-head will be again on the back center, but the cross-head has lost the 2 feet that it gained in the forward stroke and has only traveled a distance of 3 feet and 6 inches, but the 7 feet and 6 inches it traveled on the forward stroke and the 3 feet and 6 inches on the back stroke will equal 11 feet, or the circumference of the wheel. It's going ahead all the time.

318. Valve Travel with Lap and Lead.—"Will the valves of an engine having lap and lead travel when the reverse lever is in the center notch of the quadrant and the engine is drifting? If they will travel, why and how much?"

Answer.—A valve will always travel twice the lap and twice the port opening, whatever the cut-off may be, and

many locomotives have a valve travel that is greater than twice the lap and the width of the steam port, but they never have less. To illustrate the answer to this question, we will take an engine with 5-inch valve travel and eccentrics 5-inch throw, 1-inch outside lap set with 1-32 inch lead opening in full gear both motions. In the 6-inch cut-off, the lead would be increased to 3-16-inch with a maximum port opening of 5-16 inch. We would have a valve traveling 5 inches at full gear, but when working in the 6-inch cut-off would only travel twice the lap, which is 1 inch and twice the port opening, which in this case is 5-16-inch, or a total travel in this notch of 2⅝ inches. Therefore, it is clear that the valve will travel twice the lap and port opening, whatever it may be, and, as the lead increases as the lever is notched up toward the middle gear, it can be easily figured from the marks on the valve rod. Why do the valves travel? Because the motion is imparted to the link arm of the rocker by the eccentric strap and rod. When the eccentric rod is in line with the link block, or nearly so, that eccentric controls the action of the valve. But when the link is raised to mid-gear, both eccentrics control the action of the valve, and the travel is decreased as the link is raised from full gear to center. Figure that the back motion eccentric coupled to the lower end of the link is the fulcrum, the link block the weight, and the forward motion eccentric the power or force to move the lever, which in this case is the link, and you have the explanation as to why the valves travel and how much in any position in which the reverse lever may be placed.

319. Leaving Back Port Open in Case of Breakdowns.—"Would it be advisable or practicable, in case of broken eccentric strap, link rocker-box or arm, to

leave the back port open a little to admit steam and oil to cylinder, instead of taking down main rod?"

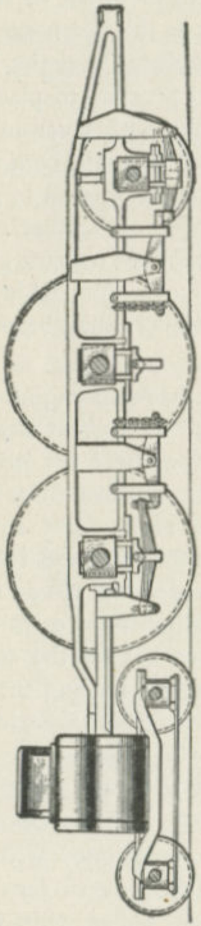
Answer.—Yes, unless prohibited by the rules of the mechanical department. By clamping the valve in position to allow steam to enter the back port, steam and oil will be admitted to the cylinder and it will not be necessary to take down main rod. The amount of opening of the port that should be left open may be determined by opening the throttle and blocking the cylinder cock open, or remove the valve from the cylinder cock. Some roads advocate taking the cylinder cock out entirely and blocking the valve in position to allow a reasonable amount of steam to escape at all times when the throttle is open. Then, in case the engine should stop on a center, on the good side, closing the cylinder cock or replacing valve or cock sufficient steam will be admitted to the cylinder to complete the stroke on the disabled side, which will place the good side again on the quarter; the valve or cock can again be removed on the broken-down side and you are in position to start the engine when ready to go. With heavy power it is impossible for train crews to pinch engines off a center or handle the rod if they succeeded in getting the strap bolts out, which is often a difficult thing to do. This is practiced on some of the important lines at the present time and is considered the correct method.

320. Cylinder Packing Blowing.—"Where does the cylinder packing blow the most—at the beginning of the stroke, on the eighth, or on the quarter?"

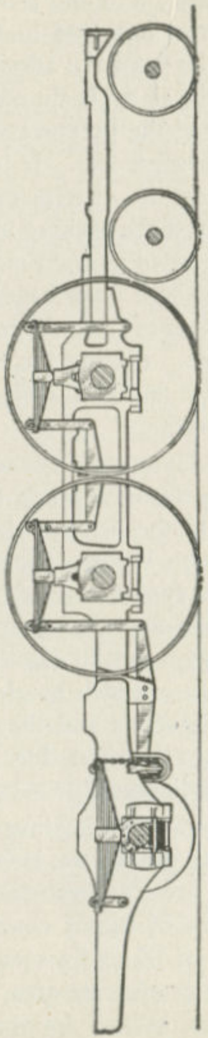
Answer.—Some kinds of cylinder packing will blow the most at the beginning of the stroke, because the steam has not set it out against the cylinder walls until the stroke has commenced. If the cylinder is round and not cut or scored and of the same diameter through its entire length, and the guides properly lined to keep the piston running true in the cylinder, the greatest blow should be from the admission line to the point of stroke where the steam is cut off, and then as the steam expands in volume the pressure would be reduced and the blow would become less. It is the usual practice to place an engine on the quarter or half stroke with lever in full gear to test the packing blows on that side, but both sides may be tested at one time by moving the engine in position that both cross-heads are opposite each other or of equal distance from the back end of guides or back cylinder heads. Placing the engine as above, the packing on both sides and both ends of the cylinders may be tested in two positions.

321. Heating Surfaces.—"We have an engine here in heavy transfer work that has given a great deal of trouble to the fireman about steaming; here are her dimensions: Weight 160,500 pounds, tractive force 36,400 (no engine trucks), heating surface 1,905 square feet, grate area 29 square feet, cylinders 22x28 inches, drivers 57 inches in diameter, steam pressure 180 pounds. She has a 5-inch nozzle and no petticoat pipe; is very hot at the door and the smoke does not fill the stack, but strikes the right side. Is this enough heating surface for the cylinders?"

Answer.—The heating surface of this boiler, in proportion to grate area, is 65½ square feet per square foot of grate area, and compares favorably with the average, as boilers of recent construction are designed with an average of 66 to 83 square feet of heating surface per square foot of grate area, this includes boilers with wide fire-boxes. When designing a boiler, it is the custom to allow a certain amount of heating surface for each cubic



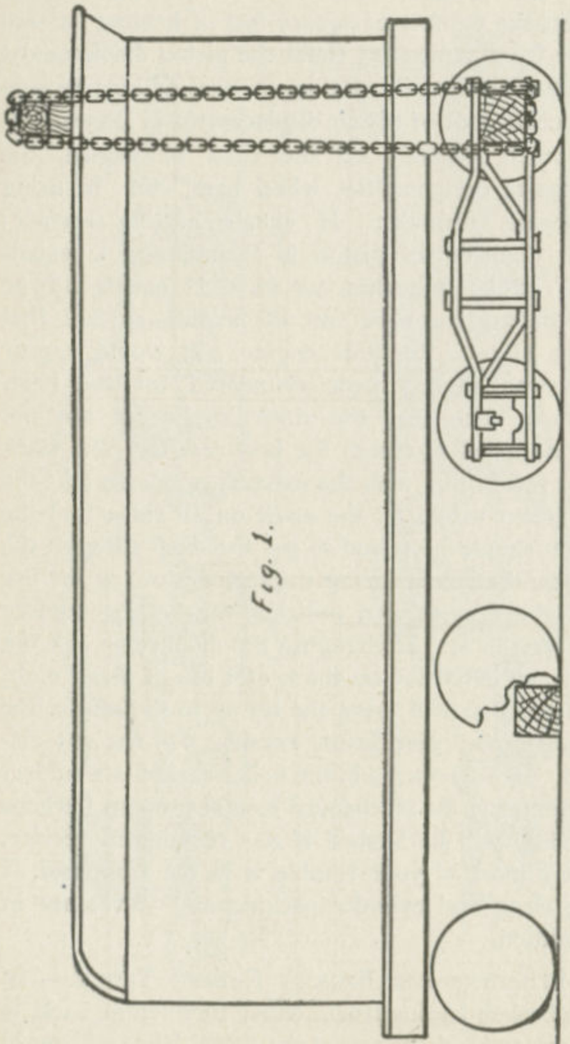
Showing What to Do in case of Broken Main Driving Spring on an Underhung Engine.



How to Handle a Broken Trailer Tire or Broken Trailer Equalizer.

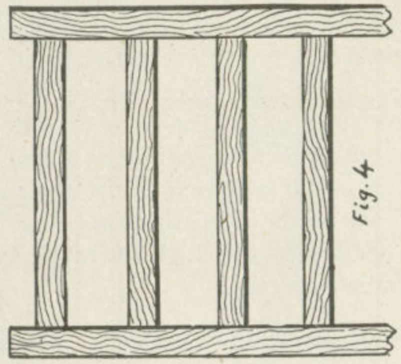
foot of piston displacement. Experiments have determined that the number of square feet of heating surface should be from 320 to 415 times the piston displacement in cubic feet; ordinarily 385 square feet of heating surface per cubic foot of piston displacement is allowed, although much depends on the class of engine, the service she is designed for, wheel base, etc. In using the following formula: H equals heating surface: D equals diameter of piston in inches, and L equals length of stroke in inches, we have H equals $.175 \times D^2 \times L$, or 2,371 square feet of heating surface that should be allowed for this engine. It would appear that she was slightly over cylindered for the heating surface; also that the draft appliances are not properly adjusted to obtain the best results. The stack should be put in line with the exhaust nozzle so that the exhaust steam would fill the stack on all sides, and the diaphragm should be raised to get the draft through the upper flues, thereby reducing the temperature at the fire door for the fireman and utilizing the heating surface that you now have. If changing the diaphragm can not effect this, an extension on the nozzle top of about eight or ten inches that will bring the tip up to the center line of the boiler may give better results. Do not get discouraged. Improvements in the boiler design is a subject that is interesting the mechanical men at present. Perhaps the cylinders will be bushed if she remains in service. Would say most of your trouble is in the front end, if flues are clean and cylinder packing and valves are in good condition.

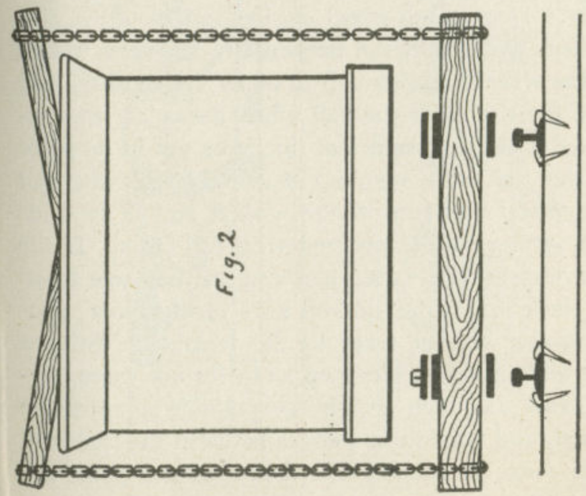
322. Blocking for Broken Engine Truck.—"In case of a broken engine truck, either forward or back, is it necessary to block on top of the front driving boxes?"



SHOWING (AT FRONT) METHOD OF SLIDING BROKEN ENGINE OR TENDER TRUCK WHEEL TO SIDE TRACK, BY PLACING TIE IN FRONT OF DEFECTIVE WHEEL.

Also showing (at rear) chain from ties on top of tank as arranged in Figs. 2, 3, and 4 on opposite page, to tie placed between arch bars, with oil-boxes removed for the purpose.





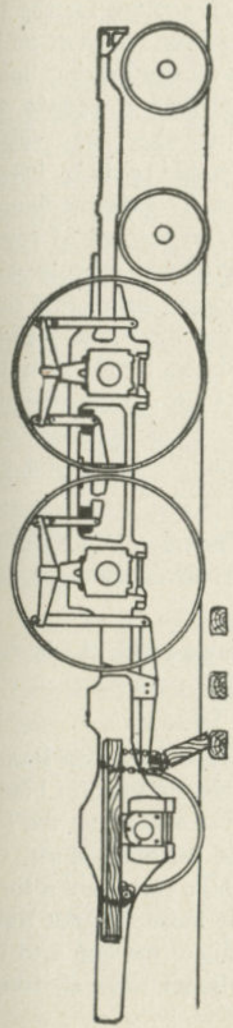
HOW TO BRING A TENDER IN WITH BROKEN TRUCK WHEEL.

Ties are laid over top of tank as in Fig. 4; two locking and overhanging ties are placed as in Fig. 3; from these are hung chains as in Fig. 2, passing around tie placed between arch bars, with oil-boxes removed for the purpose. A side view of the arrangement is shown in Fig. 1 on opposite page.

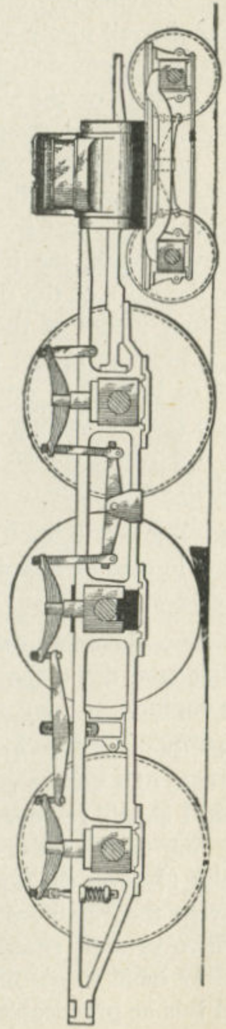
Answer.—It may be necessary to block on top of front driving boxes and run the front drivers up on wedges to relieve the weight on the engine truck so that it can be easily raised and properly chained to an engine frame. If a mogul or an eight-wheel engine, it is usually necessary to block on top of the front driving boxes, but six and eight-wheel coupled engines as a rule do not require it. It is up to the judgment of the engineer in all cases. Block on top of the front driving boxes if necessary to keep the pilot sufficiently high for safety in passing frogs and crossings.

323. Broken Tire.—"In case of a broken tire, where the tire can not be removed, should the wheel be raised to clear the rail, leaving the good wheel on the rail? Would the cramped position not be injurious to the engine?"

Answer.—If on a ten-wheel engine and the front tire was broken, would run the broken tire up on a wedge to raise the wheel high enough to allow for settling, and still have the tire clear the rail when the cellar was removed, and a block of sufficient thickness put in its place to keep the tire from coming in contact with the rail when the wheel was run off the wedge, and if the rods were not sprung, would proceed with full train. If the main tire was broken would block up in the same manner and slack up on the siderod keys on that side, running carefully without train to the terminal. With a back tire broken would block up as in former cases, trying to throw as much weight as possible against the good wheel, and would use wedges between the tank and engine to assist in keeping the flange of the good tire close up to the rail, running carefully, especially around



Method of Raising Cross-Equalizer.



Method of Raising and Blocking Wheel for Broken Tire curves. Having any one wheel high enough for the tire to clear the rail nicely will not cramp the boxes or be injurious to the engine. If the sides of the driving boxes were a close fit on the sides of the shoes and wedges, the driving-box would cramp when one wheel was raised higher than the other, and damage would result by breaking off the flanges of the driving box. To save the flanges of the driving-boxes from breaking on account of rough or uneven track, the inside of the flanges are beveled where the sides of the shoes and wedges fit, so that only about four inches of the sides of the shoes and wedges have a bearing in the center, and the bevel from the center to both ends on the side of the flange obviates damage from cramping the flanges of the driving-boxes when one wheel center is raised slightly higher on one side than on the other.

324. Broken Back Driving Wheel.—"What should be done in case of a broken-back driver on an eight, ten, or twelve-wheel engine?"

Answer.—Handle in the same way as with the broken tire, but take down the opposite side rods on each side of the engine.

325. Broken Go-ahead Eccentric Strap or Blade—"In case of a broken go-ahead eccentric strap or blade, suppose I should remove the broken parts and tie the top of the link to the lower arm of the tumbling shaft, set the valve to cover the ports and tighten the gland a little to prevent the gland from being too loose, but not tight enough to prevent reversing, and allow the valve to be moved by hand to get oil to the cylinder while drifting. Would this be practicable?"

Answer.—It is the rule to take down both eccentrics

in a case of this kind, because, when a rule is made, it is of general application. If the tumbling shaft has the link arm over the top of the link, and it could be secured near its proper position, it would be safe enough if the lever was not hooked up or reversed, but in case of a flag or an emergency and the engine was reversed, further damage would result. It would be safest to take down both eccentric rods. However, if this should happen to you where an engine was not available and train could not be handled on one side, if you could turn the engine on a Y or a table, ask train dispatcher to let you turn engine around; get on to the train and back up to the terminal, keeping the lever in full gear back motion. This would bring the back motion eccentric rod nearly in line with link block on the disabled side, and would enable you to work both sides of your engine and take in your full train, which would be a credit to you. Such work is usually appreciated.

326. Compound Locomotives.—"What is the small equalizing valve on the end of the main steam valve on a Baldwin four-cylinder compound? What does it do? Where is it located? The reason the question is asked is because in Locomotive Up-To-Date, by McShane, on page 347, paragraph 1, it says: 'If the small equalizing valve on the end of the main steam valve is broken or removed it will convert that side of the engine into a high pressure engine. The work being done by the low pressure cylinder the high pressure piston would be approximately balanced.' I am unable to find anything that looks like an equalizing valve on either end and would thank you for an explanation."

Answer.—We are not familiar with the equalizing valve mentioned in this paragraph as applied to the four-cylinder type of Vauclain Compound engines, and are inclined to think that it should appear with, and applies to the Baldwin two-cylinder type and refers to the reducing valve.

A full description of the construction and operation of compounds, with questions, will be found in "The Art of Railroading," published by Railway Publications Society, Chicago.

327. THROTTLE VALVE LEAKING.—"Why does a throttle valve leak when boiler is full of boiling water and the valve is perfectly dry, with 200 pounds pressure of warm water?"

Answer.—This is due to the expansion of the throttle valve and box, and the manner in which the valve is ground to its seat, as well as to the construction of same. A throttle valve with a small diameter of 5 inches and a large diameter of 5½ inches may be ground even, or both seats ground to a tight joint for water pressure, and will be perfectly tight when under steam pressure. But a larger valve with small diameter of 5¾ inches and a large diameter of 7½ inches, will, usually be a better job, when the small end of the valve is ground to a tight joint and the large end of the valve ground to a loose fit, or so it would leak slightly under water pressure. Then when the boiler is under steam, expansion of the valve and box will take place and the valve that leaked under water pressure will be perfectly tight at 200 pounds boiler pressure at a temperature of 388 degrees. If it were possible to grind the throttle valves to their seats, at a temperature of the steam at working pressure, there would be no occasion to make allowance for expansion of the valve or box due to the difference in diameter and amount of metal in the valves.

328. ADJUSTING THE CUT-OFF.—"In running over the cut-off on an engine I found she carried steam too far on one side, and I found it necessary to shorten link hanger on that side. Engine cut off steam on the right side at 9 inches, both ends, and on the left side she cut off at 8 inches, both ends. I marked the link block and then raised the link ¾ of an inch, and again run over the cut-off and found by raising the link ¾ of an inch it made 1¾ inches difference in the cut-off. Now, I want to know how to use proportion so I can shorten the hanger in proportion to the ¾ of an inch I raised the link, so I can get the desired cut-off of 8 inches on that side of the engine?"

Answer.—A rule of proportion can not be given that would be accurate, although it may be obtained approximately by comparing the length of the link from center to full gear, to the cut-off. For instance, the cut-off in full gear is 24 inches on an engine with 26-inch stroke and the distance from the center of the link to the point opposite the blade pin when in full gear is 6 inches. Then ¼ inch on the link would represent 1 inch on the cross-head or cut-off. If the link hanger is not the proper length, the difference would be greater in 7 or 8 inches than in 15 or 20-inch cut-off. It was a mistake to shorten the hanger ¾ inch to obtain 1 inch less cut-off, as 3-16 would possibly have made it about right.

A sure method of ascertaining the correct amount to shorten the hanger would be to place the cross-head at 8 inches, the desired point of cut-off for that side, then mark the link, next raise or lower the link, as the case may be, by moving the reverse lever until the port mark on the valve rod or stem comes to the tram, then mark the link again at that point, and the difference between the two marks on the link will be the amount that the link hanger should be changed.

329. CYLINDER PACKING RINGS.—"How much larger in diameter should a cylinder packing ring be than the cylinder before the ring is cut so that it will press out against the cylinder walls, and thus prevent the leakage of steam?"

Answer.—Up to 12 inches diameter 1-16 is considered sufficient, and from 12 to 20 inches diameter, ¼ to 5-16 is the general practice, although some roads have a standard of ring ½ inch larger outside diameter of ring than the cylinder for all classes of engines.

330. STEAM CHEST JOINTS.—"How much should be allowed to draw down, and for clearance, between pressure plate and valve for new and old joints on steam chests on an Allen balanced valve?"

Answer.—If a round gasket is used to make a tight joint on the steam chest, 1-16 inch should be allowed for drawing down the cover when tightening nuts on the studs, while if a flat copper gasket is used it is not customary to allow for drafts, as it would be very slight. The space, or clearance, between the back of the valve and the bottom of the pressure plate may be 1-16 or ⅛ inch, and should not be less, in order that the valve may lift when excessive compression takes place, which, if not relieved by the valve lifting from its seat, would possibly rupture cylinder head.

331. DECREASE IN LEAD.—"If an engine is turned out of the shop new, or with general repairs, valves set with 1-16-inch lead, after six months' service will the lead increase, decrease or remain the same?"

Answer.—When an engine is new or has received general repairs, the lost motion is, or should be, taken out of the valve gear. Much depends on the design of the engine and service engaged in. When in service the wear of the eccentrics, straps, link block, eccentric and valve-rod pins, rocker boxes, etc., will occur that will cause the engine to lose the lead given the valve when the parts were ground to a good working fit, therefore, the engine will lose its lead in proportion to the wear of the valve gear.

332. INSIDE AND OUTSIDE ADMISSION VALVES.—"Why have compound engines got inside admission valves on one side, and outside admission valves on the other?"

Answer.—Where this method is employed, the special reason is better design and steam distribution, as well as to obtain the suitable steam passages in cylinder saddles.

333. OFFSET OF ROCKER ARMS.—"Why are the rocker arms offset on some engines?"

Answer.—This is done to get equal port opening at each end of the cylinder. When the center of the hole in the lower rocker arm is on a straight line with the center of the axle, when the top or upper rocker arm is plumb, there need be no offset in rocker arm, but when the center of hole in the lower rocker arm is below this line, it is given offset to bring it at right angles to center line of motion or at right angles to a line drawn from the center of the axles through the center of hole in the lower rocker when the top rocker is plumb.

334. LENGTH OF ROCKER ARMS.—"Why are the rocker arms on one side of the engine longer than on the other? I think this refers to compound engines."

Answer.—When the rocker arms are of equal length the travel of the valve is equal to the throw of the eccentric. When the travel of the valve is greater than the throw of the eccentric it is increased by lengthening the top arm of the rocker. If it is necessary to give the valve on one side of a compound locomotive greater travel than on the other, it is the easiest way to lengthen the rocker on that side the desired amount.

335. LUBRICATOR CHANGED FROM LOCOMOTIVE TO STATIONARY ENGINE.—"Will you kindly explain why a pint size Michigan lubricator would not work on a stationary engine, when it worked satisfactorily on a locomotive. We made the following test: We attached a lubricator with a ¾-inch pipe to a 3-inch steam pipe, boiler pressure about 70 pounds. Engine worked all right, but under no circumstances would the lubricator feed. We tested it on a locomotive and it worked fine."

Answer.—Temperature and conditions no doubt are responsible for the failure of the lubricator to work on the stationary engine. When it was applied to the locomotive you had a higher steam pressure and a difference of pressure in the pipe where you made steam connection and delivery pipe, also a higher temperature. When you had the lubricator on the steam pipe to the stationary the pressure was low and the ¾-inch pipe connecting to lubricator no doubt filled with water, and the pressure being equal at the delivery end of the pipe or connection did not produce a current of pressure, and the temperature of the oil was so low that it congealed and would not feed through the nipple. Get a circulation of steam through the pipe to warm the oil in the lubricator and hold a pail of hot water so the lubricator will be immersed in it and you will very likely get it started all right.

336. DIRECT AND INDIRECT VALVE GEAR.—"Can you give me the definition of a direct and an indirect valve gear, also what engine would it be that has the eccentrics on the front axle to the one on which the main pins are. I have an idea that this is the only indirect engine. Am I right?"

Answer.—Not quite. A valve gear designed so that the valve rod moves in the opposite direction to the eccentric rod is said to be indirect motion. When the valve rod travels in the same direction as the eccentric rod the engine is said to be direct. This is usually accomplished by using a rocker with both the link arm and valve arm pointing either down or up. "The Art of Railroading," published by Railway Publications Society, Security Building, Chicago, fully explains this in detail.

337. BLOCKING LINK FOR BROKEN REVERSE LEVER OR REACH ROD.—"It is claimed that one link being blocked on top of the link block is sufficient in case of a broken reverse lever or reach rod. According to our examination we answer, 'Block both links top and bottom.' Now, a friend of mine claims that a chunk of waste on top of one link block will do to run forty or fifty miles. Please say which of us is correct, as I claim it would be impossible to run any distance with link blocked this way."

Answer.—Blocking on top of one link block at the required cut-off is the quickest and best. It answers the purpose, and in case it is necessary to reverse the engine all that you have to do is to change a long block for the short one, and you are ready to back up. If you block top and bottom of both links you have more blocks to change and you are more liable to block without allowing space for the slip of the link on the block, which might result in further damage, such as a sprung link hanger or a broken saddle pin. A chunk of waste would answer in an emergency, but this would give you full stroke, which may not be necessary. Care should always be taken to see that there is sufficient blocking, wood, waste, or anything else that is handy to keep the top of the link from striking the link block. If it does strike the block it may increase the travel of the valve beyond the clearance limit in the steam chest and valve yoke, and may break a valve rod, rocker arm, or eccentric blade.

338. Locating Valve for Broken Balance Strip or Spring.—"What is the best method of locating the valve when a balance strip or spring is broken in an engine with a single nozzle and no drip ports drilled into the exhaust passages in cylinder saddle, and why should the spring or strip broken cause the valve to handle so much harder than the ordinary slide valve without the balance feature, and require so much more oil and then not handle as easy? If we break a spring or strip in these small engines, it seems as if the engine would break something before getting to terminal."

Answer.—To locate which side the strip or spring is broken on an engine as above described, place engine on quarter, open throttle, and give engine steam enough to produce a good blow at cylinder cocks. Then close cylinder cocks and move lever from full gear forward to full gear backward motion. This will give you full travel of the valve on that side, and if it moves easy you will know that side is all right and that the valve has its usual balance. Then place engine on the quarter on the other side and repeat the operation. If the lever is

harder to move forward and back with the throttle opened the same, you may safely report the valve that is hardest to move the lever when that side is on quarter or at half stroke. Another method is to get out on the running-board when engine is working slow and take hold of the valve rod, and you can easily determine which one has the broken strip or spring. The reason that a valve with a broken strip or spring requires more oil is due to the oil being blown from the chest past the defective strip through the hole in the back of the valve into the exhaust cavity, instead of going to the valve seat and lubricating it and the face of the valve. This causes the valve and seat to become dry and increases the resistance and makes the lever handle hard, and with a broken strip the steam chest pressure exerting a downward pressure on the back of the valve also increases the resistance. When the strips are all right they protect the inclosed area on the back of the valve from this pressure, but when they are defective the area of the back of the valve inclosed by the strip is exposed to the pressure without any relief only the amount of steam that escapes through the hole in the back of the valve. This amount of steam causes a blow similar to the steam from the blower, and is noticeable when the throttle is open. If you could get the surface of the valve and seat lubricated with a broken strip as well as you get the plain slide valve lubricated, a valve with a broken strip of the same area and pressure would not handle harder than the plain slide valve.

339. Freezing of Injector Delivery Pipe.—"Explain how the water in the delivery pipe can be protected from freezing."

Answer.—By using the heater, having the steam valve slightly opened, with the overflow valve closed, steam will flow back into the tender through the feed pipe and at the same time flow forward into the branch pipe. The heater cock should be opened to drain the condensed steam or water from the delivery pipe, otherwise it will fill with water and freeze. The steam valve should not be open so far as to cause water to become overheated in the tender, preventing the injector from working or damaging the paint on the tender.

INDEX TO QUESTIONS

Following is an index to the topics covered in the preceding questions. *The numbers given are the question numbers.*

TABLES

AND

USEFUL POINTERS

TABLES

TABLE OF APPROXIMATE NUMBERS FOR VARIOUS PURPOSES.

Diameter of a circle x 3.1416=circumference.
Diameter of a circle x .8862=side of an equal square.
Diameter of a circle x .7071=side of an inscribed square.
Square of diameter x .7854=area of circle.
Circumference of a circle x .31831=diameter.
Side of a square x 1.128=diameter of equal circle.
Square root of area x 1.12837=diameter of equal circle.
Square of the diameter of a sphere x 3.1416=convex surface.
Cube of the diameter of a sphere x .5236=solidity.
Diameter of a sphere x .806=dimensions of equal cube.
Diameter of a sphere x .6667=length of equal cylinder.
Square inches x .00695=square feet.
Cubic inches x .00058=cubic feet.
Cubic feet x .03704=cubic yards.
Cylindrical inches x .0004546=cubic feet.
Cylindrical feet x .02909=cubic yards.
Cubic inches x.003606=imperial gallons.
Cubic feet x .6232=imperial gallons.
Cylindrical inches x .002832=imperial gallons.
Cylindrical feet x 4.895=imperial gallons.
183.346 circular inches=1 square foot.
2,200 cylindrical inches=1 cubic foot.
Avoirdupois pounds x .009=cwts.
Avoirdupois pounds x .00045=tons.
Linear feet x .00019=statute miles.
Linear yards x .000568=statute miles.

NUMBER OF REVOLUTIONS AT DIFFERENT SPEEDS.

This table gives the number of revolutions that are made by the driving wheels of different sizes, (from 4 feet to 7 feet in diameter), per minute, at different speeds, from 5 to 60 miles per hour:

Diameter of Driving Wheels.		Speed per Hour in Miles.											
		5	10	15	20	25	30	35	40	45	50	55	60
		Revolutions per Minute.											
Feet.	Inches.												
4	0	35	70	105	140	175	210	245	280	315	350	365	420
4	3	33	66	99	132	165	194	231	264	297	330	362	395
4	6	31	62	93	124	156	186	217	249	280	311	342	373
4	9	29½	59	88	118	147	177	203	236	265	295	324	354
5	0	28	56	84	112	140	168	196	224	252	280	308	336
5	3	26⅔	53	80	107	133	160	187	213	240	267	293	320
5	6	25½	51	76	102	127	153	178	204	229	255	280	306
5	9	24⅓	48	73	97	122	146	170	195	219	243	267	292
6	0	23⅓	46	70	93	117	140	163	186	210	233	255	280
6	3	22½	45	67	89	112	134	156	178	201	223	244	268
6	6	21½	43	64	86	108	129	151	172	194	216	237	259
6	9	20¼	40	61	81	111	121	142	164	182	222	223	243
7	0	20	40	60	80	100	120	140	160	180	200	220	240

SECONDS PER MILE IN MILES PER HOUR.

Seconds per Mile	Miles per Hour	Seconds per Mile	Miles per Hour
24	150	58	62
25	144	59	61
26	138.5	60	60
27	133.3	61	59
28	128.5	62	58
29	124.1	63	57.1

Seconds per Mile	Miles per Hour	Seconds per Mile	Miles per Hour
30	120	64	56.2
31	116.1	65	55.3
32	112.5	66	54.5
33	109	67	53.7
34	105.8	68	52.9
35	102.8	69	52.1
36	100	70	51.4
37	97.3	71	50.7
38	94.7	72	50
39	92.3	73	49.3
40	90	74	48.6
41	87.8	75	48
42	85.7	76	47.3
43	83.7	77	46.7
44	81.8	78	46.1
45	80	79	45.5
46	78.2	80	45
47	76.6	81	44.4
48	75	82	43.9
49	73.4	83	43.3
50	72	84	42.8
51	70.5	85	42.3
52	69.2	86	41.8
53	67.9	87	41.3
54	66.6	88	40.9
55	65.4	89	40.4
56	64.3	90	40
57	63.1		

TEMPERATURE OF STEAM AT VARIOUS PRESSURES.

Pressure	Degrees Fahr.	Pressure	Degrees Fahr.
.0	212	135	358.2
5.3	228	140	360.8
15.3	250.4	145	363.3
25.3	267.3	150	365.8
35.3	281	155	368.1
45.3	292.7	160	370.6
55.3	302.9	165	372.8
65.3	312	170	375.1
75.3	320.2	175	377.3
85.3	327.9	180	379.5
100	337.8	185	381.5
105	340.9	190	383.7
110	344	195	385.8
115	347	200	387.8
120	349.9	205	389.7
125	352.8	210	391.7
130	355.5	215	393.6

DECIMAL EQUIVALENTS.

1-64 in.	.015625	33-64 in.	.515625
1-32	.03125	17-32	.53125
3-64	.046875	35-64	.546875
1-16	.0625	9-16	.5625
5-64	.078125	37-64	.578125

3-32	.09375	19-32	.59375
7-64	.109375	39-64	.609375
1-8	.125	5-8	.625
9-64	.140625	41-64	.640625
5-32	.15625	21-32	.65625
11-64	.171875	43-64	.671875
3-16	.1875	11-16	.6875
13-64	.203125	45-64	.703125
7-32	.21875	23-32	.71875
15-64	.234375	47-64	.734375
1-4	.25	3-4	.75
17-64	.265625	49-64	.765625
9-32	.28125	25-32	.78125
19-64	.296875	51-64	.796875
5-16	.3125	13-16	.8125
21-64	.328125	53-64	.828125
11-32	.34375	27-32	.84375
23-64	.359375	55-64	.859375
3-8	.375	7-8	.875
25-64	.390625	57-64	.890625
13-32	.40625	29-32	.90625
27-64	.421875	59-64	.921875
7-16	.4375	15-16	.9375
29-64	.453125	61-64	.953125
15-32	.46875	31-32	.96875
31-64	.484375	63-64	.984375
1-2	.5	1	1

USEFUL POINTERS

MELTING POINT OF METALS, ETC.

	Fahr.
Platina	4590°
Antimony	842
Bismuth	487
Tin	475
Lead	620
Zinc	700
Cast Iron	2100
Wrought Iron	2900
Steel	2500
Copper	2000
Glass	2377
Beeswax	151
Sulphur	239
Tallow	92

CARE OF FLUES.

By John Tonge.

Use copper ferrules not less than 7/8 inches wide.
Roll flues first.
Use Prosser expander with large shoulder.
If flue bursts with Prosser, examine material.
Remove all front dump grates.
Use brick arch six inches from flue sheet.
Use finger grates suitable for coal.

Use charcoal iron tips.

Have good beads on flues in fire-box.

See that boiler-maker does not work flues away from sheet.

Space flue sheet bridges, top 5/8 inches, bottom 1 1/8 inches.

If water permits, use three quarts of soda ash for 100 miles.

Wash boilers regularly.

Don't allow copper ferrules to get under beads.

ADHESION AND TRACTION OF LOCOMOTIVES.

ADHESION PER TON OF LOAD ON THE DRIVING WHEELS.

When the rails are very dry...........600 lbs. per ton.
When the rails are very wet...........550 lbs. per ton.
In misty weather if the rails are greasy..300 lbs. per ton.
In frosty or snowy weather...........200 lbs. per ton.

In coupling engines the adhesive force is due to the load on all wheels coupled to the driving wheels.

The adhesive power must exceed the tractive force of an engine on the rails, otherwise the wheels will slip. For loads on driving wheels, see the following.

DISTRIBUTION OF WEIGHT IN LOCOMOTIVES.

The average distribution of the weight of a six-wheeled locomotive on its wheels is:

Assuming the total weight of the engine in working order to be 1:

	Passenger Engines	Freight Engines
Load on leading wheels...........	.32	.34
Load on driving wheels...........	.48	.36
Load on trailing wheels...........	.20	.30
Total weight of engine..............	1.00	1.00

TO FIND THE LOAD WHICH AN ENGINE WILL TAKE ON A GIVEN INCLINE.

Let G = Resistance due to gravity on the steepest gradient in lbs. per ton.

Let R = Resistance due to assumed velocity of train in lbs. per ton.

Let T = Tractive power of engine in lbs., as found above.

Let W = Weight of engine and tender in tons.

The load the engine can take in tons, including the weight of the cars, but not that of engine and tender will equal $\frac{T}{G + R} = W$.

TRACTIVE POWER.

HOW TO FIGURE WHAT A LOCOMOTIVE WILL PULL.

With the engine adjusted to steam freely, a valve motion that will insure a good steam distribution and the machine properly lubricated, the next problem is the capacity of the engine to move tons of freight or passenger trains over the road. It costs money to operate a railroad and the revenue is obtained from the sale of transportation. Assuming that the locomotive is of modern design and assigned to the class of service best adapted for, the next point to determine is the draw bar pull or how much tractive power will be developed to overcome the train resistance. First the adhesion or weight placed on the drivers must be greater than the resistance of the train, and this weight is usually limited by the condition of the road bed, weight of rails and strength of bridges. Here is where the engineering department specify to the mechanical officers the number of pounds that may be placed on the driving wheels of the locomotive. The diameter of the driving wheels, diameter of cylinders, length of stroke of the piston in inches and the number of pounds of steam pressure per square inch carried on the boiler, will enable us to determine approximately the tractive power, when the use of a dynamometer car is not available. The tractive power, developed by a single expansion locomotive at slow speed may be ascertained by assuming that 85 per cent of the boiler pressure will equal the mean effective pressure in the cylinders and using the formula:

$$\frac{C^2 \times S \times P}{D} = T$$

Now this is not at all hard and a little time will make this and other formulas easy to figure.

C^2 indicates that the diameter of the cylinder should be multiplied by itself, or squared.

S equals the stroke of the piston in inches.

P—— the mean effective pressure in pounds or 85 per cent of the boiler pressure.

D equals the diameter of the driving wheels in inches and placed under the line means that when the diameter of the cylinder is multiplied by itself or squared, that number multiplied by the number of inches of stroke and then by the number of pounds mean effective pressure, all this above the line should be divided by D or the diameter of the driving wheel in inches, which will give T or the tractive power.

Example: An engine 20x26" cylinders, 56" wheels, 200-lb. boiler pressure.

$C^2 = 20 \times 20$		20
		20
S = 26"		400
		26
	200	2400
85% of P =	.85	800
	1000	10400
	1600	170
	170.00	

```
                      728000
                      10400
                  ___________
Diam. of Driver 56 ) 1768000 ( 31,571 lbs. Trac. Force.
                     168
                     ____
                      88
                      56
                     ____
                      320
                      280
                     ____
                       400
                       392
                      ____
                        80
                        56
                        __
                         4
```

$$T = \frac{C^2 \times S \times P}{D} \text{ or } 31.571 \text{ Pounds—that is,}$$

31.571 pounds tractive power developed by the engine that can be used to overcome the resistance of the locomotive and train. This rule is applicable to any size single expansion engine.

For a two-cylinder compound use this formula:

$$\frac{C^2 \times S \times 2\text{-}3\,P}{D} = T.$$

using two-thirds of the boiler pressure and considering the high pressure cylinder only.

Example: What is the tractive power of a two-cylinder compound:

```
     22
Cyls. — x 26"  Drivers 63"        Boiler Pressure 210 lbs.
     33
                    22
                    22
                    __
                    44
                    44
                   ___
                   484
                    26
                   ___
                  2904
                  968
                 _____
                 12584               2-3 of 210 = 140 lbs.
                   140
                 _____
                503360
                12584
               _______
D =  63" ) 1761760 ( 27,964 Pounds, Tractive Force
           126
           ___
           501
           441
           ___
            607
            567
            ___
```

406
378
———
280
252
———
28

The tractive power of a four-cylinder compound may be ascertained by the following formula:

$$\frac{C^2 \times S \times 2\text{-}3\,P}{D} + \frac{C^2 \times S \times \frac{1}{4}\,P}{D} = T$$

Work this out separately for the high and the low pressure cylinders the same as was done for the simple and add the quotients.

Example: What is the tractive power of a four-cylinder compound:

Cyls. $\frac{15}{25}$ x 26″ Drivers 73″ Boiler Pressure 220 lbs.

High Pressure Cylinder.

15
15
———
75
15
———
225
26
———

1350
450
———
5850
2-3 of 220 = 146
———
35100
23400
5850
———
73) 854100 (11,700
73
———
124
73
———
511
511
———
00

Low Pressure Cylinder.

25
25
———
125
50
———
625
26
———
3750
1250
———

```
                 16250
¼ of 220 =          55
                 -----
                 81250
                81250
                ------
73 ) 893750 ( 12,243
     73
     ---
     163
     146
     ---
      177
      146
      ---
       315
       292
       ---
        230
        219
        ---
         11
```

11,700 + 12,243 = 23,943T.

TRAIN RESISTANCE OR LOCOMOTIVE RATING.

To overcome the resistance of one ton, 2,000 lbs., on a straight and level track at a speed of ten miles per hour or less, careful tests have demonstrated that it varies from 5 to 8 lbs. per ton, or an average of 6½ lbs. per ton. It is safe to allow 8 lbs. per ton for train resistance on a level, and by dividing the tractive power by 8 it would give the number of tons rating. This rule covers the axle or journal and rolling friction only. If on a grade, multiplying the feet per mile rise in grade by .3788 will give the resistance due to grade per ton and will be sufficiently correct to establish a rating in the absence of a regular test or a dynamometer car; or if preferred, add ⅜ lbs. = to .375 per ton for each foot per mile rise in the grade. Either of the above decimals will answer for grade resistance. Curve resistance may be figured as 9.16 lbs. per ton for every degree of curve, 9.16=.5625. Using this decimal and multiplying by the number of degrees in the curve we get the curve resistance.

Example: What is the resistance per ton of train on a grade of 100 feet per mile with 4 degree curve.

Allowing	8	lbs. for friction.
100x.375=	37.5	lbs. for grade.
4x.5625=	2.25	lbs. for curve.
	47.75	

we have 47.75 lbs. resistance per ton.

These figures are not given as absolutely correct in establishing a rating, but will serve to work from in making up trains for test. The only correct method to rate an engine is to take several engines of the same class and make actual tests in service to get the hauling capacity, then reduce the tonnage of train to meet the requirements of the service and leave a sufficient margin of power to insure proper time being made under average conditions. The old method of "the last car she will pull" lost out long ago, and the most economical rating at the present time is a train that can be handled and gotten over the road, without tying up opposing or following trains.

SHORTCUTS IN ARITHMETIC.

To find the circumference of a circle multiply its diameter by 3.1416.

To find the diameter of a circle multiply its circumference by .31831.

To find the area of a circle multiply the square of its diameter by .7854.

To find the cubic inches in a ball multiply its cube of diameter by .5236.

To find the revolutions of drivers per mile divide 1680 by the diameter of the wheel in feet.

To find revolutions per minute multiply the speed in miles per hour by 28 and divide the product by the diameter of the driving wheel in feet.

To find piston speed in feet per minute multiply revolutions per minute by twice the stroke of piston in feet.

To find the speed of train per second multiply speed in miles per hour by 22 and divide by 15.

To find time when rate of speed and distance is given multiply distance by 60 and divide by rate of speed.

To find rate of speed when distance and time are given, multiply distance by 60 and divide by the time in minutes.

To find the distance when the time and rate of speed are given, multiply the time by the rate of speed and divide by 60.

To find the number of tons of coal in a bin: Length,

height and width of pile in feet multiplied together, divide by 30 for hard coal, by 35 for soft coal, by 128 for cords of long wood, and by 135 for cords of sawed wood.

To find the pounds of coal used per 100-ton mile multiply pounds of coal by 100 and divide by tons multiplied by the miles hauled.

To find the pressure in pounds per square inch of a column of water multiply the height of the column in feet by .434.

HYDRAULICS.

A gallon of water (U. S. standard) weighs 8 1-3 lbs., and contains 231 cubic inches.

A cubic foot of water weighs 62½ lbs., and contains 1,728 cubic inches, or 7½ gallons.

Doubling the diameter of a pipe increases the capacity four times.

Each nominal horse power of boilers require 1 cubic foot of water per hour.

In calculating horse power of steam boilers, consider for Tubular boilers 15 square feet of heating surface equivalent to 1 horse power; Flue boilers 12 square feet of heating surface equivalent to 1 horse power, and Cylinder boilers 10 square feet of heating surface equivalent to 1 horse power.

To find the area of a piston, square the diameter and multiply by .7854.

To find the pressure in pounds per square inch of a column of water multiply the height of the column in feet by .434. (Approximately we generally call every foot elevation equal to ½ lb. pressure per square inch.)

To find the capacity of a cylinder in gallons. Multiplying the area in inches by the length of stroke in inches will give the total number of cubic inches; divide this amount by 231 (which is the cubical contents of a gallon in inches), and product is the capacity in gallons.

GENERAL INDEX

NOTE—A special index covering all topics included in the Questions and Answers, will be found commencing on page 249.

ILLUSTRATIONS

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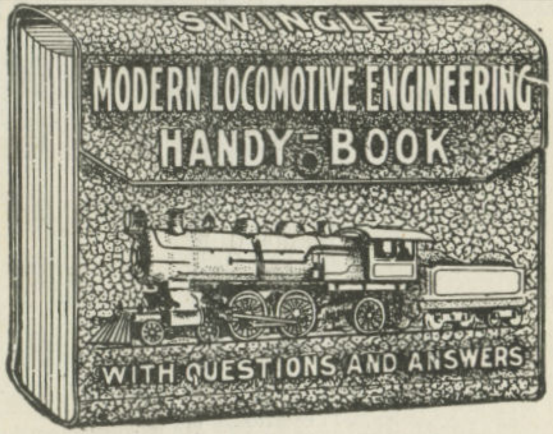

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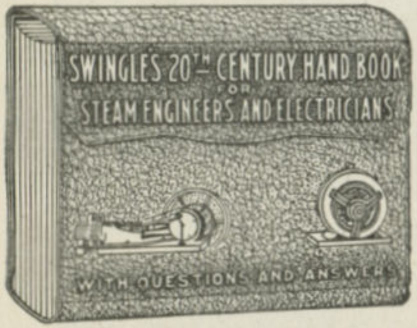

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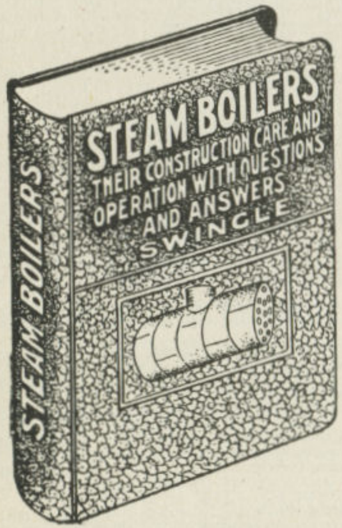

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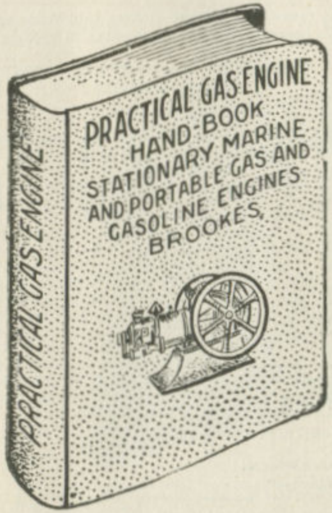

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