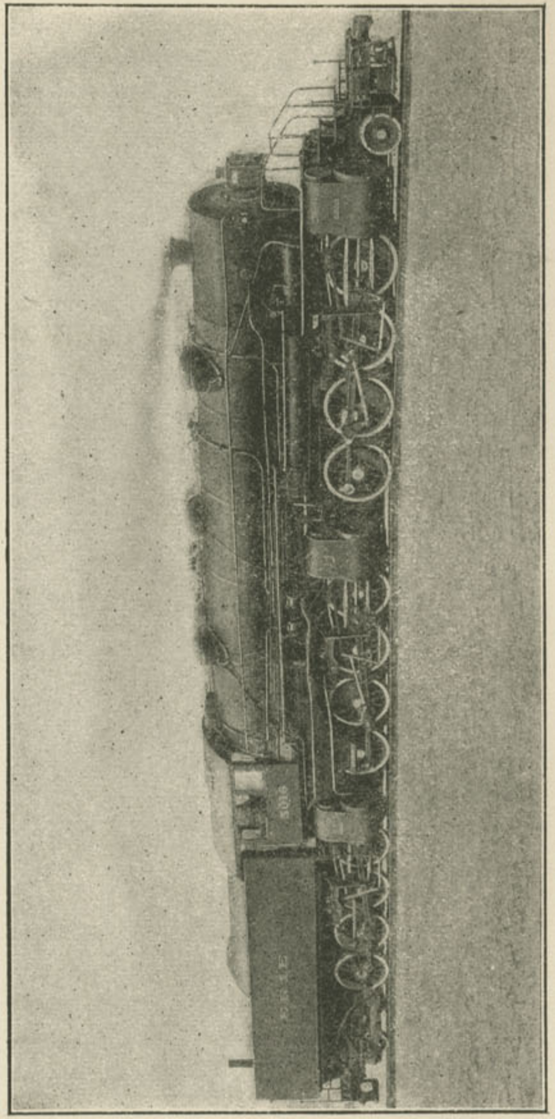
LOCOMOTIVE CATECHISM

GRIMSHAW



Triple Articulated Engine No. 5016, Erie R.R. (Am. Locomotive Co.)

LOCOMOTIVE CATECHISM

A Practical and Complete Work on the Design, Construction, Running and Repair of All Kinds of Locomotives

Up-to-Date Information on the

AIR-BRAKE, SUPER-HEATER, WALSCHAERT VALVE GEAR, COMPOUND, ELECTRIC AND UNAFLOW LOCOMOTIVES

For

FIREMEN, ENGINEERS, TRAINMEN, SWITCHMEN, SHOP HANDS AND ROUNDHOUSE MEN

Containing

4,000 EXAMINATION QUESTIONS WITH CORRECT ANSWERS

Including Official Questions used by Prominent American Railways in examining Firemen and Engineers for Employment and Promotion

By ROBERT GRIMSHAW, M. E.

Formerly member of American Railway Master Mechanics' Association, Master Car Builders' Association, American Society of Mechanical Engineers, etc.

Fully Illustrated with 468 Engravings

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PREFACE TO THE THIRTIETH EDITION

The catechetical or question-and-answer form is chosen because enabling the inquirer on any given topic to find and use at once the desired information; leaving it to more leisure time to study carefully all the underlying and correlated principles.

While the four thousand or so questions which this edition contains do not cover the entire ground of inquiry in this line, they at least embrace the most important and up to date. They have been contributed both by novices and by experts and suggested by myself as one considered competent to know what engineers and firemen are likely to ask, and should ask, themselves or others, in the course of their daily work. Some are taken bodily from examination papers given to candidates for appointment or promotion.

In the present edition especial attention is paid to certain branches more recently brought to the engine-runner's and the fireman's notice—for instance, the unaflow engine, the improved superheater, the latest design of power brake, and the electric locomotive; while the chapter on accidents has been greatly enlarged and improved; and the man on the foot board has been initiated more fully than before into the entertaining and practically valuable mysteries of value diagrams, traction curves and motion studies.

I hope that this edition will prove, as the many others have that preceded it, of daily use to thousands of those who tame and train and drive "the iron horse."

ROBERT GRIMSHAW

New York, June, 1923.

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LOCOMOTIVE CATECHISM

CHAPTER I

GENERAL DESCRIPTION

Q. What are the essential features of a steam-driven locomotive engine?

A. (1) Boiler, (2) engines, (3) running-gear.

*Q. What name is applied to the type of boiler usually employed for such locomotives?**

A. Horizontal tubular with internal fire-box.

Q. What name might be applied to the engines usually employed on locomotives?

A. Twin horizontal double-acting high-pressure non-compound, non-condensing link-motion slide-valve engines.

Q. Are all locomotive engines of the twin type?

A. Nearly all; some, however (compounds, for instance), have the cylinder on one side of different diameter from that on the other; some have one cylinder on each side and one in the center; some again have four cylinders.

Q. Are all locomotive cylinders horizontal?

A. Nearly all; but some are slightly inclined downward toward the crank-pin, and while nearly horizontal are not strictly so.

Q. What is the meaning of "double-acting"?

A. An engine is double-acting when steam is admitted on both sides of its piston, instead of on only one, as in a Westinghouse stationary engine.

Q. Are all locomotive engines double-acting?

A. Yes.

* See special section under heading "Boilers," page 30.

Q. What is the meaning of "high-pressure"?

A. It is a misnomer. The term came in when non-condensing engines were first made, to represent the difference between an engine which worked with high-pressure steam (either with or without a condenser, but particularly without) and one which worked usually by the aid of the vacuum produced by a condenser.

Q. What is the difference between a compound and a non-compound engine? *

A. In a compound the steam exhausted from one cylinder is passed into another, there to do more work as it expands further. In a non-compound the steam after being exhausted from one cylinder does not go into any other.

Q. Is there any relation between compound and condensing engines; that is, may an engine be both?

A. Yes; many engines, particularly marine, are both compound and condensing; that is, the steam after being exhausted from one cylinder, in which it has done work, passes into another cylinder, there to do further work, and then goes into a condenser.

Q. What is a condensing engine?

A. One in which the steam, after having done work in a cylinder, is exhausted therefrom at a certain pressure above vacuum or above the atmosphere, and at a certain temperature, then passes into a chamber where it is cooled by contact with a jet or spray of cold water, or with sheets or tubes cooled by cold water circulating on the other side thereof.

Q. Are most locomotives non-compound?

A. Yes; but compounds have been used in Europe for some years; and in this country, since 1890, orders for them have been increasing in proportion.

Q. Are all locomotives non-condensing?

A. Yes; it would be impossible, at least in the present state of steam engineering, to carry on a train that would

* See special section on "Compound Engines."

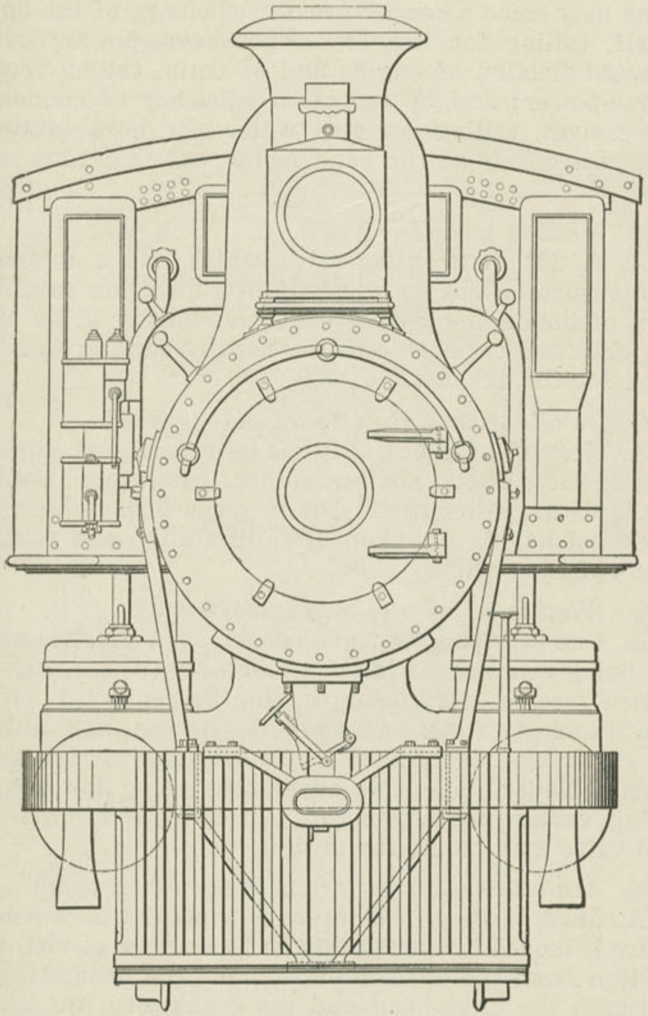


Fig. 1. Front End View, Pennsylvania R. R. Engine, Class "O."

pay expenses, enough water to cool the exhaust. The time may come when by greater efficiency of the engine itself, calling for less steam per horse-power; by decreased friction of engine and of train, calling for less horse-power; and by increased efficiency of condensers themselves, calling for less water per horse-power—a locomotive may be run condensing; but that time is not yet.

Q. What is a slide-valve? *

A. A flat distributing-valve which has a to-and-fro motion upon a flat seat, usually in a direction parallel to that of the engine piston; this valve having in its working face one or more cavities, usually serving as a passage for the exhaust.

Q. Do all locomotives employ slide-valves?

A. Nearly every one that has been built has employed a slide-valve of one sort or another. Attempts have been made to use other types, but in general have been failures, not having the simplicity, durability, and range of work of the ordinary slide.

Q. What is a link-motion engine?†

A. One in which the valve (generally a slide) is moved by being connected with a bar or link (usually slotted) which receives a vibrating motion by connection with a rod attached to strap surrounding an eccentric disk set on a driving-axle. There are usually two such disks for each cylinder, to enable reversing. The link position being varied, the amount of motion that it imparts to the valve may be altered at will.

Q. Are all locomotives of the link-motion type?

A. Most of them; but there is a system in which the valve is moved by an attachment to levers receiving their motion from the cross-head, or from the connecting-rod between the cross-head and the crank-pin; the amount

* See special section on "Slide Valves."

† See special section on "Valve Gears."

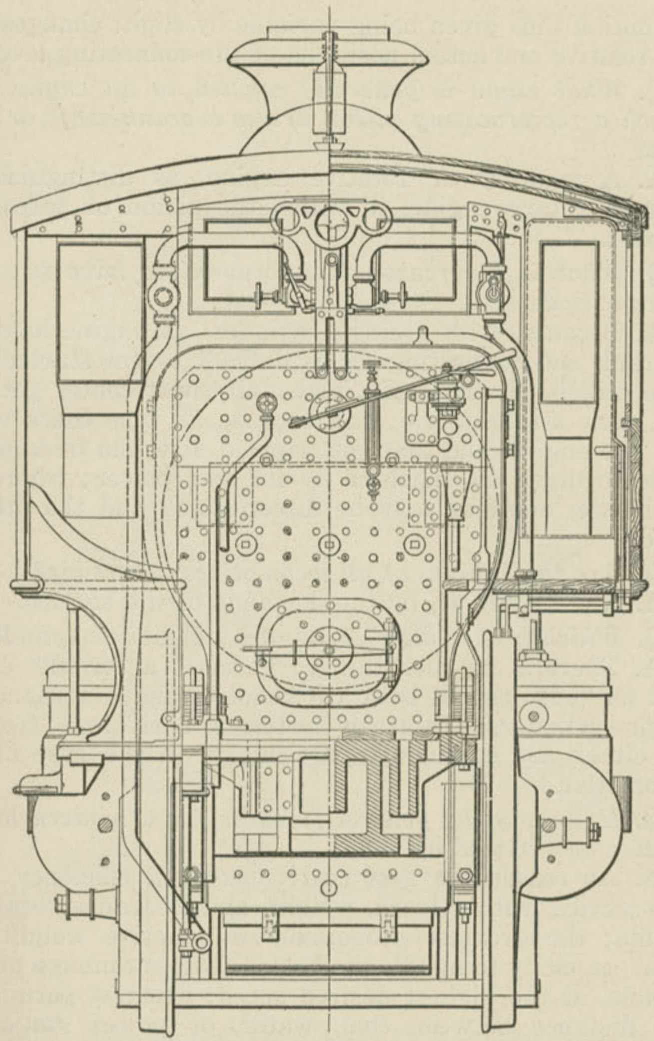


Fig. 2. Rear View, and Part Section through Cab, Pennsylvania R. R. Engine, Class "O."

of motion thus given being variable by slight changes in the relative and actual positions of the connecting levers.

Q. What name is generally applied to an engine in which a reciprocating piston drives a crank-shaft or an axle?

A. A rotatory or rotative engine, as distinguished from a rotary engine, in which the piston or follower rotates.

Q. What is the reason that locomotives have two or more cylinders?

A. Because, with a single cylinder, an engine having a crank and connecting-rod is difficult to get started in case crosshead, crank-pin, and main-shaft center get in the same straight line; and because, in case there was but one engine, and that got crippled, it would be impossible to move the machine by its own power; whereas with two, one side may be disconnected and the other used.

Q. Are the engines of all locomotives reversible?

A. Necessarily so, by the demands of the service.

Q. Which is the "back" head of a locomotive cylinder?

A. There is no such thing. There is a "crank" end, and an "out" end of both a locomotive and a stationary engine cylinder. The use of the terms "back" and "front" on either are confusing, particularly in the case of a locomotive.

Q. How may the general features for a modern locomotive be summed up?

A. As reasonable first cost; maximum efficiency for the service, within track, weight, and clearance requirements; the greatest proportion of adhesive weight to total; capacity to handle the heaviest gross tonnage practicable, at the highest desired speed; greatest permissible distance between coal, water, or power stations; economy as regards maintenance and fuel and water consumption; substantial construction of the least number of parts; and capacity to perform continuous service without liability of failure.

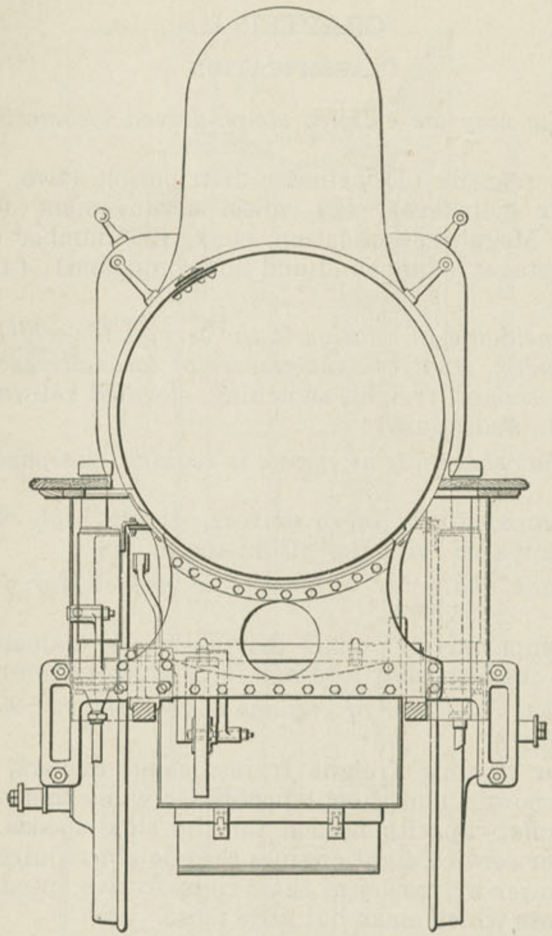


Fig. 3. Cross Section, Pennsylvania R. R. Engine, Class "O."

CHAPTER II

CLASSIFICATION

Q. How may we classify steam-driven locomotive engines?

A. As regards (1) cylinder distribution (two, three, and four cylinders), (2) wheel arrangement (eight-wheeler, Mogul, consolidation, etc.), (3) number of expansion stages (compound and non-compound), (4) service, etc.

Q. Considered in relation to the service for which they are intended, what are the classes of locomotives?

A. Passenger, freight, switching, elevated railway and suburban, and mining.

Q. What character of engine is required for passenger traffic?

A. Comparatively large drivers, giving high engine-speed compared with the piston-speed.

Q. What character of engine is needed for freight service?

A. Comparatively small driving-wheel diameter, to give the crank greater leverage for a given piston-stroke.

Q. What character of engines is required for work in large cities?

A. For hauling freight trains, small drivers, great tractive power, and short wheel-base; while there is not much boiler-capacity needed for the slow speeds. For passenger service, light engines that do not require great boiler-power by reason of their comparative speed. For both, those which make but little noise.

Q. What character of engine is required for suburban business?

A. Those that can start heavy trains and run them at high speeds; and usually it is well for them to be double-

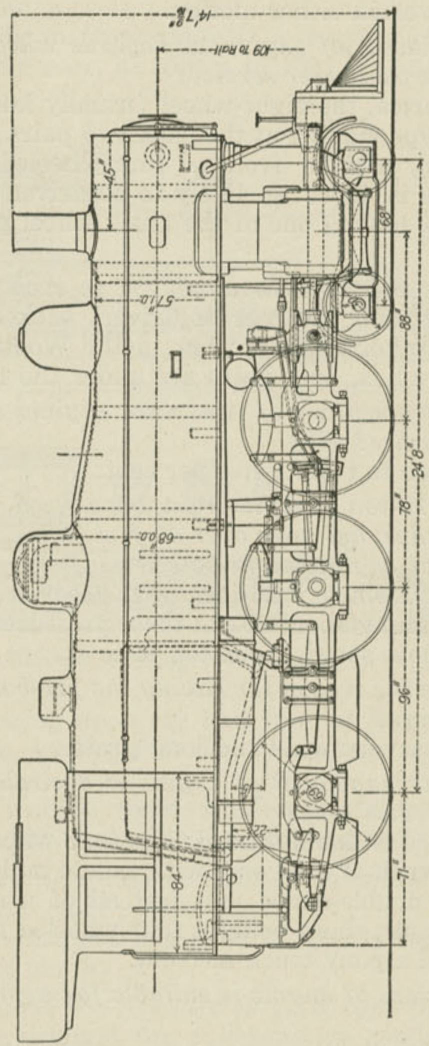


Fig. 4. "Ten Wheel" Type, New York Central and Hudson River Railroad.

enders or to have valve-gear, etc., permitting them to be run equally well in either motion.

Q. What classes of engine, as regards wheel-base, are most used for passenger service?

A. In America, the eight-wheel (usually known as the American) type, having at the back two pairs of driving-axles coupled, and in front a four-wheeled swiveling truck. (This is, however, likely to be driven out by the Atlantic type, having one of the truck wheel pairs at the rear.)

Q. What is the wheel arrangement in such engines?

A. Usually with one pair of drivers back of the fire-box and the other in front; but in the Wootten engine, with wide fire-box, both pairs are under the fire-box.

Q. What proportions of American engines are used in passenger service?

A. From ten to twenty-five per cent.

Q. For a 70-ton freight train on a good road, with plenty of grades, but none over 50 feet in the mile or say 1 in 100, what engine might be selected?

A. Say an 18-inch x 26-inch with 62-inch wheel centers, and weighing about 65 net tons; pressure about 180; traction at slow speed about ten tons.

Q. What is the reason for having the fire-box over both pairs of drivers?

A. To get a very wide and long grate.

Q. What arrangement of engine is desirable for local passenger service only?

A. One type is double-ended; has four wheels coupled, and a pony truck at each end, with saddle tank. Another type is also double-ended, but instead of a saddle tank has a back tank; there being a four-wheeled truck under the tank, and a pony truck in front.

Q. What class of engine is suitable for express passenger service?

A. First of all, the American or eight-wheeled type, having two pairs of drivers coupled, and a four-wheeled

truck in front, as in Fig. 5; then a modification of this has also four wheels coupled, but instead of a four-wheeled truck in front there is a pony truck there and another in the rear, as shown in Fig. 6 (Atlantic type).

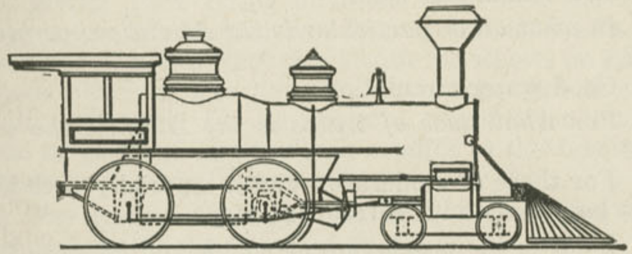


Fig. 5. Express Passenger Engine, American Type.

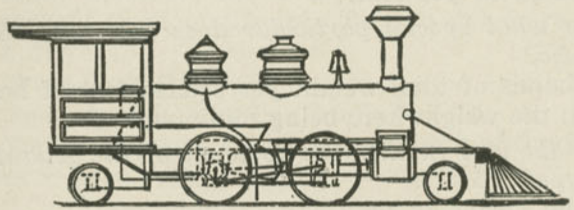


Fig. 6. Express Passenger Engine, with Pony Truck.

Q. In deciding upon the best type of locomotive for a given service, what points must be taken into consideration?

A. Train weight, speed, grades, curvature, frequency of stops, smooth operation, and low cost of repairs.

Q. What is desirable in relation to smooth operation and low repair cost?

A. The fewest possible driving wheels that will give good starting power.

Q. Of what is the Atlantic or 2-4-2 type the outcome?

A. Of the demand for a locomotive combining large heating surface and grate area with large driving wheels, to meet conditions which could not be met by the so-called "American" or 4-4-0 type.

Q. *For what class of fuel is the Atlantic type specially suited?*

A. For bituminous coal.

Q. *In what other particular is the Atlantic type favorable?*

A. Good water circulation.

Q. *For what class of trains is the Atlantic the ideal type?*

A. For those of moderate weight, especially with relatively long runs with infrequent stops.

Q. *What is the proportion of weight on drivers of the Atlantic type to the total weight?*

A. About 55 per cent.

Q. *In what special particular does this type show a high ratio?*

A. Pounds of total weight per square foot of heating surface; the weight here being minimum.

Q. *What is a further development of the Atlantic or 2-4-2 type?*

A. The Pacific or 2-6-2.

Q. *For what class of service is this type best adapted?*

A. To meet the exactions of the heaviest passenger service—as for instance trains of 500 to 600 tons weight, where the cars are to be heated and lighted from the locomotive.

Q. *How large do the grate areas run?*

A. From 40 to 50 square feet.

Q. *What is the average proportion of total weight on drivers in this class?*

A. 60 per cent.

Q. *What kinds of trailing trucks have the Pacific type?*

A. Two, with inside and with outside bearings.

Q. *Of these two, which is the more simple and the lighter?*

A. The inside bearing style.

Q. *What is the special advantage of the outside bearing type?*

A. A wide supporting base at the rear of the locomotive, giving good riding qualities. Further, the brake hangers for the trailing wheels may be attached to the truck frame, so that they move with the wheels on curves. Outside bearings also have the advantage that they are readily accessible for lubrication, examination and renewal of packing, and for such repairs as the renewal of springs and journal bearings.

Q. *For metropolitan and suburban traffic what is the most frequently used type of engine?*

A. The regular American eight-wheel; but there are a good many that have only a two-wheel ("pony") or Bissell truck in front of the cylinders, to put more weight on the drivers.

Q. *Where are the water and fuel often carried on engines for city and suburban traffic?*

A. On an extension of the frames, back of the fire-box, and borne by a pony truck. (See Fig. 7.)

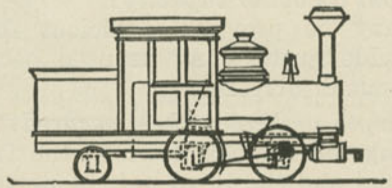


Fig. 7. Switching and Local Passenger Service, with Back Tank. Modified Forney Type.

Q. *What name is given to this latter type?*

A. Forney, from its inventor.

Q. *What is the principal type of engine used for freight?*

A. In this country, the eight-wheel type is doing most of the work in this line too, but where specially intended for this traffic they usually have smaller drivers than for passenger work.

Q. For heavier freight service, where greater tractive power is desired than can be had with only two driver pairs, what arrangement is made?

A. More drivers are added, as in (1) the Mogul (Fig. 8), in which there are three pairs of drivers and a pony or two-wheel truck; (2) the consolidation, in which there are four pairs of drivers and a two-wheel truck (Fig. 9); (3) the ten-wheeler, in which there are three pairs of drivers and a four-wheel truck (Fig. 10); (4) the twelve-wheeler, in which there are four pairs of drivers and a four-wheel truck; and (5) the decapod, in which there are five pairs of drivers and a two-wheel truck (Fig. 11.)

Q. For what class of service is the Mogul or 2-6-0 type adapted?

A. For freight service on comparatively level roads; or on heavy rails, where a large load per axle is permissible, and even for comparatively fast freight service.

Q. What proportion of the total weight of the Mogul is on the drivers?

A. Averaging 80 to 85 per cent.

Q. What about its boiler capacity?

A. There may be provided sufficient for moderate speeds; and wide grates may be used because of the usually chosen small drivers.

Q. How is depth of throat sheet secured?

A. By sloping the fire-box down at the front end between the second and the third pair of drivers.

Q. What class of engine is best adapted for fast freight?

A. The ten-wheeler is coming into great favor for this purpose; having six wheels coupled and a four-wheeled truck, as shown in Fig. 10, page 17.

Q. For what other class of traffic is the "ten-wheel" or 4-6-0 type adapted?

A. For heavy and fast passenger service; requiring a

tractive power that six wheels alone can give without overloading the fish plates and does not require too much steam. Having great hauling capacity in proportion to

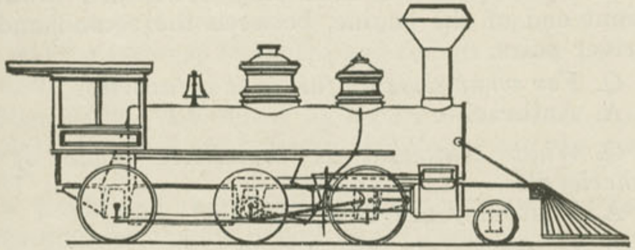


Fig. 8. Mogul Freight Engine with Tender.

the total weight, it is a good type for passenger service, not calling for sustained high speed. It is also good for freight trains of moderate weight and high speed, having more speed than the 2-8-0 or Consolidation type.

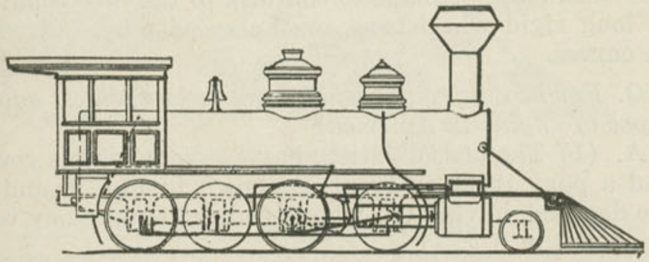


Fig. 9. Consolidation Engine for Heavy Freight.

Q. With what sized drivers is it best adapted as an "all-around" engine for passenger and fast freight service?

A. About 63 to 69 inches.

Q. What is the limitation of this type in passenger service?

A. The driver diameter, as where the drivers are over 73 inches the fire-box may not be extended laterally over the rear drivers.

Q. How may the throat sheet be given sufficient depth with this type, where the drivers are, say, 69 inches in diameter?

A. By sloping the mud ring downward toward the front end of the engine, between the second and third driver pairs.

Q. For what class of fuel is it a favorite?

A. Anthracite.

Q. What complaint is sometimes made of "ten-wheelers"?

A. That they are easily derailed.

Q. Is this complaint justified?

A. Only this far, that the fault is as much that of the track as of the engine. Where the rigid wheel base is long, the track must have easier curves, or a wider gage on curves, or the train must go more slowly around curves than where the rigid wheel base is short. Either the track must be made to conform to the new conditions of long rigid wheel base, or the speed must be reduced on curves.

Q. For heavy freight what seem to be the best adapted types of engine in America?

A. (1) The consolidation, having eight wheels coupled and a pony truck in front as shown in Fig. 9, and (2) the decapod, having ten wheels coupled and a pony truck, as shown in Fig. 11.

Q. For what service is the consolidation or 2-8-0 type especially suited?

A. For freight service requiring high starting power, as it has a large proportion of the weight on the driving wheels, and permits, by reason of large cylinders and comparatively large drivers, starting heavy trains and working steep grades. Where desired, the fire-box may be extended laterally over the rear drivers.

Q. What proportion of the total weight may be on the drivers?

A. From 85 per cent to even as high as 90; although this latter is rare.

Q. How may the front fire-box end be given sufficient depth?

A. By sloping it downward toward the front of the engine, ending between the third and fourth driver pairs, below their tops.

Q. What is the difference, as regards the wheel-base and weight distribution, between the Mogul and the ten-wheeler?

A. In the Mogul the front drivers are nearly as far from the main or middle driver as the back drivers are; in the ten-wheeler, Fig. 10, by reason of the back-wheels,

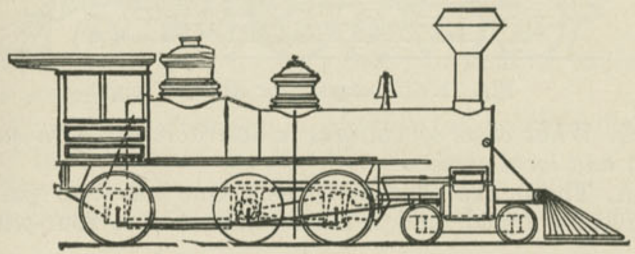


Fig. 10. Ten-wheeler for Fast Freight.

which are in the rear of the cylinders, the front drivers are quite close to the middle pair, and thus get proportionately less weight.

Q. What is the advantage of increasing the number of drivers?

A. It enables adding to the engine weight, which gives traction, without putting so much load on any one pair of drivers as to wear the rail unnecessarily or to be injurious to rail-joints.

Q. Is the Mogul engine ever used for passenger service?

A. Yes, but it is usually restricted to freight work.

Q. What is the general make-up of switching engines?

A. They usually have two or three driver pairs, short wheel-base and no truck, if for switching only, and seldom have tenders, the fuel and water being carried on the engine; if they do, the tenders have instead of two trucks, only two wheel pairs. Such an engine with three pairs of drivers may be seen in Fig. 16.

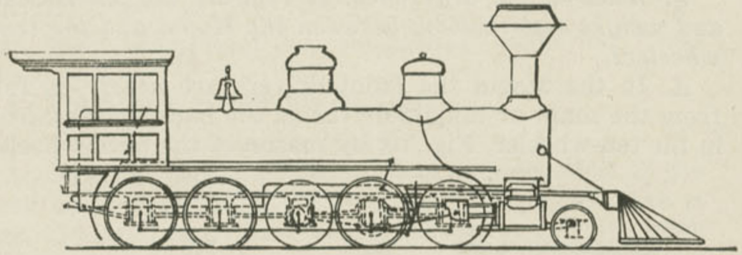


Fig. 11. "Decapod" for Heavy Freight.

Q. What class of engines is desirable for both switching and local service?

A. There are several types. One has two pairs of drivers coupled, and a back tank, with a four-wheeled

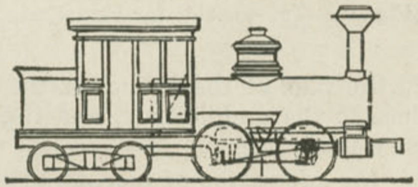


Fig. 12. Engine for Switching and Local Service, with Back Tank. (Forney Type.)

truck under it; this being the Forney type. (Fig. 12.) Another has two pairs of wheels coupled, and a pony truck in front, with a four-wheel tender, as in Fig. 15. A third is of the Forney type, that is, with a back tank supported on its own wheels borne by the engine-frame; but there is only one pair of such wheels, as shown in

Fig. 7. A fourth class has four wheels coupled, and a back tank; this being a double-ender and having a pony truck under the tank and another in front, besides two pilots. (Fig. 14.) A fifth class has four wheels coupled, a pony truck in front, and a saddle tank, as shown in

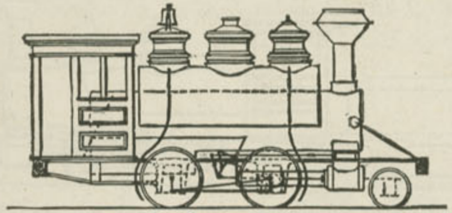


Fig. 13. Switching Engine, Saddle Tank.

Fig. 13. A sixth type, for very heavy switching, has six wheels coupled, a saddle tank, and no truck.

Q. What class of engine is suitable for heavy switching and local freight?

A. The double-ended saddle-tank engine having six wheels coupled and a pony truck in the rear, as last men-

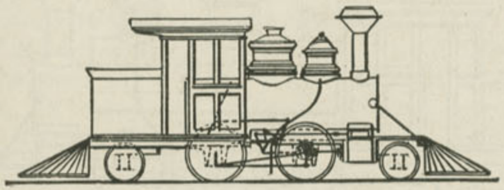


Fig. 14. Switching and Local Passenger Engine.

tioned, as used for light switching, etc.; or a double-ended engine with back tank borne on a four-wheel truck, and having six wheels coupled. A third class is a double-ender, with both a saddle tank and a back tender, the latter being borne by a four-wheel truck, there being six wheels coupled. (See Fig. 16.)

Q. Why are all the wheels of switching-engines usually drivers?

A. In order to utilize for tractive purposes every pound of weight of the comparatively light machine.

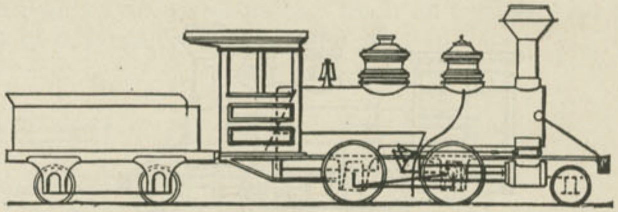


Fig. 15. Switching Engine, with Four-wheeled Tender.

Q. Why are its fuel and water borne by the switching-engine instead of carried in a tender?

A. To increase traction for a given amount of dead weight; also because it shortens the train.

Q. What may be said of the wheel-bases of switching-engines?

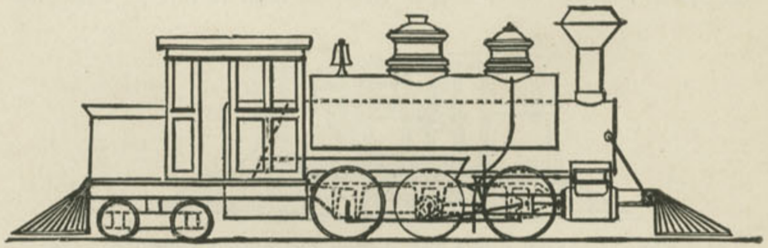


Fig. 16. Heavy Switching and Local Freight Engine, with Saddle Tank and Back Tank.

A. They are usually very short, to enable the engines to pass over curves and sharp switch-angles.

Q. What is the disadvantage of short wheel-base?

A. The pitching or see-saw motion which it gives the engines.

Q. How may this be remedied?

A. By a single pair of truck-wheels at one end.

Q. What class of engines is needed for mining purposes?

A. Very low, with excessively short stacks; and with water-supply borne by tanks saddling the boiler or otherwise borne by the engine itself; the fuel also being carried thereon.

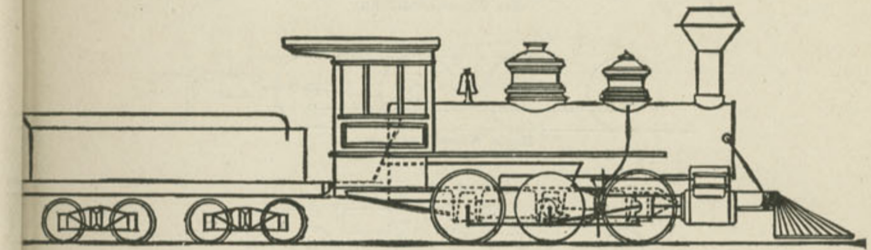


Fig. 17. Heavy Switching Engine, Six Wheels Coupled, with Tender.

Q. What is one advantage of the six-wheel outside-connected type of engine, especially for mine work, or where there is much tunneling and bridging?

A. By reason of its greater length, the boiler-diameter may be reduced for a given weight of engine and size of cylinders, as compared with four-wheel-connected engines of the same power; thus enabling reduction of height and width, without reducing power.

Q. What is a so-called electric locomotive?

A. A self-propelled traction vehicle, running on rails and having one or more electric motors that drive its wheels and thereby propel the entire machine and enable it to haul cars. The motors usually are supplied with electrical current either from a continuous rail laid near to, but insulated from the track rails, or from a wire suspended above the track lengthwise thereto, contact with the wire being made by a trolley or wheel on the end of

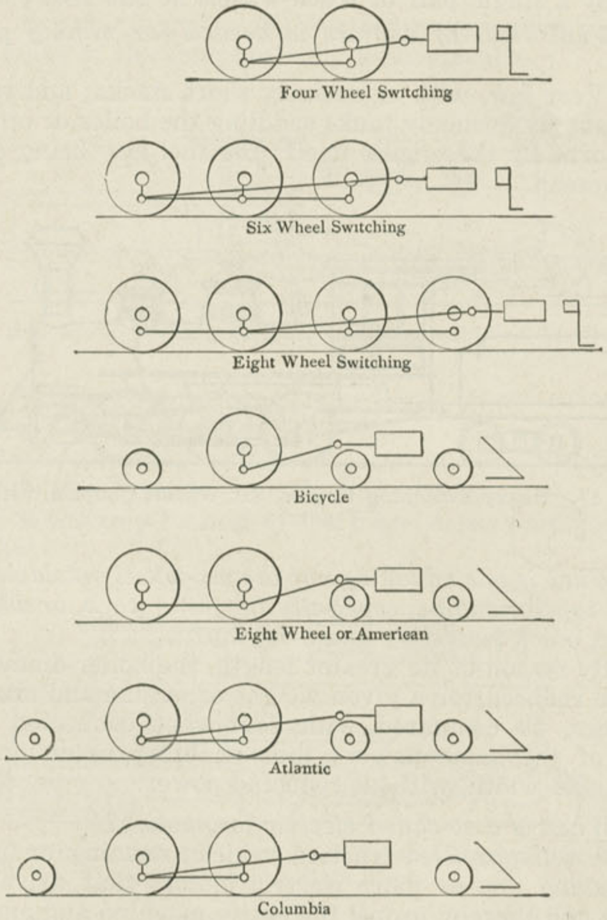


Fig. 18. Wheel Base Types.

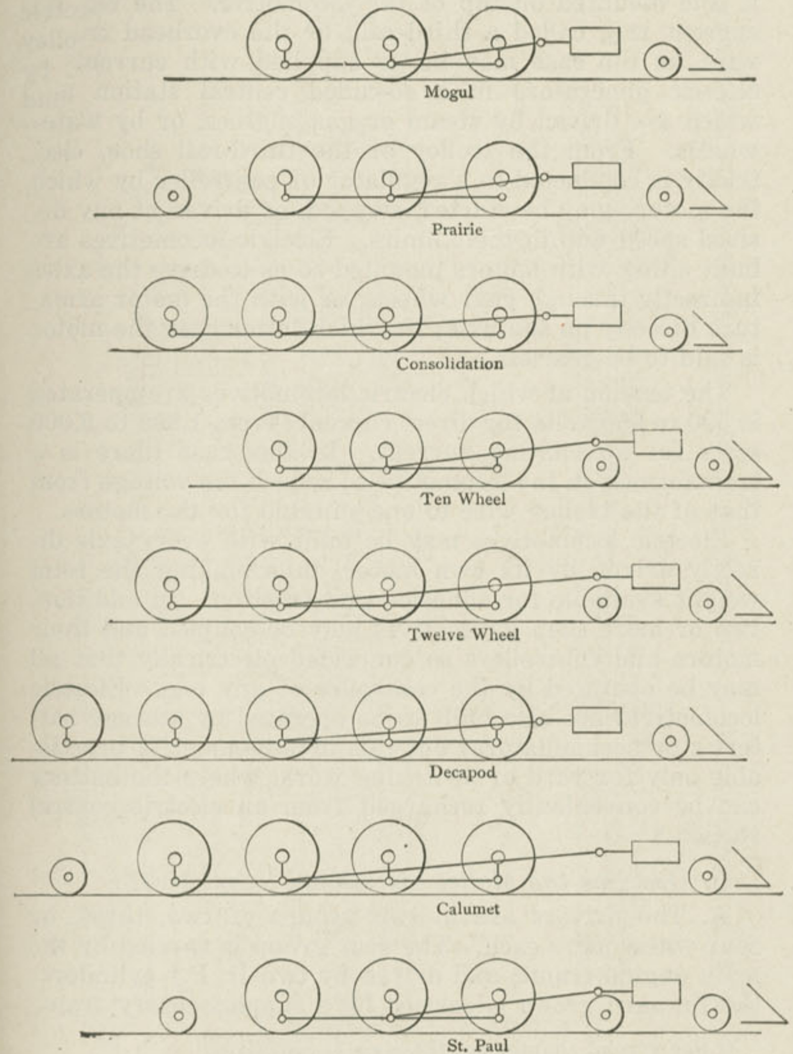


Fig. 19. Wheel Base Types.

a pole mounted on top of the locomotive. The electric current rail, called a third-rail, or the overhead trolley wire, as the case may be, is supplied with current by electric generators in a so-called central station and which are driven by steam or gas engines, or by water wheels. From the trolley or the third-rail shoe, electricity is conducted to a regulator or controller by which the motors may be started, stopped, or driven at any desired speed within their limits. Electric locomotives are built either with motors mounted so as to drive the axles indirectly through gear wheels, or with the motor armature directly on the axle; in which latter case the motor is said to be gearless.

The tension at which electric locomotives are operated is 500 to 650 volts for direct current; from 1,800 to 3,000 volts for alternating current. In this case there is a transformer on the locomotive to reduce the voltage from that of the trolley wire to one suitable for the motors.

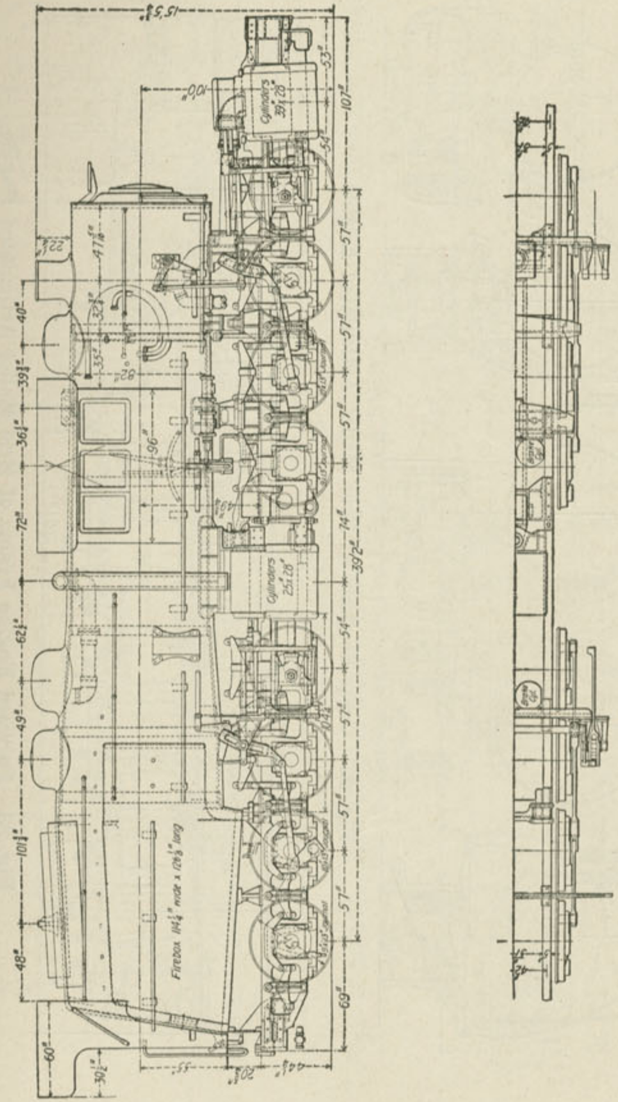
Electric locomotives may be built with every axle directly driven by its own motor, thus making the total weight available for adhesion and traction. In addition, two or more such locomotives may be coupled and their motors and controllers so connected electrically that all may be operated by the controller of any one. Electric locomotives are also built to be operated by storage batteries or accumulators; but this arrangement is practicable only for yard or switching work, where the battery can be conveniently recharged from an electric central station.*

Q. Describe the Mallet articulated locomotive?

A. The drivers are in two groups of two, three, or four wheel pairs each. The rear group is carried by the main engine frame, and driven by two H. P.† cylinders; the forward group is carried by a supplementary frame

* See special chapter on "Electric Locomotives."

† H. P. stands in this connection for high pressure, throughout this book.



Figs. 20 and 21. Mallet Articulated Locomotive, for Heavy Pushing Service, built by Erie R. R. Co.

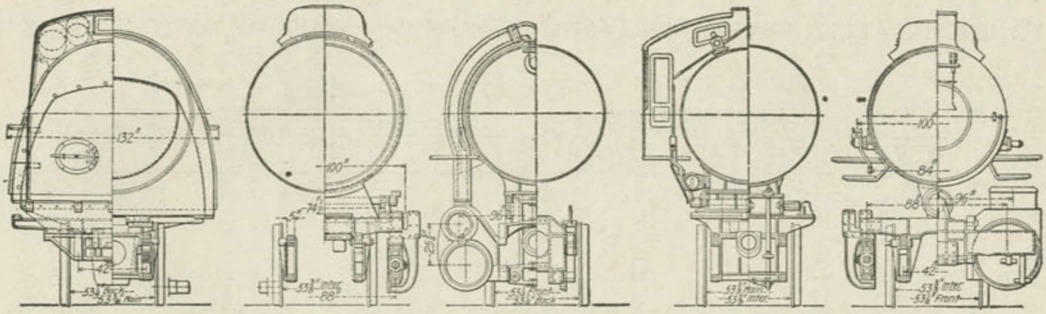


Fig. 22. Cross Sections of Erie Mallet Articulated Engine.

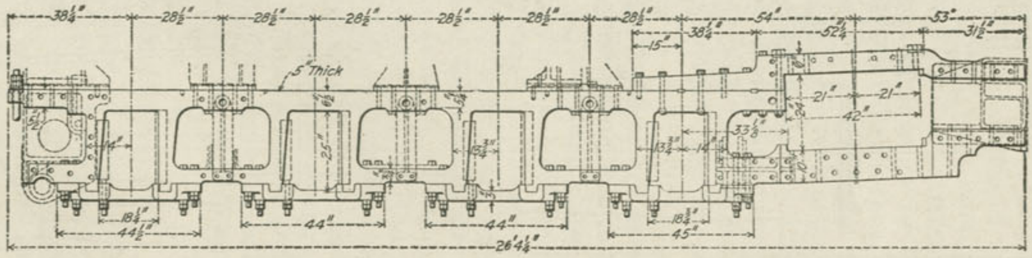
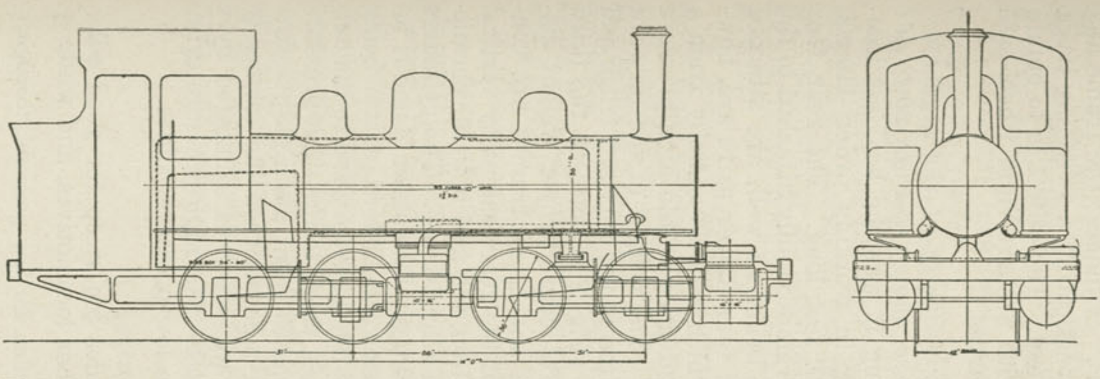


Fig. 23. Forward Engine Frame of Erie Mallet Articulated Engine.



Figs. 24 and 25. Four-Coupled Mallet Articulated Compound Engine. Adapted for Light Freight Service over Heavy Grades and Sharp Curves.

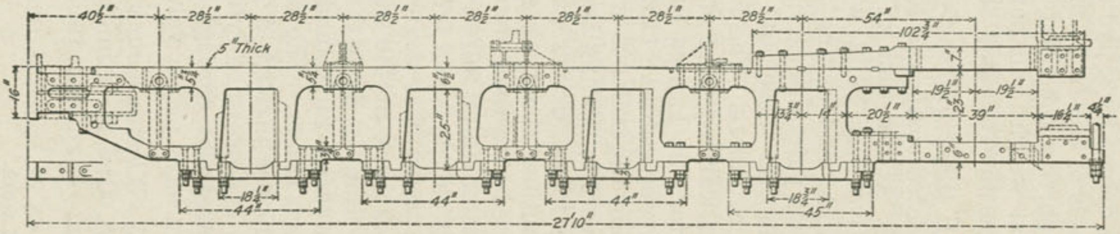


Fig. 26. Rear Engine Frame for Erie Mallet Articulated Engine.

and driven by a pair of L. P.* cylinders; the frame and wheels of the L. P. engine constituting a swiveling truck supporting the front boiler end. The object is to obtain great weight and power, with a short rigid wheel-base to permit rounding sharp curves.

Q. *What are the peculiar features of the Mallet articulated compound locomotive, shown in Figs. 20 to 26?*

A. At the time of building it was the heaviest locomotive ever built, weighing in working order 410,000 pounds, and having flues 21 feet long. The rear four driver pairs are carried in frames rigidly attached to the boiler; to these, and to the boiler as well, are attached the cylinders. The forward four driver pairs are, however, carried in a truck, which swivels radially from a center pin, located just in advance of the high-pressure cylinder saddle. (Fig. 21.) The weight of the forward end of the boiler is transmitted to the forward truck and drivers by sliding bearings (Fig. 20) between the third and fourth driver pairs. To secure proper weight distribution, the back ends of the front frames are connected with the front ends of the rear frames by vertical bolts having a universal motion, top and bottom, permitting play between front and rear frames. The cylinders are attached to the truck frames. The steam dome is located back of the high-pressure cylinders, steam being led from the dome through a dry pipe forward to the outside steam pipes, and through these to the high-pressure steam chests. The steam passes from the high-pressure cylinders through a jointed pipe between the frames to the low-pressure cylinders, whence it is exhausted by a jointed pipe through the stack. The high-pressure cylinders have piston valves, the low-pressure, slides.

Q. *What is a rack locomotive?*

A. One for climbing grades too steep for good adhesion. It runs on rails as other locomotives, and while on moderate grades the driving wheel adhesion is sufficient, on the steepest grades there is a rack rail between the two running rails and with it engage gears keyed on the driving axle, thus giving a positive tractive effort.

* L. P. stands in this connection for low pressure, throughout this work.

Q. *How are rack locomotives prevented from running away down grade?*

A. They have powerful air, hand, and water brakes.

Q. *What is the purpose of freight helper locomotives?*

A. Increasing the capacity of an up-grade or a heavily taxed track, balancing the power on the division, reducing the number of locomotives and crews required to handle heavy freight tonnage over a busy mountainous district.

Q. *What are the prime requisites of a steam locomotive for freight helper service?*

A. Maximum adhesion for tractive and braking power, minimum rail pressure per driving wheel, and short rigid combined with a long flexible, driving-wheel base, to adapt it to a mountain line having considerable curvature and gradient.

Q. *To accomplish this, what solution is adopted?*

A. Americanizing foreign railroad practice by making use of the Mallet articulated feature, which permits of the use of a maximum effective wheel base, with materially reduced rigid wheel base, and provides for developing an average through-freight train speed without excessive wear. Subdividing the power through the use of four independent cylinders, pistons, main rods, crank pins and frames, in place of two, and better balancing of the reciprocating parts, result in less strain on all parts, and reduce the liability for breakage and failure.

CHAPTER III

THE BOILER AND ACCESSORIES

Q. *What is the most important part of a locomotive?*

A. The boiler.

Q. *What are its essential parts?*

A. They are usually six (sometimes seven) in number; cylinder, main shell, or barrel, waist (in many cases), shell or outer fire-box, dome, inner fire-box or fire-box proper, tubes or flues, combustion chamber, smoke-box or arch, and stack or chimney.

Q. *What materials are used?*

A. Wrought iron and mild steel; the latter now coming into use to the exclusion of the former.

Q. *What are the advantages of soft steel for locomotive boiler construction?*

A. Great tensile and compressive strength, ductility, and uniformity of structure; thus enabling a boiler to stand more pressure for given weight, or to be lighter for given pressure.

Q. *What is the peculiarity of the locomotive boiler, as distinguished from the stationary?*

A. In having but one shell for both furnace and boiler.

Q. *How are locomotive boilers classified?*

A. By their shape, as "straight top," having the cylindrical shell of uniform diameter from the fire-box to the smoke-box; as "wagon top," having a conical or sloping course of plates next to the fire-box, tapering to the cylindrical courses; "extended wagon top," having one or more cylindrical courses between the fire-box and the sloping course which tapers to the main shell diameter. They are further classified as "wide fire-box," "narrow fire-box," Belpaire, Wootten, etc.

Q. *Describe a locomotive boiler and explain the use of its various parts?*

A. The locomotive boiler is usually in form a cylindrical shell joined to a rectangular one, the rear or rectangular end containing the fire-box, usually also of rectangular shape to conform to the shape of the outer shell. The fire-box is supported at the bottom by the mud ring, or foundation ring, and at the sides, front, and back by stay-bolts screwed through the outside sheets and fire-box sheets, and hammered over. The space between the fire-box and outer boiler sheets varies from 3 to 9 inches. The fire-box roof or crown sheet is supported by crown bars in some forms of boilers, and radial stays (long stay-bolts) in other types. To each side sheet near the bottom are bolted the grate rests, which support the grates. The fire-box is entirely surrounded by and covered with water, and forms the most efficient heating surface in the boiler. The cylindrical part of the boiler to which the fire-box end is jointed contains the tubes, or flues, which vary in number according to the size of the boiler. They are usually in locomotive practice from 2 to 2¼ inches in diameter. These are also surrounded by water and form the greater part of the heating surface, all the hot combustion gases distilled passing through them.

To the upper part of the boiler, and usually ahead of the fire-box, is riveted the cylindrical dome, which is a storage reservoir for the steam generated. Its object is to obtain drier steam. It also contains the throttle and stand-pipe connecting to the dry pipe, used to convey the steam from the boiler to the cylinders.

Riveted to and forming an extension of the cylindrical part of the boiler is the smoke arch, to which the cylinder saddles are bolted, and which also contains the steam pipes that convey the steam from the dry-pipe to the cylinders, the exhaust nozzle, through which the steam escapes to the stack, the diaphragm sheets, the petticoat pipe or draft pipe, used to regulate the draft on the fire, and a netting to prevent spark-throwing. At the top of the smoke arch is the smoke stack, while at the bottom in some types is a hopper for the discharge of the sparks that may accumulate in the front end.

Under the fire-box is bolted the ash-pan (to catch the ashes), either or both ends of which are fitted with a damper to prevent ashes or coals from falling out, and to regulate the admission of air to the fire-box.

Q. *What are the chief requirements of a boiler?*

A. That it shall be strong enough in all parts to stand the maximum pressure which will be put on it; deliver steam enough for the cylinders under maximum duty; be economical of fuel, and able to use various sorts of fuel advantageously; be readily inspected and readily and cheaply repaired; shall not foul, and not be readily lessened in steaming power by scale.

Q. *What is an extended wagon-top boiler?*

A. A locomotive boiler having a shell made of one or more cylindrical plate courses next to the fire-box, a conical course tapering down to smaller diameter, and one or more adjoining cylindrical courses of reduced diameter next to the smoke-box.

Q. *Why put the cylindrical course next to the fire-box?*

A. To provide a place for the steam dome, thus doing away with crown-bar staying over the crown-sheet as in an ordinary wagon-top boiler.

Q. *What name is given to the cylindrical part of a locomotive boiler?*

A. The waist or barrel.

Q. *What about the diameter of straight boiler-shells as compared with those of the wagon-top type?*

A. With the straight shell the waist is about two inches greater in diameter than with the wagon-top, for a given steam-space and water-room.

Q. *This being the case, which type gives, with an equal number of flues, the more circulation-room for water between flues?*

A. The straight shell type, by reason of its larger diameter.

Q. *What is another advantage of the straight shell?*

A. It is stronger than where there is a wagon-top.

Q. *How many pounds per square inch should good steel boiler-plates stand?*

A. 60,000 pounds per square inch of cross-section, lengthwise with the fiber; 54,000 across.

Q. *To how much of this pressure is it proper to subject a steel boiler in use?*

A. To about one-fifth, so that any strains which may be applied to it will not make it permanently stretch or otherwise change its form or dimensions.

Q. *What is the strength of wrought-iron boiler-plate as compared with mild steel?*

A. About one-sixth less.

Q. *What is the test of a good wrought-iron or steel boiler-plate, stay or rivet?*

A. It should stand not less than 50,000 pounds per square inch of cross-section without breaking, and stretch about one-eighth of its length before breaking; if not over an inch thick should be capable of being bent double when hot, without cracking. If under one-half inch it should be capable of being bent double when cold, without cracking. A hot rivet-shank when flattened to half its diameter should stand having a hole punched through it without tearing at the hole.

Q. *Of what kind of steel should rivets be made?*

A. Of the very softest or mildest, to lessen the danger of their getting hard and brittle in working and in use.

Q. *What is the reason that metal of the highest tensile strength is not desirable for steel boiler-plates and rivets?*

A. It is apt to be hard and brittle, and the soft ductile metal is safest for such work.

Q. *How strong is a rivet-seam between two plates of equal thickness and strength, as compared with the plates which it fastens together?*

A. That depends on the diameter, quality, spacing, and arrangement of the rivets.

Q. How should rivet-holes be made?

A. The best way, in steel plates, is to punch them smaller than desired and then ream or drill them to the required size; as this gives smoother walls and also cripples the fibers less, in the vicinity of the walls.

Q. How is a single-riveted lap-welded boiler-seam liable to give away?

A. (1) By the plate tearing away between the rivet and the edge of the plate; (2) by the plate splitting between the hole and plate edge, or (3) by the rivet itself being sheared off.

Q. To what does the first method of giving away point?

A. To the desirability of having the rivet-holes not too close to the sheet edge.

Q. Which is it desirable to have the stronger: the rivets, or the plates between the holes?

A. The plates, by reason of their being liable to be strained in punching and otherwise working.

Q. Which is of the most importance in riveting boiler-work: strength of seam, or tightness?

A. Tightness; because no matter how strong the seam may be originally, if not tight it will lose strength by corrosion.

Q. Which are stronger in single-riveted lap-seams: a large number of rivets close together, or a smaller number further apart?

A. The smaller number further apart.

Q. What limits the possibility in this direction?

A. We run into the difficulty of not having the seams tight, and our strong seams would soon become weak.

Q. What would be another way of increasing the strength of a boiler-seam?

A. By drilling the rivet-holes, or by punching them too small and reaming them or re-drilling them.

Q. What special advantage is there in drilling rivet-holes or in punching them too small and then enlarging with a reamer?

A. In punching, the holes in each plate must be made separately, and there is some difficulty in making the distance between them exactly the same; but in drilling or in reaming, the two plates may be worked at the same time, to insure absolute equality of spacing. Also, there is more likelihood of the rivets filling and fitting drilled or reamed than punched holes.

Q. As against this, what is the advantage of punched holes?

A. They are always slightly hour-glassing, and for this reason, if put with their small ends together, the rivet may be given a slight dovetail effect, increasing its strength against certain strains.

Q. What sets the limit to wide spacing of rivets?

A. The fact that the shearing strength of the rivet increases as the square of its diameter, the crushing strength of the metal only in direct proportion to the diameter of the rivet pressing on it.

Q. What is the largest diameter of rivet which can be used in 3/8-inch plates?

A. Seven-eighths of an inch.

Q. What would be the strongest seam that we could get with a single row of 7/8-inch iron rivets in 3/8-inch iron plates?

A. One and three-quarter inches between rivet-edges, or 2 5/8 between rivet-centers.

Q. How are boiler-seams made tight, besides being drawn together by the contraction of the rivets when they cool?

A. By what is miscalled calking; the metal on the edge being driven down against that below it, by a blunt chisel-like tool, and a hammer; the plate-edges being in the best work planed off true and beveled before the plates are put together.

Q. What is likely to happen if calking is done too vigorously?

A. The plates are liable to be forced apart, between the rivet-line and their edges.

Q. What is the best tool for calking boiler-seams?

A. One having a rounded edge, making a concave track on the plate-edge.

Q. What is the objection to a square-ended calking tool?

A. It is likely to score the lower plate along the calking-edge, and make the plate liable to give way along the scored line. It is also more liable to force the plates apart than the round-ended tool.

Q. How much strain, tending to open the lengthwise seams, is there on the barrel of a boiler 50 inches in diameter and 12 feet long, where the steam pressure is 160 pounds?

A. $50 \times 12 \times 12 \times 160 = 1{,}152{,}000$ pounds.

Q. What precaution should be taken in making a locomotive boiler shell, as to its curve?

A. It should be a true circle, else the tendency of the steam-pressure will be to make it of true circular section, and that would spring things out of shape, besides not doing the seams any good.

Q. How are the flat ends of locomotive boilers kept from being bulged out or blown out by the pressure within?

A. By either stay-rods or gusset stays (sheet stays) carrying to the cylindrical part some of the strain that is put on the flat part. The tubes also act as lengthwise stays. (See Fig. 30.)

Q. What may be said about the strength of the crow's feet or other devices by which to attach a stay to a sheet or head?

A. They should be as strong as the stays themselves.

Q. How can allowance be made for boiler expansion?

A. By leaving space enough to slip a thickness of sheet-tin between the frame and the expansion plates and buckles. Where bolts pass through, cut the holes oblong about ¼ inch, and the same on the back boiler-brace holes.

Q. What construction is better than expansion-plates and buckles?

A. Two heavy cast-iron plates, one fastened to the boiler, the other to the frame, and keyed together.

Q. In how many different ways can a properly made riveted joint give way?

A. By tearing the plate along a line through the outer rivet row; by shearing the rivets; or by crushing either the plate or the rivets.

Q. What is meant by "a properly made" riveted joint?

A. One with sufficient lap and proper distance between the rivet rows.

Q. In what way can the joint be given maximum strength?

A. By having the tearing, shearing and crushing strength equal.

Q. What is the rule for doing this?

A. Add the number of rivets in each group that are in double shear, to the number in each group in single shear. Divide this sum by itself plus the quotient of the tensile strength of the rivets (in pounds per square inch) by their crushing strength (also in pounds per square inch).

Q. What was the early tendency in boiler design?

A. Toward shallow fire-boxes above the frames and having about 3½ feet grate width, and length up to 10 feet.

Q. What is the modern tendency?

A. Towards grates 6 to 8 feet wide.

Q. What does this involve?

A. Putting the fire-box over some of the wheels—as in the Wootten type, where the boiler was also raised, but the grate often higher than the bottom tubes.

Q. For what fuel was this satisfactory?

A. Anthracite only.

Q. What other types have very wide fire-boxes?

A. The Atlantic and the Pacific.

Q. For bituminous coal, what is the type now desired for engines weighing from 75 to 100 tons?

A. Like the old ones, but with wider grate, as in Fig. 27, with 3,000 square feet of heating surface.

Q. What is the principal peculiarity of boilers for anthracite?

A. Their large grate surface.

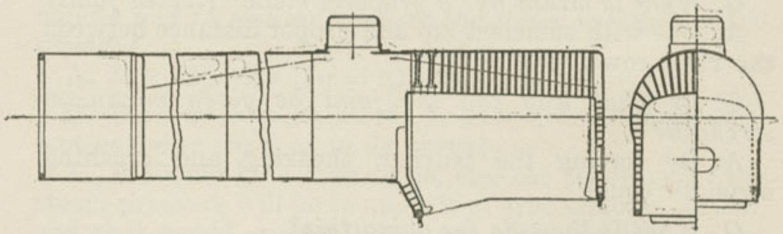


Fig. 27. Showing Fire Box with Radial Sling Stays.

Q. Have English engines as a general rule more or less heating and grate-surface than American?

A. Less. The Gladstone, on the L. B. and S. C. Railway, has only 1,485 square feet of total heating surface and 20.65 square feet of grate (with a ratio of 72 to 1). The maximum indicated horse-power of the Gladstone being 1,040, we have 50.35 horse-power per square foot of grate, and 1.43 square feet of heating-surface per horse-power, or 0.7 horse-power per square foot of heating surface.

Q. What is the evaporating capacity of an average American locomotive?

A. From 3½ to 7½ gross tons of water per hour, for an engine weighing 40 tons and having two cylinders 18 inches in diameter and 24 inches stroke.

Q. What is the average amount of coal required to evaporate 6 to 8 tons of water per hour in such an engine?

A. One ton per hour, as one pound of the usual run of coal will make from 6 to 8 pounds of steam with the boiler in average condition.

Q. What are the disadvantages of high boiler pressures?

A. Heavier and dearer boiler, and increased maintenance expense all over boiler and cylinders and their appurtenances.

Q. What are the advantages?

A. Smaller cylinders necessary; better thermal utilization, both because the steam carries more heat per unit of weight and because it can be cut off earlier if desired.

Q. Does this heat advantage extend indefinitely?

A. No; where expansion is to less than back pressure it is a disadvantage.

CHAPTER IV

THE FIRE-BOX

Q. Describe in a general way the construction of the fire-box?

A. There is an inner and an outer shell, forming a double bottomless box of boiler-plate, and having in front, through both walls, a doorway closed by a furnace-door. The bottom is formed by the grate, upon which the fuel is placed, and below which is the ash-pan which receives the ashes that fall through the grate, and which is supplied with suitable dampers to regulate the amount of air admitted under the grate. The top of the fire-box inner wall is usually flat, and is called the crown-sheet; the top of the outer shell or wall over this is sometimes convex, sometimes flat—usually the former. (See Figs. 27, 28, 29, 30 and 31.)

Q. What materials are used for fire-boxes?

A. In this country, wrought iron, wrought steel, and Bessemer steel; in Europe, principally copper.

Q. What is the advantage of copper fire-boxes?

A. They let the heat pass through more readily than either iron or steel does.

Q. Will the same fire-box do for all kinds of fuel?

A. No; there should be a special design and construction for each kind of fuel.

Q. What fire-box is usually employed for hard coal?

A. One with a very thick grate, and having less provision for letting air in above the fire.

Q. Describe the Milholland fire-box for hard coal?

A. It is shown in Figs. 29 and 31. The furnace top slopes downward from the boiler barrel, and the crown-sheet is stayed with screw stays, except for a short dis-

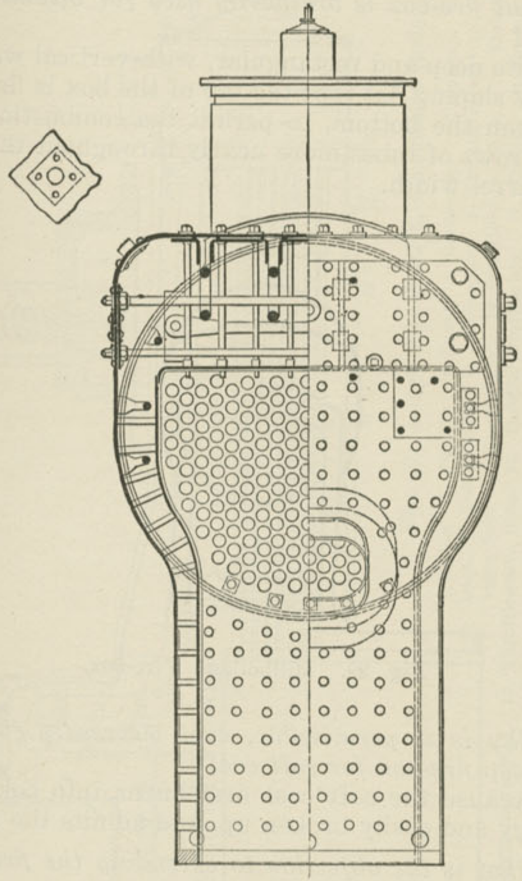


Fig. 28. Cross Section, Pennsylvania R. R. Boiler, Class "O."

tance back of the tube-plate; water grates, *B, B,* are used, as shown.

Q. *What fire-box is ordinarily used for bituminous or soft coal?*

A. Quite deep and rectangular, with vertical walls and a slightly sloping flat top; the top of the box is flared out larger than the bottom, to permit the combustion gases to enter rows of tubes more nearly throughout the entire boiler-barrel width.

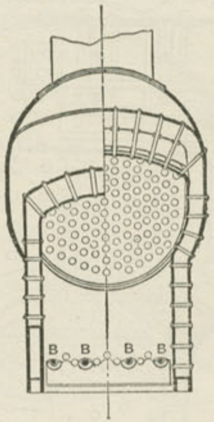


Fig. 29. Millholland Fire-box.

Q. *Why is it permissible, even necessary, to give a small deep fire-box for soft coal?*

A. Because the soft coal first burns into coke, which is spongy and easily broken up, and admits the air.

Q. *What is the objection to extending the fire-box too far lengthwise of the engine?*

A. It makes firing difficult.

Q. *What class of fire-box is necessary for burning wood?*

A. One that is very deep.

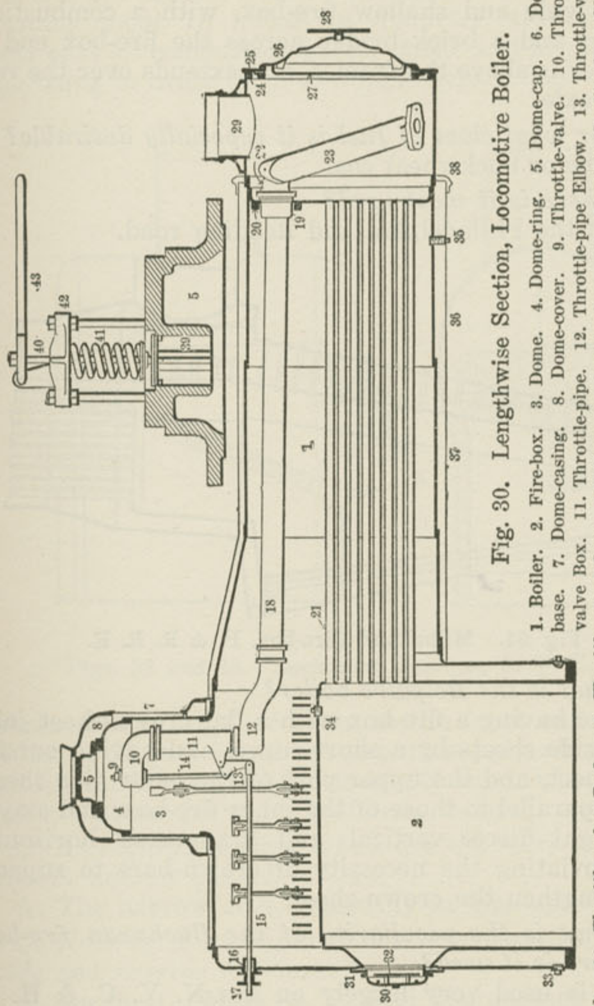


Fig. 30. Lengthwise Section, Locomotive Boiler.

1. Boiler. **2.** Fire-box. **3.** Dome. **4.** Dome-ring. **5.** Dome-cap. **6.** Dome-base. **7.** Dome-casing. **8.** Dome-cover. **9.** Throttle-valve. **10.** Throttle-valve Box. **11.** Throttle-pipe. **12.** Throttle-pipe Elbow. **13.** Throttle-valve Crank. **14.** Throttle-valve Rod. **15.** Throttle-valve Stem. **16.** Throttle Stuffing-box. **17.** Throttle Stuffing-box Gland. **18.** Dry-pipe. **19.** Dry-pipe, Front End. **20.** Dry-pipe Ring on Tube-sheet. **21.** Tubes. **22.** Double Cone. **23.** Steam-pipes, L. and R. **24.** Smoke-box Ring. **25.** Smoke-box Front. **26.** Smoke-box Door. **27.** Smoke-box Door-liner. **28.** Number-plate. **29.** Smokestack Base. **30.** Fire-door. **31.** Fire-door Frame. **32.** Fire-door Liner. **33.** Corner-plug. **34.** Fusible-plug. **35.** Waist-Plug. **36.** Lagging. **37.** Jacket. **38.** Smoke-box Band. **39.** Safety-valve. **40** Safety-valve Stem. **41.** Safety-valve Spring. **42.** Safety-valve Spring Cap. **43** Relief-lever.

Q. What is the Wootten fire-box?

A. A wide and shallow fire-box, with a combustion-chamber, and a brick bridge across the fire-box end of this latter is above the frames, and extends over the rear driving-axle.

Q. For what class of fuel is it especially desirable?

A. Fine or buckwheat coal.

Q. Where is it most used?

A. On the Philadelphia and Reading road.

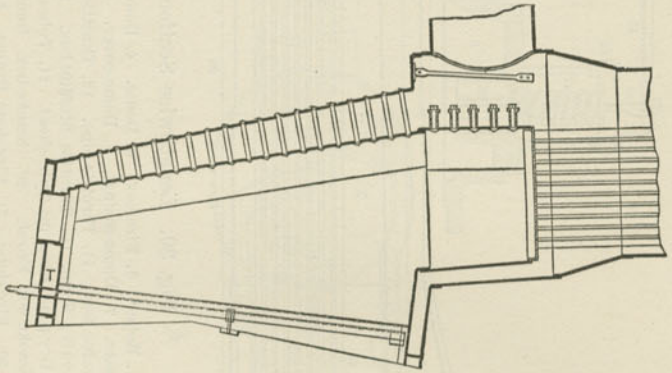


Fig. 31. Milholland Fire-box, P. & R. R. R.

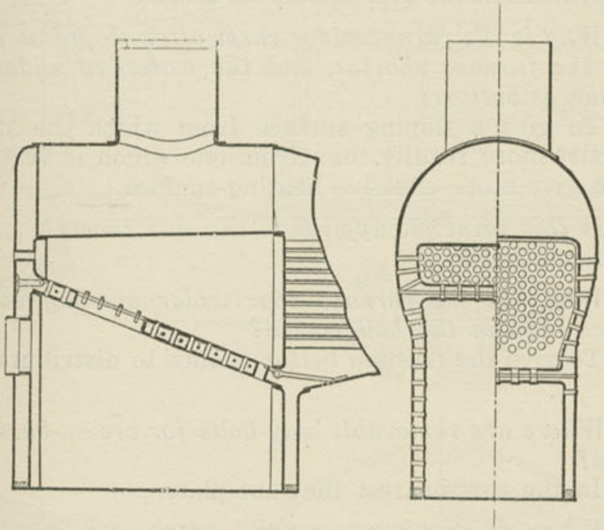
Q. What is the Belpaire boiler?

A. One having a fire-box with a flat crown-sheet joining the side sheets by a short curve, and having outside crown-sheet, and the upper part of the outer side sheets flat and parallel to those of the inner fire-box, and stayed by straight direct vertical and transverse horizontal stays, obviating the necessity of crown-bars to support and strengthen the crown-sheet.

Q. What is the peculiarity of the Buchanan fire-box, and where is it used?

A. It is used very largely on the N. Y. C. & H. R. R. R., and its peculiarity consists principally in a water-table, as shown in Figs. 32 and 33, inclining from the back plate downward to the tube-plate just below the

bottom row of tubes, and dividing the box into an upper and a lower compartment. Through it there is a round opening about 18 inches in diameter, through which must pass all combustion gases, smoke and air, the intention being to cause them to mingle before they strike the



Figs. 32 and 33. Buchanan Fire-box, C. V. R. R.

tubes. There are four tubes in the front end and four in the back, just above the fire, to supply air above the grate. Each has a conical nozzle through which may be passed a steam jet which will draw in an air current.

Q. As regards repairs, which are the more economical, wide or narrow boxes?

A. The narrow ones, especially in high-speed engines.

Q. How is it as regards coal consumption, between wide and narrow fire-boxes?

A. On the C., M. & St. P. road, the engines with narrow fire-boxes use 17.45 pounds of coal per 100 ton-miles; those with wide ones 17.56.

Q. What is the advantage of having the top of the wagon-top considerably higher than the boiler-barrel?

A. It gives more steam-room, and, by permitting the use of more tubes, allows more heating-surface than possible with the flush-top boiler; also there is more room for workmen inside over the crown-sheets.

Q. Why is the furnace-door sheet often sloped so as to make the furnace shorter, and the water-leg wider, at top than at bottom?

A. To give a sloping surface from which the steam may part more readily than from one which is vertical; and to give more effective heating-surface.

Q. Is this principle applied to the side sheets?

A. Sometimes.

Q. Why has the furnace door wider opening in the furnace than in the boiler-head?

A. To give the fireman better chance to distribute the fuel.

Q. Where are removable stay-bolts for crown-bars desirable?

A. In the row nearest the tube-plate.

Q. When do fire-boxes usually crack—while on the road or after a trip?

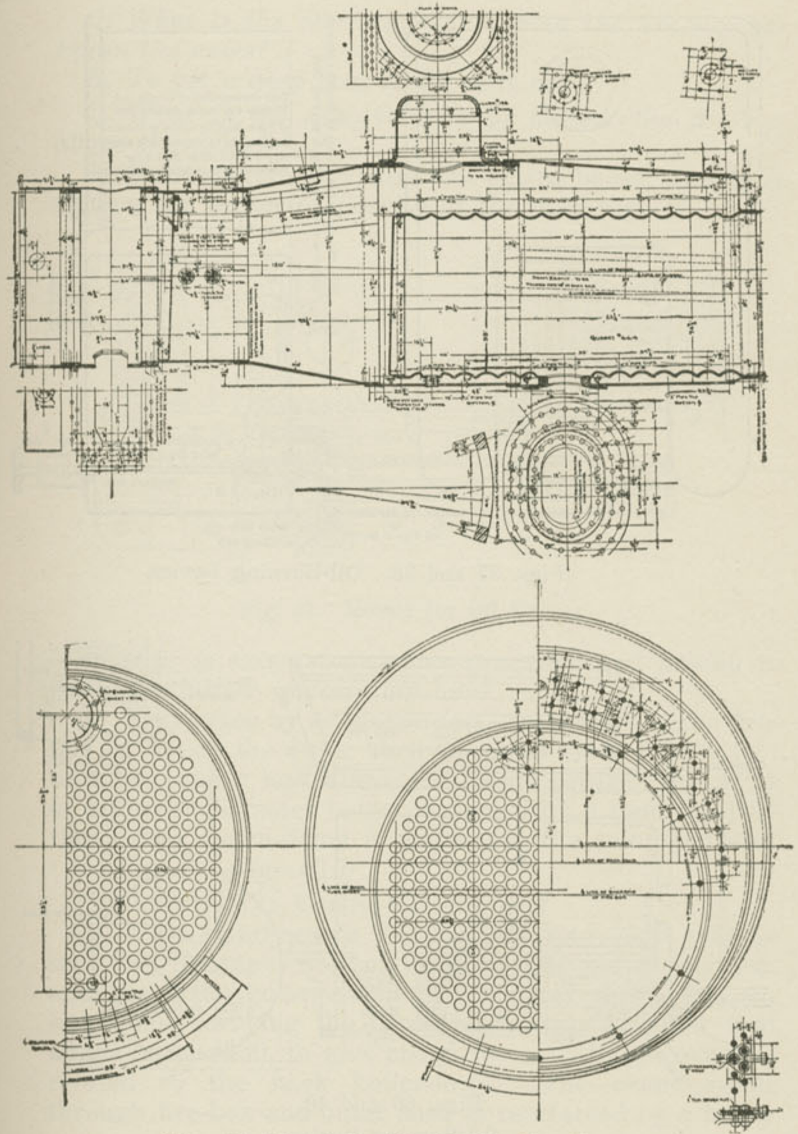
A. Seldom on the road.

Q. To what does this point?

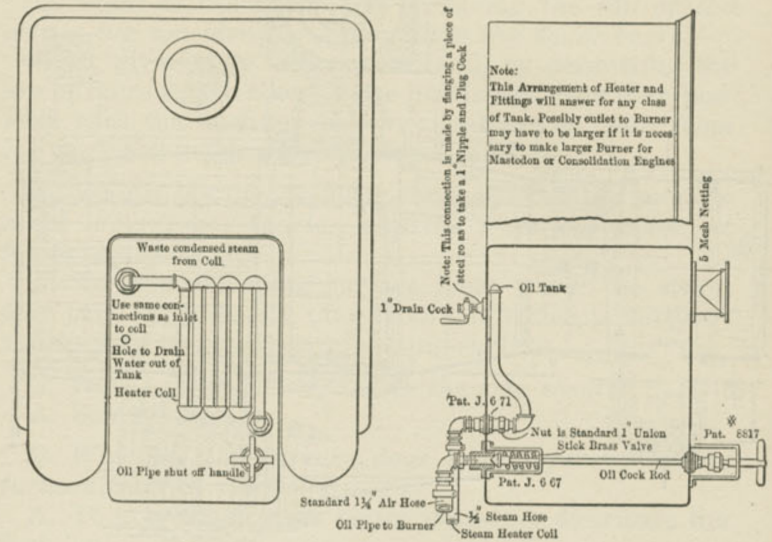
A. To the desirability of arranging, as the Pennsylvania Railroad does in some round-houses, stationary boilers with pipe connections for each stall, so that when an engine comes in and the fire is drawn, she is kept hot until ready to be fired up again. The same thing is done on the C., N. O. & T. P. R. R.

Q. What is the Colburn or "Mother Hubbard" fire-box?

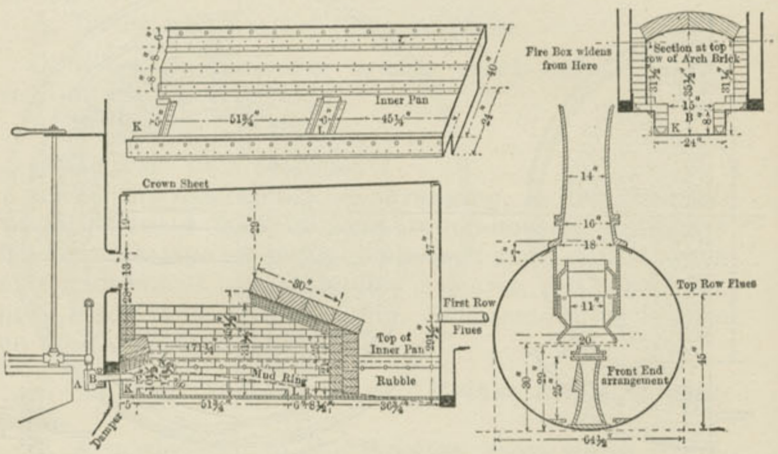
A. A predecessor of the Wootten, from which it differs only in the absence of a combustion chamber.



Figs. 34, 35 and 36. Vanderbilt Fire-Box.



Figs. 37 and 38. Oil-Burning Device.



Figs. 39 and 40.
Oil-Burning Device.

Q. What is the advantage of having the fire-box between the axles?

A. To get a deep box, as for soft coal.

Q. What is the disadvantage of having the fire-box above the axles?

A. It necessitates raising the entire boiler, and thus raising the center of gravity of the machine.

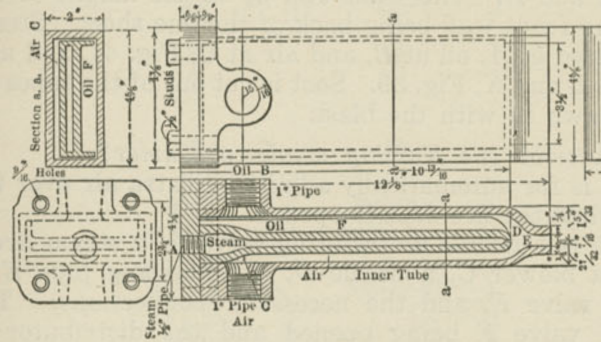


Fig. 41. Nozzle for Oil Burner.

Q. How is extra steam-room given without having to carry the water undesirably low?

A. Very often by a "wagon-top," a part above the fire-box in which the outer shell is raised from half a foot to a foot and a half above the barrel proper; the parts of different diameter being connected by a tapering portion. The steam-dome is added for the same purpose. (See Fig. 30, page 43.)

Q. Describe the Vanderbilt fire-box?

A. With reference to Figs. 34, 35 and 36 it will be seen that the inner fire-box is cylindrical and corrugated, and lies in an enlargement of the outer shell (this enlargement carrying the dome). Its axis is below that of the outer shell, to give steam-room. At the rear it is riveted to the back boiler-head. The cleaning-hole through fire-box and outer shell is reinforced by a heavy ring, which takes part of the weight of the box. Thus it is free to expand forward, without straining either itself or the outer shell. There is a fire-brick wall.

Q. Describe an oil-burning device?

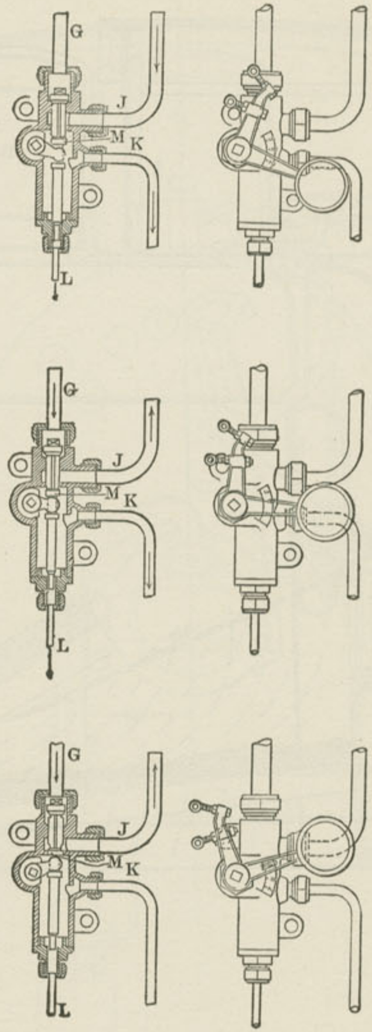
A. As shown in Figs. 37, 38, 39 and 40, the grates are replaced by an inner pan, supporting side walls and arches, and covered with fire-brick except at the air-inlets *L* and *K*. The walls run up to the height of the arch; the front wall being back of the flue sheet. Steam is admitted at *A*, oil at *B*, and air at *C*, Fig. 41, and also through *L* and *K*, Fig. 39. Soot is cut out of the tubes by sand drawn in with the blast.

Q. Describe the Körting smoke consumer?

A. It is for automatically admitting extra air over the grate when the fire-door is opened.

There is a double distributing-valve *A*, a steam drum *B*, a jet blower *C*, a nozzle *D*, a connecting pipe *E*, a shutoff valve *F*, and the necessary connections. The shut-off valve *F* being opened and the distributor *A* closed, steam passes from the boiler to this latter, and no further. (Figs. 48 and 49.) When the door is opened, *A* automatically admits steam to the drum *B*, in amount depending on the time during which the door is open. Closing the door, communication between drum and blower is opened by a second part of *A* between *B* and the jet blower; thus driving a blast into the fire-box. At first, when most air is required for the new fuel, the high-pressure steam in the drum drives in considerable; this diminishes gradually; and the length of time during which this subsidiary supply continues may be regulated for a given steam pressure and a given length of time during which the fire door is open. But always the higher the steam pressure and the longer the door is open, the more air is forced in.

Every time the throttle is closed the regulating valve is half closed, as seen in Fig. 48, and steam passes to the drum and also to the blower. When the throttle is



Figs. 42, 43, 44, 45, 46 and 47.
Valves of Körting Smoke Consumer.

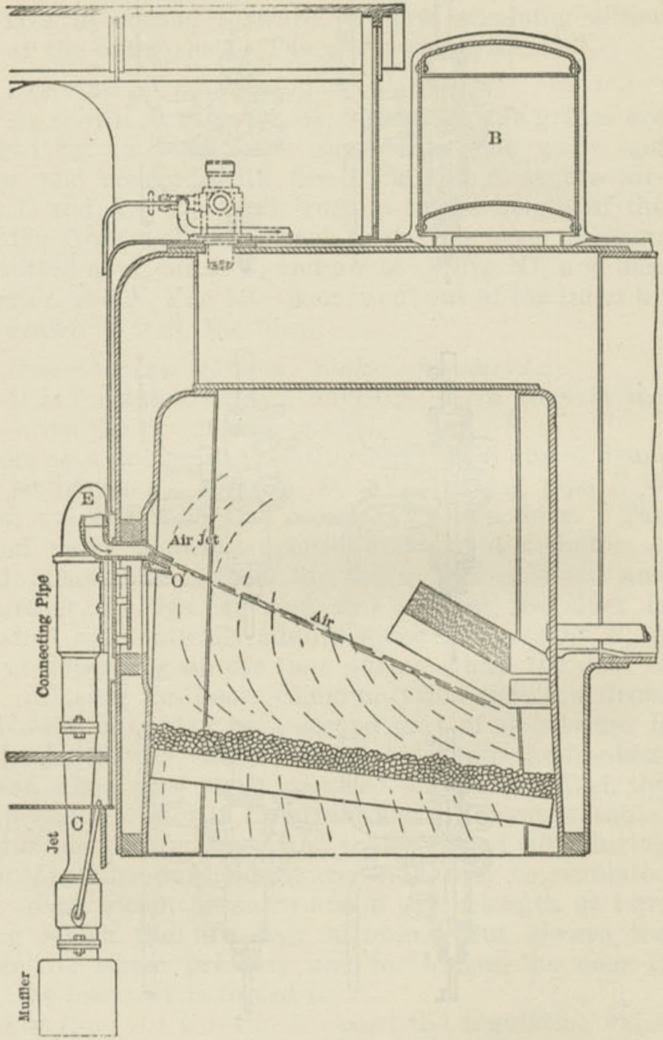


Fig. 48. Körting Smoke Consumer.

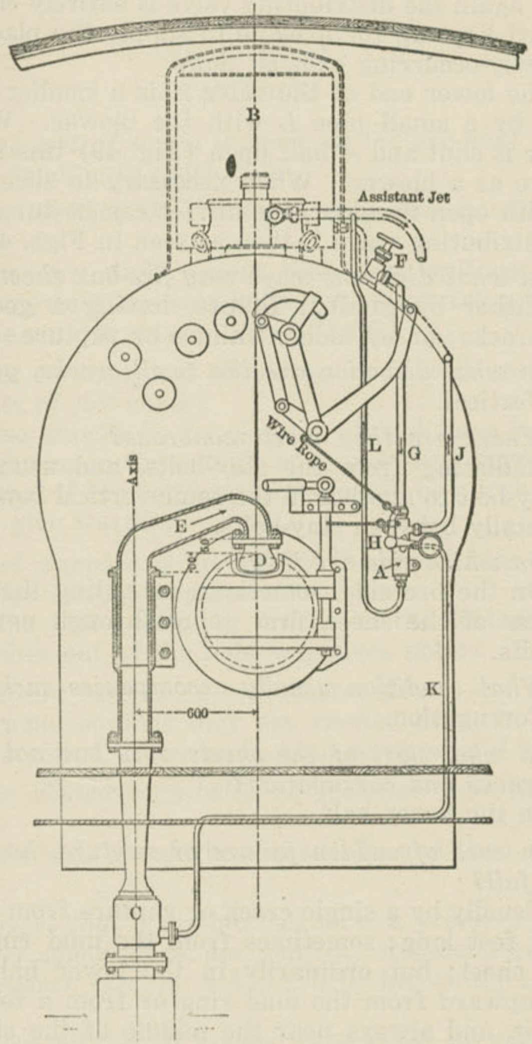


Fig. 49. Körting Smoke Consumer.

opened again the distributing valve is entirely closed and the blast kept up for a while to supply the place of the but slowly-occurring exhaust puffs.

At the lower end of the valve *A* is a smaller one connected by a small pipe *L* with the blower. When the throttle is shut and *A* half open (Fig. 49) this is opened to serve as a blower. When necessary to slice the fire, etc., with open fire-door, the air jet can be turned aside. The distributing valve is then as seen in Figs. 42 to 47.

Q. In what different ways may fire-box sheets fail?

A. Either by gradual failure, having a good many small cracks; or by hidden failure or rupture.

Q. In what direction are the small cracks, generally?

A. Vertical.

Q. Where are they most numerous?

A. Radiating from the stay-bolts, and usually from one stay-bolt to another in the same vertical row; seldom horizontally between stay-bolts.

Q. On which side are they?

A. On the fire side, sometimes extending through the thickness of the sheet, first going through next to the stay-bolts.

Q. What condition usually accompanies such cracks?

A. Corrugation.

Q. In what part of the sheets does one not find the most cracks and corrugation?

A. In the lower half.

Q. In case of sudden failure or rupture, how do the sheets fail?

A. Usually by a single crack or rupture from a foot to several feet long; sometimes from the mud ring to the crown sheet; but ordinarily in the lower half of the sheet, upward from the mud ring or from a few inches above it, and always near the middle of the side sheet lengthwise.

CHAPTER V

STAY-BOLTS

Q. What sort of strain is there on the fire-box?

A. One tending to crush it in.

Q. What resists the tendency to crush in the side sheets?

A. To a very slight extent their own stiffness; to a very great extent the stay-bolts, extending from the inside to the outside sheets. (See Fig. 50.)

Q. What arrangement should be made with stay-bolts or tie-bolts of fire-boxes?

A. These should be tubular, or should have a small hole lengthwise in the outside end, extending beyond the plate, so that if the bolt breaks there will be a leak at the break, to give warning.

Q. What purpose is served by the small hole drilled in the outer end of stay-bolts?

A. If the bolt breaks or cracks in the water space, water rushes out at the hole and gives notice.

Q. How are these stay-bolts fastened?

A. In some engines they are riveted over; in others they are screwed in; in some, both screwed and riveted.

Q. How should stay-bolts be fastened into the side sheets?

A. Their ends should be screwed in and then riveted over.

Q. Suppose that a fire-box has on it a pressure of 160 pounds per square inch, and that the stay-bolts are four inches between centers; what will be the strain on each bolt?

A. There will be 16 square inches held by each bolt, making 2,560 pounds that the bolt will have to hold.

Q. What is the object of riveting over the stay-bolt ends?

A. To "make assurance doubly sure;" because sometimes screw-threads slip, and again the bulging of the sheets from undue expansion will tend to open out the holes, leaving the entire strain on the bolt-heads. If there were no heads the bolts would then be useless.

Q. What kind of stay-bolts are used in England for fire-box walls?

A. Copper.

Q. When a stay-bolt breaks, what takes the strain?

A. The eight bolts nearest thereto.

Q. How much is their strain thus increased?

A. One-eighth each.

Q. What is the principal cause of the strain on stay-bolts?

A. The inner fire-box expands more than the outer.

Q. What is their usual distance apart?

A. About four inches between centers.

Q. What may be said of stay-bolts as a cause of explosion?

A. After low water and hot crowns they are the most usual causes of explosions.

Q. Where do they usually break?

A. Close to the outer sheet.

Q. What rows show the most broken stay-bolts?

A. The two or three upper ones along the sides, and the first six or eight toward the ends.

Q. Which break the more readily, long stay-bolts or short ones?

A. Short ones.

Q. What is the best way to test stay-bolts?

A. To drill a 3/16-inch hole, one inch deep, in the outer end; they will tell of themselves if they crack or break.

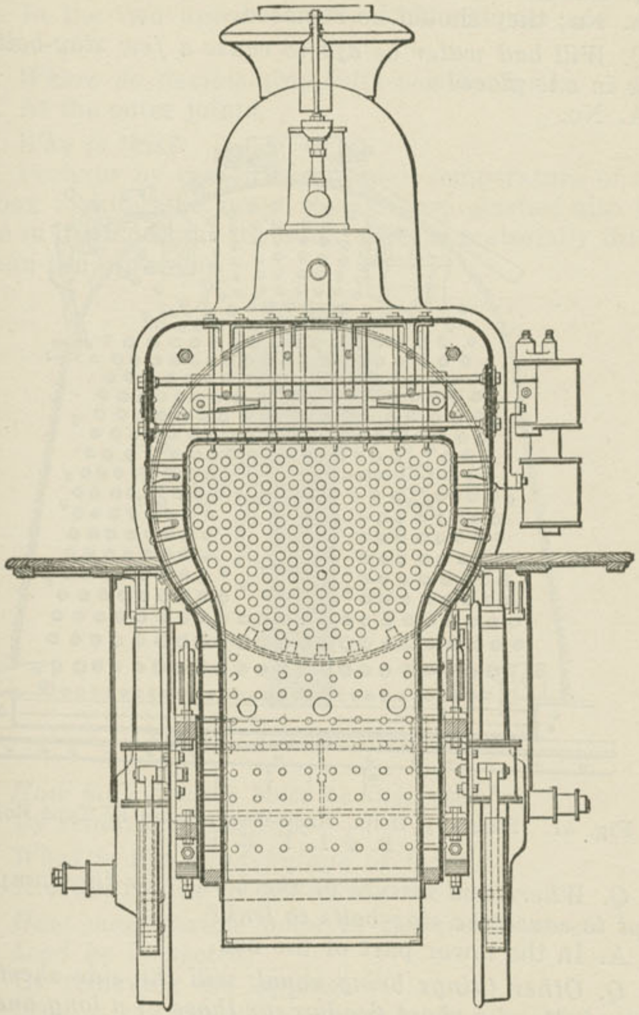


Fig. 50. Cross Section, Pennsylvania R. R. Engine, Class "O."

Q. Should defective stay-bolts be plugged?

A. No; they should be replaced.

Q. Will bad water be apt to cause a few stay-bolts to leak in one place?

A. No.

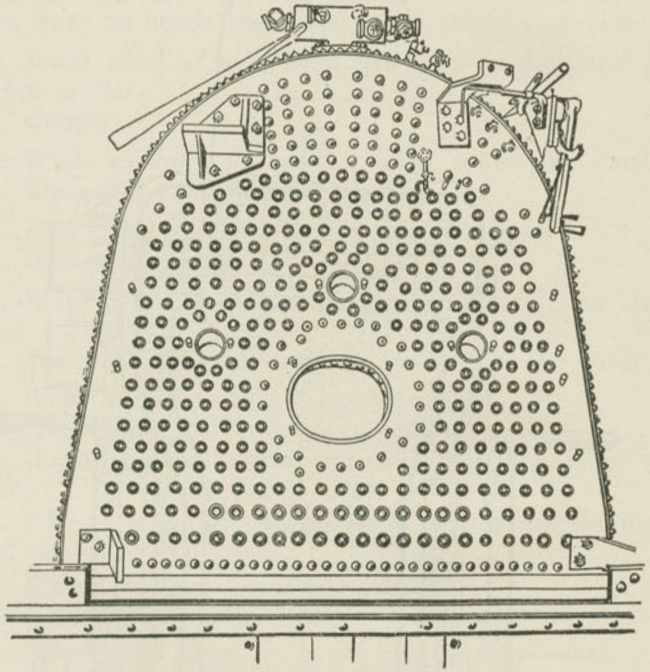


Fig. 51. Flannery Bolts, Back Head, Santa Fé Type Boilers, B. & L. E. R. R.

Q. Where will misuse of the blower or the damper be apt to cause the stay-bolts to leak?

A. In the lower part of the box.

Q. Other things being equal, will the side sheets and stay-bolts of a short fire-box, or those of a long one, give most trouble?

A. Those of a short one.

Q. Where do flexible stay-bolts do the most good?

A. In the two upper corners of the throat and side sheets.

Q. Where do flexible stay-bolts usually fail?

A. At the outer joints.

Q. Why is this?

A. Perhaps by reason of the high temperature of the fire-box making the inner sheets more elastic; also because in most designs the outer sheet is materially thicker than the inner one.

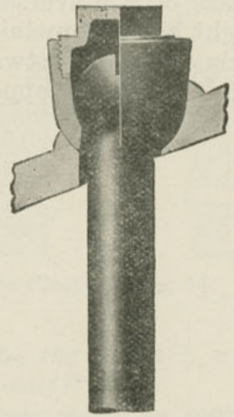


Fig. 52. Flannery Stay-Bolt.

Q. How may flexible bolts be inspected?

A. By removal of the cap.

Q. What is the disadvantage of this?

A. It often results in destroying the cap.

Q. How may flexible bolts in the inside sheets and back head be inspected?

A. By removing the lagging.

Q. What is the principal difficulty with which the flexible stay-bolt has to contend?

A. Incrustation. The deposit of solid matter around the bolt and its parts will defeat the purpose of the flexible bolt, making it of little more value than a rigid one.

Q. What is the disadvantage of the flexible bolt?

A. The sleeve being larger than the bolt, weakens the sheet more.

Q. Describe the Flannery flexible stay-bolt.

A. There are many forms. One, shown in Fig. 51, as applied to the back head, and singly, in Fig. 52, has one end threaded, the other with a ball head slotted for a screw driver, and over which a two-piece head (sleeve and cap) forming the case of a universal joint, is screwed by a spanner. A light band of metal deposited by electric-arc welding seals the joint between the sleeve and the sheet; and each sleeve has a copper gasket.

CHAPTER VI

THE MUD-RING

Q. How are the bottom edges of the fire-box side sheets fastened?

A. Usually there is a mud-ring, as thick as the water-leg, between the inner and outer sheets; rivets extend through outer sheet, mud-ring (a casting which is either solid or flanged), and inner sheet.

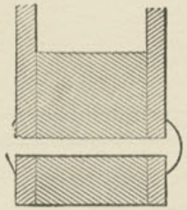


Fig. 53. Solid Mud-Ring.

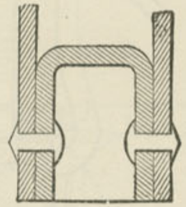


Fig. 54. Flanged Mud-Ring.

Q. What would be the result if a leg of the fire-box became filled with mud?

A. The inner sheets would be burned in that portion thus filled.

Q. Is there any other way of making the joint than by a mud-ring?

A. Instead of the solid mud-ring as in Fig. 53, there may be a boiler-plate ring flanged over so as to have a section as in Fig. 54, with both the inner and the outer sheets riveted thereto.

Q. What other name is given to the mud-ring?

A. The foundation-ring.

CHAPTER VII

THE FIRE DOOR

Q. What is the most usual type of fire-box door?

A. Simply a plain flap hinged on the left, outside the

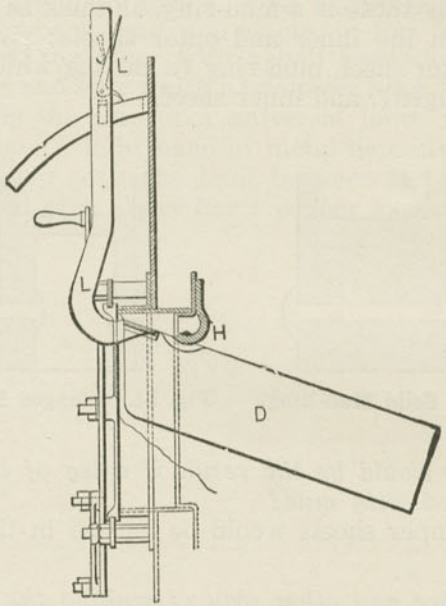


Fig. 55. Hudson Furnace-door Deflector.

doorway, and having a chain by which to raise its latch and swing it.

Q. What is the objection to this type?

A. When it is opened, cold air rushes into the flues and causes imperfect combustion and visible smoke, besides cracking plates.

Q. How is this remedied?

A. In part by placing an inverted shovel at an angle inside, so as to throw the air current downwards on the fuel instead of letting it go through the flues; still more thoroughly by a sheet-iron deflecting plate inside of the box and hinged at its upper edge, with a contrivance by which it may be thrown up when the coal is to be laid.

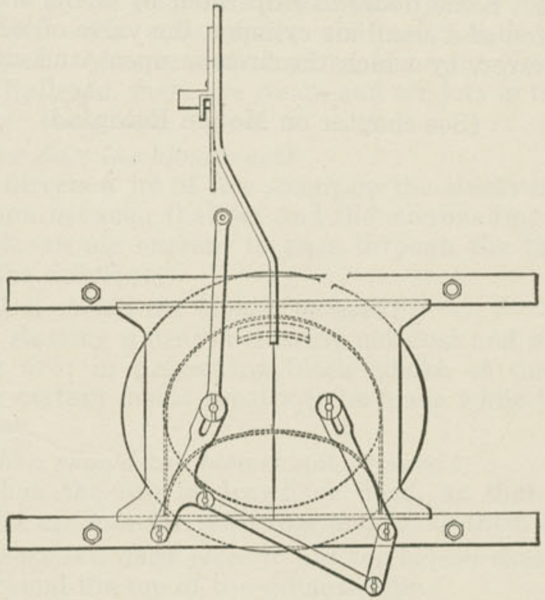


Fig. 56. Hudson Furnace-door Deflector.

Q. Describe the Hudson furnace-door deflector.

A. It is shown in Figs. 55 and 56. *D* is a deflector hung from a hook *H* attached to the fire-box over the door; a lever *L* is fastened to the deflector, by which to move it out of the way when coal is thrown on. The deflector position is regulated by the lever and a latch *L* at its upper end. A pair of sliding doors is usually employed.

Q. Name some other types of fire-door.

A. Some types of doors are made to slide, and are moved by a lever or handle. Swinging doors have a handle and a chain fastened to the boiler-head for convenience in opening and closing. There is a catch or notched rod, on various points of which the door handle may be set, to regulate the amount of air admitted above the fire. Some doors are operated by a rod moved by the piston of a small air cylinder, the valve of which has a foot lever, by which the fireman opens and closes the door.

(See chapter on Motion Records.)

CHAPTER VIII

THE BLOWER AND PAN DAMPERS

Q. How can the fire be urged when the engine is not running and there is no exhaust blast?

A. By a steam jet sent up the stack from a pipe connected with the steam-space and controlled by the blower-cock. Also, in some engines, as on the New York Central Railroad, there are steam and air jets in the fire-box above the grate.

Q. How does the blower act?

A. It directs a jet of live steam up the stack, causing, by friction between that jet and the surrounding air in the stack, an air current to pass through the tubes to supply the deficiency.

Q. When should the blower be used?

A. In starting a fire; in clearing out dust and ashes in cleaning fire; in preventing black smoke at times; in enabling certain inside repairs to be made while the fire is burning.

Q. When should the blower not be used?

A. When the fire is drawn or dead, as that would draw cold air into the hot tubes and make them leak.

Q. Where is a good place to put the blower discharge?

A. Around the top of the exhaust-pipe.

Q. What are the chief uses of the dampers?

A. To prevent cinders and burning coals being dropped where not desirable, and to enable the draft to be completely checked when doors or dampers are closed.

Q. How are the ash-pan dampers worked?

A. By a bell-crank and rod communicating with a handle in the cab.

Q. Why is it necessary to have the dampers on a wood-burning locomotive shut air-tight, while on a coal burner *the dampers are not tight and some of them cannot be closed?*

A. Wood requires so little air to keep it burning, and a wood fire is so open, that air will readily pass up through it and keep it burning so freely when engine is shut off, that the dampers must be air-tight to control the fire. With coal a strong draft is required to burn it; so the natural draft does not have the same effect on a coal fire. If the fire is thick, very little air will draw up through it. However, it is a mistake to allow the dampers and ash-pan to be so open that the draft cannot be controlled, especially with free-burning coal. Some little air is said to be needed constantly to keep the grates cool with a thin fire. This is a matter on which there is a difference of opinion. English engines have very tight ash-pans and dampers. The English find it pays to keep them so.

Q. *What is the effect of working a long distance with closed dampers?*

A. To warp ash-pan and dampers.

Q. *What is the Hale ash-pan?*

A. A device on the bottom of the ash-pan hopper, consisting of a lever or hanger, pivoted at its upper end to a frame or bracket, and fastened at its lower end to the hopper bottom. When the hopper is closed the upper end of the hanger is back of the center of the hopper. Consequently, when the dump lever is operated, the hanger pushes the bottom away from the hopper. It facilitates dumping the ash-pan should the hopper be frozen.

Q. *What is the ash dump in a stayless boiler?*

A. A cylindrical chute or pipe, usually 18 or 20 inches in diameter, leading from an aperture in the bottom of a corrugated fire-box to the outside shell below, to discharge the ashes into the ash-pan.

CHAPTER IX

THE CROWN-SHEET

Q. *What is the most effective heating surface in a locomotive boiler?*

A. That of the crown-sheet.

Q. *How is the crown-sheet kept from being forced down by the steam-pressure between it and the boiler top?*

A. By sling-stays or by crown-bars.

Q. *In what direction do sling-stays extend?*

A. As nearly as possible at right angles to the surfaces which they connect. (See Fig. 30, page 43.)

Q. *What is the objection to staying crown-sheets by sling-stays?*

A. That to be of the greatest effectiveness, they should be perpendicular to both the surfaces which they connect. Now ordinarily, if at right angles to the crown-sheet they will be oblique to the shell, except right in the center line of the boiler.

Q. *How can this trouble be got around without discarding sling-stays?*

A. By making the boiler-shell over the crown-sheet flat and parallel therewith, so that each stay-bolt will be at right angles to both the surfaces which it connects, as shown in Figs. 57 and 58.

Q. *What name is given to this type of fire-box?*

A. The Belpaire.

Q. *What other advantage has this fire-box?*

A. That its sides can spring a little when the inner sheet is heated more than the outer one.

Q. *What is the advantage of having the fire-box top curved?*

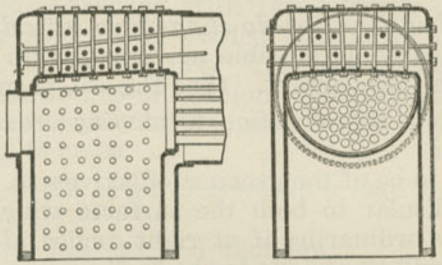
A. To enable the use of more radial stays than otherwise possible, and to give a good surface for reception of the radiated heat. The curved crown-sheet gives more full threads than the flat one, and affords less lodgment for impurities in the water.

Q. What is the disadvantage of curved crown-sheets?

A. They necessitate either throwing out too many tubes in the upper corners of the furnace, or else increasing the boiler-diameter.

Q. Where is the Belpaire fire-box undesirable?

A. On roads where there is bad water, by reason of its affording too good lodgment for scale.



Figs. 57 and 58. Belpaire Fire-box, Matanzas R. R.

Q. For what class of engine is the Belpaire box least desirable?

A. For eight-wheel and ten-wheel engines, as it throws too much weight on the leading truck.

Q. What is the reason of this?

A. The necessity of having a large waist for steam room.

Q. What other objections are raised to the Belpaire fire-box?

A. The difficulty of keeping the crown-stays tight near the ends of the braces which run from the back head to the top of the fire-box shell.

Q. How may this difficulty be done away with?

A. By substituting for the round back-head braces, gussets attached to the roof sheets by long angle irons; sometimes by running braces forward to the waist; by running them clear forward to the flue sheet; and by riveting heavy angle irons crosswise to the roof sheet as near as possible to where the brace ends are attached.

Q. What is the disadvantage of attaching the braces to the front flue sheets?

A. The vibration tends to produce leaks.

Q. What is another objection to the Belpaire type?

A. The difficulty of keeping the top turns of the thread tight where they join the shell.

Q. Should a crown-sheet be perfectly level?

A. No, it should have such inclination that when the engine is on a level the back sheet end will be lower than the front, to keep water on the back part after the front end may have got exposed.

Q. Why does the crown-sheet of a long furnace slope toward the back?

A. To keep it covered in running down a very steep grade.

Q. Does not this make it dangerous for the front end of the sheet in running up a steep grade?

A. No; as the front end is nearer the center of the length of the boiler, it is not so apt to be uncovered as the back end.

Q. What is the action of the crown-bars?

A. They serve as trusses to keep the top sheet from buckling in.

Q. How are the crown-bars fastened?

A. They have at each end feet resting on the side-sheet beam, and holding them slightly above the sheet; they are double, and between them and the sheet is a thimble through which, as well as through the sheet and the bar, goes a bolt; then the bars are slung from the boiler-shell, so that they support the crown-sheet, and the boiler-shell holds up the bars.

Q. What is the advantage of crown-bars for supporting crown-sheets?

A. Greater ease of repair than where direct stays are used.

Q. What are the disadvantages of the crown-bar system?

A. It affords good chances for scale and mud to collect on the crown-sheet, is heavy and expensive, and the bars take up considerable of the water room on the sheet; it does not afford good facilities for inspection or for washing out mud and scale; it is not practical for large boilers having wide crown-sheets and carrying high pressures.

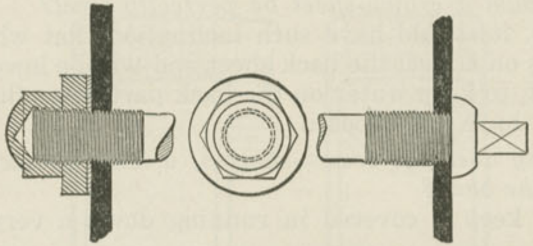


Fig. 59. Crown-stay Bolts and Nuts, Pennsylvania R. R., Class "O."

Q. What is the advantage of having the crown-bar bolts and the holes through which they pass, slightly tapering?

A. They are more readily taken out in case leaks occur.

Q. What is the advantage of having crown-bar washers tapering toward the sheet?

A. It gives more surface of the sheet in contact with the water, and lessens the liability to overheating around the bolt.

Q. Why are direct-stayed boilers flat-topped over the fire-box?

A. If they were not flat-topped, and were direct-stayed, the crown-stay bolts would not go squarely through the outside sheet.

Q. What difference would that make?

A. A full thread could not be had for the bolt in the outside sheet.

Q. Why is the dome on direct and radial stay boilers, ahead of the fire-box?

A. If over the fire-box, that portion of the crown-sheet directly under the dome could not be properly stayed.

Q. What is a radial-stay boiler?

A. One upon which that portion over the fire-box is round-topped and the dome is ahead of the box.

Q. Why is that staying called radial?

A. Because the crown sheet is somewhat round-topped and the crown stay-bolts are run straight through it, radiating from the smaller circle (crown-sheet) to points proportionately spaced on the larger circle (outside sheet).

Q. How is that portion of the boiler-head above the crown-sheet supported?

A. By braces, the ends of which are attached to crow-feet on the shell and boiler-head itself.

Q. What is the disadvantage of sling stays?

A. The difficulty of giving all equal strain.

Q. What is the disadvantage of radial stays?

A. That some of them are at such an angle that they have too little hold in the thread.

Q. What precaution is it well to take with them?

A. To give the center six or more rows down, the length of the fire-box, button heads under the crown-sheet.

CHAPTER X

THE BRICK ARCH

Q. How is the brick arch placed, and what are its functions?

A. It is built across the front of the fire-box, from side to side; and extends forward and upward, forming above the grate a diagonally-placed baffle-plate, preventing the flames and combustion gases from the front of the grate going directly into the lower tubes, and compelling them first to flow backward and upward; thus not only giving them time to get more thoroughly aflame, but causing more intimate mixture. Besides this, its fire-bricks get white hot and tend to assist the combustion when new coal is put on, especially with bituminous coal. It lessens black smoke by highly heating the unconsumed combustion products; also shields the flue-sheet and the flues from sudden influx of air when the furnace door is opened.

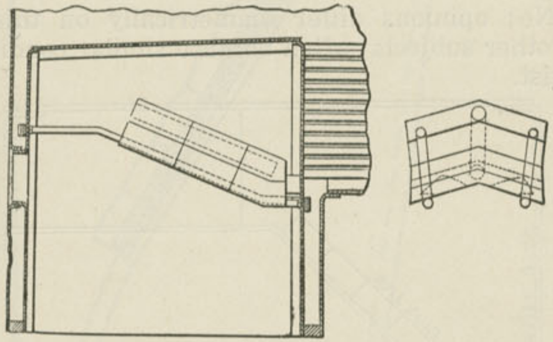
Q. How are the bricks of the brick arch held up?

A. By bent tubes secured into the crown-sheet and the tube-sheet, thus making water communication between the water-leg and the water on the crown-sheet; or by tubes between the front and the back leg. (See Figs. 60 to 63 inclusive.)

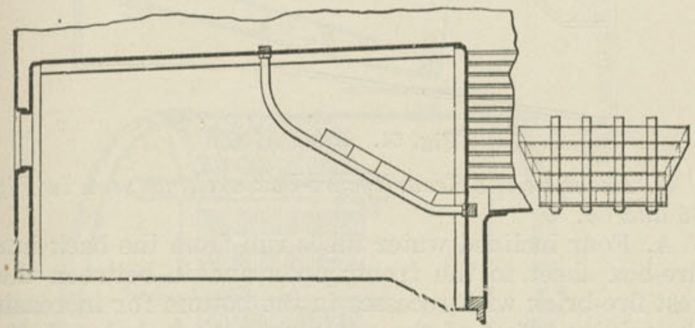
Q. Have any experiments been made as to the exact value of the brick arch?

A. Yes. Mr. J. N. Lauder, of the O. C. R. R., took two engines of the same dimensions and in about the same condition, and put them to run alternately on the same trains, one having the Pennsylvania Railroad style of brick arch supported by water-tubes, the other a plain fire-box. They ran "opposite each other" for two months, and care was taken to see that no extra work was done by either that would lessen the value of the

performance report. For one month the engine with the plain fire-box ran 50.87 miles per ton of coal; that with the brick arch, 58.22. For the preceding month the advantage was about the same. The train-weight was 160



Figs. 60 and 61. Brick Arch on Water-tubes.



Figs. 62 and 63. Brick Arch on Water-tubes.

tons besides the engine; the run, 36 miles, made in 52 minutes, with eight or ten "slows" and several "know-nothing" stops. The coal consumption was 34.3 pounds of coal per train mile with the brick arch and 39.3 with the plain fire-box, showing about four per cent saving.

Q. What about the necessary height of brick arch?

A. It should be higher than the fire-door, so as to deflect the air down on the fire when the door is open.

Q. Are all master mechanics, engine-runners, and firemen agreed as to the value of the brick arch?

A. No; opinions differ diametrically on this as on many other subjects; often because similar conditions do not exist.

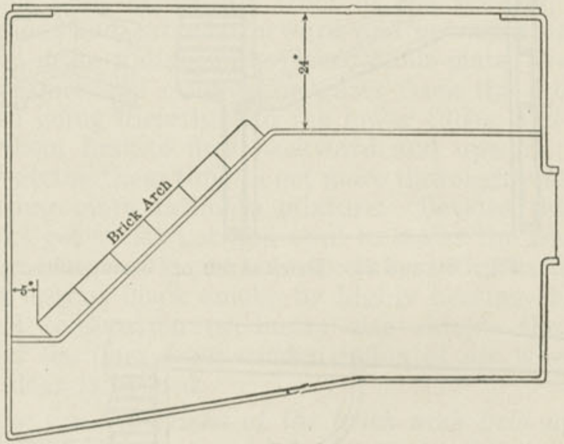


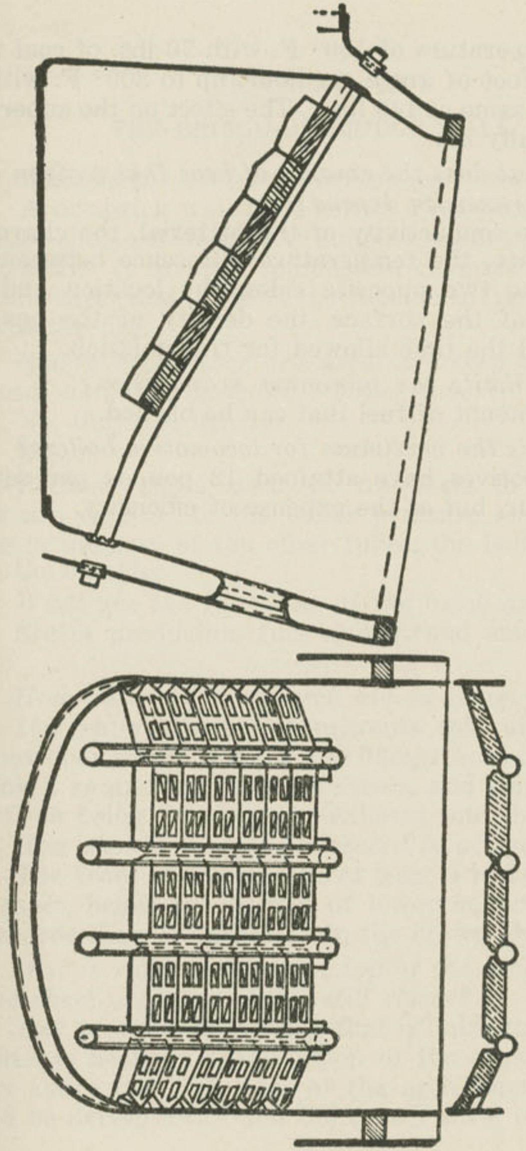
Fig. 64. Brick Arch.

Q. Describe the Security fire-box arch, as seen in Figs. 65 and 66.

A. Four inclined water tubes run from the back inner fire-box sheet to the front; upon and in between them rest fire-brick with recesses in the bottom for increasing the mixing effect of the gases, deflecting cinders better, and holding back the molten slag, which might otherwise honeycomb the flue sheet. The bricks may readily be removed to permit access to tubes and stay-bolts. Their ends are so shaped as to prevent their fusing together.

Q. What is the effect of such an arch on the fire-box and flue gas temperatures?

A. Tests on a Mikado engine showed an increase of



Figs. 65 and 66. Security Arch.

fire-box temperature of 100° F. with 70 lbs. of coal fired per square foot of grate per hour, up to 300° F. with 30 lbs. and the same at 140 lbs. The effect on the superheat was practically *nil.*

Q. On what does the amount of heat that a given area of surface transmits depend?

A. On the conductivity of the material, the character of the surface, the temperature difference between the fluids on the two opposite sides, the location and arrangement of the surface, the density of the gas, its velocity, and the time allowed for transmission.

Q. What limits the minimum evaporation?

A. The amount of fuel that can be burned.

Q. What is the maximum for locomotive boilers?

A. Locomotives have attained 12 pounds per square foot per hour, but at the expense of efficiency.

CHAPTER XI

THE BRIDGE OR BRIDGE WALL

Q. What is the bridge or bridge-wall in a fire-box?

A. A fire-brick wall built across a fire-box in front of the tube-sheet; often used to support the front end of the brick arch. It forms a combustion chamber in front of the tube-sheet and protects the tube ends from the direct heat of the fire.

Q. Where arch tubes are used, are they of the same material as other locomotive boiler tubes?

A. No, they are heavier.

Q. Why?

A. Because tubes used in fire-boxes to carry arch brick are exposed to the boiler pressure on the inside, while in the case of the other tubes, the boiler pressure is on the outside.

Q. What are the functions of the brick arch?

A. Steam producing, fuel saving, and smoke prevention.

Q. How does the brick arch aid in steam producing?

A. If rightly situated it prevents cold air from the fire-box door going direct to the flues, forces the flame up and back against the fire-box sheets, and stops the light coal from being lifted by the exhaust into the flue ends.

Q. How should an arch be located to get good results?

A. The front end should be at least 5 inches from the flue sheet, below the bottom of lower boiler tubes, and not nearer than 18 inches from the crown sheet.

Q. If it is right to keep the top of the arch that close to the sheet, why not go up still closer?

A. Any position closer than that is liable to cause such an intense heat, on that portion of the crown sheet directly above the high part of the arch, that the water would be driven away and the crown sheet blistered.

Q. Is the plan of setting arches on studs, screwed into the side sheets, better than setting them an arch tubes?

A. No; because where arch tubes are used the benefit of their heating surface is a great advantage in steaming.

Q. How many square feet would three arch tubes, two inches diameter, nine feet long, add to the heating surface?

A. About 14, or perhaps 8 to 10 per cent.

Q. Do you take into consideration that arch tubes sometimes burst, causing injury to men on the engines?

A. That does happen, but if the tubes are washed out every time the boiler is washed there is little danger of that.

Q. Do you mean that tubes fail oftener because of being allowed to fill with mud, than from any other cause?

A. Yes; other failures can be avoided by careful inspection.

Q. What is a water table?

A. A device for improving the combustion in the firebox. The form invented by William Buchanan, of the N. Y. C. & H. R. R. R., consists of two flat, parallel plates, extending diagonally upward from the tube sheet to the back fire-box sheet. These plates, which are about $4\frac{1}{2}$ inches apart, are strengthened with stay-bolts in the same manner as the inner and outer fire-box sheets, and form an inclined water leg connecting the front and back legs. A hole 18 or 20 inches in diameter is made through the center of the table for the passage of the combustion gases to the upper part of the fire-box on their way to the tubes.

Q. Is it extensively used?

A. No.

CHAPTER XII

THE GRATE

Q. What should be aimed at in grate designing?

A. To get the greatest possible percentage of air space between the bars without letting unconsumed or partly consumed fuel fall through.

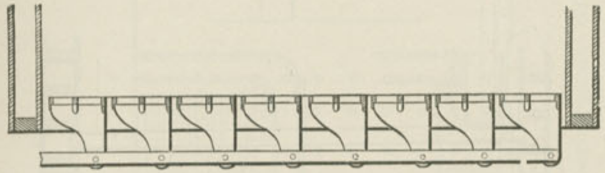


Fig. 67. Rocking Grate.

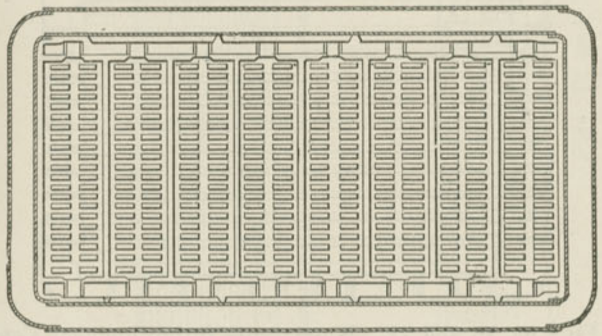


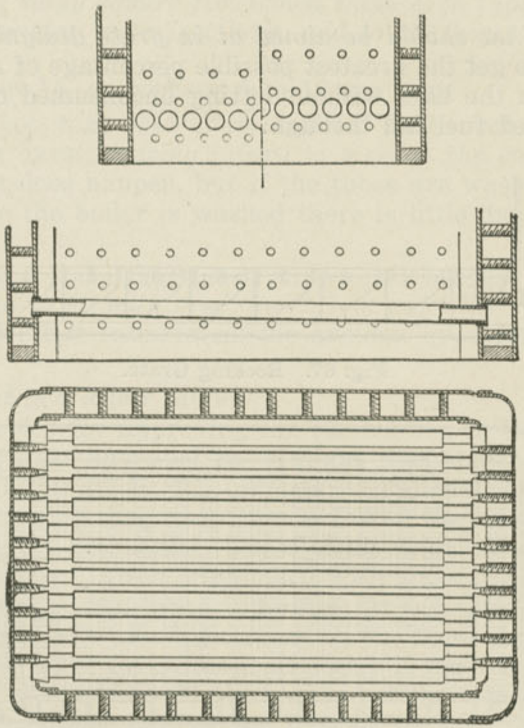
Fig. 68. Rocking Grate.

Q. How can the action of the fire on cast-iron bars be lessened?

A. By making the upper surface of each bar slightly concave or "guttered"; a film of ashes lies in the gutter and protects the iron.

Q. What is the best section for grate-bars?

A. They should be wider at the top than below, to lessen the liability of clogging with ashes or cinders the spaces between them.



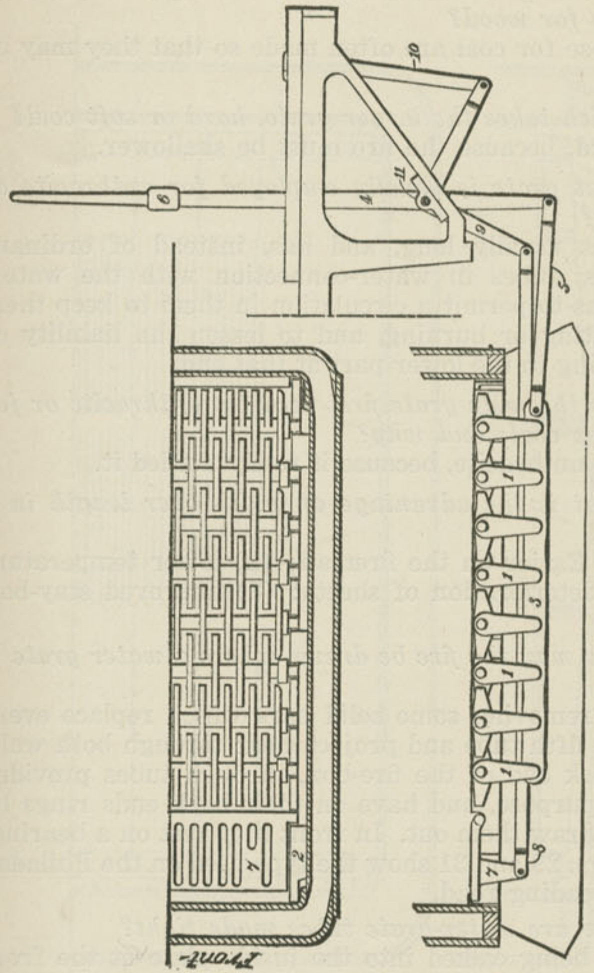
Figs. 69, 70 and 71. Water-grate for Bituminous Coal.

Q. What sort of a grate is required for burning anthracite coal?

A. One consisting of water tubes and pull bars.

Q. What class of grates are used for wood?

A. Stationary bars, ordinarily placed close together.



Figs. 72 and 73. Rocking-grate Work.

1. Bar. 2. Frame. 3. Connecting-bar. 4. Lever. 5. Lever-rod. 6. Lever-handle. 7. Drop-plate. 8. Drop-plate Rod. 9. Drop-plate Crank. 10. Drop-plate Crank-handle. 11. Drop-plate Crank-bearing.

Q. What difference is there between grates for coal and those for wood?

A. Those for coal are often made so that they may be shaken.

Q. Which takes the larger grate, hard or soft coal?

A. Hard, because the fire must be shallower.

Q. What grate is usually employed for anthracite or hard coal?

A. It is usually long, and has, instead of ordinary grate-bars, tubes in water-connection with the water-space so as to permit a circulation in them to keep them from melting or burning, and to lessen the liability of mud settling in the lower part at that end.

Q. Was the wide grate first used for anthracite or for bituminous coal; and why?

A. For anthracite, because it really needed it.

Q. What is the advantage of width over length in a fire-box?

A. (1) Easier on the fireman; (2) lower temperature and less deterioration of sheets; (3) improved stay-bolt service.

Q. How may the fire be drawn where a water grate is used?

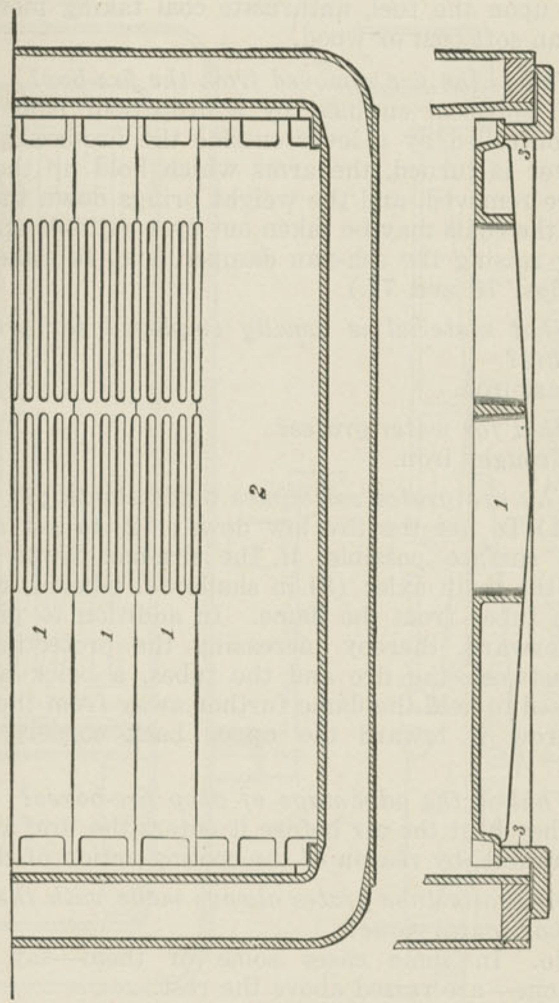
A. By removing some solid bars which replace every fourth or fifth tube and project clear through both walls of the back end of the fire-box, through tubes provided for that purpose, and have on their back ends rings by which to draw them out. In front they rest on a bearing-bar. Figs. 29 and 31 show the type used on the Philadelphia & Reading road.

Q. How are water-grate tubes made tight?

A. By being calked into the inside plate at the front and back end of the fire-box.

Q. How large a grate is needed to burn one ton of coal per hour?

A. About eight square feet. This of course depends



Figs. 74 and 75. Plain Grate for Wood.

1. Bar. 2. Dead plate. 3. End-holder.

largely upon the fuel, anthracite coal taking more surface than soft coal or wood.

Q. How is the fire removed from the fire-box?

A. In soft-coal engines, by a drop door held up by arms controlled by a lever outside the fire-box. When this lever is turned, the arms which hold up the drop door are removed, and the weight brings down the door so that the coals may be taken out by a suitable opening, and, by raising the ash-pan damper, may be raked out. (See Figs. 76 and 77.)

Q. What material is usually employed for ordinary grate-bars?

A. Cast iron.

Q. What for water-grates?

A. Wrought iron.

Q. Why are grates sometimes made slanting?

A. (1) To get the fire low down; (2) to get all the heating surface possible, if the fire-box front comes behind the main axle; (3) in shallow fire-boxes, to protect the tubes from the flame. In addition to pitching them forward, thereby increasing the protecting distance between the fire and the tubes, a brick arch is often used to hold the flame further away from the tubes and throw it toward the upper back corner, where needed.

Q. What is the advantage of deep fire-boxes?

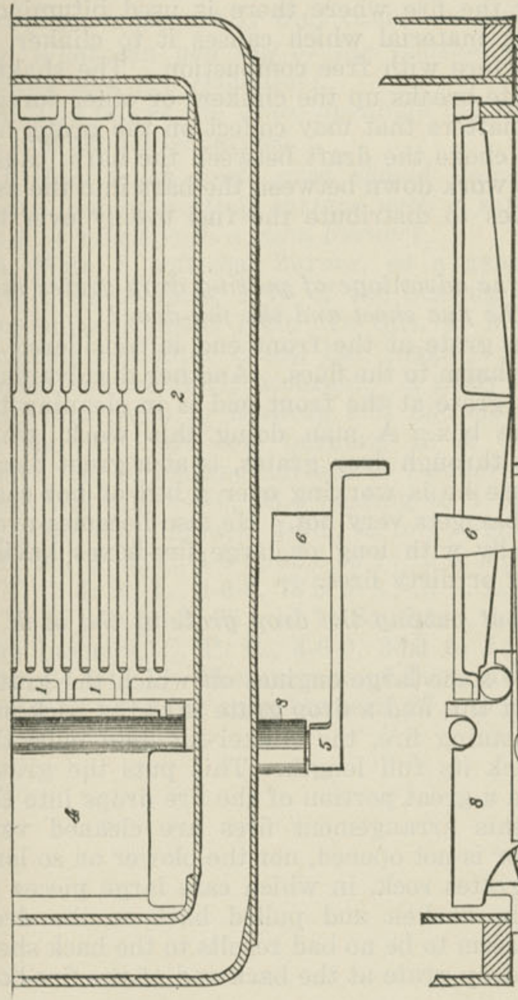
A. They heat the air before it enters the fire, and are more durable, by reason of the cooling action of the air.

Q. Are water-tube grates always made with the tubes in one horizontal plane?

A. No. In some cases some of them—say every fourth one—are raised above the rest.

Q. What is the objection to the method of putting water-tubes in from the front end?

A. They are more difficult to get at for cleaning.



Figs. 76 and 77. Plain Grate for Soft Coal.

1. Bar. 2. Dead-plate. 3. End-holder. 4. Drop-plate. 5. Drop-plate Handle. 6. Drop-plate Handle Support. 7. Drop-plate Shaft. 8. Drop-plate Shaft Bearing.

Q. What is the use of rocking grates?

A. To clear the fire where there is used bituminous coal containing material which causes it to clinker, or otherwise interfere with free combustion. The shaking or rocking grate breaks up the clinkers or other foreign or residuary matters that may collect on the grate, and which tend to choke the draft between the bars; causes such matter to work down between the bars into the ash-pan; and serves to distribute the fuel evenly over the grate.

Q. What is the advantage of putting drop grates mid-way between the flue sheet and the fire-door?

A. The drop grate at the front end is considered by many as doing harm to the flues. Another disadvantage of having this grate at the front end is in cleaning the fire out of the box. A man doing this work, while poking cinders through drop grates, is at a great disadvantage, because he is working over a bed of hot coals and the slash bar gets very hot. He also becomes over-heated, especially with long or large fire-boxes having badly clinkered or dirty fires.

Q. What about putting the drop grate at the back of the box?

A. There are some large engines on which the grates do not rock, but tip; and a drop grate is at the back end of box. In cleaning fire, the clinker-pit man pulls the grate lever back its full length. This puts the grates straight up and a great portion of the fire drops into the pan. With this arrangement fires are cleaned very quickly, the door is not opened, nor the blower on so long as where the grates rock, in which case large pieces of clinker must be broken and pulled back to the drop grate. There seem to be no bad results to the back sheet by having the drop grate at the back end of the fire-box.

Q. Is it possible to lower the grates in a fire-box; if so, how?

A. The grates should be as low as possible in order to

get all possible heating surface on the sides and ends of the fire-box. Their location, however, is limited by the mud-ring; consequently they cannot be lowered farther.

Q. What can you say of the relation between grate opening and fire thickness?

A. The larger the grate openings the thicker the fire can and should be carried.

Q. How much grate area should there be for each square foot of heating surface with a soft-coal burner, and how much with a culm burner?

A. With a soft-coal burner, as a general rule, the grate area is about 1/70 of the heating surface; with culm burners about 1/30. In this, as in other things, circumstances alter cases, but roughly speaking these proportions are fairly accurate. A study of various engines illustrated in *Railway and Locomotive Engineering* shows: Soft coal burners, B. & O., 2-8-0, 49.1 square feet of heating surface to 1 square foot of grate area; Wabash, 4-6-0, 83.4 heating to 1 of grate; D. & W., 2-8-0, 60.1; Monon, 4-6-2, 66 to 1; Frisco, 4-6-0, 61.9 to 1; M., K. & T., 4-6-0, 92.8 to 1; B. & M., 2-8-0, 61.5 to 1; N. C. & St. L., 4-6-0, 78.5 to 1; O. S. L., 4-6-2, 61.5 to 1; N. & W., 4-6-2, 76.1 to 1; Southern, 4-6-2, 71.4 to 1; culm burners, C. P. R., 4-6-0, 30.4 to 1; D., L. & W., 4-4-0, 24.4 to 1. The average of these soft coal engines is 69.3 to 1; of the culm burners, 27.4 to 1.

CHAPTER XIII

THE COMBUSTION CHAMBER

Q. What is a combustion chamber, and what are its uses?

A. A compartment of space in a boiler between the fire-box and the back tube-sheet to promote combustion and secure additional heat from the combustion gases before they enter the tubes. It is not yet commonly used. The back tube-sheet is in this case from 8 to 20 inches or more ahead of the fire-box throat, because with wide, shallow fire-boxes, the tubes give trouble by leaking unless kept away from the direct heat of the burning coal, where they are subjected to sudden and decided changes of temperature, as by putting on a strong blast, or by leaving open the fire door.

Q. Have combustion chambers been tried with locomotive boilers?

A. Yes, and especially recently with success. They tend not only to favor combustion but to keep the flues from the action of the flames.

Q. Is there any difficulty with combustion chambers filling up?

A. There is some accumulation of fine ash, but not enough to make trouble.

Q. What is the disadvantage of a combustion chamber?

A. With a given length of boiler, there is less actual heating surface.

Q. Then where is the principal advantage?

A. In lessening the repair bill and improving the combustion.

Q. How is the combustion improved?

A. Time is given to the unconsumed solid particles of fuel, and carbonic monoxide to combine with the oxygen of any free particles of air, the whirling action aiding.

CHAPTER XIV

THE TUBES AND FLUES

Q. What is a combustion chamber, and of what are its flues made?

A. In America, of iron and of Bessemer steel; in Europe, of these metals and also of copper and of brass.

Q. When were copper and brass flues or tubes abandoned in America?

A. After coal was substituted for wood.

Q. What are the usual dimensions of locomotive flues or tubes?

A. Ten to 14 feet long, two inches in diameter.

Q. What is the best length of locomotive flues?

A. From sixty to eighty times the diameter—from 12.4 to 14 feet gives the best results.

Q. What is the disadvantage of great length?

A. Increased friction; less heating power at the front end than at the back; leakage owing to vibration.

Q. What is the minimum distance apart for tubes?

A. Eleven-sixteenths inch in the clear; ¾ inch is better.

Q. What is the disadvantage of having them close?

A. They weaken flue sheets, retard circulation, and give sediment better lodging.

Q. What is the most difficult boiler trouble to control?

A. Leaky tubes.

Q. Will wide spacing cure leaks?

A. No.

Q. What are the influences affecting this leakage?

A. Length of flue, quality of water and of coal, method of firing and of working the injectors or pumps, weather, and severity of service; also the size of the nozzle.

Q. What is the influence of the nozzle on the flue or tube?

A. The smaller the nozzle the more trouble with them leaking.

Q. What causes tend to compel a reduction in the size of the nozzle?

A. Poor coal and severe service.*

Q. Why is this?

A. The smaller the nozzle the more severe the blast and the greater the blow-pipe action on the flue ends, making them hotter than the sheet in which they are expanded, so that when they cool down they become smaller than the holes in the sheet.

Q. In what part of the sheet are there usually the most leaky flues and tubes?

A. Usually below the boiler axis.

Q. What does this indicate?

A. That the short flames of highest temperature go into the lowest flues.

Q. To what design would this seem to point?

A. To one having a great depth of box below the flues, to keep them from the action of these hottest flames.

Q. Which are apt to have more trouble with leaking flues; through trains or heavy locals?

A. The latter, because as a rule with the severe exhaust in starting with the lever in the corner the ash-pan opening is not able to take care of all the draft, taking it through the fire-box and heating it before it comes to the flues; therefore a certain amount of cold air comes through the fire-box door.

Q. How can this be avoided?

* See under "Exhaust Nozzles."

A. Only by a milder exhaust in pulling out from stations.

Q. Which ends of the flues give most trouble?

A. Those in the fire-box.

Q. Why not use tubes of a larger diameter?

A. Because it is best to divide the combustion-gases into small streams, each of which has it outer surface next a surface of metal, on the other side of which there

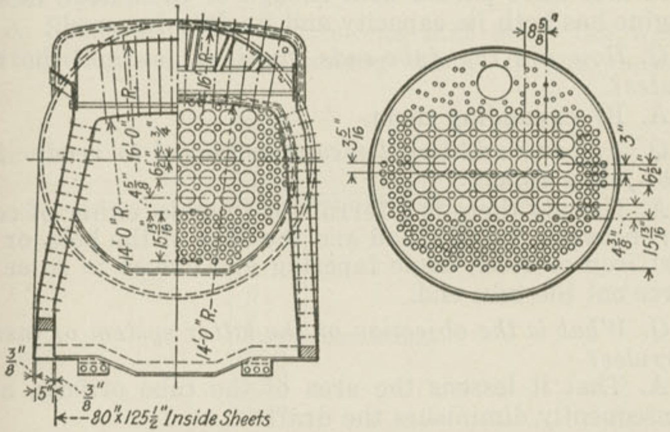


Fig. 78. Cross Section, Tube Sheets, K 4 s Engine, P. R. R.

is water to be heated. If the tubes were four inches in diameter, nearly all the heat of the central portion (say two inches in diameter) would be wasted, not having time to be delivered to the metal and through to the water on the other side.

Q. Why not have tubes only one inch in diameter, and give still more heating-surface?

A. Because there would be too great liability of clogging up, and also too much friction between the gases and the tube-surface.

Q. What is the disadvantage of excessive total cross-section of tubes?

A. Too slow draft, causing soot deposit.

Q. What is the disadvantage of too small total cross area of tubes?

A. Obstruction to the draft; besides which, the tubes are more liable to be clogged with cinders, and there is less space left when they are clogged.

Q. What is the disadvantage of too short tubes?

A. The combustion-gases get into the smoke-box before they have parted with enough of their heat, so the engine has both its capacity and its duty lessened.

Q. How are the tube-ends fixed steam-tight in the plates?

A. By expanding them.

Q. Are any additional means employed to render the tube-joints tight?

A. Usually there is a ferrule or thimble, either of copper, between the tube end and the edge of the hole, or of cast iron or steel, made tapering and driven in so as to force out the tube-end.

Q. What is the objection of the latter system of inside ferrules?

A. That it lessens the area of the tube orifices, and consequently diminishes the draft.

Q. What is the result of flue stoppage?

A. (1) There is less heating-surface, and (2) there is less draft to enable what heating-surface there is to be of use.

Q. How many tubes are there in a locomotive boiler?

A. From 180 to 450.

Q. How much heating-surface is needed to evaporate six to eight tons of water per hour with the consumption of one ton of coal per hour?

A. From 1,000 to 1,500 square feet.

Q. Is there any other reason, besides the greater proportionate amount of heating-surface, for having small tubes?

A. They may be thinner to stand the same external pressure; this of course makes them cheaper, lessens the engine weight, and makes it raise steam rather more quickly.

Q. Why is the tube-plate thicker than the shell?

A. Largely by reason of its being greatly weakened by the large number of holes cut in it, and partly because it has to sustain half the weight and sag of the tubes.

Q. Are tubes best arranged in vertical or in horizontal rows?

A. Some think in vertical, as that gives the water better chance to ascend among them. Others contend

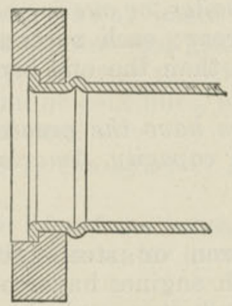


Fig. 79. Counterbored Tube Sheet.

that it is no advantage to have the water rise too fast; that it is better to have it delayed a little in its upward passage, so as to be longer in contact with the tubes. But it must be remembered that the bottoms of the tubes are not their hottest portion.

Q. What is an undoubted advantage of up and down as against crosswise rows of flues?

A. They are more easy to free from scale.

Q. How are the tubes made tight in the flue-sheet?

A. By being expanded from within so as to bear hard and steam-tight against the reamed edges of the hole;

also by being spread or beaded over on their outer ends, which have been left slightly projecting. This also gives a lengthwise stay to the sheets.

Q. What is the advantage of counterboring heavy tube sheets?

A. The amount of flue that is exposed to the heat and is not protected by the water is diminished. (See Fig. 79.)

Q. Which is more effective, a square foot of heating-surface in the fire-box, or an equal area in the tubes?

A. That in the fire-box.

Q. Which is the more effective, a foot of tube length in the front of the boiler, or one in the rear?

A. One in the rear; each successive foot in length being less effective than the one back of it, nearer the fire.

Q. Which engines have the greatest heating surface, for a given cylinder capacity, American or English?

A. American.

Q. Why?

A. They have iron or steel tubes and fire-boxes, whereas the English engines have copper fire-boxes and brass tubes, that are better conductors of heat.

Q. What is the disadvantage of the Serve tubes, with radial inward projections?

A. They fill up too rapidly.

Q. Do flues choked with cinders always indicate that the petticoat-pipe is not doing proper duty?

A. No; they may be caused by fuel that is too rich in tarry material; particularly by certain kinds of soft wood which make on the inside of the tubes a sort of varnish with which the cinders get mixed, thus very readily obstructing the flues.

Q. What other cause of stopped-up flues is there?

A. Unskilful or careless firing, by which pieces of coal are badly deposited in the lower flues.

Q. What effect has the stoppage of a large number of flues?

A. It lessens the draft of the heating surface, consequently, the development of steam.

Q. What steps will tend to prevent or lessen leaky flues?

A. (1) To educate enginemen to bring engines to roundhouse or coal dock with full boiler of water and good fire. Then the hostler and roundhouse man will not be required to put cold water in the boiler when the fire is dying down, being cleaned out, or after the engine is in house; (2) to use the blower very lightly—just strong enough to carry away gases and dust from the cab; (3) to see that the flue and grate cleaners and flue calkers do not put the blower on wide open when they go in the box to clean or calk flues, after the engine has just arrived in the house.

Q. What is apt to be the effect of a rainy season on a boiler?

A. To shorten the life of the tubes, especially if there is scale on them; the rain water loosens this and lodges it between the tubes.

Q. Are all the flues of the same diameter?

A. No; very often the upper ones are much larger, in order to permit the use of concentric super-heater tubes.

Q. What effect has greater tube length on combustion rate?

A. Diminishes it.

Q. Why?

A. Friction between combustion gases and tube walls.

CHAPTER XV

THE DOME

Q. What is the use of the dome?

A. Theoretically, to serve as a reservoir for steam and to give the steam a chance to drop some of its entrained water.

Q. Is it as effective in this particular as has been supposed?

A. No; a dome holds but a very few cylinderfuls of steam—not enough for ten seconds' supply; and usually weakens the shell by reason of the large hole cut therein. Practically it is only a convenient place of attachment for throttle-valve, safety-valve and other fittings. Many engines are without them, without appearing to have lost anything by the omission.

Q. Where is the dome usually placed?

A. In America, sometimes over the fire-box; in England (if at all) at about the center of length of the boiler, or in front.

Q. Why is the dome usually placed on the wagon-top?

A. Not to serve as a reservoir for steam, but to bring the dry-pipe inlet as high as possible above the water-level.

Q. How is the dome fastened to the shell or wagon-top?

A. Sometimes flanged at the bottom, to fit the circular top, and riveted on with two or three rows of rivets; up-to-date practice is with a steel collar, one side of which fits the circular top of boiler, and to the other side of which the circular portion of the dome is riveted.

Q. What do these collars resemble?

A. A "plug" hat with the top cut off, the rim being

riveted to the top of the boiler, and the other part where the shell of the dome is riveted.

Q. What is used to form the top of locomotive boiler domes?

A. Usually cast-iron, to the bottom or flange of which is riveted the dome shell. It also has a flat top into which are set the studs that hold the dome-cover.

Q. Of what are dome covers made?

A. Generally cast-iron; sometimes cast-steel.

Q. Why are dome covers made small when it would be so much handier in making repairs, if they were larger?

A. Because there is no means of staying them, except the studs around the rim, and it is therefore necessary, at least on high-pressure engines, to make the surface of the dome cover exposed to steam pressure as small as practical, or just large enough to let a man through the opening.

Q. What is the advantage of a stiffening-ring about the dome base?

A. To keep the shell from spreading at the dome where weakened by the dome-hole.

CHAPTER XVI

THE SMOKE-BOX

Q. What is the use of the smoke-box?

A. To afford an easy passageway in which the combustion-gases may turn from a horizontal to a vertical course in leaving the tubes and entering the stack; and

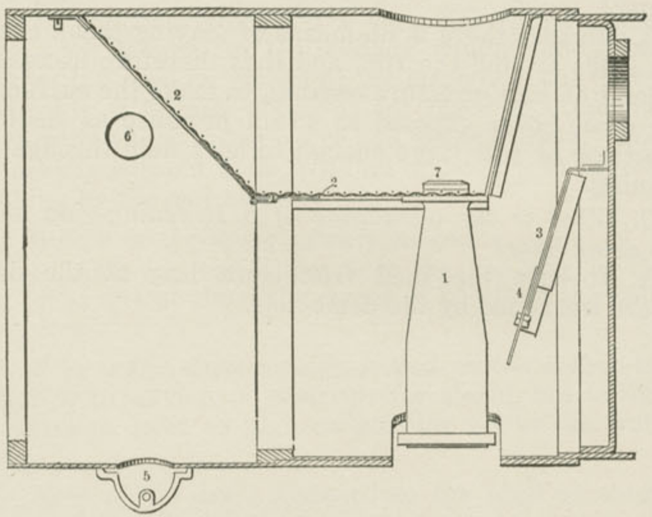


Fig. 80. Smoke-box and Fittings (Lengthwise View).

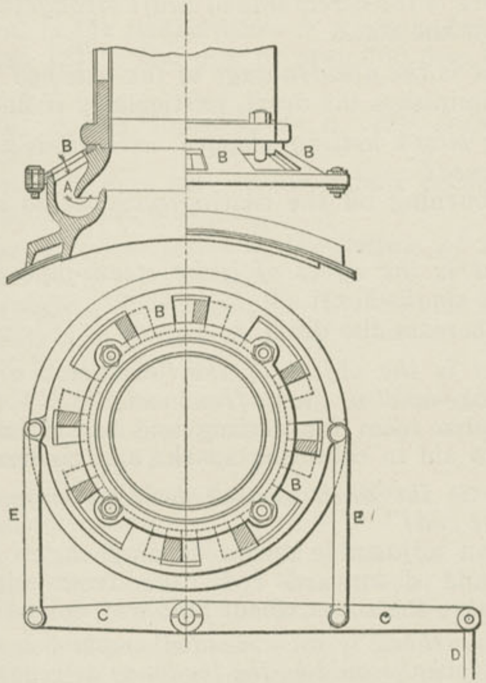
1. Exhaust-nozzle. 2. Netting. 3. Deflecting-plate Slide. 4. Deflecting-plate Slide. 5. Spark-ejector. 6. Cleaning-hole and Cap. 7. Exhaust-thimbles.

to serve as a receptacle for solid particles that have been drawn along through the tubes from the fire-box; to give room for the spark-arrester; also as a place in which the exhaust-nozzles may be properly inspected and adjusted; to keep the live steam hot on its way to the cylinders,

and to prevent the exhaust being chilled and thus losing its power of entraining air with it.

Q. Of what is the smoke-box front usually made?

A. Cast-iron, having in its center a large outward-opening door which permits inspection and repair of parts inside. (Fig. 80.)



Figs. 81 and 82. Luttgens' Damper for Coal-burners.

Q. How are engines with short front ends prevented from throwing too many cinders?

A. By "diamond stacks" having cones and nettings, against which the sparks and cinders are thrown, and which deflect them downwards, while permitting the combustion gases to go out.

Q. What are "sparks"?
A. Unconsumed or partly-consumed pieces of fuel.

Q. What is the object of the diaphragm in the smoke-box?
A. To prevent the upper rows of tubes getting too much draft and the lower ones too little.

Q. Where is the direct line of draft strongest?
A. Below the stack.

Q. What is the disadvantage of the netting?
A. It diminishes the draft, particularly if fine.

Q. How may a netting clogged with dirt and burnt oil be cleaned?
A. By burning off the coating with waste soaked in coal oil.

Q. What is the effect of leaky steam-pipe joints inside of the smoke-box?
A. To increase the draft.

Q. What is the object of the "extension arch" "extended smoke-box" or "long front end?"
A. To give room for netting and to act as a dead-chamber to aid in collecting sparks and cinders.

Q. How is the draft regulated in an engine with a "long front end?"
A. By an adjustable apron or diaphragm extending forward and downward from the front tube-sheets, slightly above the tubes, about half way down.

Q. Where there is an extended smoke-box or "long front end," what would be the tendency as regards draft-distribution?
A. For the upper rows of flues to get too much.

Q. How is this counteracted?
A. By the diaphragm-plate.

Q. If the exhaust-nozzles lie above and back of the wire netting, as in the long front end, how can they be got at for adjustment or repair?

A. By a man-hole or hand-hole in the netting; this being covered with netting in ordinary conditions.

Q. What is the effect, on the heaviness of fire required, of the long front end?
A. A light fire may be carried without danger.

Q. What effect has the long front end on the draft?
A. It weakens it.

Q. What is the temperature in a smoke-box?
A. From 121 to 650 deg. or even 700 deg. C. (250 to 1292 deg. F.)

Q. What is the objection to a very deep cast-iron cinder-box?
A. If it once gets afire inside it may become red hot and crack or break off.

Q. How is the material in the bottom of the smoke-box removed?
A. Through a discharge-pipe in each side of the bottom of the box, controlled by a valve or slide; being blown out by a steam-jet.

Q. What is the cause of making nettings get worse?
A. Getting them gummed with oil, caused by too hasty starting up after valve-oiling.

Q. Do stack-nettings (spark-arresters) tend to economy in steam-raising?
A. On the contrary, they are a cause of lowering the duty of the engine; and if it were not for the danger of causing fire by throwing sparks, should be abandoned.

Q. What is a good sign of a very bad spark-arrester?
A. When the combustion-gases tend to come out of the fire-box door when it is opened and the steam is shut off, that shows how much obstruction the spark-arrester causes.

Q. How should the inflow of air through the grates, and the outflow of air through the flues, be distributed?
A. Equally over their surfaces. Any front end that draws air through grates at any given point or through

any certain number of flues is defective, and will injure the tubes and fire-box, and, in addition, waste coal.

Q. How is the draft produced?

A. By creating a vacuum in the smoke arch. The front end that will produce the greatest amount of vacuum there, and give uniform distribution of air through the grates and flues without causing back pressure in the cylinders, is to be desired.

Q. What form of front end was formerly most used?

A. The short one with a diamond stack, bearing a large cone for breaking up and deadening the cinders. The top of the stack contained a netting to further reduce the cinders and lessen the danger from fires. A petticoat pipe, adjusted to a certain hight above the nozzle tips at the bottom and below the base of the stack at the top, controlled the draft. The smoke-box was usually of the same length as the cylinders.

Q. What led to a change in the form of front end?

A. The smoke and cinders thrown out of the stack were disagreeable to passengers, the cone braces would burn off, and the inside of the stack barrel, as well as the netting, would burn out, and thus increase the danger of fires.

Q. To what did experiments with the front end then lead?

A. To the "extension front end."

Q. Describe it?

A. An extension was added to the smoke arch front, of a length about equal to the short front end smoke-box. This was intended to hold the sparks until dumped out, at some designated point where the engine stopped, through a hopper on the smoke-arch bottom. A peep-hole was put on the smoke-arch side, so the condition of the smoke-box could be seen from without.

Q. What was used in the place of the cone in this type?

A. A deflector, or baffle-plate, and a netting in the front end below the smoke-stack base. A certain amount

of cinders was thrown, even at the commencement of a trip, with the front end clean; and if this was arranged so that cinders could not be thrown out at all, the engines would not steam and the front end would fill up in a few miles and require frequent cleaning out. Gradually these front ends were modified until they would go over the road without being cleaned out; so that after a certain amount of cinders lodged in the front end they were virtually self-cleaning. This style was supposed to lessen the danger of fire over the short front end.

Q. What objections were found to this style?

A. Fires were still set out. The front ends filled up and burned the smoke-arch so that it cracked and leaked, destroying the front end vacuum. Peep-hole plates leaked and frequently became lost; cinder hoppers burned out and leaked, and were hard to keep in good condition.

Q. What conclusion did locomotive men come to?

A. That if a front end cleaned itself out nearly all the way over the road it might as well do it all the way, and unnecessary equipment be done away with, and the whole front end be bettered thereby.

Q. What causes a partial vacuum in the front end when engine is working?

A. The exhaust from the cylinders escaping through the stand-pipe and passing up out of the stack. By reason of the force with which it escapes it draws along with it part of the contents of the front end.

Q. How is this vacuum refilled?

A. By air rushing in through the dampers, grates and flues to the front end and carrying with it a certain portion of the fire-box contents. As the exhausts come so rapidly as to be in a measure continuous when the engine is moving rapidly, the air passing through the grates to the front end is really a continuous current moving with a high velocity, which fans the fire into a fierce flame.

Q. Why does a leak about the smoke arch destroy the vacuum in the front end?

A. The air coming in at that point fills the vacuum in the smoke-box and diminishes the rush of air through the grates. This injures the draft and also the steaming qualities.

Q. Would elimination of the spark arresters in the front end make the engine steam more freely?

A. Yes; it would give better draft through the fire.

Q. With what is the partial vacuum in the front end commensurate?

A. The frequency and force of the exhaust.

Q. What effect on the front end has the blower when in use, or the air-pump exhaust when in the smoke arch?

A. The same as the cylinder exhaust only in a minor degree.

Q. What definition is given this form of draft?

A. Forced draft.

Q. What is the other form of draft?

A. Natural draft.

Q. Define natural draft?

A. The tendency that heated air and other gases have to rise, allowing cold air to come in and take their place. This is the draft that a locomotive has when standing idle with fire burning and blower and air pump exhaust closed. An engine that steams well under natural draft usually will with forced draft, and this indicates a well-arranged front end.

Q. What regulates the draft with the short front end?

A. The variable arrangement of the petticoat pipe with the nozzles as an auxiliary aid.

Q. What regulates the draft with the extension front end?

A. The baffle, or diaphragm plate, with the nozzles as an auxiliary.

Q. Has the fuel anything to do with the size of nozzle that may be successfully used?

A. Yes. A soft, easily-igniting coal, free from dirt and slate, will allow the use of larger stand-pipe tips than a harder coal containing more waste material and igniting more slowly. The larger the nozzle, the more economical will be the coal consumption.

Q. What would the result be if the baffle plate ran solidly from the top to the bottom of the smoke arch?

A. No communication from fire-box to smoke-box. Some forms of extension front ends almost reached this extreme by a roundabout road, and their creators seemed to wonder why their engines did not steam.

Q. What effect has raising the baffle plate from the bottom of the smoke arch?

A. The more it is raised, the freer the communication between fire-box and front end, and the less the deflection of the gases and sparks.

Q. What effect has the arrangement of the baffle plate on the flues?

A. The lower flues, being opposite the points of the most open communication, are naturally drawn on the hardest, and give out most quickly.

Q. To what was this early failure of the bottom flues often charged?

A. To their being in line with the fire-box door and receiving the rush of cold air through it when the door was opened in firing.

Q. Did the brick arch overcome this trouble?

A. Not altogether. Finally it was evident that about one-third of the tubes were doing three-fourths of the work, and that this result was chargeable to the front end.

Q. What aided in forming this conclusion?

A. The fact that with very large engines the upper rows of flues would fill up with ashes in a single trip, indicating that the same draft force was not exerted on these as on the lower ones.

Q. *In changing from the extension front end to the self-cleaning front end, what questions confronted master mechanics?*

A. Whether it would save coal; if a saving could be made in flues and the general care of the fire-box; if the cinders thrown out by the self-cleaning front end would be no more disagreeable to the traveling public, and involve no more danger of fire. The latter seems to have been the verdict after a fair trial, for the self-cleaning front ends have come into very general use.

Q. *What can be dispensed with in the self-cleaning front end, that was a necessary part of the extension front end?*

A. All that portion used to contain cinders, the cinder hopper and the peep-hole plate.

Q. *Does the short stack on a big engine give as good steaming results as the long stack?*

A. No.

Q. *How is this in a measure overcome?*

A. By a suitable petticoat pipe. Some roads have tried using an extension of the stack down into the smoke-box.

Q. *Has this proved on the whole satisfactory?*

A. It has not. It causes the smoke and gases to back up, as there is no opening to the stack at the bottom of the smoke-arch; this destroys the natural draft, and the smoke and gases coming out in the cab when the engine is not working steam make it very disagreeable for the men there.

Q. *Has the effort to dispense with petticoat pipes been a success?*

A. No. The locomotive requires smaller nozzles, therefore uses more coal and is more liable to back pressure. It steams more slowly when fired up, and the blower is not so effective, when an attempt is made to

force the draft. The exhaust becomes scattered and does not pass directly from the stand-pipes and the stack, as it should to create the best draft.

Q. *What should limit the length of the smoke-arch?*

A. The area of netting desired.

Q. *Is there any difference appreciable in the use of the single or double nozzle?**

A. Apparently not. Those using each type seem to consider that particular kind the best. The height of the nozzle in conjunction with the petticoat pipe seems of greater importance than the mere fact that the nozzle is single or double. The short nozzle is to be used with the long petticoat pipe, and *vice versa.*

Q. *How can the draft be changed with the baffle plate?*

A. An overlap plate is used at the bottom of the diaphragm plate. This can be raised or lowerd at will, to change the opening at the bottom of the smoke-arch and give a more open draft space.

Q. *Why is the baffle plate a disadvantage to the locomotive?*

A. Because the smoke and gases, coming almost instantly in contact therewith when they leave the flues, are deflected before being allowed to escape. Hence the name deflector or baffle plate.

Q. *What care should be taken in placing a baffle plate?*

A. It should be placed so that it will not be too close to the flue sheet, and angled away therefrom so that the sparks and gases will not be deflected too sharply downward. An engine with the baffle plate too nearly parallel with the flue sheet would not steam well.

Q. *If nozzle tips were extended above the stack base, what would result?*

A. The required vacuum would not be produced in

* See under heading "Nozzles."

the front end, and deficient draft would result. The nozzle tips must be enough below the stack base to draw on the contents of the smoke-arch. The petticoat pipe will remain for some time, at least, as a part of the smoke-arch equipment.

Q. *Why is it important that there be no holes through the smoke-box sheets or front, and none in the smoke-box seams or joints?*

A. Because these would tend to lessen the draft, or even to make a back draft when the engine was moving forward.

Q. *Is a fierce blast on the fire any indication of the best possible draft?*

A. No. The fierce blast is usually effected by a small nozzle, put in to overcome some other shortcoming of the draft arrangement, and causes the engine to consume more coal than it should to do its work, if it had a proper front end. Small stand-pipe tips very frequently cause back pressure in the cylinders, as the avenues of escape for the exhaust are too small.

Q. *What is the effect of different rates of evaporation on the smoke-box temperature?*

A. The temperature falls between the limits of 590 deg. F. and 850 deg. F., with hourly evaporation between four and 14 pounds per square foot of heating surface.

Q. *How does the steam pressure affect the smoke-box temperature?*

A. Practically not at all.

Q. *Give an equation showing the smoke-box temperature with relation to the water per square foot of heating surface per hour?*

A. According to Prof. Goss, $T = 488.5 + 25.66\ H$; T being the smoke-box temperature in degrees Fahrenheit and H the pounds of water hourly evaporated from and at 212 deg. F. per square foot of heating surface.

Q. *About how much draft will a locomotive have in the smoke-box?*

A. It will run from that corresponding to $3\frac{1}{2}$ inches of water pressure to 12 or even 13 inches.

Q. *What is the relation between the coal consumed per square foot of grate surface per hour and the draft in inches of water in the smoke-box?*

A. It is about 0.05; that is, the draft in inches of water is 1/20 the number of pounds of coal consumed per square foot of grate per hour; so that 200 pounds of coal per square foot of grate per hour would call for 10 inches of draft.

Q. *What may be said of the quality of the combustion-gases in the smoke-box of a locomotive as compared with that in the power plant stacks?*

A. It compares very favorably; the carbonic acid gas averaging between 10 and 13 per cent.

Q. *What may be said of the efficiency of a locomotive boiler at minimum and at maximum coal consumption?*

A. At maximum coal-consumption rate it will run from 39 to 60 per cent; at minimum from 63 to 79; the average being between 55 and 68 per cent; and in most cases above 60 per cent. Stationary boilers in first-class order and regulation settings, with every convenience to obtain good results from the use of fuel at comparatively low combustion rates do not often run over 70 per cent.

Q. *What is most to be desired in designing a front end?*

A. A design that will give the best possible result in the way of draft.

Q. *What is meant by "the best possible result?"*

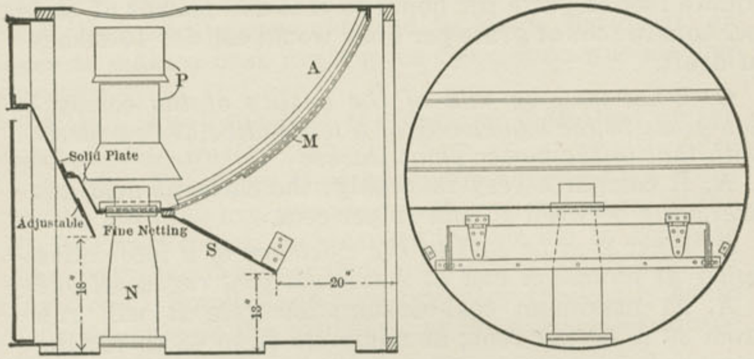
A. The greatest possible amount of steam that can be produced from a given amount of coal consumed, to perform a given work in a given time.

Q. *What is a cause of warping and cracking long front ends?*

A. Leaky doors on the front, causing the hot cinders to burn.

Q. Describe a self-cleaning front end?

A. Referring to Figs. 83, 84, there is a perforated steel table plate *A* with manhole *M;* back of the exhaust pipes *N* and petticoat pipe *P* there is an ordinary adjustable daphragm, set as high as possible. An adjustable front diaphragm or baffle-plate carries the draft far enough ahead to make the front end self-cleaning.



Figs. 83 and 84. Self-cleaning Front End.

Q. Can front ends without petticoat pipes be made self-cleaning?

A. Yes, as shown in Figs. 85 and 86.

Q. Why will not lead gaskets keep a blower joint in the smoke-box tight?

A. Because lead melts at 627 deg. F. (364 deg. C.) and the flue temperature is often as high as 1,000 deg. F. (say 575 deg. C.).

Q. Is the smoke-box temperature any gage of the capacity of the engine runner?

A. Yes, a good engineman can keep the temperature 100 deg. F. (55.6 deg. C.) lower than a poor one.

Q. What may the temperature of the gases in the smoke-box be?

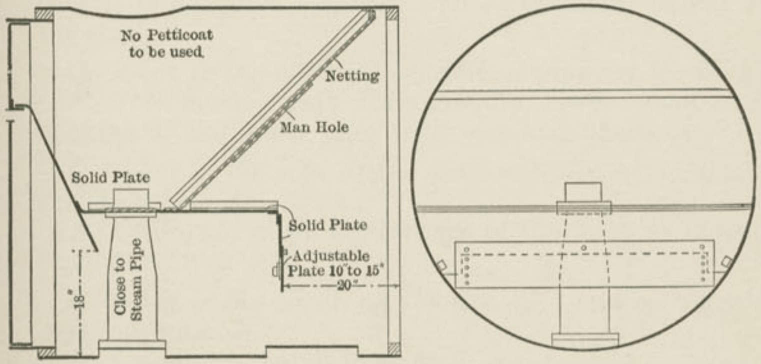
A. Anywhere from 400 deg. to 900 deg. F.

Q. When it is hot enough to melt lead gaskets in the blower-pipe joints is it too hot?

A. As lead melts at about 625 deg. F. the melting of the blower-joints in the smoke-box should show that heat was going up the stack, which should be utilized in steam-making.

Q. How should the studs which fasten the steam-pipes to the saddle be put in?

A. First greased, then rolled in graphite (plumbago; black lead) so that they can more readily be got out.



Figs. 85 and 86. Front End without Petticoat.

Q. What causes burning or warping of the "long front end"?

A. Burning of cinders therein, caused by a leak in the smoke-box; or by the door being partly open, or being warped so as not to close air-tight.

Q. When should the long front end be cleaned out?

A. When standing still, to avoid the sharp cinders cutting the machinery when blown back.

Q. What is the Sturm spark-arrester?

A. It is arranged so that the front and back screen sheets are closed automatically by a steam piston when the throttle is open; otherwise they are open, so as to give good draft.

Q. How may the draft be lessened, although the engine is running with a sharp exhaust, without opening the fire-door?

A. By a chimney-damper, as shown in Fig. 80. It admits air at the stack base, thus doing away with the necessity of opening the fire-door and admitting cold air into the box.

CHAPTER XVII

THE PETTICOAT-PIPE AND EXHAUST NOZZLES

Q. What is the use of the petticoat-pipe?

A. To insure uniformity of draft; that is, that the draft shall come from all the flues equally, notwithstanding the tendency of the upper ones to get the most; and that it is delivered centrally and at the right height in the stack.

Q. What is the effect of a petticoat-pipe set too high?

A. Too much draft through the lower flues, and choking of the upper ones with soot and fine ashes.

Q. What is the sign of the petticoat-pipe being set at the right height?

A. Uniformly clean appearance of the flues, as judged from the front end.

Q. What is the effect, on the fire, of a badly-arranged petticoat-pipe?

A. Usually to tear it in spots.

Q. How may this be remedied?

A. Partially by firing very heavily.

Q. How may the working of the petticoat-pipe and nozzle be judged while on the run?

A. By opening the fire-box door on a hard pull and seeing if the combustion is more vivid in certain places than in others. If this is the case, on several inspections, it may be concluded that these places are getting more draft than their neighbors.

Q. What becomes of the exhaust steam?

A. In a single-expansion (non-compound) engine the exhaust passes from the exhaust-passage through the exhaust-pipe, thence through the nozzle and up through the smoke-box into the stack, drawing with and around it a current of air and combustion-gases from the fire-box.

Q. What controls the amount of draft caused by the exhaust-nozzles?

A. Partly the point of cut-off, partly the degree and time of exhaust-opening of the slide-valve, partly the diameter and general character of the exhaust-nozzle, and partly the character and position of the petticoat-pipe or of the diaphragm.

Q. What object is there in having the exhaust steam go through the stack?

A. To create a draft.

Q. What is the blower pipe?

A. A pipe to convey steam from a valve on the boiler head to the exhaust-nozzle tip or stack base, to create a draft to stimulate the fire when the engine is standing; also to lessen black smoke when steam is shut off, as when approaching a station.

Q. How is the locomotive boiler given the strong draft that distinguishes it from other types?

A. When not running, by the blower. When running by the exhaust from the cylinders escaping through exhaust-nozzles or blast-orifices, discharging parallel with the axis of the stack so as to draw the combustion gases by friction with the steam-jets which they discharge. Of course the greater the steam consumption the stronger the draft, and the greater the steam generation by reason of the greater frequency or volume of the exhaust.

Q. How is the draft regulated in an engine with a short front end?

A. By a lift-pipe or petticoat-pipe between the nozzles and the stack, and which is larger than the nozzles and smaller than the stack. Raising or lowering this regulates the draft.

Q. What is the action of the exhaust-blast in making increased draft?

A. The jet of exhaust steam is usually of cylindrical section; whether it is or not, it has not smooth sides, and there as a certain amount of friction of the air in the stack, against it. As it moves up it carries with it by friction a certain quantity of that air, the place of which must be supplied by other air. As the easiest way in which air can get into the stack to supply the place of that which the blast has drawn out is through the grate, fire-boxes and tubes, we have at every puff of the exhaust a supply of air entering the fire-box through the grate.

Q. Of what material are the exhaust pipes?

A. Cast iron.

Q. Is there usually one nozzle or two?

A. Two; although there have been a number of plans by which the two blasts may be converged into one orifice; as for instance by one being conducted through an annular pipe surrounding the other.

Q. How are the exhaust orifices varied in diameter?

A. The nozzles are often removable, being fastened by set-screws so that they may be readily taken off or attached. There are also what are known as variable exhausts, by which the exhaust orifice diameter may be changed without changing the nozzle itself; but these are usually too complicated.

Q. What is the disadvantage of too large exhaust orifices?

A. Insufficient draft without the use of the blower, which latter of course calls for a consumption of live steam.

Q. What is the disadvantage of too small exhaust orifices?

A. Back pressure in the cylinders.

Q. How has it been attempted to draw the combustion-gases from the lower ranks of tubes with the exhaust orifices at the level of the upper ranks?

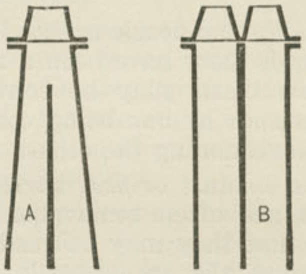
A. By what is known as the vortex nozzle, which has a central passage around which the exhausts discharge, and through which the friction of the inside of the annular exhausts draws combustion-gases from below; while the friction of the outside of the same annular exhausts draws these gases from the upper ranks of tubes.

Q. *What is the advantage of a double-nozzle exhaust-pipe?*

A. That neither cylinder interferes with the other.

Q. *What is its disadvantage?*

A. That the blast is not quite concentric with the stack.



Figs. 87 and 88. A Single and a Double Exhaust Nozzle.

Q. *How can these troubles be got around?*

A. Usually by having one nozzle surrounding the other.

Q. *Should the exhaust nozzle be larger for a hard or for a soft-coal fire?*

A. For hard coal and thin fires.

Q. *Is it feasible to reduce the blast-pressure and still have the boiler generate enough steam?*

A. Yes; as it is now, too much dependence is placed on the exhaust; and in England and in this country; it has been found that compound engines with soft blast have given just as good capacity and duty as high-pressure non-expansive ones with sharp.

Q. *As between the two kinds of exhaust nozzles shown in A and B, Figs. 87 and 88, what are the relative advantages and disadvantages?*

A. Style A has the advantage of giving a central jet through the stack, but as it does not exactly divide one cylinder from the other, the exhaust of one may slightly influence that from the other. Style B thoroughly divides the exhaust from one cylinder from that of the other, but does not give a central jet.

Q. *Do small nozzles cause saving or loss of fuel?*

A. Loss.

Q. *What is the objection to too small nozzles?*

A. They tend to tear the fire, and they cause back pressure in the cylinders.

Q. *As between single and double nozzles, which are preferable?*

A. Usually double ones, as the single ones tend to influence one cylinder by the exhaust of the other.

Q. *How may it be known that the nozzles are too small?*

A. Usually by the tearing of the fire, as well as by too sharp exhaust.

Q. *In what form does the steam jet, after leaving the nozzle, ascend the stack?*

A. In a screw or spiral.

Q. *Assuming that the jet "whirls," what would be the effect of the petticoat-pipe being too large?*

A. It would not keep the steam jet within proper bounds; some part might strike the smoke-arch top and interfere with the draft.

Q. *Of two exhaust pipes, one high and the other low, for the same stack dimensions and other conditions, which should be the larger?*

A. The low one, to give the same draft.

Q. *Will an engine draw smoke and cinders from the smoke arch in the steam chest and cylinder when run-*

ning down grade with the throttle closed and reverse lever in the forward notch?

A. Yes. The suction through the nozzles is very slight when running with reverse lever in full gear, but there is always some. When running notched up the action is very decided.

Q. *Do the diameter and length of the stack in any way affect the efficacy of a locomotive as a "steamer"?*

A. Yes; with some front-end arrangements a long stack does better than a short one. The general tendency is to reduce the height of the stack, and rely on the adjustment of exhaust tips, etc., to produce the best blast or draft.

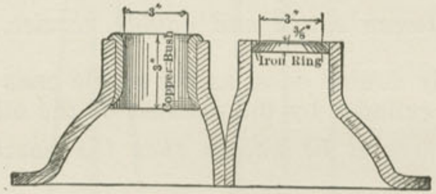


Fig. 89. Fig. 90.
Exhaust Nozzle.

Q. *Has the form of the exhaust nozzle, independently of the diameter, any influence on the draft?*

A. Yes. Fig. 89 shows a 3-inch copper bushed, Fig. 90 a 3-inch iron-ring bushed nozzle, where the saving in fuel was about 15 per cent.

Q. *What is the disadvantage of a very sharp exhaust?*

A. The combustion gases are drawn through the tubes too rapidly to be able to part with their heat.

Q. *Do contracted nozzles save or waste fuel?*

A. Waste it.

Q. *Does a high or low cone most obstruct the draft?*

A. A low one, particularly if wide.

Q. *Does a single exhaust nozzle need half the cross section than a double one has?*

A. No; because the exhausts are not simultaneous; but it must be somewhat larger.

Q. *How many nozzle-tips usually come with each engine?*

A. Three.

Q. *What does it indicate when the exhaust and smoke from an extension-front engine, of the M. M. S. pattern, all pass up to one side, or in front, or back of the stack?*

A. A poor steaming engine, with one of the following defects: 1, stack to one side, or front, or back of the exhaust pipe; 2, petticoat-pipe not set in true; 3, exhaust-nozzle not set squarely on the pipe, leaving a shoulder.

Q. *Will any other defect cause this side exhaust?*

A. Yes; when a petticoat-pipe is used, and that gets out of proper "line."

Q. *What is the object of the petticoat-pipe in extension-front locomotives?*

A. Its main purpose is to direct the steam jet from the exhaust-nozzle into the smoke stack, and also to make a more continuous pull on the fire.

Q. *Can the "pull" on the fire be manipulated to any extent by changing the position of the petticoat-pipe?*

A. Yes; the greater the space between bottom of smoke stack and top of pipe, the less continuous the "pull."

Q. *Does the diameter of the pipe cut any figure?*

A. The smaller the diameter (within certain limits) the stronger the "pull," because the smaller pipe gives velocity to the escaping matter from the front end, thereby causing the fire to burn more strongly.

Q. *How can you tell if the stack, exhaust pipe, and nozzle are all in line with each other?*

A. Stand between head-light and stack and hold the end of a stick over the inside, passing it around the top, when the engine is working. If the exhaust strikes the stick harder on one side than on the other, the stack is out of line, or not filled by the exhaust.

Q. Why not test this by sight from the cab?

A. Because the stack might be out of line front or back, and this would not show.

Q. How can the exhaust stand-pipe be tested for leak?

A. When the steam-pipes are tested with cold-water pressure, close the relief valves and cylinder cocks, plug the nozzle, fill all up with water, and put on the pressure.

Q. What is the best time and way to test the tightness of steam joints?

A. After the engine has been in the house some time, with fire dumped and about 40 pounds of steam, to open out the front end and cool the smoke-box, then give steam with lever in the center and cylinder-cocks shut, and test with a torch on a stick.

Q. What is a common cause of leaky exhaust-pipe joints?

A. Where the nozzle is fitted to the stand-pipe with a flat ground joint and only two studs, there is apt to be an opening at the quarter places between the studs.

Q. What is the remedy?

A. Two more studs.

Q. What is the prevention?

A. Three studs instead of two.

Q. How can a leaky exhaust-pipe joint be tested?

A. By plugging the nozzle, opening the angle-cock on rear of tender, closing the cylinder-cocks and relief-valves, and pumping up air; the torch will show any leak at the joint.

Q. Suppose the air-pump exhaust is not coupled into the main exhaust?

A. Break the joint, red-lead one face; bolt the joint together, and see if complete metal-to-metal contact has been made.

Q. If a gasket be used here, what is the best kind?

A. Soft copper.

Q. What precaution should be taken to prevent the engine from throwing fire?

A. Not to cut off so sharply; to increase the size of the exhaust nozzles.

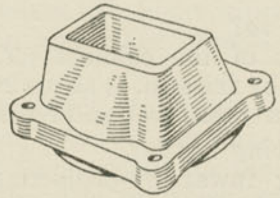
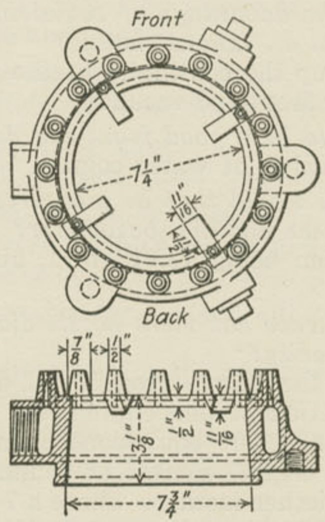


Fig. 91. Rectangular Nozzle.



Figs. 92 and 93. Wing Nozzles.

Q. Give a concrete example of saving effected by changing the exhaust nozzle tip?

A. On a Mikado engine a change of 3/8-inch in the tip diameter increased the draft so that the fire-box temperature rose 400 degrees. The saving effected was $57,000 a year.

Q. *What is the most effective cross section of exhaust nozzle?*

A. Rectangular, with the long axis in the axial line of the boiler.

Q. *Why is this so?*

A. The surface of the exhaust jet, that draws the combustion gases by friction, is about 20 per cent greater than for a circular cross section of the same area.

Q. *What is a wing nozzle?*

A. One having inwardly projecting radial pins to prevent the whirl of the exhaust and combustion gases. (Figs. 92, 93.)

Q. *What is the advantage of radial internally directed projections in an exhaust nozzle?*

A. To break up the continuity of the exhaust jet and create a greater front-end vacuum.

Q. *What would be a good front-end draft?*

A. 15 to 18 inches of water column.

Q. *How much would that be measured by a mercury column, such as we find in a barometer?*

A. The relation being 13.612 to 1, about 1.1 to 1.31 inches.

Q. *What influence has mere nozzle diameter upon the evaporation capacity?*

A. Reducing the nozzle from 7 in. diameter to 6¼ in., the evaporation of one engine was increased from 53,600 actual or 72,500 equivalent pounds per hour to 59,300 actual or 81,900 equivalent pounds, that is, 10.63 per cent. In another instance where a 7-inch nozzle was replaced by a 6¾-inch and an 8 in. wide deflection plate joint on the edge of the table plate in front of the nozzle there was an increased evaporation of 14 per cent.

CHAPTER XVIII

THE STACK

Q. *What is the object of the stack?*

A. To make a draft and to remove the hot combustion-gases and cinders to a hight which will enable them to clear the train and other objects near the ground-level.

Q. *What is the object of making it larger at the top than at the bottom, when it is so done?*

A. It gives a better passage for the combustion gases, and lessens the distance to which sparks are thrown; thus it helps the draft.

Q. *Into what classes may stacks be divided?*

A. Into inside and outside.

Q. *What is an outside stack?*

A. One which does not extend into the smoke-box.

Q. *What is an inside stack?*

A. One which extends down into the smoke-box.

Q. *With a tapered stack, what relation is there between the diameter for best results and the hight?*

A. The diameter does not vary with the hight.

Q. *Is the diameter for a stack affected by the hight of exhaust tip?*

A. Yes; the diameter for the best result is greater as the nozzle tip is lowered.

Q. *What is the relation between the stack diameter and the front end when the exhaust tip is at the center of the boiler?*

A. The smallest stack diameter should be one-quarter as great as the front-end diameter.

Q. *What is the relation between the diameter and the hight of the outside stack?*

A. The diameter does not need to be varied when the hight is changed.

Q. With inside stacks, what is the relation between the diameter and the degree of penetration?

A. As the penetration into the smoke-box increases, the stack diameter should be reduced.

Q. What is the disadvantage of a false top for an inside stack?

A. It interferes with free access to the front end.

Q. What gives practically the same result as a false top for a stack?

A. A ring or flange; a bell is almost as good.

Q. What kind of a stack is usually given with the long front end?

A. A plain cylindrical one like a straight pipe. (Fig. 95.)

Q. What is the diamond stack?

A. It has a central pipe, above the axial line of which is a cast-iron cone-like deflector against which the sparks and cinders strike, this causing many of them to fall, besides lessening the force with which the others strike the wire netting that is put over the top of the pipe to prevent live cinders getting into the open air. Below the cone is a chamber into which the sparks may fall, and where they may cool. (See Fig. 96.)

Q. What gives its name to the diamond stack?

A. The outline of its top.

Q. What name is given to the conical plate suspended in the axis of the diamond stack, near its top?

A. The spark-deflector or cone.

Q. For what classes of fuel is the diamond stack specially adapted?

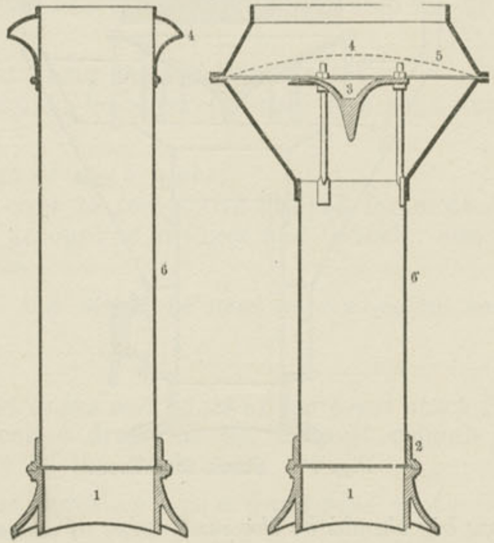
A. For bituminous coal and for wood, when the smoke-box is small.

Q. What may be said of the annular space between the two cylindrical shells of the stack for wood-burning engines?

A. It must be wider than for other fuel, to receive sparks.

Q. What other form of stack besides the diamond stack is used for burning wood?

A. The form shown in Fig. 97, in which there is a very wide double cone-top surrounding a central cylin-



Figs. 95 and 96. Smoke-stacks (old type).

1. Base. 2. Base-flange. 3. Cone. 4. Top. 5. Netting. 6. Body. 7. Chamber. 8. Inside Pipe. 9. Hand-hole and Plate.

drical pipe, a cone deflector, and a central wire netting. The space around the central pipe serves as receptacle for cinders and is supplied with a hand-hole through which they may be removed.

Q. Of what materials are smoke-stacks usually made?

A. For ordinary requirements the outsides are of sheet iron; sometimes with cast-iron tops to prevent abrasion. Where the climate is very damp and warm, copper is sometimes used for the stack. For all climates, the nettings are of iron or steel wire.

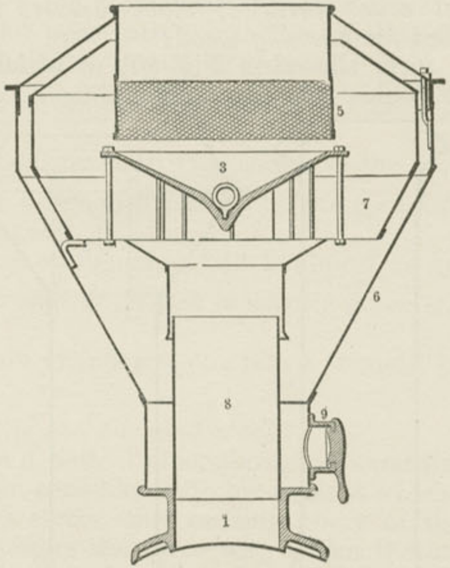


Fig. 97. Stack for Wood.

Q. How big should be the inner pipe of a smoke-stack?

A. For non-compound engines, about an inch smaller than the cylinder-diameter; sometimes of the same diameter as the cylinders.

Q. What is the disadvantage of a stack that is too large at the bottom?

A. It will get clogged at the bottom, by soot.

Q. What is the test of the correctness of stack diameter?

A. If the exhaust keeps it clean along its full length, it is all right.

Q. How high should the stack be?

A. The higher the better, by reason of the greater draft which can be given; but this is limited by the tunnels and bridges, etc., along the line, to 14 or 15 feet above the rail. Of course in such an engine as the Wootten—the central line of the boiler of which usually stands about a foot and a half higher than in other engines—this makes a proportionately short stack, and proportionately less draft, which must be made up for by other means.

Q. What about the stack diameter?

A. It should be several inches less than that of the cylinder.

Q. What of stack hight?

A. Not over 15 feet above the rail for most American roads, on account of bridges and tunnels; less for British engines.

Q. Can the stack be used as a so-called smoke consumer?

A. No.

Q. What is the evil effect of too great stack diameter?

A. Defective draft, as the exhaust column does not sufficiently fill the stack area.

Q. What influence has a draft-pipe on the necessary stack diameter?

A. The presence of a draft pipe calls for a stack of smaller diameter than would be used without it; but no possible combination of single draft-pipe and stack gives a better draft than can be obtained by a properly proportioned stack without a draft-pipe.

Q. What are the advantages of a double draft-pipe?

A. It makes a small stack workable.

Q. Can it give a draft equal to that which may be obtained without them, if the plain stack is suitably proportioned?

A. No.

Q. Why are some stacks made with an inner and an outer shell?

A. To give an air space to keep the outer shell cool and prevent its being cut away by cinders. Cast-iron stacks do not require it.

Q. Are there any kinds of locomotive smoke-stacks which may be said to save fuel?

A. It seems to be the sense of many master mechanics that smoke arches may be arranged to prevent sparks from setting fire to fences, etc., but that all the saving which has been done upon engines having the "long front end" and special spark-arresting devices, is by reason of the brick arch in the fire-box.

CHAPTER XIX

PRESSURE-GAGES

Q. How is the engine-runner informed of the pressure in the boiler?

A. By a steam-gage, the essential part of one kind of which is a shallow circular metal box having opposite sides of elastic corrugated plates which the pressure of the steam tends to force apart. The amount of their

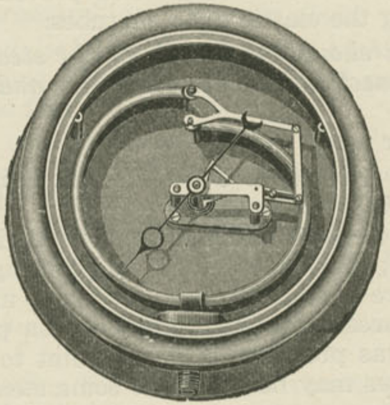


Fig. 98. Interior of Crosby-Bourdon Steam-gage.

movement is indicated by a pointer traveling about a circular dial graduated to indicate the pressure in pounds per square inch above atmospheric pressure.

Q. Is there no other form of steam-gage than the one with disks forced apart by the pressure?

A. There is the Bourdon type, in which the pressure is made to straighten more or less a curved flattened elastic metal tube. (Fig. 98.)

Q. What is the tendency of increased internal pressure on the bent flat tubes?

A. To straighten them.

Q. Name some makes using tubes?

A. Bourdon, Crosby, Ashcroft.

Q. Using disks?

A. Utica.

Q. What precaution is taken to prevent the steam taking the temper out of steam-gage disks or tubes?

A. They are put on with a turn or two of the pipe between boiler and disk; the bend of the pipe gradually filling with condensed steam, which prevents live steam from touching the elastic disks or tubes.

Q. To what should the handle of the steam-gage point when the connection between the latter and the boiler is shut off?

A. To **O** or zero.

Q. Does its pointing to **O** *when steam is shut off necessarily show that it is covered?*

A. No. If it point to a figure above **O**, it is certainly out of order; but the fact of its pointing to **O** when steam pressure is shut off does not prove its correctness even at low pressures. It might keep on pointing to **O** when there was pressure on it; or point to 90 with 100 pounds. Gages may be "fast" at some steam pressures, "slow" at others.

Q. What is the most dangerous steam-gage to have, a "fast" or a "slow" one?

A. A "slow" one.

Q. How should steam-gages be tested?

A. Against a standard mercury column, and by competent persons.

CHAPTER XX

STEAM PRESSURE

Q. What is your understanding of steam pressure, as shown by the steam-gage?

A. It is pressure per square inch on the interior of the boiler and connected parts over and above the atmospheric pressure of about 14.7 pounds per square inch. (Pressure including such atmospheric pressure is called "absolute pressure" or "pressure above vacuum.")

Q. Is it advisable always to carry high pressure?

A. Yes; just below the blowing-off point; this saves water, hence fuel.

Q. What are the causes of this water saving?

A. They are two : (1) Less water is carried over mechanically by the high-pressure steam; (2) this high-pressure steam is from the purely caloric standpoint more economical. There is also less risk of knocking out a head.

Q. How may a sudden rise of pressure be counteracted?

A. By opening the heaters, starting the feed, damping the fire, and even blowing the whistle, after muffling its bell by a rag over its mouth.

Q. Do you consider it wasteful to have an engine blow off steam frequently?

A. Decidedly; also in less degree to be always whistling.

Q. What are the advantages resulting from using high pressure steam with short cut-off, as compared with throttled steam and late cut-off?

A. (1) Drier steam; (2) Less water evaporated and less coal burned to do the same work; (3) less steam to get rid of at stroke end, free exhaust, especially for high speeds; (4) the expansive force of high-pressure steam being much greater than that of low-pressure steam, there is increased economy.

Q. With how much steam should the engine come in to the terminal station?

A. With enough to run into the round-house after the fire-box is cleaned out.

Q. What precaution should be taken in drawing the fire?

A. To use the blower sparingly, in order to prevent causing leaks.

Q. What should be done as soon as the ash-pan is cleaned out?

A. All dampers closed, to let the sheets and flues cool gradually.

Q. How much more than the regular working pressure should a boiler be able to stand before bursting or otherwise giving way?

A. Five or six times as much.

Q. What is the theory of explosions advanced by the Railway Master Mechanics' Association?

A. Explosions occur from over-pressure; it matters not whether the whole boiler or a portion is too weak to resist the pressure.

Q. What is the most prolific source of locomotive boiler explosions?

A. Broken staybolts are said to account for nine-tenths of them.

Q. How often should the pressure-gage be tested?

A. Monthly.

Q. How are pop-valves set?

A. First, one against the other. The one that loses the least steam should be set to be the first to open. This should then be screwed down, the other set at two or three pounds more than boiler pressure, then the first one opened out to boiler pressure.

Q. What about the proper steam-pressure to secure best fuel economy?

A. It should be kept just below the blowing point; giving drier steam and enabling the surmounting of difficulties.

Q. What are the disadvantages of increasing the pressure of a locomotive boiler?

A. Increased weight for a given amount of heating surface; with feed water of poor quality, increased difficulty of maintaining the working condition of the injectors and boiler checks; increased difficulty of keeping the boiler tight; increased incidental losses, especially those from leaks of steam or water from the boiler and the cylinders.

Q. Can you quote a table showing the coal saving resulting from the employment of high pressure?

A. Yes; that made from the tests by Goss is as follows:

	Coal		
	Per I. H. P.	Saved for Each Increment of Pressure	
	Per Hour	Pounds	Per Cent
240 pounds boiler pressure.....	3.31	....	...
220 pounds boiler pressure.....	3.35	0.04	1.2
200 pounds boiler pressure.....	3.40	0.50	1.5
180 pounds boiler pressure.....	3.46	0.06	1.7
160 pounds boiler pressure.....	3.53	0.07	2.0
140 pounds boiler pressure.....	3.67	0.14	3.8
120 pounds boiler pressure.....	3.84	0.17	4.4

Q. Can you give a table from actual practice, showing *the steam per horse-power per hour under normal conditions of running, at various pressures?*

A. Yes; that of Goss is as follows:

	Steam per H. P. hr.		Steam per H. P. hr.
120 pounds boiler pressure	29.1	200 pounds boiler pressure	25.5
140 pounds boiler pressure	27.7	220 pounds boiler pressure	25.1
160 pounds boiler pressure	26.6	240 pounds boiler pressure	24.7
180 pounds boiler pressure	26.0		

Q. Does the rate of increase per pound of pressure increase or diminish?

A. The tests show that it decreases with each successive equal increment of pressure; thus an increase of pressure from 160 to 200 pounds results in an hourly saving of 1.1 pounds of steam per horse-power, while a similar increase from 200 to 240 pounds improves the performance only 0.8 pound.

Q. Do successive equal increments of pressure cause equal increase in coal savings?

A. No; an increase from 160 to 200 pounds results in the saving of 0.13 pound of coal per horse-power hour, while a similar change from 200 to 240 pounds results in a saving of but 0.09 pound.

Q. What effect have successive increments of pressure on the difficulties of maintenance of boiler and cylinders?

A. They increase with successive increments.

CHAPTER XXI

TRY-COCKS AND WATER GAGES

Q. How can the engine-runner know the hight of the water in the boiler?

A. By try-cocks or by a water-column.

Q. Where are try-cocks usually placed?

A. On the back end of the boiler, where they may be readily seen and got at.

Q. Where are they placed as regards the water-level?

A. One where it is desired to keep the water level, one about four or five inches above this, another about four or five inches below.

Q. What provision should there be for taking away the water that is discharged from the try-cocks?

A. There should be a drip into which each may discharge, and from which the water is carried through the cab floor by a drip-pipe.

Q. What precaution should be taken as regards the proper reading of the try-cock indications?

A. To let them discharge for a second or so to see whether the water which comes away is from below the water-level, or is steam that has been condensed in the gage-cock or its connection.

Q. What safety appliance should try-cocks have?

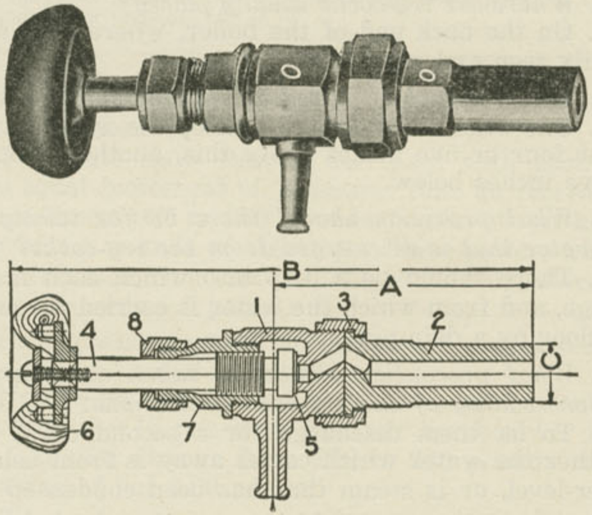
A. A check-valve, to close in case of accident to the cock.

Q. Is it safe to run an engine with one or more of the gage-cocks stopped up?

A. No. All should be in working order. If there was no water glass in working order and all gage cocks stopped up, the engine would be disabled as far as handling a train safely is considered. Because some men have done it, it is no sign that it is safe.

Q. What is the peculiarity of the Lee gage cock?

A. It consists of two parts, end to end, the outer one of which can be shut off from the boiler to permit repacking or renewing the working parts, without detaching the whole from the boiler. When the parts are in the position shown in Fig. 100, there is through steam communication; but turning the outer one through 180 degrees steam is cut off from the front parts.



Figs. 99 and 100. Lee Gage Cocks.

Q. Describe a water-gage or water-column?

A. There are two openings in the end of the boiler, one above and the other below the desired water-level. Into each is secured a fitting supplied with a screw-down valve which shuts it off from connection with the boiler space, and having a socket in which is inserted, with suitable packing, a strong glass tube. When the valves are open, the water should stand in the tube at the same

level as in the boiler with which the latter is in connection. There is from the lower one a drip-cock by which the tube may be drained when the valves are closed; suitable rods guard it from accidental breakage from outside. The tube may be either vertical or inclined; in either case the water-level should be at the same hight therein as in the boiler.

Q. Of what is it a sign when the water in the glass does not move up and down when the engine is on?

A. Of a closed bottom cock.

Q. Why "bottom cock?"

A. Because if the bottom cock were open, the water would bob just the same as if the top one were open.

Q. Then the water glass is not reliable?

A. Not if it is closed. The same might be said of the steam gage.

Q. Is the indication of water level by the gage glass a safe indication, if the water level in the glass is not moving up and down when the engine is in motion?

A. No; it is a sign that the tube connections are stopped up.

Q. Is any more water used when an engine foams than when water is solid?

A. Yes; because water is carried away into the cylinders with the steam.

Q. A fireman was firing a heavy Mogul engine, and there was a leak in the pipe from the boiler to the top of the water glass. This latter showed full when only one gage was in the boiler. He stopped the leak by a new gasket; the water then dropped to within two inches of bottom of glass. Explain this.

A. The false register was due to the leak in the pipe. The actual pressure in the pipe might not have been one ounce less than that at the bottom cock, but even that would raise the water in the glass six inches.

Q. Where should extra gage-glasses be kept?

A. In a tray in the tool-box, where they can be got at at once.

Q. What precaution should be taken about the gage-glasses?

A. To have them cut to length all ready to put in place, and with washers or hemp packing complete.

Q. Is the water-glass safe to run by, if the water line in the glass is not in sight, and moving up and down when the engine is in motion?

A. No. You could not tell the correct level of the water in the boiler. The cocks might be stopped up or closed.

Q. Under what circumstances can it be used to show the hight of water, if you cannot see the top line of water in the glass?

A. If water-level is above top end of glass, open blow-out cock at bottom of glass. If water-level drops and then suddenly rises when this blow-out cock is closed, the water is higher in the boiler than the glass will show. If below where it will show in glass, open throttle and start engine ahead quickly. The water will raise and show in the glass, but deaden the fire.

Q. With what class of valves are water-gage glasses generally equipped?

A. With automatic ones, which in case of a broken tube close and prevent hot water and steam escaping, thereby protecting its occupants and also saving the crown-sheet from burning, in case the breakage should occur when no one was in the cab.

Q. To render unnecessary drilling a number of holes in the boiler-head or shell for the various fittings, what is the best way?

A. To have a steam-stand with holes for the injector-valves, cylinder-oil cups, blower-valve, steam-gage cock, and brake-valves.

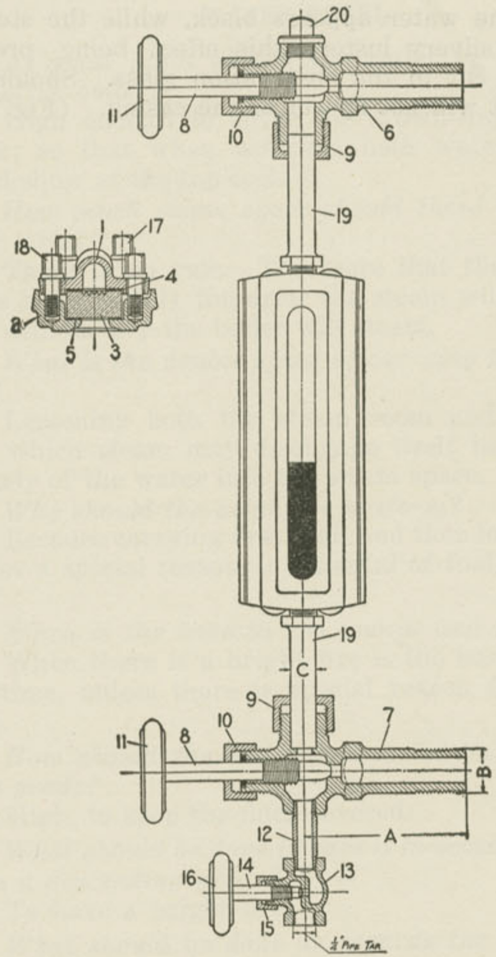


Fig. 101. "Klinger" Gage.

Q. What is the peculiarity of the Klinger reflex water gage?

A. The water appears black, while the steam shines with a silvery luster; this effect being produced by grooves cut in the observation glass. Should the tube break, it will not fly out of the casing. (Fig. 101.)

CHAPTER XXII

WATER LEVEL

Q. At what hight should the water be carried in a locomotive boiler?

A. High enough to cover the crown-sheet about six inches; so that when working, both water and steam should show at the top cock.

Q. How much steam space should there be above the water level?

A. There is no rule. The more that there is (other things being equal) the drier the steam will be, and the more satisfactory the boiler will steam.

Q. What is the double effect of carrying the water too high?

A. Lessening both the steam room and the surface from which steam may disengage itself in rising from the body of the water into the steam space.

Q. Why should the height be uniform?

A. Because carrying first high and then low water, unless for a special reason, is wasteful of fuel and hard on flues.

Q. When is the time to use pumps and injectors?

A. When there is a bright fire is the best, in fact the only time, unless there is special reason for otherwise doing.

Q. How should the water be carried on approaching an up grade?

A. High, to keep the flues covered.

Q. What should be done in case it is necessary to pump up on a descending grade?

A. To have a bright fire.

Q. What should be done as regards the fire on a descending grade?

A. If no water is put in, the fire should be leveled and covered to keep the steam-pressure down.

Q. Is there any advantage in having the boiler moderately full when pulling out of a station or when starting a hard pull for a hill?

A. Yes.

Q. How should the water level be at the top of an up grade?

A. Still high.

Q. What is the advantage of starting down grade with full boiler?

A. The injectors can be shut off and the boiler temperature kept uniform.

Q. If necessary to feed while the throttle is closed, what should be done?

A. The blower put on, to prevent sudden lowering of boiler temperature.

Q. What evil may accompany this?

A. Loss of steam from blowing off.

Q. Are enginemen likely to feed hard when working hard?

A. No; as this runs down the steam.

Q. Are they likely to do it with closed throttle?

A. Yes, because the circulation is less active and the steam pressure might remain high while the water chilled locally.

Q. Are the temperatures of steam and water in the boiler the same?

A. Yes, in those parts where the steam is in contact with the water; but at certain places the water may be colder, and the steam hotter, than the average.

Q. What advantage is claimed for carrying the water low?

A. More steam room and less lifting of water.

Q. Under what conditions is this safest?

A. With light trains and on level roads and where the feeding appliances are thoroughly reliable.

Q. What are the advantages of high water-level?

A. The boiler can be kept at a more uniform temperature, and there may be less trouble in "negotiating" grades; further, in case of failure of the feed there is more time to look into the difficulty.

Q. Under what circumstances can the water-glass be used to show hight of water if you cannot see the top line of water in glass?

A. By closing the top cock, or by suddenly opening out the throttle.

Q. If gage-cocks are stopped up, or the water-glass cock filled up so water does not come into glass freely, what is your duty?

A. To report the matter at once and not take out the engine.

Q. Is any more water used when an engine foams than when water carries well?

A. Yes.

Q. What is the effect of using black oil in the boiler and through the injectors?

A. It is apt to soften hard scale and to facilitate the injector working.

Q. Would you use valve-oil or lard oil for the same purpose?

A. No; it would cause foaming.

Q. What damage does it do to an engine to work water through the cylinders?

A. Often breaks out packing-rings or knocks out cylinder-heads.

Q. Is it a good plan to let an engine slip at such times?

A. No.

Q. What is it liable to do?

A. To break the cylinder-packing rings or cylinder-heads.

Q. Should the engineman run by the glass gage or by the cocks?
A. By neither alone. Either can give false indications. The one checks the other.

Q. Why does the water-level rise when the throttle is opened?
A. Because pressure is taken from the water, and the steam forms in greater quantities, lightening it.

Q. How can water be found in the boiler if the water drops below the bottom gage-cock?
A. By suddenly opening the throttle or blowing the whistle.

Q. When an engine is foaming badly, how must the true water-level be found?
A. By first shutting off steam.

Q. Which gage-cock is it most important to keep open and in perfect working order?
A. The lower one.

Q. Does water remain at the same level when the throttle is shut off?
A. No.

Q. What is the least depth of water on the crown-sheet that is safe?
A. One gage.

Q. How much water on the crown-sheet with one, two, and three gages respectively?
A. Usually the gages are three inches above the sheet and between each other.

Q. Do you consider it safe to run an engine with one or more of the gage-cocks stopped up?
A. No.

Q. Is the water-glass safe to run by if the water-line in the glass is not moving up and down when the engine is in motion?
A. No.

Q. If you were stopped on the road and found your water dropped out of sight, how would you try to raise it.
A. By opening the blower or the throttle, so as to make something like working conditions.

Q. Suppose that would not raise it to a safe hight, what would you do?
A. Deaden, draw or dump the fire.

Q. What should be done in case of failure of the water supply in the tender?
A. The train should be left and the engine and tender run to a water-tank, unless there was some stream, pond or other source of water that might be used.

Q. What should be done in case the water in the tender got low, in time of snow blockade?
A. The tender should be filled with snow, and this melted by the heaters.

Q. What should be done in case of the tank-valve getting off its stem and dropping into the seat so as to keep the water out of the hose?
A. The heater should be put on with full force for an instant, to drive the valve off the seat.

Q. Why not keep it on?
A. For fear of bursting the hose.

Q. How rapidly should water be supplied to the boiler?
A. As a rule, on levels, at the same rate at which it is evaporated; where, however, an up grade is to be taken, the feed should be shut off at the crest the injector may be put on to prevent over-steaming. If there is a down grade following, more feed may be put on than if there is a level at the top of the grade.

Q. Can a boiler explode if full of water?
A. Yes.; especially in starting out.

Q. Is injecting feed water on heated plates liable to cause an explosion?

A. No.

Q. What would be likely to take place?

A. Leakage at the seams.

Q. Describe the Sentinel low water alarm.

A. This is an appliance, mounted on the fire-box roof, and consisting of a small whistle in connection with the steam space, and the valve of which is operated by the expansion of a nearly horizontal pipe in communication with a vertical pipe reaching down to the level at which it is desired to give an alarm. Normally, this latter pipe is sealed and the expansion pipe is at a temperature under that of the usual steam in the boiler. If, however, the water level falls and unseals the vertical pipe, steam enters and expands the other one, which opens the whistle valve.

CHAPTER XXIII

THE WATER

Q. What is a bad effect of blowing out when hot?

A. Baking on mud or other foreign substances.

Q. How should a boiler be cooled down quickly?

A. By blowing off the steam and replacing it with cold water; then replacing the warm or hot water in the shell with cold. Or, running down two gages under forty pounds of steam, then cooling down gradually.

Q. What is an occasional source of grit in the water?

A. Holes in the tank top, through which cinders and coal may fall and clog the strainers.

Q. How can heavy mud deposits best be prevented?

A. By frequent washing only.

Q. How may water for locomotives be treated for carbonate of lime, sulphate of lime, and sulphuric acid?

A. By lime and soda ash.

Q. What is sometimes the effect of this treatment?

A. To cause the boilers to foam.

Q. What are the usual effects of limy water?

A. Leaky heating-surface, and incrustations.

Q. How may leaky flues or stay-bolts be cured temporarily?

A. By putting bran or potatoes in the feed-water, care being taken not to put in enough to cause foaming, and not to depend on it longer than to get home with.

Q. What is a good practical test of whether water in a tank is good enough for boiler-feeding?

A. If it curdles instead of making a lather with ordinary soap, it is too hard for boiler use, and should not be employed if any other can be had within reasonable distance, and in sufficient quantity.

Q. Do difficulties with bad water increase or decrease with the pressure?

A. They increase; with low-pressure there is practically no difficulty in washing out the sediment. With high pressures the temperature of the water delivered by the injector is sometimes so high that scale is deposited in the check valve and delivery pipe and in the injector delivery tube.

Q. Is there any one dope or compound that is a good antidote medicine for any and every sort of water?

A. No; a material, either simple or compound, that would be beneficial in the case of one kind of water might be inert when used with another; or might indeed be deleterious.

Q. What compound seems to be good for more kinds of water than any other?

A. Tannate of soda.

Q. Does the character of the water vary from season to season?

A. Yes; especially in districts where the melting snow or heavy rain dissolve out the soluble salts in the soil and carries them to the source of the station water. The composition of the water may even change from day to day.

Q. Are there any other sources of undesirable substances in the feed water than those furnished by Nature?

A. Yes; factories sometimes discharge, either regularly or occasionally, dye solutions, sludge, etc., that eventually find their way into the tender tank unless eliminated by filtering or chemical neutralization.

Q. Can chemical neutralization make such contaminated water even worse?

A. Yes, unless the resultant insoluble new compounds are filtered out before they reach the station tank or the the tender.

CHAPTER XXIV

THE SEPARATOR

Q. What is a separator?

A. A device by which entrained water may be separated from the steam—usually by wings or blades against which the steam impinges and which deflect and retard the water, while permitting the steam to pass on.

Q. Are separators much used?

A. Very little; the dry pipe is made to serve this purpose, and the use of superheated steam will probably cause them to disappear altogether.

Q. Why is it necessary to keep the cylinders free from water?

A. Because if water, which is practically incompressible, were to come between the piston head and the cylinder head, the latter might be broken out.

Q. In what condition is the entrained water usually contained in the steam?

A. In the form of small bubbles, each of which may be said to be surrounded by a film of steam not quite so hot and dry as that immediately surrounding it; in fact, a sort of intermediate stage between dry steam and water; the bubbles being kept in motion and above the bottom of the passages through which they are carried by friction and momentum.

Q. What is the injurious action of entrained water other than the danger which it brings to the cylinders?

A. It acts both mechanically and thermally; mechanically by simply reducing the volume of steam that reaches the cylinders—or at least the separator or the superheater; thermally by carrying over fewer heat units per unit of weight than steam does, even in the same container or passage. In this way it defeats the object of the engine—to turn as many heat units as possible in a given time into mechanical work. So after all the separator is a constant source of saving, and an insurance against serious and expensive accident.

CHAPTER XXV

SAFETY PLUGS

Q. What is a safety-plug?

A. A brass plug screwed into the crown-sheet at the point most likely to be burned, and having drilled through it a hole which is filled with an alloy that fuses at a temperature but slightly above that of the water and steam in the boiler at the highest pressure carried. Should the crown-sheet be left uncovered by reason of low water, and the plug be exposed to the fire, it will melt, and the steam will pass into the fire-box, not only giving warning but damping the fire; thus enabling the crown-sheet to be saved.

Q. Are these fusible plugs infallible?

A. No; sometimes their composition changes so that their melting point rises; sometimes they get covered over with scale so that they do not work.

Q. How often should they be renewed?

A. Every two or three months.

Q. For what reason?

A. Because with time the heat and the fire-box gases act upon the fusible core of the plug, so that it is not certain to melt at the desired dangerous temperature—say 445 deg. F., which is the fusing point of Banca ("Straits") tin, which is the temperature determined as best by the U. S. inspectors for marine boilers and generally adopted; also for locomotive practice.

Q. Can you give formulas for other alloys fusing at or about that of Banca tin just quoted?

A. The following may be considered as reasonably reliable:

Components	*Fusing Point*
Lead, 3; tin, 1	500°F.
Lead, 2; tin, 1	440° to 445°
Tin, 8; bismuth, 1	392°
Lead, 1; tin, 1	370° to 400°

CHAPTER XXVI

THE FEED-PUMP

Q. What is the usual type of feed-pump for locomotives?

A. There is a horizontal barrel with a plain round pole or plunger playing in a stuffing box. Below one end of this barrel is a suction-chamber, into the bottom of which the suction-pipe from the tank enters, and which contains a central pipe surrounded by an annular space serving as an air-chamber. Above the barrel and at the same end with the suction-chamber is a discharge-chamber through which projects a central discharge-pipe, leaving around it an annular air-chamber. Between suction-chamber and barrel is an upward-opening valve; between discharge-chamber and barrel is another upward-opening discharge-valve or pressure-valve; each of these being an inverted cylindrical brass cup resting water-tight on a brass seat, and working in a cage guide. When the plunger is withdrawn from the barrel there is formed (if the joints are tight) a partial vacuum, which is filled (if the plunger does not return too quickly) by water from the tank, which rises through the suction-valve. When the plunger again enters the barrel this water is discharged through the pressure-valve into the boiler—or at least into the air-chamber and pipe between the pressure-valve and the boiler—displacing other water that is in the same line. At the end of the feed-pipe furthest from the pump is another upward-opening valve called a check-valve, serving as a check or extra precaution lest the pressure-valve should not be tight, or should be injured, or held from its seat by a chip or other piece of foreign matter. The check-valve may be either inside or outside the boiler. The horizontal pump-barrel has attached to it a top chamber 2 (see Fig. 102), and a bottom chamber 3. The valves 4 above, and below it are practically the same, and play in cages 5 which may be readily detached from the pump-barrel and the chamber by running the nuts off the chamber-studs 10. The plunger 6 plays through the gland 7 which is inserted in the stuffing-box, and is held in by gland-studs 9.

Q. Where are the pumps usually placed and driven?

A. They are placed, usually, on the frames back of the cylinders, and driven direct from the crosshead; although sometimes they are inside the frames and driven by a small eccentric on one of the axles; sometimes again, although very rarely, they are outside the wheels, and worked by a connecting-rod from a short crank attached to the crank-pin.

Q. What name is given to cross-head-driven pumps?

A. Full-stroke pumps.

Q. What name is given to those worked by eccentrics from the driving-axles, or by cranks from the crank-pin?

A. Short-stroke pumps.

Q. Is the suction air-chamber always used?

A. No; but it is desirable to relieve the suction-valve from shock.

Q. How can the pump be dismounted for examination of the valves?

A. The pump-barrel and air-chamber are bolted together; breaking this joint and removing the air-chamber exposes the pressure-valve and cage. The suction air-chamber (or suction-valve chamber where there is no suction-chamber) may be similarly taken down from the barrel. An outside check-valve may be taken out by breaking the bolt-and-nut joint which holds up its valve-seat.

Q. What is the peculiarity of the locomotive feed-pump?

A. Its plunger is working at all times, whether water is needed in the boiler or not; making it necessary to have some means of controlling the supply.

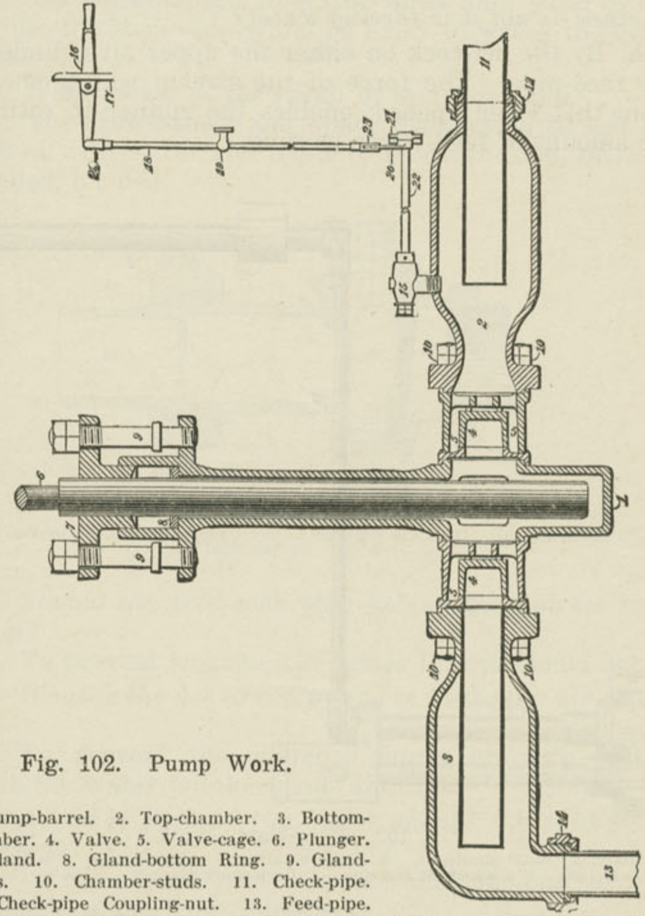


Fig. 102. Pump Work.

1. Pump-barrel. 2. Top-chamber. 3. Bottom-chamber. 4. Valve. 5. Valve-cage. 6. Plunger. 7. Gland. 8. Gland-bottom Ring. 9. Gland-studs. 10. Chamber-studs. 11. Check-pipe. 12. Check-pipe Coupling-nut. 13. Feed-pipe. 14. Feed-pipe Coupling-nut. 15. Pet-cock. 16. Pet-cock Lever in Cab. 17. Pet-cock Lever Fulcrum. 18. Pet-cock Lever-rod. 19. Pet-cock Lever-rod Guide. 20. Pet-cock Crank. 21. Pet-cock Crank-hanger. 22. Pet-cock Crank-rod. 23. Pet-cock Crank-jaw. 24. Pet-cock Lever-jaw.

Q. As the pump runs all the time that the engine is working, but is not always feeding, how can it be told whether or not it is forcing water?

A. By the pet-cock on either the upper air-cylinder or the feed-pipe. The force of the stream which emerges from this when opened, enables the runner to estimate the amount of feed-water passing.

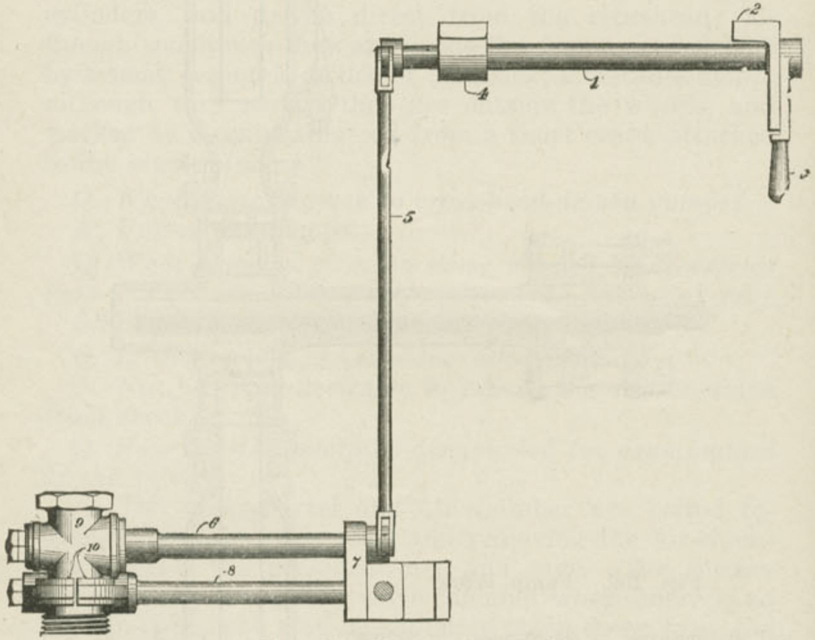


Fig. 103. Feed-water Work.

1. Shaft. 2. Shaft-quadrant. 3. Shaft-handle. 4. Shaft-hanger. 5. Shaft-rod. 6. Cock-shaft. 7. Cock-shaft Bearing. 8. Cock-shaft Hanger. 9. Cock. 10. Pipe-clamp.

Q. How is the supply of feed-water furnished by the pump regulated?

A. By a feed-cock in the suction-pipe, regulating the amount that can pass to the pump (see Figs. 102 and 103) ; also by the valves between tank and tender-hose.

Q. What would be the result of over-feeding the boiler?

A. The steam-space would be filled and water would get into the steam-pipes and be likely to wreck the cylinders.

Q. What would be the result of under-feeding?

A. The crown-sheet and upper flues would be left uncovered with water and liable to be overheated, or, as it is called, burned.

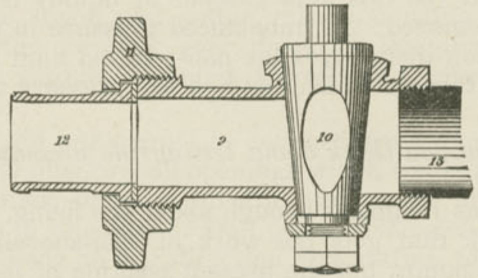


Fig. 104. Feed-cock.

9. Feed-cock Body. 10. Feed-cock Plug and Nut. 11. Hose-coupling Nut. 12. Hose-swivel. 13. Feed-pipe.

Q. Should the feed-cock plug extend through its case, or not?

A. To prevent leakage it is better that it should not.

Q. What is the use of a dip-pipe in the upper air-chamber?

A. To prevent the chamber filling up with water, where the water is taken from the top.

Q. At what part of the boiler should the feed-pump discharge?

A. In the coolest part; say one and one-half or two feet back of the front flue-sheet.

Q. How is the pump prevented from freezing and bursting, in case the engine is lying by without steam on?

A. By a frost-cock or bleeder on the lower air-chamber, to permit the water to be let out. A similar contrivance is usually on the feed-pipe.

Q. How is the water in the pump, suction-pipe and tank prevented from freezing without being bled out?

A. By heater-pipes communicating either with the steam in the boiler or with injectors, and discharging into the suction-pipe.

Q. Is there such a thing as "suction"?

A. Indirectly there is. So-called "suction" takes place when the pressure in one direction upon the "sucked" or "drawn" fluid (be this fluid gaseous or liquid) is partly or entirely removed; the unbalanced pressure in the opposite direction then forces the non-relieved fluid toward that portion thereof which has had the pressure thereon lessened.

Q. What do you think about letting the fireman pump the engine?

A. If he has judgment enough about the firing, and as it is his back that gets the work of coal-shoveling, he should be let pump; but the present position of injectors would make it difficult.

Q. What is the best way to pump an engine, to avoid leaky flues?

A. Fill the boiler at the start and pump light, in accordance with the steam demand.

Q. How should an engine be pumped—continuously from beginning to end of trip, or would you shut off the injector when pulling out after each stop?

A. Shut off the injector when the throttle is opened to start, and start it again as soon as lever is hooked up after train is under way, or steam pressure begins to raise again. When pulling out after a stop the steam pressure must be kept up against a large amount being used by the cylinders, the fresh coal put in on a fire that has not been burning fiercely while engine was shut off, and supply of water put in by the injector. As water rises when the throttle is opened, with some engines it is an advantage to ease or shut off the injector for a minute or two at the instant of pulling out, and keep injector at

work after shutting off, while fire is still burning fiercely, and thus save that heat which would make engine blow off. This method will help along a poor steamer; if it does that, it will help a good steamer burn less coal.

Q. How can the boiler be filled while the engine is being towed in?

A. By plugging whistle and relief valves, screwing down the plugs over the injector overflow-valves, opening injector steam and water valves, shutting cylinder cocks, putting reverse lever down in the direction in which the engine is being towed, and opening the throttle.

Q. How can one engine be pumped from another?

A. (1) By plugging all openings which would admit air into the boiler, opening throttle and steam and water connections to injectors or feed pump, setting the reverse lever for towing in one direction and getting towed fast enough to oil the valves through hand oilers. A vacuum being formed in the boilers by the air being pumped out, the water will flow in from the tender. (2) By connecting a hose from the delivery or overflow pipe of the live engine, and injector suction of the dead one, or even feeding through whistle, safety-valve, or wash-out plug.

Q. How would you fill the boiler and get the engine alive when fire is drawn on account of low water?

A. If another engine was handy, get her to pump my engine up; otherwise take out the safety-valve and fill with pails.

Q. What are the advantages of pumps over injectors?

A. The water-supply is exactly proportioned to the steam-consumption as long as the cut-off is kept the same.

Q. What are the disadvantages?

A. Feeding can not be done when the engine is standing still; the water is fed cold.

CHAPTER XXVII

THE CHECK VALVE

Q. What enables removing the pump for inspection or repair, while steam is on the boiler, or the latter is full of water?

A. There is between it and the boiler a valve which, as it opens only in the direction of flow of the water from the pump to the boiler, permits the water to pass only in

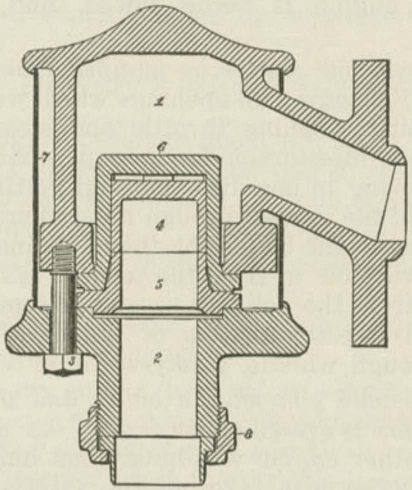


Fig. 105. Pump-check.

1. Check-body. 2. Check-flange. 3. Check-flange Studs. 4. Valve. 5. Valve-seat 6. Valve-cage. 7. Casing. 8. Check-pipe Coupling-nut.

that direction. Fig. 105 shows a pump-check composed of a check-body 1 and flange 2, held together by check-flange studs 3. The valve 4 contained in the valve-cage 6 seats itself on the valve-seat 5; the whole being surrounded by a casing 7 and attached by a check-pipe coupling-nut 8.

Q. Where is it usual for such a check-valve to be placed?

A. Outside the boiler, in the feed-pipe.

Q. What is the objection to an outside check-valve?

A. It is liable to be knocked off in a collision or other accident; and in this case there would be an escape of hot water, followed by steam, which is liable to injure the engineer and fireman or other persons, and also tends to cripple the boiler.

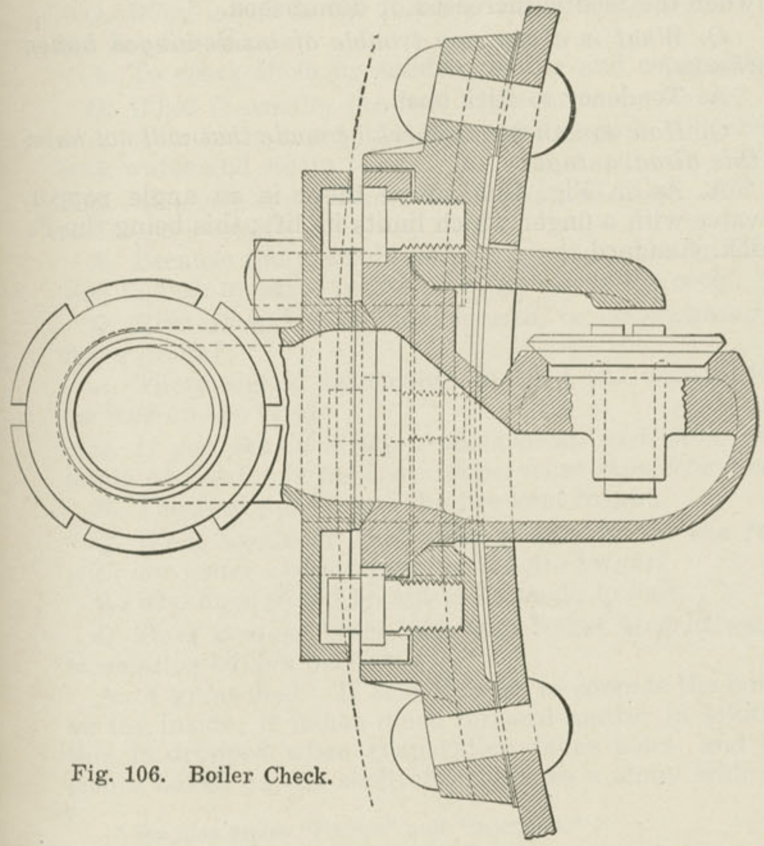


Fig. 106. Boiler Check.

Q. Where, then, should the check-valve be placed?

A. Just inside the shell, where the feed-pipe discharges into it.

Q. Why are boiler checks set so far ahead?

A. So that the cooler water of the lower temperature will enter as far as possible from the firebox and work from the point of least evaporation to where the greatest evaporation is taking place; this helps out the circulation and reduces the strains from expansion and contraction when the feed is increased or diminished.

Q. What is a common trouble of inside-hinged boiler checks?

A. Tendency to stick open.

Q. How can an inside check be made that will not have this disadvantage?

A. As in Fig. 106, where there is an angle poppet valve with a finger which limits its lift; this being the P. RR. standard.

CHAPTER XXVIII

FEEDING THE BOILER*

Q. Where is the feed water usually introduced, and why?

A. Pretty well forward, so that the cold entering feed-water will not strike the hot part of the boiler.

Q. What would be the result of introducing it right on the fire-box sheets?

A. To crack them by sudden cooling and contraction.

Q. What is usually the best hight to carry water?

A. At such a hight that the top try-cock will show both water and steam.

Q. Why not carry water so that it will show solid at the top try-cock?

A. Because there would be no knowing whether there was ¼ inch or three inches of water above the cock.

Q. How should water be carried in approaching a down grade?

A. There should be enough to keep the crown-sheet covered on the grade.

Q. If you should strike a down grade and show both steam and water in the lower gage, what should be done?

A. The feed put on and the fire kept bright.

Q. What would be the result of putting on the feed with low water and not keeping the fire bright?

A. The flues would be apt to be made to leak.

Q. Does it make much difference what kind of water locomotive boilers get?

A. A great deal. If acid it tends to corrode the boiler on the inside; if it has much mineral matter in solution this is dropped when evaporation takes place, and becomes baked on the shell and tubes as a stony scale; if

* See also under "Pumps" and "Injectors."

there is undissolved vegetable or mineral matter, this is deposited on the bottom as slush and sometimes baked on.

Q. How can acid get in the water?

A. The water from streams in the Pennsylvania coal-mining regions is impregnated with sulphuric acid; the same or similar causes produce similar results elsewhere.

Q. Would alkaline water be an advantage?

A. Not usually, because the dissolved alkali would be deposited on the shell when the water was evaporated. There are, however, cases where by using an acid water from one station and an alkaline from another, one will counteract the other; but it is not well to trust to any such luck.

Q. When should the injector be on, and when off?

A. On between stations, but not in pulling out, when more steam is used. It also lessens the smoke nuisance.

CHAPTER XXIX

BLOW-OFFS

Q. How may loose mud and other loose dirt be removed from a locomotive boiler?

A. Through large blow-off cocks near the bottom of the fire-box, and which may be opened when steam is on, thereby letting much of such loose material be blown out.

Q. How is the remainder removed?

A. By hand-holes or mud plugs in the fire-box corners near the bottom; sometimes also by a hand-hole at the bottom of the front tube-sheet. By this the mud may be loosened and much of it removed, and a hose used to clean out the loose material.

Q. When the check-valve is near the front of the boiler, as usually the case, what may be said about the blow-off cocks?

A. There should be one right under the check-valve, by which to blow off the material that has dropped under it.

Q. What is the blow-off cock usually like? And where is it placed?

A. A plug valve having a large opening and usually screwed into the front water leg, but sometimes into the back head above the crown-sheet.

Q. Is it safe to depend entirely on one blow-out cock?

A. No; it is better to have more than one.

Q. Is the front of the boiler always the only place, or even the best place, to put one?

A. No; sometimes the rear is also desirable; occasionally also the side or sides; depending upon the general design of this boiler, the position of the machine parts, the character of the water and even the gradients of the road, as it may in case of accident be necessary to blow out the boiler on a steep up grade or in a derailment accident in which the front end was well uptilted.

Q. Will the blow out cocks discharge mud and scale that are not entirely loose?

A. No; the mud plugs and hand holes are needed.

CHAPTER XXX

THE SAFETY-VALVE

Q. What is to prevent the boiler blowing up, in case steam is made faster than used?

A. Up to a certain point, the evaporation of a greater weight of water than is passed out as steam, causes increase of pressure; this would continue until all the water was evaporated, or the pressure got too great for the boiler to stand. To prevent the boiler bursting or exploding, there is a large valve, opening from the steam-space and held down by a spring, the tension of which is adjustable so that the valve will lift when the pressure upon it from below reaches a certain point, very much below the safe working-pressure of the boiler. When the steam-pressure reaches the point at which the valve is set to blow, there is discharge of steam; and if the valve has sufficient area to let through all the steam that the boiler can make, there will be no explosion. In order to diminish the chances of explosion there are often two of these valves side by side, set to blow at the same or about the same pressure.

Q. What is to prevent the engineman screwing down the safety-valve so as to give more steam pressure than he would otherwise have; or what is to prevent some malicious person rendering the boiler liable to explosion by doing the same thing unknown to the engine-runner?

A. One of the valves is usually arranged so that the spring which holds it down cannot be readily got at to change the pressure at which the valve will blow.

Q. What precaution should be taken as to that safety-valve which is held down by a lever and not locked?

A. It should be raised daily, to insure that the disk is not corroded on the seat, or otherwise inefficient.

Q. How may the pressure in the boiler be relieved if necessary, before the safety-valve blows?

A. By lifting the safety-valve by the relief-lever.

Q. What is the advantage of the ordinary safety-valve with long lever?

A. Without leaving the cab it may be readily adjusted to blow at any desired pressure.

Q. What is the advantage of the "pop" safety-valve?

A. It gives larger discharging-area than the ordinary valve.

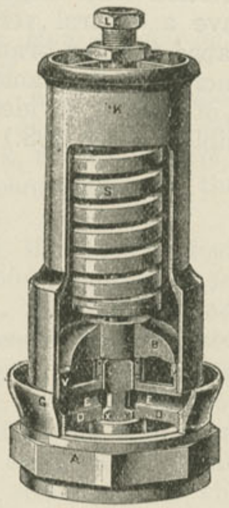


Fig. 107. Crosby Locomotive Pop Safety-valve.

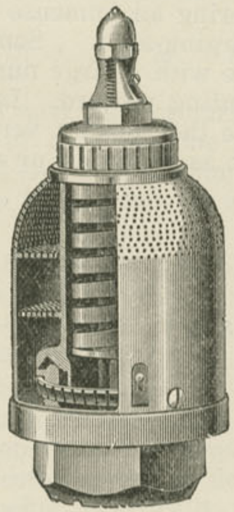


Fig. 108. Meady Muffled Locomotive Pop Safety-valve.

Q. How is the Crosby pop safety-valve constructed?

A. The valve rests on two flat ring-shaped seats lying in the same plane and forming part of the shell, which is in two parts, an inner and an outer cylindrical chamber, connected by hollow horizontal radial arms between which the steam passes, acting on that part of the valve which shows above and between the two valve-seats. (See Fig. 107.)

Q. How is the noise of steam which escapes from the safety-valve lessened, to prevent frightening horses when trains are standing at stations, and from being a general nuisance?

A. By a muffler, one form of which consists of a wire coil through the interstices of which the steam escapes, making much less noise than where it has to pour through a more contracted area. Other mufflers are made of boxes full of glass beads or of similar substances offering an immense amount of friction with large discharging-area. Some, again, have a central vertical pipe with a large number of L-shaped tubular branches pointing upward. In all, the principle is the same; to give the steam a very large area of escape, divided up into as many jets or sheets as possible. (Fig. 108.)

CHAPTER XXXI

LAGGING

Q. How is radiation from the boiler lessened?

A. By lagging the boiler and dome with a non-conductor of heat, as wood strips, and covering these with a Russia-iron jacket; sometimes by covering with wool felt, then with wood strips and Russia iron; sometimes by asbestos cloth or some plastic material, as magnesia cement and Russia iron.

Q. What are the advantages of magnesia lagging?

A. It does not char, as do felt and wood, nor get hot, as does asbestos, and may be removed for inspection purposes.

Q. How are fire-boxes lagged in the L. S. & M. S. Railway?

A. A sheet of asbestos is placed next the hot surface, and over that placed a covering of hair felt one inch thick, the whole kept in place by a sheeting of kalamein or planished iron; the boiler-heads being done the same way.

Q. What is the disadvantage of hair felt as a non-conducting, lagging or jacketing material?

A. Although an admirable non-conductor of heat, it is readily disintegrated by high temperatures.

Q. Is asbestos in itself a good non-conductor?

A. It is not; the natural stone in a mass is much less so than the fibers into which it separated for weaving, but even then the value of all asbestos coverings lies in the resistance to charring (it being practically fireproof) and in the air in the spaces among the fibers.

Q. What is the disadvantage of plastic coverings?

A. They do not show, as a rule, where leaks are, but indicate a spot far away, so that search often calls for skinning a comparatively large area, usually higher than where the leak apparently is indicated.

Q. Should a boiler have a lagging thickness proportionate to its diameter?

A. Yes; there being a greater mass of hot steam and water behind the lagging.

CHAPTER XXXII

THE WHISTLE AND MUFFLER

Q. How does the steam-whistle act?

A. There is an inverted cylinder, cup or bell of thin metal, with a sharp circular edge, against which an annular sheet of steam is discharged from an annular orifice; the force of the escaping steam causes the bell or cup to vibrate and give out a musical tone, the pitch of which depends on the diameter and the depth of the cup. (Fig. 109.)

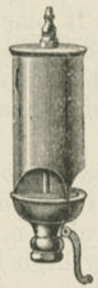


Fig. 109. Chime Whistle.

Q. What is the advantage of the chime whistle?

A. Its sound is less disagreeable than that of one giving only a simple tone, as it produces a pleasing chord of three tones.

Q. How is this triple effect produced?

A. By the bell being divided lengthwise into three compartments of different lengths. The shortest gives the highest tone.

Q. What is a muffler?

A. A device by which the steam which escapes from the safety-valve is quieted; necessary where the shrill noise of the escaping steam would produce prejudice

against the company or injury to the community within hearing.

Q. How is it constructed?

A. By having instead of one orifice for the steam, numbers of small slits or holes, or letting it pass through a chamber filled with glass balls.

Q. What is the disadvantage of the muffler?

A. It causes back-pressure, gets clogged and has to be cleaned out, which is a difficult operation.

CHAPTER XXXIII

THE THROTTLE

Q. How is the steam admitted to the steam-chest, or cut off therefrom?

A. By the throttle-valve, usually placed at the end of the throttle-pipe or vertical extension of the dry-pipe, in the dome, where there is one; although sometimes in the front end of the horizontal part of the dry-pipe, particularly where there is no dome.

Q. How are throttle-valves at present usually made?

A. When in the dome, of double poppet-valves, consisting of two disks on a stem, and covering corresponding openings in the case with which the pipe ends. Moving the valves and the stem lengthwise of the latter either closes the disks against the circular openings or removes them therefrom, leaving annular openings through which the steam flows.

Q. When in the smoke-box what is their character?

A. Plain slides.

Q. Why is the double-poppet form of throttle-valve chosen for the dome?

A. Because the steam pressure on one disk balances that on the other, instead of there being, as where slide-valves are used, an unbalanced pressure in one direction, tending to make it difficult either to open the valve or to close it. Also, it delivers drier steam.

Q. Are the disks of the same size, and does the pressure on one exactly balance that on the other?

A. No; each disk must be larger than the opening which it closes, and one must be small enough to pass through the opening which the other covers. This being the case, the upper disk is the larger, and the pressure is not quite balanced. there being a tendency to keep the

valve closed, which is of advantage, after steam has been shut off.

Q. How is this valve, which is in the steam space, opened and closed?

A. By the throttle-lever, which is connected by the throttle-stem with the lower arm of a bell-crank, the upper arm of which is connected by a rod with the valve-stem. The throttle-stem works through a stuffing-box in the back end of the boiler; being enabled to work in a straight line through the stuffing-box by a small vibrating link. (See Fig. 110.)

Q. How is the throttle-lever held in any desired position?

A. Usually by a latch gearing into a sector and operated by a trigger connected to the latch by a rod.

Q. What is the objection to the ordinary throttle-lever having two links back of the fulcrum, and a quadrant and clamp?

A. It requires two hands, this being inconvenient and at times objectionable.

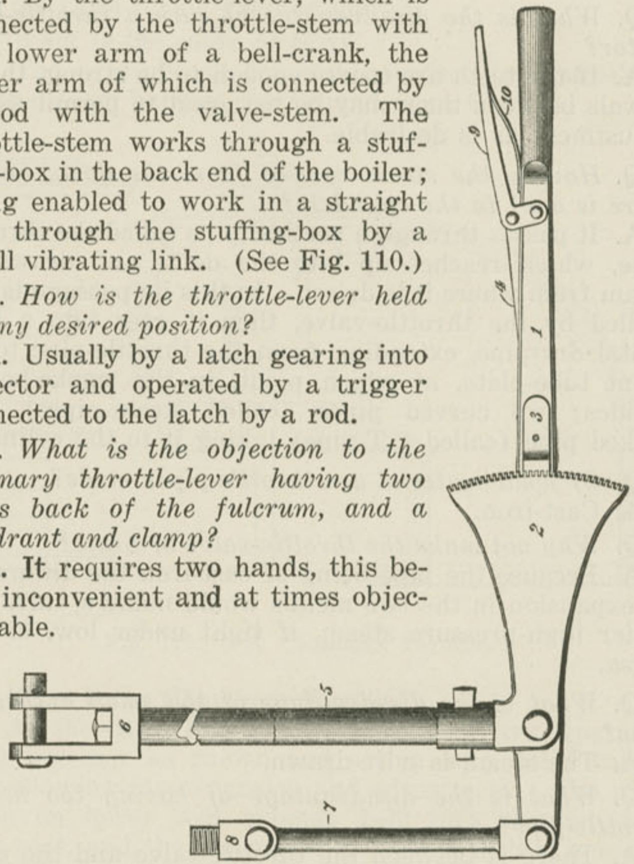


Fig. 110. Throttle Work.

1. Lever. 2. Quadrant. 3. Latch. 4. Latch-link. 5. Rod. 6. Jaw. 7. Link. 8. Link-stud. 9. Handle. 10. Handle-spring.

Q. What would be better than the clamping-rig?

A. A notched sector or quadrant such as used with the reverse-lever, but with notches of saw-tooth style so as to permit the throttle to be very quickly closed and prevent it from being jarred open. (See Fig. 110.)

Q. What is the disadvanatge of such a throttle-lever sector?

A. If the teeth are coarse enough to be strong, the intervals between them may be too great to permit as fine adjustment as is desirable.

Q. How is the steam carried from the dome (where there is one) to the cylinders?

A. It passes through a vertical pipe called the throttle-pipe, which reaches up into the dome and draws the steam from where it is driest. In this its passage is controlled by the throttle-valve, then it goes into a horizontal dry-pipe, extending from the throttle-pipe to the front tube-plate, at which point, in the smoke-box, it divides; two curved pipes (called steam-pipes) or a forked pipe (called a T-pipe) taking it to the cylinders.

Q. Of what material are throttle-pipes made?

A. Cast-iron.

Q. Why not make the throttle-valve of brass?

A. Because the pipe being of cast-iron the differences of expansion in the two metals would make a valve leak under high-pressure steam, if tight under low, or *vice versa.*

Q. What is the disadvantage of too small a throttle-pipe?

A. The steam is wire-drawn.

Q. What is the disadvantage of having too large a throttle-pipe?

A. There is between the throttle-valve and the cylinders too much steam, which requires to be worked off before the engine will stop.

Q. Where is the throttle-valve placed?

A. As high as possible, to avoid getting entrained water and thus to lessen priming.

Q. What is the result, on the water level, of opening the throttle?

A. To raise it one gage or more.

Q. What is the cause of this?

A. The pressure on the water-surface is diminished, and the steam bubbles can expand more freely.

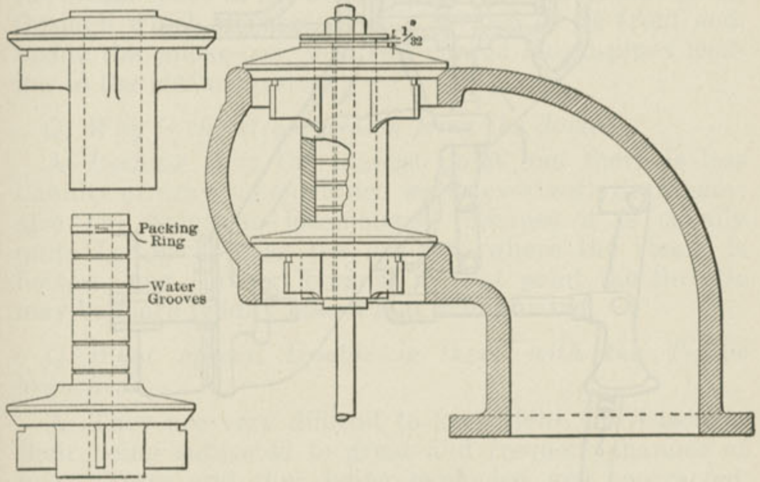


Fig. 111. The Chambers Throttle.

Q. What is the Chambers throttle?

A. As shown in Fig. 111, the two seats are separate, fitting together as shown and acting as a solid valve, while allowing for expansion and adjustment. The projection on lower seat extends 1-32 inch through the upper seat, and the movement is limited to this amount by a washer on the stem, as shown.

Q. How may a throttle valve be thoroughly tested for tightness?

A. By fastening it down, removing the relief-valve or the chest, connecting with steam heat hose there and putting on steam.

Q. Why not use water instead of steam?

A. The steam expands the parts to working condition.

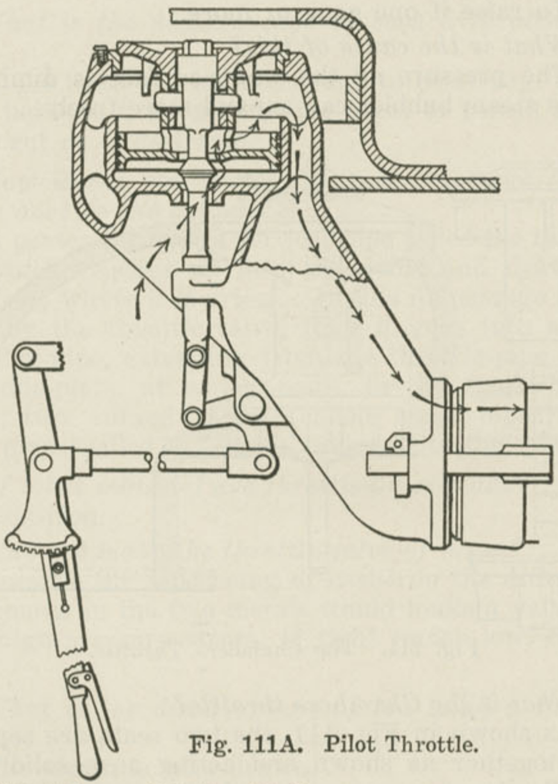


Fig. 111A. Pilot Throttle.

Q. What is a pilot throttle?

A. A valve having one part that opens with the first few turns of the hand wheel or movement of the lever, admitting steam enough to warm up the chest and cylinder and start the engine slowly without load. It also equalizes the pressure on both sides of the main throttle valve, thus lightening its operation.

CHAPTER XXXIV

DRY-PIPE AND STEAM-PIPES

Q. From what point in the steam-space is the steam taken to supply the cylinders?

A. Where there is a dome, it is taken from that by what is known as the dry-pipe, extending along through the steam-space in the boiler shell to the front tube-plate, through which it passes; being divided at its front end, inside the smoke-box, into two curved steam-pipes leading to the steam-chests.

Q. Why is the steam drawn from the dome?

A. Because it is the highest point and there is less liability of drawing entrained water over with the steam; also (in American locomotives) because it is usually quite far back, near the fire-box, where the steam is hottest; and further, because at that point the throttle may be more readily placed and manipulated.

Q. What special trouble is there with the T-pipe branches?

A. They are very difficult to keep tight, by reason of their being subjected to great and frequent changes of temperature and thus being expanded and contracted. Also, the lack of rigidity of American engines makes it difficult to keep them tight, independently of expansion and contraction.

Q. How are flexibility and expansibility provided for in the steam-pipes?

A. By connecting them with so-called ball joints—their ends being flanged and also one turned spherically convex and the other spherically concave, with the same radius, so that one may play upon the other without marring the joint.

Q. In what direction does this ball-joint arrangement provide flexibility?

A. Laterally only.

Q. How is movement in an up-and-down direction provided for?

A. By a false end on one of the pipes, this false end having one side spherically convex and the other plane, so that it may slide up and down on the end of the pipe; or by having such a sliding device at one end of the pipe and a ball joint at the other.

CHAPTER XXXV

FOAMING AND PRIMING

Q. What causes foaming in the boiler?

A. Oil, alkali, or other matter, causing the water to froth, like soap-suds; large throttle, dry-pipe, steam-pipe and ports, together with a small dome.

Q. What is a sign of foaming?

A. Water showing at the stack, particularly if coupled with the valves pulling the lever or with squeaking valves or pistons.

Q. If water should show at the stack, what should be done?

A. The throttle should be closed and the water-level allowed to settle, to permit finding out whether the show of water was due to overpumping or to foaming.

Q. What is priming in a boiler?

A. Lifting of water in a body.

Q. What causes priming?

A. Too little liberating-surface at the top of the water.

Q. What would be the test in this case?

A. Sinking of the water to the lowest gage after the throttle was closed would be a sign of foaming.

Q. What is the effect of foaming on water consumption?

A. To increase it.

Q. What other evil effect has it?

A. To cause breakage of cylinder heads, packing-rings, etc.; also to take the oil off rubbing surfaces and increase friction and cutting.

Q. Should an engine be allowed to slip to get the water out of the passages?

A. By no means.

Q. What should be done to stop foaming?

A. The feed should be put on, and the surface blow-off started.

Q. What should be done in case of foaming, not as a matter of prevention of the evil but as a measure of safety to the engine?

A. The cylinder-cocks should be opened, to prevent the heads being knocked out by the excess of water.

Q. How may oil in the tank be got rid of?

A. By overflowing it for considerable time, coupled with use of the heaters.

Q. What is the danger when the boiler foams badly?

A. Burning the crown-sheet, cutting the valves, breaking the piston-packing rings, or knocking out cylinder-heads.

Q. In case of foaming what should be done?

A. First it should be seen whether the foaming was by reason of soap, oil, or alkali in the boiler, or by reason of too much water; then if by reason of foreign material in the boiler (as would be shown by the try-cocks), with the throttle shut off, the surface-cock should be opened to let the foul water blow off, and the injectors or pumps put on to keep up the level. If by doing this the engine would not get to working rightly, and the water should still discharge from the stack, the fire should be drawn or damped to save the boiler. If necessary to keep running and the boilers did not seem in danger, the cylinder-cocks should be opened to save the heads; the throttle closed slowly and the water-level tried. If there is a surface blow-off it should be opened. If there is insufficient water supply the pumps or injector should be set to work. The throttle should be slowly and slightly opened and the foul water worked through the cylinders, the hight of water being tried then with closed throttle.

Q. What should be done to remedy foaming caused by grease in the tank?

A. The tank should be overflowed the first chance that there is to get water. A couple of quarts of unslaked lime put in will help matters; or a piece of bluestone (sulphate of copper, blue vitriol, which may be had at almost any local telegraph office) will aid if put in the hose back of the screen, if there has been no lime or other alkali used.

Q. Why should the throttle be closed slowly, in case of foaming?

A. To keep the water from dropping suddenly below the crown-sheet in case there was an insufficient quantity.

Q. Why open the surface-cock in case of foaming?

A. Because foaming is usually caused by grease, which will be floating on the water and may be blown off by the surface-blow.

Q. Why is lime put in the tank in case of foaming by reason of greasy water?

A. It neutralizes the grease.

CHAPTER XXXVI

SCALE AND MUD

Q. What is scale?

A. A hard deposit left on sheets and tubes from water which contains mineral substances in solution or in suspension.

Q. What are its usual constituents?

A. Lime is the most common, in some of its compounds, as carbonate or sulphate; magnesia and iron are also found, as is ordinary clay.

Q. What are preventives of scale?

A. (1) The choice of water having therein no mineral substances that will be left behind in the boiler when the water has been turned into steam; (2) filtration of the water, to remove substances which are only mechanically contained therein; (3) chemical treatment of the water to make it deposit the mineral substances before it reaches the boiler; 4, chemical treatment simultaneously with its supply to the boiler.

Q. Where must the second and the third preventives be resorted to?

A. In the station tank or before the water reaches it.

Q. What are resorted to to remove scale once it has formed in the boiler?

A. Petroleum, and various chemicals which exert a loosening effect on the scale already deposited.

Q. Will black oil soften all kinds of scale?

A. No.

Q. Would lard oil or valve oil help?

A. No; it would cause foaming and not affect the scale.

Q. How is mud deposit prevented?

A. (1) By filtering; (2) by using pure water; or (3) by frequent blowing off, *hot.*

Q. What can you say as to the influence of scale in heat transmission in locomotive boilers?

A. Tests go to show that conductivity is diminished from two to 10 per cent by scale and being from 0.02 to 0.085 inch thick.

Q. How would you rate the quality of feed water according to the contents of incrusting solids?

A. I would say that for calcium carbonate, magnesium carbonate, or magnesium chloride, only 8 grains per U. S. gallon would be very good; 20 to 30 bad; over 30, very bad. For sulphate of calcium and magnesium only one-fourth as much would be permissible for the same rating.

Q. What materials cause incrustation?

A. Mud, soluble salts, bicarbonates, organic matter, lime sulphate.

Q. What causes corrosion?

A. Animal fats and other organic matter, magnesium chloride or sulphate, sugar, acids; either CO_2 or oxygen in solution.

Q. What feed water impurities cause priming?

A. Sewage, alkalies, sodium carbonate, in large quantities.

Q. Is there any one "boiler compound" that is good for all kinds of bad feed water?

A. No. Some will work well with one water and injure boilers using water obtained a hundred miles away on the same road.

Q. How can you classify boiler compounds?

A. Into those causing a loose deposit, readily removed, those enveloping the deposited particles with a coating that prevents their agglomerating, and those dissolving or disintegrating the scale-forming substances.

Q. What is the effect of using crude oil as a scale preventer?

A. It makes a tough scale that causes bagging.

MUD-DRUM AND HAND-HOLES

Q. What provision is necessary where the water is very impure?

A. A mud-drum—a wrought-iron cylinder below the boiler, usually at the front end, and having a blow-off cock and a removable cast-iron bottom cover. There being in this drum but little water-circulation, most of the mud and scale collects there, instead of being burned on the sheets of the main shell.

Q. How may hard mud and scale be removed?

A. Either (1) through oval hand-holes in the corners of the fire-box, near the bottom, and closed with two plates, one inside and the other outside, connected and fastened with a bolt, or (2) through holes in which are screwed mud-plugs. After as much as possible has been scraped out through these holes, a hose may be inserted and a strong stream of water used to slush out other material not within reach of scrapers.

CHAPTER XXXVII

ESSENTIALS OF A LOCOMOTIVE BOILER

Q. What are the essentials of a good locomotive boiler?

A. (1) Reliability and mechanical maintenance—that is, freedom from cracked sheets, leaky seams and flues, leaky and broken stay-bolts.

(2) Continuous development of maximum horse-power within the capacity and endurance of the ordinary fireman.

(3) An efficiency as near as possible to that of the best stationary and modern boilers.

Q. On what do reliability and low cost of maintenance depend?

A. Principally on freedom of circulation around the fire-box.

Q. What elements go to facilitate such circulation?

A. Depth of box and width of water legs.

Q. Should depth be obtained by depth of throat sheet, or by raising the crown sheet?

A. By depth of throat sheet.

Q. Is the ordinary fire-box calculated to withstand the heat of perfect circulation?

A. No; but the better the circulation the less the trouble with the fire-box.

CHAPTER XXXVIII

THE INJECTOR

Q. What is an injector?

A. An apparatus in which a jet condensed by water imparts to the latter its velocity, so that the final velocity of the combined steam and water is greater than that at which the water would issue from the boiler. This difference of energy in favor of the jet passing through the injector enables it to enter the boiler.

Q. In a general way, how are the two kinds of injectors classified?

A. As "single tube" when they have a single set of nozzles, and as "double tube" when they have two sets; one of the latter kind lifts the feed water and delivers it to the forcing jet, which latter imparts to the water enough velocity to cause it to enter the boiler.

Q. What are the essential parts of an injector?

A. The nozzles, which force the water into the boiler, and the operating mechanism, such as the lifting, steam, and water valves, etc.

Q. What is the theory of the apparently paradoxical action of the injector by which steam from the boiler forces water against its own pressure?

A. It is a question of velocity, not of pressure. At a given pressure, steam escaping from an orifice has a higher velocity (say 2,000 feet per minute) than water under the same pressure (say 150 feet). In issuing from the injector-nozzle the steam strikes the water that also enters the combining-tube, condenses, and at the same time imparts to the feed-water, together with the condense, its own velocity, this driving it into the delivery tube; and as this feed-water has a higher velocity than water would have under the given steam pressure in issuing from the boiler, it can overcome the pipe friction, raise the check-valve and enter the boiler against the water pressure. The continual condensation of the steam causes a vacuum, which new water rushes in, from the feed supply, to fill.

Q. What follows in case the steam is not perfectly condensed in the combining-tube?

A. In most so-called "automatic" injectors, the steam will be broken and the apparatus will not lift on feed.

Q. What is the object of the overflow tube?

A. To relieve the injector of excess of feed-water or condense.

Q. What is the combining-tube?

A. A flared tube in which the streams of feed-water and condensed steam may mingle before passing on to the feed-pipe.

Q. What is a lifting injector?

A. One that will lift the water to the hight of the combining-tube, from a source that is not under pressure.

Q. What happens in case the flow of steam or water is cut off?

A. They "break," get hot, and start again with difficulty.

Q. What is a non-lifting injector?

A. One which must have the water fed to it by gravity or under pressure, as from a water main. On a locomotive it must be placed below the level of the tender-tank bottom.

Q. What is a re-starting injector?

A. A lifting injector that can work with a broken water-supply stream, delivering anew each time that the water is supplied.

Q. What class of overflow have lifting injectors?

A. Generally closed.

Q. Which is better—a closed or an open overflow?

A. The former has the advantage that it wastes no water, even when the pressure varies greatly.

Q. What are the advantages of non-lifters?

A. They run cooler than and do not get clogged with sediment so soon as those of the lifting type.

Q. How many types of lifting injectors are there?

A. The principal ones are: (1) Single tube, non-starting; (2) double tube; (3) re-starting.

Q. What part of an injector wears out most quickly?

A. The delivery-tube, owing to the high velocity of the water, and particularly if there is sand, mud, or grit in the water.

Q. Which will draw the hottest water—high-pressure or low-pressure steam; and why?

A. Low-pressure, because more easily condensed than high.

Q. What is one of the principal advantages of the injector over the pump?

A. That it heats the feed-water.

Q. Does this save coal?

A. Not directly; but it saves boiler-sheets and also lessens the lowering of temperature caused by pumping in ice-cold water.

Q. How may the injector be converted into a heater?

A. By opening the feed-pipe cock, closing the overflow, and allowing a slight quantity of steam to pass through the starting-valve.

Q. Which heat the water the higher—lifting or non-lifting injectors?

A. Non-lifting. The heat of the steam can not lift, heat, and force, all in maximum degree. Where the lift is greater, either the heating or the pressure against which the apparatus can force, will be less; where the pressure against which the apparatus must force is greater, it can not lift so high nor heat so much.

Q. With an ordinary injector, when too much steam is admitted, what is the effect?

A. To draw air through the overflow opening, and cause the delivery of a stream of water mixed with air and with uncondensed steam; and when excessive, the injector will "break."

Q. What is the effect of giving too much water for the steam?

A. To cause overflow.

Q. When the injector does not work, what is the first thing to see to?

A. Whether the relative amounts of steam and water supplies are tight; next whether the strainer is not choked; if it is neither of these causes a choke in the jet should be looked for.

Q. What other causes of non-working of injectors are there?

A. Steam leaking through the steam-valve or check-valve, so as to heat the injector-valve and cause it to jam; cocked injector-valve; grit under the check-valve, especially where this is horizontal.

Q. What is the maximum temperature at which lifting injectors can deliver water in a boiler?

A. About 160 deg. F. = about 71 deg. C.

Q. What happens in a re-starting injector, when the water breaks?

A. The steam escapes into the air, thus making a continuous suction, which will hold and draw the valve when the supply is renewed.

Q. Will it re-start if the overflow be shut?

A. No.

Q. What is a sign of dirt in the delivery-tube or elsewhere in the injector?

A. Steam passing into the tender.

Q. What precaution should be taken with the tank-screen?

A. To take it down, and clear it, if necessary, before each run.

Q. What is the best sort of steam for an injector?

A. Dry and saturated.

Q. What may be said of the steam passages?

A. They should be large enough to allow full boiler pressure at the steam nozzle.

Q. *What is the effect of wet steam on an injector?*
A. To cut the valve seats and nozzles.

Q. *What is the effect of superheated steam on an injector?*
A. To reduce its mechanical efficiency and its capacity.

Q. *What is the velocity of steam in different parts of the injector at 200 pounds pressure, at the smallest part of the nozzle?*
A. About 1,500 feet per second; increasing to 2,800 at the terminal flow, and reaching 3,847 feet at the time of impact with the water.

Q. *To what is the cutting action of salt or dirt in the injector proportionate?*
A. To the velocity of the jet which carries it.

Q. *What will tend to prevent cutting the exterior and interior surface of injector tubes with lime-bearing salts?*
A. Keeping them submerged in cold water.

Q. *How many checks should an injector have?*
A. Two; one bolted or screwed to the main boiler shell, the other near the injector.

Q. *Should the delivery pipe be as large as the suction?*
A. No; there is always ample forcing power to overcome the valve and pipe resistance of ten to 50 pounds counter-pressure.

Q. *In an injector, what can be said of the area of the entrance to the combining tube?*
A. It should be small, so that the water shall have a high velocity during its contact with the steam.

Q. *What may be said of the area of the suction pipe and connections?*
A. It should be large, to reduce friction.

Q. *What may be said of the suction pipe?*
A. It should be short and direct with easy bends, and preferably of copper.

Q. *Where should a lifting injector be placed?*

A. About six inches above the upper level of the water in the tank.

Q. *How tight should the suction pipe, hose, and connections be?*
A. Under 30 pounds pressure.

Q. *On what does the successful working of an injector depend?*
A. On the way it is piped, the size of the main steam and check-valves, tank-valve, strainer, suction hose, and waterways. Wrong proportions of these with respect to those of the injector itself lead to dissatisfaction.

Q. *Where is the injector usually placed?*
A. On the side of the boiler, inside the cab, where it may be readily got at by the engineman.

Q. *Should there be a check-valve between the injector and the boiler?*
A. By all means.

Q. *What may be said about frequency of use of the injector?*
A. It is well to use it often in order to keep it in good order.

Q. *How may this be arranged where there are two injectors?*
A. One of them may be used when running, the other when standing still; say, in the latter case, the left-hand one.

Q. *Where should an injector get its steam supply?*
A. Over that part of the boiler or dome which gives the driest steam.

Q. *Would an injector work with compressed air instead of steam?*
A. No. An injector depends for its successful operation on the condensation of the steam at the moment it gives its force to the water while passing through the combining-tube. This steam changes into water after setting the stream of water in motion, goes into the de-

livery-tube with the rest of the water, and does not again resume its original volume (as steam) until again heated in the boilers. If compressed air were the moving power to force the stream of water through the combining-tube, it would not be condensed, but would expand to its original volume while passing through the space between the end of the combining-tube and the opening of the delivery, and the stream would break. This is what happens when there is a leak in the suction pipe, so that air is drawn in with the water; in fact, the introduction of air in considerable quantities is fatal to the working of an injector, from whatever source it may come.

Q. What is the effect of using an injector at lower steam pressures than those for which it is intended?

A. Excess of water supply causes overflow.

Q. What is the reason of an injector delivering more water at low steam pressures?

A. Too little water enters to condense the steam.

Q. What is the effect of having too small an opening of the combining-tube?

A. The injector will not take hot water.

Q. Why do some injectors "break" if the valve is throttled?

A. The steam is not condensed; the overflow will not let it escape freely so that it blows back into the suction.

Q. Where the steam-valve is too large, how can the injector's working be improved?

A. By throttling the steam-valve.

Q. What is the effect of too large a steam-valve?

A. Too much back pressure.

Q. How can lime scale be removed from an injector?

A. By pickling the parts in a ten per cent solution of muriatic (hydrochloric, chlorhydric) acid.

Q. What is the cause of the air not being able to get in the tender as fast as the water should leave it through the injector?

A. Water splashing around, freezing all the top airholes shut.

Q. How can a non-lifting injector be helped?

A. By shutting the throttle on boiler.

Q. How can the injector be prevented from freezing?

A. By opening the frost-cocks and draining it and its pipe-line.

Q. Should both injectors be used?

A. Yes, alternately, so as to be sure that both are in working order. On heavy grades both will usually be needed.

Q. How should a lifting injector be started?

A. The lifting-valve should be opened, and when the water appears at the overflow, the forcing valve opened gradually to its full extent.

Q. How should a non-lifting injector be started?

A. The water should be admitted first to the apparatus, and when it appears at the steam overflow, the steam-valve should be opened gradually to its full extent.

Q. Why are holes sometimes drilled in the combining-tube of an injector?

A. To be a sort of auxiliary overflow to lessen the shock which takes place when the rapidly moving steam jet strikes and combines with the slow-moving body of water. The water forced out of these holes eventually passes out of the main overflow. Their presence also enables the injector to work with water a few degrees higher in temperature than if they were not there.

Q. How can the injector be used to save fuel?

A. By shutting it off when a hill is in sight, so as to save the steam which it would otherwise use; and when the crest is reached, starting it at full capacity to check steaming.

Q. What is the difference between feeding with the injector and feeding with the pump?

A. As the latter delivers cold water, and the former uses hot, the injector may be used where the pump would chill the boiler.

Q. Under what conditions can an injector be used continuously?

A. Where it has a wide range of capacity and the road is straight and level, with the feed throttled, without the jet breaking.

Q. Will an injector work with an air pressure the same as steam; that is, if you had a full head of air pressure in boiler, and no steam at all, could you work the injector?

A. Not as a boiler feeder, against the pressure of the boiler supplying the air. For an injector to work against the pressure equal to that which supplies it with motive fluid, the matter that gives velocity to the jet of water must lose its identity by condensation; and air is not condensable.

Q. Would an injector using air as a motive fluid force air, water, or light solids against a less pressure than that which drives it?

A. Yes; such injectors are in common use as blowers, sprayers, ash ejectors, etc.

Q. What is the usual limit of reliable lift of a locomotive injector?

A. About seven feet.

Q. Which is more easily kept in order in cold weather—an injector or a pump?

A. An injector.

Q. Which works best with sandy water—a pump or an injector?

A. An injector; although the action of the sand eventually cuts the nozzles so that their form and size is changed and the apparatus will then not work so well.

Q. If the tender tank were air-tight and the injector put to work, would it make any difference in the operation of the injector when a vacuum is created in the tank?

A. The injector would not work properly, and would be subject to breakage. On many roads where they used to have a wooden lining for the lid of the tank, it was necessary to keep the lid raised a little to make the injector work properly.

Q. Describe the Sellers self-acting injector, Class NS (1922).

A. As seen in Fig. 112, there is a main casing 25, with steam-supply pipe 19, water-supply pipe 23, overflow-pipe 57, and feed-pipe. The steam nozzles 3, controlled by the spindle 7, deliver steam to the combining-tube 2 and the heated stream passes through the delivery tube 1, issuing axially. The water supply is controlled by the valve 17; the overflow by the valve 309; there is a check-valve 20e to prevent return of water from the boiler.

Q. How is this injector started when lifting the water?

A. By pulling out the starting lever 33.

Q. How is it shut off?

A. By pushing in the same lever.

Q. How is the quantity of feed regulated?

A. By the water-valve 17.

Q. How is it used as a heater?

A. By closing the waste-valve 30 by the lever 34, and drawing the starting-lever 33.

Q. What special precaution is necessary in starting with hot water and on high lifts?

A. To draw the lever 33 slowly.

Q. What is the minimum capacity as compared with its maximum?

A. Forty per cent as much.

Q. What parts are most subject to wear?

A. The delivery tube 1, combining-tube 2, and steam nozzles 3.

Q. How should this injector be set?

A. Horizontally.

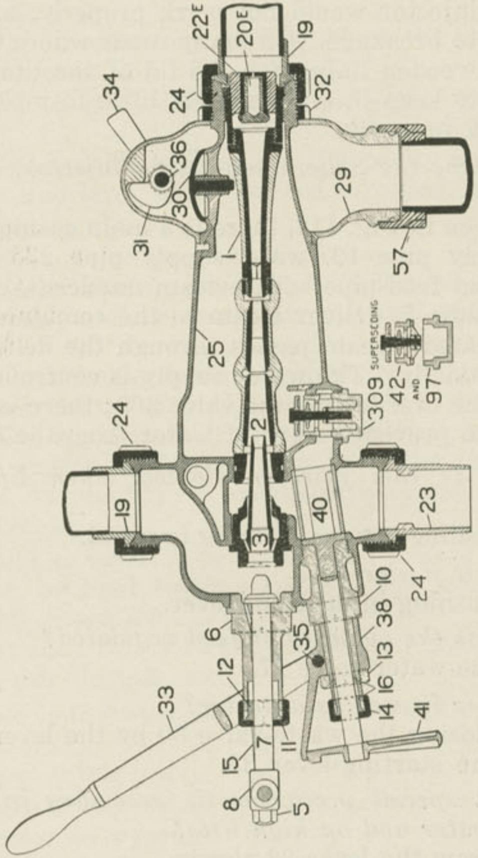


Fig. 112. Sellers' Self-acting Injector, Type NS.

Q. When it is desired to attach a pipe to the overflow, what about its diameter?

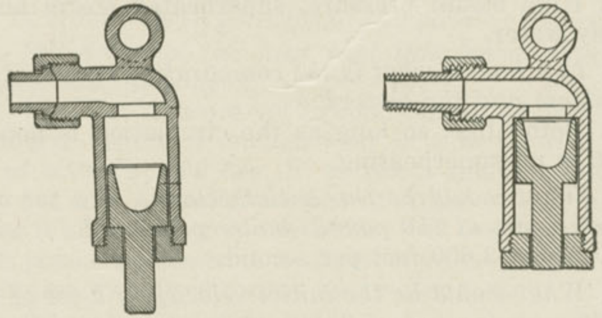
A. It should have an inside diameter not less than that of the overflow.

Q. What is an injector indicator?

A. A locomotive cab attachment permitting safe and convenient operation of an injector below the running board; also acting as a safety device for a lifting injector when the dip-pipe is fixed, especially when the injector is outside the locomotive cab.

Q. Describe the Sellers type.

A. It consists of a vertical cylinder about four inches long, with a loose-fitting piston, seating at each stroke end and having a projecting end that is visible to the engine-runner when resting on its lower seat. The upper end of the cylinder is connected with the overflow chamber of the injector. The partial vacuum in the overflow chamber raises the indicator piston to its upper seat and causes the projecting steam to disappear from the runner's view.



Figs. 113 and 114. Injector Indicator.

Q. What happens if the injector starts to waste?

A. The overflow-chamber vacuum is broken, the piston drops and exposes the plug, warning the engine-runner that it is time to close the lazy cock partly and thus stop the waste.

Q. What happens if there is an interruption of steam of water supply, and the injector "flies off"?

A. The piston drops to its lower seat and cuts off steam outflow.

Q. What is the use of this indicator when the injector is used as a heater?

A. It shows that the indicator is not feeding and that there may be danger of overheating the tank water.

Q. What is a double-tube injector?

A. One having one set of tubes to lift or draw the water and deliver it to a second set which forces it into the boiler.

Q. What is the advantage claimed for the use of a special set of lifting tubes?

A. That it acts as a governor to the forcing tubes, delivering the proper amount of water for the condensation of the steam, thus enabling the apparatus to work under greater ranges of steam pressure, water temperature, and amount of feed delivered.

Q. What is the most difficult service for an injector?

A. High steam pressure, superheated steam and hot supply water.

Q. In a boiler, what is the comparative temperature of the steam and the water?

A. Both alike, so long as the circulation is good and there is no superheating.

Q. What would be the initial velocity of a jet of saturated steam at 180 pounds boiler pressure?

A. About 3,600 feet per second.

Q. What would be the initial velocity of a jet of water at 180 pounds pressure?

A. About 164 feet a second; say 1/32 that of the saturated steam at the same pressure and temperature.

Q. What is the tendency of a steam jet after emerging from a nozzle?

A. To enlarge rapidly.

Q. What velocity must a water-jet have to enter a steam boiler under 180 pounds pressure?

A. A trifle over 164 feet per second.

Q. Suppose a pound of steam at a velocity of 3,600 feet a second is condensed by 10 pounds of water at a velocity of 40 feet a second, what would be the velocity of the combined stream, supposing they met in the line of discharge?

A. 3,600 + (40 × 10) divided by 11; that is, 366 feet per second.

Q. Assuming that half of this velocity is lost on account of friction and imperfect mingling, what would be the pressure exerted by the stream?

A. About 206 pounds per square inch.

Q. Would this be sufficient to enable the stream to force its way into the boiler under 180 pounds of steam?

A. Certainly; with 26 pounds to spare for friction in feed-pipes, etc.

Q. How much power is required to run an injector that delivers 3,000 gallons an hour?

A. With ordinary pressures, from 65 to 120 H.P.; that is, from 8 to 15 per cent of the power of the engine.

Q. But does not the heat that this power represents go back into the boiler?

A. Yes; but it is not yet in condition to be used in the cylinders. There is enough heat in a locomotive boiler full of water at 200 deg. F. to run a small engine, if it were put into a smaller weight of steam at 300 deg. F.; but as it is, locked up in the water, it is useless for immediate power purposes in a steam-engine cylinder unless the engine were used merely as a water motor.

Q. What is one of the principal uses of a good injector?

A. To regulate the steaming; being taken off on up grades and put on on down grades.

Q. Will an injector deliver more cold water, or more hot, per pound of steam of any given temperature?

A. More cold.

Q. With increase in steam pressure and temperature, what change should be made in the supply water temperature?

A. It should be colder.

CHAPTER XXXIX

COMBUSTION

Q. What is combustion?

A. Another name for burning. It is the rapid union of a substance or of a combination or a mixture of substances with oxygen; this union being attended with the giving out of heat and more or less light.

Q. What is oxygen?

A. A colorless gas which, mixed with another colorless gas called nitrogen, forms about the weight and the bulk of the air which we breathe.

Q. Will iron burn?

A. Yes, if heated red hot and put in pure oxygen.

Q. Do you know anything about black smoke, and what it is?

A. It consists of combustion-gases resulting from the combination of the oxygen and nitrogen of the air with the carbon and hydrogen of the fuel, and mixed with unconsumed (that is, unoxidized) carbon, by reason of improper amount of air-supply. Perfectly-burned carbon produces colorless smoke.

Q. Will air enough come through the grates and fire to form perfect combustion of the coal?

A. Seldom, even with thin firing.

Q. Is it necessary to let in air above the fire?

A. Usually.

Q. What is the use of the hollow stay-bolts?

A. Two-fold; to admit air above the grate, and to enable a broken one to be at once detected.

Q. What is the object of holes in the fire-box door?

A. Partly to admit air above the grate, to facilitate complete combustion; partly to keep the fire-door from warping.

Q. Will the cold air mix with the gases from the coal and burn at once, or must it be heated first?

A. First heating would be better, but it cannot be properly effected.

Q. When the fire burns most in the front end of the fire-box, what does it indicate?

A. That the lower tubes have proportionately too much draft.

Q. How is this remedied?

A. By raising the petticoat-pipe, if there is one, or by shifting the diaphragm or adjustable apron in the case of an engine with a "long front end."

Q. Where does the combustion of coal take place?

A. About half in the grate, half in the combustion space above and beyond it.

Q. What are the gases arising from the fuel bed?

A. 10 to 28 per cent of combustible, practically no free oxygen.

Q. How then is this combustible to be burned?

A. By air admitted above the grate; if necessary, by the help of the blower.

Q. On what does the completeness of burning with any size combustion space depend?

A. On air excess and rate of firing.

Q. On what does the completeness of gas combustion depend?

A. On the volume and proportions of the combustion space.

Q. What usually tend to reduce the completeness of burning of the furnace gases?

A. Too little air and too rapid and irregular firing.

Q. For any given set of conditions as to combustion rate and air excess, to what is the combustion space needed proportionate?

A. To the product of the percentage of volatile matter in the fuel, or a factor depending on its quality.

Q. What is the indicator or measure of the quality of the coal?

A. The ratio of the volatile carbon to the available hydrogen; the higher the carbon ratio the more difficult the combustion.

Q. Where two engines burn the same fuel but have different volumes of combustion space, which should have the most excess air?

A. The one with the smaller combustion space.

Q. Of two furnaces of the same size but burning different fuels, which will give the better results if there is too little excess air?

A. The one with coal lower in volatile matter and oxygen.

Q. Are the gases in the fire-box and tubes of uniform composition?

A. No; they are stratified.

Q. What is the percentage of carbonic oxide (CO) in the combustible gases?

A. About 80 per cent.

Q. What is the composition of the combustion gases from the volatile matter?

A. Various complex hydrocarbons.

Q. What takes place if these are insufficiently burned?

A. They form soot, hydrogen and carbonic oxide (CO).

Q. What causes the formation of soot?

A. It is formed at the surface of the fuel bed by the hydrocarbons being heated in the absence of air; it is not formed by chilling, as is generally supposed.

Q. Then why do we find soot in the cooling surfaces?

A. It is only collected there.

Q. What is the relation between draft and coal consumption in a locomotive boiler?

A. If with a pressure drop of half an inch of water the coal consumption was 20 lbs. of coal as fired, burned per hour, then with five inches drop it would be 58 lbs.; with ten inches, 97 lbs.; with 12 inches, 106 lbs.; the nominal horse-power developed by the boiler being 125, 575, 625 and 700, respectively.

Q. What is the average efficiency of coal-fired boilers?

A. 70 per cent.

Q. Of oil-fired?

A. 75 to 80 per cent.

Q. How many thermal units should fuel oil have?

A. At least 18,000 per pound.

Q. How much dry air as a minimum is needed for complete combustion of one pound of carbon?

A. 11.58 lbs.

Q. In practise, how much?

A. 50 per cent more; 18.37 lbs.

Q. Using 50 per cent more excess air, what would be the increase in temperature in burning a pound of carbon (not coal)?

A. About 3,000 deg. F.

Q. What relation is there between the temperature of the stack gases and the heat carried away by them?

A. For 12 lbs. of air per pound of combustible of 14,540 B.t.u., a stack-gas temperature of 300 deg. F. would cause a loss of 5.2 per cent; of 650 deg., 12.7 per cent. But 12 lbs. of air is the theoretical minimum; if 30 lbs. were used, the loss would be 12.4 per cent at 350 deg. and 30.4 per cent at 650 deg.; and for 42 lbs., 17.1 per cent at 300 deg. and 42 per cent at 650 deg.

Q. In buying coal, what points should be considered?

A. Moisture, ash, size, and calorific (heating) value.

Q. What effect has the ash percentage in the dry coal on the heating power?

A. It varies with boiler, grate and furnace; but in general it may be said that 20 per cent of ash reduces the heating value about 10 per cent; 30 per cent ash, 35 per cent; and 40 per cent ash, 100 per cent, as compared with screenings with 12.5 per cent ash.

Q. Have you any idea of the various temperatures on a recent locomotive?

A. The K 4 s Penna. R. R. engine gave the following results in a series of 44 tests:

Boiler*	Branch Pipe	Superheat in Branch Pipe	Exhaust Passage	Superheat in Exhaust
389.9°	480.5°	91.6°	217.4°	0.6°
389.5°	508.2°	120.1°	219.2°	1.2°
389.7°	576.3°	190.1°	275.7°	40.3°
389.9°	577.5°	197.2°	317.0°	71.7°
389.6°	490.8°	102.5°	212.5°	0.0°
388.7°	576.7°	188.7°	331.3°	82.1°
388.8°	591.1°	215.2°	342.9°	86.7°
389.9°	610.0°	228.6°	332.3°	82.8°
390.0°	517.0°	128.0°	218.0°	0.0°

Q. Give some details of the relations of combustion, draft and temperature in a recent heavy passenger locomotive.

A. Taking the Penna. R. R. engine of K 4 s type, we have the following out of a number of tests:

Draft, Inches of Water				Temp., Deg. F.			Coal per Sq. Ft. Grate, Lbs. Per Hr.
Front of Diaphragm	Back of Diaphragm	Fire Box	Ash Pan	Fire Box	Smoke Box	Steam in Branch Pipe	
1.2	1.0	0.4	0.11	2010°	406°	480.5°	22.17
2.0	1.4	0.5	0.13	2250°	446°	494.2°	27.11
3.3	2.2	0.7	0.24	2252°	463°	523.1°	39.20
4.1	2.8	0.9	0.22	2270°	494°	508.3°	42.13
5.	3.4	0.9	0.31	2223°	502°	542.2°	52.88
6.3	4.1	1.2	0.36	2357°	494°	559.8°	62.46
8.	5.1	1.2	0.53	2345°	549°	567.6°	69.93
10.1	6.8	1.4	0.54	2480°	618°	582.5°	75.80
12.3	7.9	2.3	0.88	2440°	546°	588.3°	101.86
15.1	10.1	2.8	0.62	2390°	586°	591.0°	126.48
18.8	11.7	2.9	0.71	2550°	700°	591.0°	*173.26*

* From Marks and Davis steam table.

Q. What would be the loss of heat in coal fired, if only two per cent of CO (carbonic monoxide) in completely burned coal in the combustion gases?

A. About seven per cent maximum.

Q. Give some idea of the relation between boiler horsepower and heating surface, for different evaporation rates?

A. The annexed figures show this succinctly:

Evaporation from and at 212° F. per Sq. Ft. per Hr.							
2	3	4	5	6	7	8	10
Sq. Ft. Heating Surface per H. P.							
17.3	11.5	8.6	6.8	5.8	4.9	4.3	3.5

(Multiplying the corresponding figures we get $2 \times 17.3 = 34.6$; $4 \times 8.6 = 34.4$; $8 \times 4.3 = 34.4$; $10 \times 3.5 = 35$—as a sort of check on these figures.)

Q. What would be an ideal boiler and furnace, from the efficiency point of view?

A. One that would yield to the water the total heat burned up in the fuel.

Q. How may one express the efficiency of the boiler and grate together?

A. By dividing the heat absorbed by the boiler, per pound of *coal as fired,* by the calorific value of one pound of that *coal as fired.*

Q. How is the efficiency of the boiler alone expressed?

A. By dividing the heat absorbed by the boiler per pound of *combustible burned* in the grate, by the calorific value of one pound of that *combustible as fired.*

Q. How is this efficiency of the grate alone expressed?

A. By dividing the efficiency of boiler and grate combined by that of the boiler alone; or otherwise expressed by dividing the amount of combustible burned by the amount fired.

Q. What is the effect of high initial gas temperature on boiler efficiency?

A. To increase the efficiency of the heating surface.

CHAPTER XL

STEAM PRODUCTION

Q. What is the maximum production of steam, in cubic feet per hour, in a medium-sized passenger locomotive?

A. It takes about five cubic inches of cylinder capacity per net ton of adhesive work to move a locomotive one inch; and about one-fifth cylinder full of steam for each single stroke of each piston. Supposing 15 inches piston diameter and 20 inches stroke with a 48,000-pound engine with 24,000 pounds of tender and enough cars to make the total train weight 212,000 pounds or 106 net tons, with seven pounds traction per net ton of train, for a speed of ten miles an hour on a straight level track (or 21 pounds on a grade) with 90 pounds of boiler pressure and cut-off at one-fifth, it would take 80 x 5 = 16 cubic inches of steam per inch, 84,480 cubic inches per mile, 8,444,800 cubic inches or 65.35 gallons per hour; to which add 20 per cent for water carried over, etc.

Q. What may be said of the quality of steam furnished by locomotive boilers?

A. Tests made with a locomotive standing in the test plant, where there was in all probability less foaming and priming than there would be in service on the road (especially if this was more or less rough) showed in the dome less than six per cent water in the worst cases, and an average not over 1½. In the steam-pipe the superheating due to wire-drawing reduced this amount one per cent; so that the average quality of steam in the branch-pipe was about 99½ per cent dry steam.

Q. What about the evaporation per pound of coal in a locomotive boiler?

A. In a constant test, using good coal with 76 per cent fixed carbon and 7 per cent of ash, the evaporation per pound of coal was for different rates of combustion as follows:

Rate of combustion.*	Minimum evaporation.†	Maximum evaporation.†
0.5	10.5	12.
1	8.5	10.
1.5	7	8.5
2	6	7.5

Q. What is the amount of water that can be evaporated per square foot of fire heating-surface per hour?

A. Referring to the steam tests already quoted, the amounts of water per square foot of fire heating-surface per hour, due to the maximum evaporation and rates of combustion above, were as follows:

Steam per square foot of heating surface per hour:

Rate of combustion.	Minimum evaporation.
0.5 lbs.	6 lbs.
1	10
1.5	12.8
2	15

Q. At the above rates, and figuring a horse-power to be represented by 34½ pounds of steam from and at 212 deg. F., how much tube fire-surface is necessary for a horse-power?

A. A little over two square feet.

Q. Putting it the other way about, what part of a horse-power may be obtained in a locomotive boiler from one square foot of surface of the fire side of the tubes?

A. Tests have showed from 0.26 to 0.41 horse-power per square foot of fire side of tubes.

Q. How does the circulation in a locomotive boiler usually proceed?

A. Along the bottom of the barrel from the front end, down the fire-box front, and up the sides and back to the

* Pounds of coal per square foot of grate per hour.
† Pounds of water per pound of coal.

fire-box; but the manner of firing may change this, or even reverse it.

Q. What are the results of tests for boiler performance?

A. Contrary to the common assumption, large boilers, when forced to maximum power, deliver as much steam per unit area of heating surface as small ones.

At maximum power, a majority of the boilers tested delivered 12 or more pounds of steam per square foot of heating surface per hour; two delivered more than 14; the second largest delivered 16.3. These values, in boiler horse-power per square foot of heating surface, are 0.34, 0.40 and 0.47, respectively.

Q. Which steamed best—passenger or freight engines?

A. The two boilers holding the first and second place with respect to steam per square foot of heating surface, were those of passenger locomotives.

Q. Give some recent concrete figures of the steaming capacity of a fast passenger engine?

A. The K 4 s engine of the P. R. R., referred to elsewhere, using superheater, evaporated from 18,157 to 87,414 lbs. of water (reckoned from and at 212 deg.; actual evaporation 14.397 to 65,400 lbs.) per hour; being actually 205.7 to 920 lbs. per hour per square foot of grate (from an at 212 deg., from 259.5 to 1,248.8 lbs.;) per square foot of heating surface 3.73 to 17.97 lbs. per hour.

Q. Show the relation between indicated horse-power and water consumption on a recent heavy passenger locomotive.

A. Taking a Penna. R. R. engine of type K 4 s, we have about 18.5 lbs. of steam per i.h.p. hour at 1,600 i.h.p; 16.1 at 1,900. Between 900 and 2,800 the rates are under 18 lbs. At minimum power (3,250 i.h.p.), the consumption increases to about 20 lbs.

But on a K 2 s a engine the water rate decreased steadily from 19 lbs. at 900 i.h.p. to 17 at 2,600 i.h.p.

Q. What is the relation between water rate and piston speed under good recent conditions?

A. Taking the Penna. R. R. K 4 s machine, we have the water rate decreasing with the piston speed from 19.6 lbs. per i.h.p. hour at 560 feet a minute, to 15.3 lbs. at 1,670 feet. The same character of relations exist in the K 2 s a type on the same road.

Q. Give some data concerning the various steam pressures in a recent locomotive.

A. As under, the tests being the same for which temperatures are given elsewhere, Penna. R. R. engine, K4s type:

Steam Pressure by Gage in		
Boiler	Branch Pipe	Exhaust Passage
206.0	203.2	2.0
204.9	201.1	2.4
205.4	191.4	8.9
206.0	182.0	13.3
205.0	201.7	2.0
202.7	176.7	15.2
201.3	172.1	19.1
205.7	184.7	15.4
206.0	203.5	3.4

Q. Give some data concerning comparative performance of a recent locomotive.

A. Taking the K4s type of the Penna. R. R., we have the following figures:

Lbs. Water Evap. per Hr.	Ratios		Superheat in Branch Pipe	Equiv. Evap. Lbs. per Hr.	Boiler Efficiency
	Water to Total Coal	Water to Dry Coal			
18580	10.03	12.74	105.4°	23580	84.67
22499	9.14	11.70	130.7°	28812	77.23
34372	8.06	10.55	173.2°	44962	70.11
50583	7.18	9.59	206.1°	67523	65.61
59953	6.03	8.08	228.7°	80235	54.53
65400	5.53	7.40	215.2°	87414	49.94

Q. How much of this evaporation was due to the superheater?

A. An average of 23.7 per cent of the equivalent per square foot of heating surface.

Q. Give an example from recent good practise of the thermal efficiency of a locomotive at various horsepowers.

A. The following is from Penna. R. R. tests of a K 4 s heavy passenger engine:

I H. P.	Pressure, Lbs. Absolute		Superheat in Branch Pipe Deg. F.	Lbs. Steam per I H. P. Hrs.	Thermal Efficiency %
	Branch Pipe	Exhaust			
709.7	217.4	16.2	91.6	18.09	13.15
1539.5	213.1	18.6	144.5	17.85	13.09
2069.6	211.6	20.4	173.2	16.53	14.02
2573.8	205.3	22.8	184.2	16.98	13.65
2766.8	200.9	24.4	206.1	18.25	12.66
2984.3	190.9	29.4	198.7	21.19	11.04
3183.9	186.2	33.2	215.2	20.53	11.40

Q. Show the effects of superheating on the water consumption under stated conditions of recent good practise.

A. Taking the K 4 s engine of the Penna. R. R., we have the following official figures:

Draft in Water	I H. P.	Heat Units per I H. P. Hr.	Deg. F. Superheat in Branch Pipe	Lbs. Superheated Steam per I H. P. Hr.	Lbs. Dry Coal per I H. P. Hr.
1.2	709.7	19353	91.6	18.09	2.13
1.6	818.2	20482	102.5	19.04	2.03
5.0	1833.6	18292	156.1	16.72	1.97
11.8	2741.6	19169	200.4	17.39	2.31
16.3	3155.3	20354	228.7	18.44	3.15

CHAPTER XLI

FEED WATER HEATING

Q. What is the object of heating the feed water?

A. To reduce the work demanded of the fuel on the grate, by utilizing some of that in the combustion gases that would otherwise escape from the stack at a high temperature; also to lessen the injurious effect of injecting cold water into a hot boiler; and to steady the evaporation.

Q. How much saving can be effected by heating the feed?

A. In theory, as expressed in the annexed table. In practise, less.

Saving for Each Degree Increased Temperature

Initial Feed Temp. Deg. F.	Gage Pressure, Lbs.				
	120	140	160	180	200
32	.0841	.0839	.0837	.0835	.0833
40	.0847	.0845	.0843	.0841	.0839
50	.0854	.0852	.0850	.0848	.0846
60	.0862	.0859	.0856	.0855	.0853
70	.0869	.0867	.0864	.0862	.0860
80	.0877	.0874	.0872	.0870	.0868
90	.0884	.0883	.0879	.0877	.0875
100	.0892	.0890	.0887	.0885	.0883
120	.0908	.0898	.0895	.0893	.0891
150	.0934	.0931	.0929	.0926	.0924
200	.0980	.0977	.0974	.0972	.0969
250	.1031	.1027	.1025	.1022	.1019

For other temperatures and pressures in the same way; that is, increasing with the initial feed temperature and decreasing with the gage pressure.

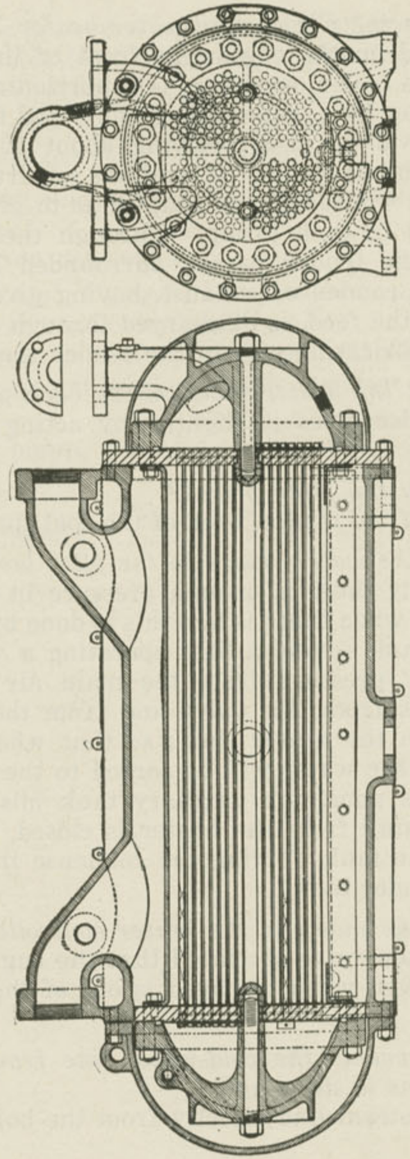


Fig. 115. Elesco Feed Water Heater.

Q. Describe the Elesco feed-water heater.

A. Forward on the engine, in front of the cylinders and under the boiler overhang, is a horizontal tank, fed from the tender by a steam pump and piped to the usual boiler check valve; also receiving about 10 to 15 per cent of the exhaust steam. It contains quadruple groups of small tubes 4 feet long, so coupled as to give the feed 16 feet travel in each group. Through these the cold water from the tender passes, surrounded by the hot exhaust. The condensed exhaust, having given up most of its heat to the feed, is discharged through a filter (to remove the lubricating oil) to the tender tank.

Q. Does not the heater increase the back pressure?

A. No; it decreases it slightly, by acting as a condenser.

Q. Where is the filter placed?

A. On top of the tender, back of the coal space.

Q. How is the water raised to the filter level?

A. Ordinarily there is enough pressure in the heater to do this; but when there is less this is done by means of an auxiliary tank having a float operating a small valve controlling air pressure from the main air reservoir. The discharges from this valve and from the tank are connected with the heater shell; so that when there is back pressure the water will be forced to the filter; but where there is none, the auxiliary tank fills, the float rises, the opening from the heater is closed, and air is admitted to the tank, forcing the condense through the filter to the tender tank.

Q. How is the pump to the heater controlled?

A. By a steam valve so placed that the engine-runner can reach it even when his head is out of the cab window.

Q. What prevents the cold-water line from freezing when the engine is standing?

A. A small steam line directly from the boiler.

Q. What rise in feed temperature is effected?

A. It can deliver feed at 212 deg. to 240 deg. F.

Q. Does not the device lessen the draft?

A. Yes; but less air is needed, as less coal is burned, due to the increased feed temperature.

Q. About how much of the heat in the coal is utilized in the cylinders?

A. About seven per cent only.

Q. Give an idea of where the rest goes—say with an engine using $900 worth of coal a month.

A. It has been estimated that the distribution, expressed in money and percentages, is about as follows:

Radiation, air pump, etc.	$90	10%
Stack	225	25
Exhaust	522	58
Utilized in cylinders	63	7
Cost bill	$900	100%

CHAPTER XLII

SATURATED STEAM

Q. What is saturated steam?

A. That with just enough heat to keep it from condensing.

Q. What is dry steam?

A. Properly speaking, saturated steam; usually, however, that which has not over two per cent of entrained water.

*Q. What is superheated steam?**

A. That which has been heated, when not in contact with water, hence has a higher temperature than saturated or dry steam at the same pressure.

Q. What is the advantage of superheating?

A. Carrying more of the heat of the fire into the cylinders, there to do mechanical work.

Q. What are the disadvantages of using saturated steam?

A. (1) Ordinary valve gears, with high speeds and early cut-offs (say 1-10 or under) have too much compression and too little initial pressure, hence too little power; (2) cylinder condensation increases with the diameter; (3) with large cylinders where the initial pressure is too high it cannot be sufficiently throttled; whereas at low boiler pressure the steam temperature is too low.

Q. What is the disadvantage of very high pressures of saturated steam, used in either compound or non-compound engines?

A. Too hard on the fire-box, and especially on the stay-bolts, thus increasing the cost of maintenance and repair.

Q. Is the average temperature of the steam in the boiler the same as that of the water?

A. It should be; and it is when the circulation is good;

* See next chapter.

but there may be short intervals when the water is colder than the steam, by reason of overfeeding, etc.

Q. What is the temperature of saturated or ordinary steam at 140 pounds pressure?

A. 361 deg. F.

Q. How many British heat (or thermal) units does one pound of it contain?

A. 1,192.

Q. What is its volume?

A. 2.92 cubic feet.

Q. How many B. H. U. (or B. T. U.) would be necessary to heat it to 680 deg. F.?

A. 153.

Q. What would be its volume then if allowed to expand?

A. 4.06 cubic feet.

Q. Its pressure, if the volume remains the same?

A. 210 pounds.

Q. Which increases, pressure or volume, in the locomotive boiler?

A. Both volume and pressure.

Q. What then would be gained by this superheating?

A. By adding only 12.8 per cent more heat, 39 per cent of volume.

Q. At what temperature is superheated steam now worked in locomotives?

A. 660 deg. F. in the cylinders.

Q. What is the highest "flash-point" of lubricant, attainable?

A. 780 deg. to 790 deg. F.

Q. How about the temperatures at pressures above atmosphere (boiler pressures)?

A. Subtract 14.7 pounds (roughly, 15 pounds) from pressures reckoned from vacuum.

Q. What have we to do with Centigrade degrees?

A. We should be able to read and understand books and reports from other countries where this system is used, and if sent to such countries to understand their units. Further, the Centigrade system is making headway in America.

Q. What is the rule for reducing Fahrenheit to Centigrade degrees?

A. Subtract 32 and take 5/9 of the remainder. Thus: 212 deg. F. = (212 — 32) × 5 ÷ 9 = 100 deg. C.

Q. What is the rule for reducing Centigrade degrees to Fahrenheit?

A. Take 9/5 of the sum and add 32. Thus: 180 deg. C. = (180 × 9 ÷ 5 = 324) + 32 = 356 deg. F.

Q. What are the freezing points on these two kinds of thermometer?

A. Fahrenheit 32 deg., Centigrade 0 deg.

Q. The boiling points of water?

A. Fahrenheit 212 deg., Centigrade 100 deg.

Q. What are the temperatures of saturated or dry steam at various pressures from 75 pounds to 200 pounds per square inch?

A. The following short table gives them both in Fahrenheit and in Centigrade (also called Celsius) degrees:

Pressure above vacuum. Pounds.	Temperature (approx.) Fahr. Deg.	Cent. Deg.
75	307.5	153
90	320.2	160
100	327.9	164
115	338	170
125	344.2	173
140	352.9	178
150	358.3	181
165	366	186
175	370.8	188
190	377.5	192
200	381.7	194

Q. How do we figure the total heat contained in steam at any given temperature and pressure?

A. By adding the latent heat of steam formation to the sensible or appreciable heat, as measured by the thermometer. Thus the total heat above 32 deg. F. is 1,083 deg. plus three-tenths of the observed temperature Fahrenheit.

Q. How do we calculate the latent heat of steam?

A. By adding the internal heat to the external or that required to increase its volume against external resistance. The rule is to take from 1,114, seven-tenths of the latent heat.

Q. Figure the total, latent and sensible or appreciable heat of steam at 160 lbs. gage pressure, reckoning from 32 deg. F.

A. The total heat equals 1,083 plus (0.3 × 371) = 1,194.3 deg. The latent heat equals 1,114 minus (0.7 × 371) = 854.3 deg. The sensible heat equals 371 — 32 deg. = 339 deg.

Q. How much of its weight does saturated steam lose by cylinder-condensation at usual cut-offs?

A. 30 per cent.

CHAPTER XLIII

SUPERHEATED STEAM

Q. What is superheated steam?

A. That which has been raised in temperature and increased in volume by the addition of heat when no more water can be evaporated by that heat.

Q. How high is that superheating carried in locomotive practise?

A. Up to 600° F., from say 375° F. at 170 lbs. gage pressure.

Q. How much is its volume increased?

A. That at 170 lbs. is increased in volume over 32 per cent by 200° of superheating.

Q. What are the advantages of superheating?

A. Saving of coal by utilizing the heat otherwise wasted through the stack; saving of water; avoidance of priming, and of cylinder condensation (hence, possibility of using larger cylinders); increase of engine efficiency when forced; reduction of boiler repairs by use of lower pressures.

Q. Does superheated steam follow the laws of perfect gases?

A. When far removed from the temperature of saturation it does follow the laws of perfect gases very nearly, but near the temperature of saturation the departure from those laws is too great to allow of calculations by them for engineering purposes.

Q. What is its volume compared with the saturated?

A. About 25 per cent greater.

Q. What is the disadvantage of superheating?

A. Increased difficulty of lubrication as the steam of high temperature breaks up the ordinary oils.

Q. Can superheated steam part with heat without being condensed?

A. Yes, up to that point where it has the temperature corresponding to saturated steam of the given pressure.

Q. Does the superheater increase the evaporative capacity per square foot of total heating surface?

A. No; on the contrary it lowers it; being in itself not so efficient as the boiler proper. For instance, in tests of the P. R. R. K 4 s engine the extreme evaporations per square foot per hour (reckoned from and at 212 deg. F.) were 4.72 and 21.62 lbs. without and only 3.73 and 17.97 lbs. with the superheater.

Q. Can the water in the boiler be superheated?

A. Yes.

Q. Can steam be superheated in the boiler?

A. Not as long as there is any water remaining therein that can be evaporated.

Q. Does superheating increase the steam volume?

A. Yes.

Q. At what rate does superheated steam expand?

A. About the same as a perfect gas; say, 1/273 = 0.003663 its volume at 32 deg. F. for each degree Fahrenheit, or 0.00599 its volume at 0 deg. C. for each degree Centigrade.

Q. In using superheated steam to save water, is there proportionate coal saving?

A. No; some heat is expended in superheating.

Q. How much heat is needed to superheat one pound of dry or of superheated steam one degree F.?

A. Nearly half a heat unit (exactly, 0.495.).

Q. To heat one pound of water one degree F.?

A. One heat unit; an energy expenditure equivalent to raising 772 lbs. of water one foot high.

Q. As between compound engines with saturated steam and non-compounds using superheat, which are the more economical of steam?

A. The superheaters.

Q. Then why not use superheat with compounds?

A. The conditions are not so favorable.

Q. What are the requirements of a successful superheater?

A. Security of operation (minimum danger of overheating), efficient heat transmission, provision for free expansion, ability to be cut out without putting the boiler out of service, and provision for keeping the surfaces free from ash, soot and scale.

Q. On what does the required amount of superheating surface depend?

A. On the degree of increase of temperature desired, the velocity of the steam and of the combustion gases, the character of the device, the weight of steam to be superheated, the amount of moisture in the steam, the temperature of the combustion gases, the conductivity of the surfaces, and their degree of freedom from ash, soot and scale.

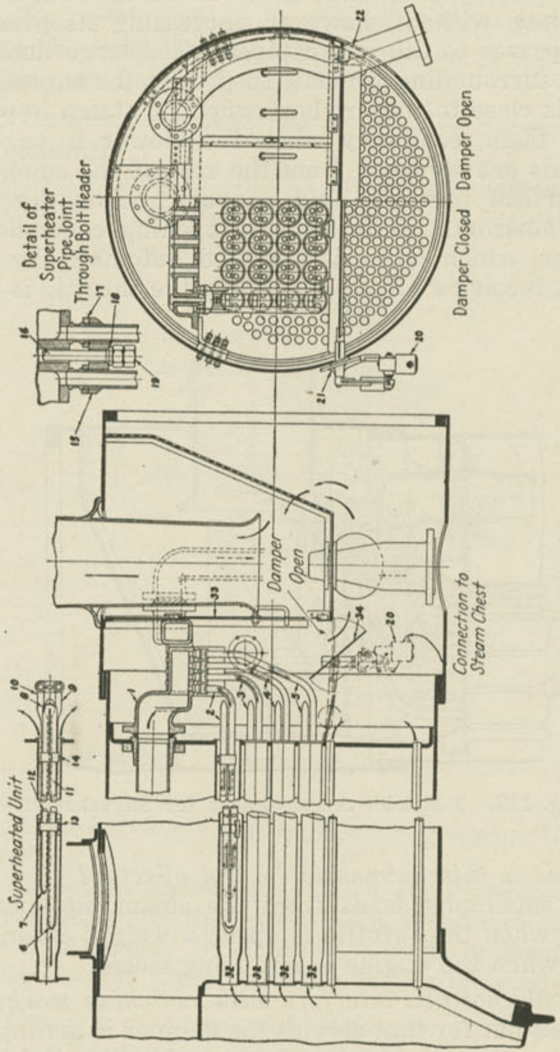
Q. Is superheated steam a better or a poorer conductor of heat than saturated?

A. A poorer.

*Q. Describe Type A "Elesco" superheater.**

A. The boiler has two sets of flues, large and small diameter, both for passage of combustion gases. The large ones, above the others, are reduced in diameter at the back flue sheet through eight inches of their length, to aid water circulation. In each large flue there projects from the smoke-box a set of four steam tubes welded at return bends to form a continuous pipe, connected with a header fed by the dry pipe and replacing the usual T head, and communicating with the steam pipes leading to the valve chests. This header has partitions compelling the steam entering from the dry pipe to pass through the superheating pipes, in which a por-

* The type of Schmidt superheater described in earlier editions of this book has been superseded by that now used in the United States and called by the trade name, "Elesco."



Figs. 116 and 117. Application of Superheater.

tion of the heat in the flue gases raises its temperature and volume, without, however, increasing its pressure. It then passes to the steam pipes. The large flues also heat the surrounding water. To protect the superheater pipe ends close to the fire-box, when no steam is passed through them, especially when the blower is on, their front ends are screened from the rest of the smoke-box by a vertical partition and support; below the large flues, a horizontal plate with an opening controlled by a damper, which latter is operated automatically by a cylinder, receiving steam only when the throttle is open.

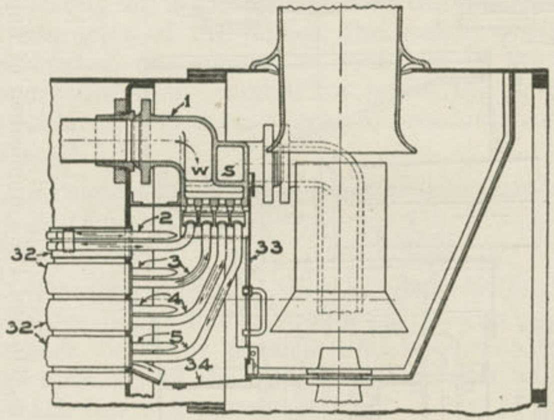


Fig. 118. T-Header Arrangement for Superheater.

Q. How is this automatic control effected?

A. A small pipe leads from the steam pipes to this cylinder when the throttle is open; a weight closing the damper when the engine is not using steam.

Q. Would not this interfere with switching work?

A. Yes; but for that service the damper is arranged to close only when the blower is on, otherwise it is open whether the throttle is open or not.

Q. How can superheater flues be kept clean?

A. By blowing steam or compressed air through from the fire-box end, and by taking care not to let water get carried over and deposit scale therein.

Q. How can the superheater pipes be prevented from overheating?

A. By a damper in the smoke-box, closing off the superheater pipes automatically when the throttle is shut.

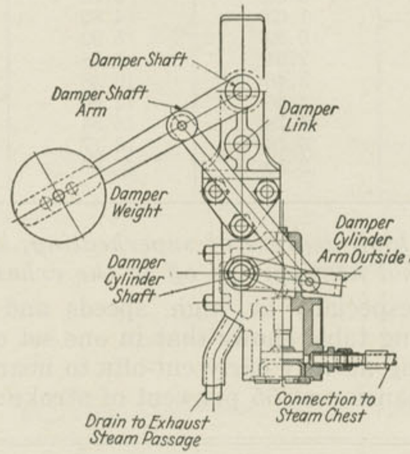


Fig. 119. Superheater Damper Closed.

Q. What is the effect of high water reaching the superheater?

A. To lessen its efficiency, as it then becomes merely an evaporator to the extent that it has to turn that water into steam. Incidentally it tends to form scale in the superheater pipes and thus reduce their effect.

Q. Can you give some authentic concrete figures showing the advantage of superheating?

A. Taking the official tests of the Penna. R. R. K 4 s engine with Schmidt superheater, we have some of the figures as follows:

Equivalent Evaporation from and at 212° F., Lbs. per Hr., per Sq. Ft. of Heating Surface			Ratio of Superheater to Boiler, Evap. per Sq. Ft. Heating Surface
Boiler without Superheater	Superheater Alone	Boiler with Superheater	
4.72	0.59	3.73	0.125
6.06	1.03	4.85	0.170
7.96	0.49	5.92	0.062
9.08	2.04	7.38	0.225
12.84	3.46	10.58	0.269
15.19	4.45	12.60	0.293
19.03	5.78	15.84	0.304
20.14	*6.16*	16.77	*0.306*
21.62	2.50	*17.97*	0.116

Q. With high degrees of superheating, is not some of the additional heat carried off in the exhaust steam?

A. Yes, especially at high speeds and late cut-offs. The following table shows that in one set of tests it ran from nothing at very early cut-offs to nearly 87 degrees F. with expansion at 65 per cent of stroke:

R.p.m.	Average Nominal Cut off, Per Cent. of Stroke									
	15	25	35	40	45	50	55	65	70	75
	Superheat and Exhaust, Deg. Fahr.									
120	0.6	1.2	1.		0.		40.3			71.7
160	0.	0.	0.		8.7		61.1		82.1	
206	0.	0.	0.9		20.1			*86.7*		
240	0.		15.5		48.8		73.5			
280	0.	0.	1.5	39.1		82.8				
320	0.				80.3					
360	0.	6.3	50.2							

Q. What would be a remedy for excessive amount of superheat carried off in the exhaust?

A. Recovery of at least a part thereof by an exhaust feed-water heater. (See under "Feed-water Heaters.")

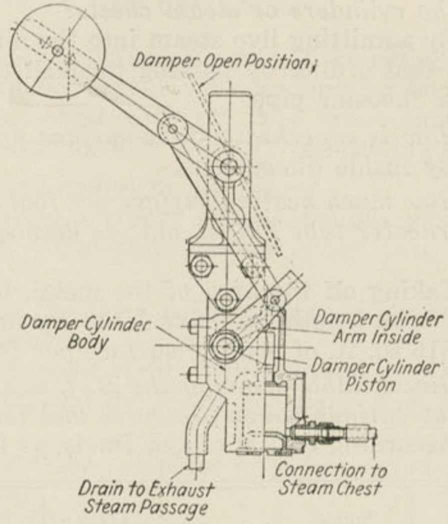


Fig. 120. Superheater Damper Open

Q. Give a concrete example of saving by the use of the Schmidt superheater.

A. On the C. & N. W. the saving produced on 4-6-2 engines were as follows:

Steam	Boiler Press	Cyl.	Direction	Saving, %	
				Coal	Water
Saturation...........	200	23 x 28	N.	34.9	36.7
Superheat............	175	25 x 28	S.	26.4	32.1

Driver diameter of each, 75″; weights of engine and on drivers practically the same.

Q. How is the undesirable effect prevented, that sometimes happens when superheated steam is used, that the ordinary lubricator feed is retarded by back pressure from the cylinders or steam chests?

A. By admitting live steam into the oil pipes, in addition to that ordinarily passing through the choke-plugs; using a "booster pipe."

Q. How is superheater-tube surface figured?

A. By inside dimensions.

Q. How much heating surface per foot of length would a superheater tube 1½ in. outside diameter, No. 9 gage, have?

A. Taking off the area of the metal, 0.628 sq. in. per foot of tube length, we have 1.138 sq. in. of steam area and 0.315 sq. ft. of heating surface per foot of length.

Q. Give a table showing the B. t. u.'s in superheated steam at various boiler pressures and temperatures?

A. According to Marks and Davis, as follows:*

Gage Press.	Super-heat F.	B.t.u.'s	Gage Press.	Super-heat F.	B.t.u.'s
150	100°	1252	220	100°	1261
	300	1352		300	1362
160	100	1254	240	100	1264
	300	1353		300	1364
180	100	1256	250	100	1265
	300	1356		300	1365
200	100	1259			
	300	1359			

*Rounded off, and atmospheric pressure counted as 15 lbs. instead of 14.7.

CHAPTER XLIV

THE CYLINDERS

Q. What are the principal parts of the cylinders?

A. (1) Cylinder proper with its bushing and stuffing-box, (2) steam-chest with its false seat (should there be one) and stuffing-box, and (3) bed-casting or saddle.

Q. How many cylinders are there?

A. Two, three, or four; non-compounds usually having only two, compounds having either two, three, or four.

Q. How can the same pattern be used for both cylinders of a non-compound engine?

A. The ports come right whichever end of the cylinder is turned front, and the heads and flanges on both ends are alike.

Q. Where are the cylinders of a two-cylinder American locomotive?

A. Outside of the frames.

Q. Where are the cylinders of most two-cylinder European locomotives?

A. Inside, between the frames.

Q. Where there are three cylinders, as in a compound locomotive with one cylinder between the frames and two outside, as shown in Fig. 122, how are the cranks arranged?

A. 120°, that is, one-third of a circle, apart.

Q. What are the advantages of the American arrangement?

A. There is no necessity for cranking the axle, and the steam chests are more readily got at.

Q. What are the advantages of inside-cylinder engines?

A. They run more steadily, where the wheel-base is short, as outside cylinders have greater leverage to twist the entire machine from side to side; and there is less loss of heat from cylinders by radiation, than where they are exposed outside the frames; the engines take up less side room, hence narrower tunnels and bridges suffice for a given engine power.

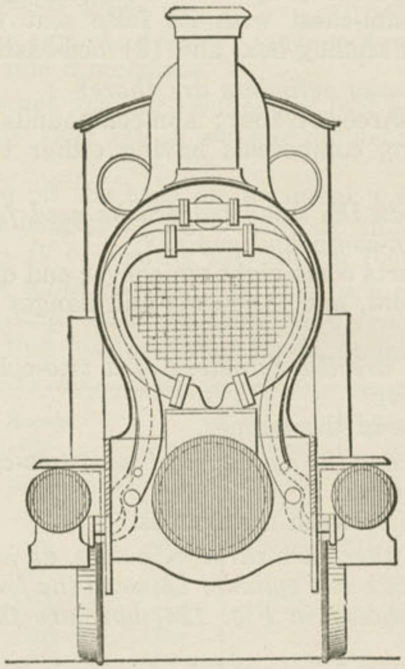


Fig. 122. Arrangement of Cylinders, Webb Compound Locomotive.

Q. What are the disadvantages of inside cylinders?

A. Danger from broken crank-axles; difficulty of getting at the cylinders for inspection, adjustment and repair, and inability to use cylinders of very great diameter.

Q. Where there are two cylinders in a compound locomotive, where are they generally arranged?

A. In an outside-cylinder engine, the high-pressure will come on one side, the low-pressure on the other. If

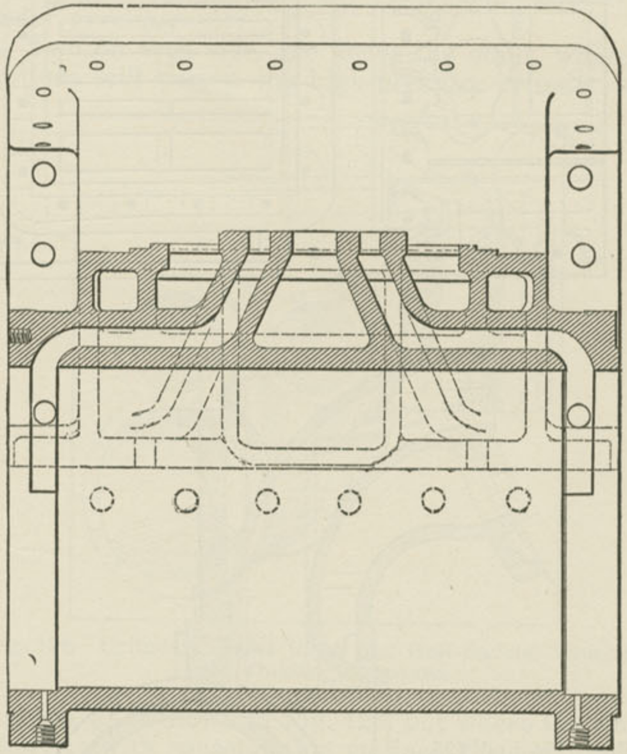
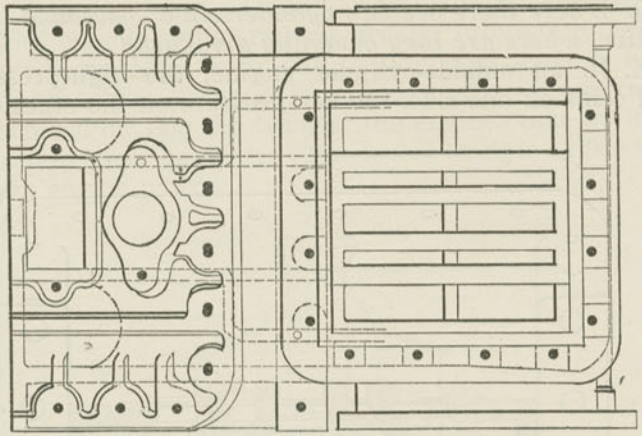
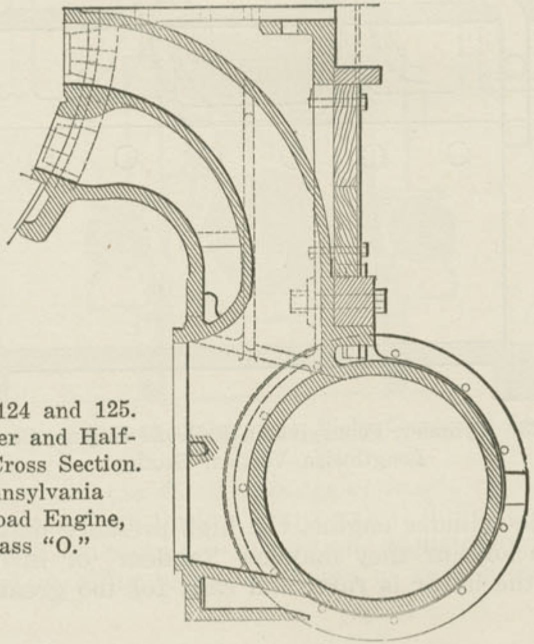


Fig. 123. Cylinder, Pennsylvania Railroad Engine, Class "O." Lengthwise Vertical Section.

an inside-cylinder engine, the high-pressure may be beside the low, or they may be "tandem" or in line; although the latter is rare, and calls for too great engine length.





Figs. 124 and 125. Cylinder and Half-saddle Cross Section. Pennsylvania Railroad Engine, Class "O."

Q. Where there is a three-cylinder compound engine, how are the cylinders arranged?

A. There may be one high-pressure cylinder between the frames, exhausting into two low-pressure outside.

Q. In the original Vauclain compound, what is the cylinder arrangement?

A. Two on each side, one above the other, where the conditions will permit the high-pressure cylinder being

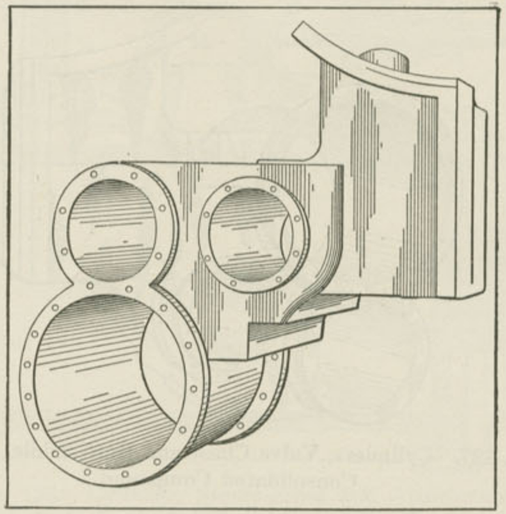


Fig. 126. Cylinders, Valve Chest and Half-Saddle, Vauclain Eight-wheeled Compound.

put on top, as is shown in Fig. 126, but where the wheels are low, as with consolidation engines, the low-pressure is above, as shown in Fig. 127.

Q. What is the objection to a four-cylinder engine having two outside cylinders, side by side, each side of the frame?

A. Complication of working parts, and greater width for the same cylinder-capacity, than where there is only one cylinder each side.

Q. Is it possible to counterpoise the connecting-rod weight so that a two-cylinder engine shall be balanced both vertically and horizontally?

A. No.

Q. Suppose that an ordinary two-cylinder engine has its connecting-rod balanced vertically, what will be the effect?

A. It will run with a series of horizontal jerks.

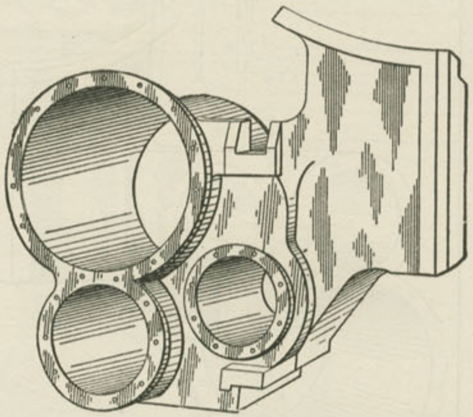


Fig. 127. Cylinders, Valve Chest and Half-saddle, Vauclain Consolidated Compound.

Q. If balanced horizontally, what will be the effect?

A. That which is ordinarily observed; there will be a series of vertical movements corresponding to the upward and downward crank motion, and the engine will sway from side to side, and give vertical blows upon the rails.

Q. How may this be done away with?

A. By having two cylinders upon a side, both outside of the frames, and each having its own connecting-rod; so that when one rod goes up the other goes down, every pound that goes up at a given velocity on one side being balanced by another pound at the same velocity in the other direction, upon that side.

Q. What is the disadvantage of steeply-inclined outside cylinders?

A. They cause a rolling motion.

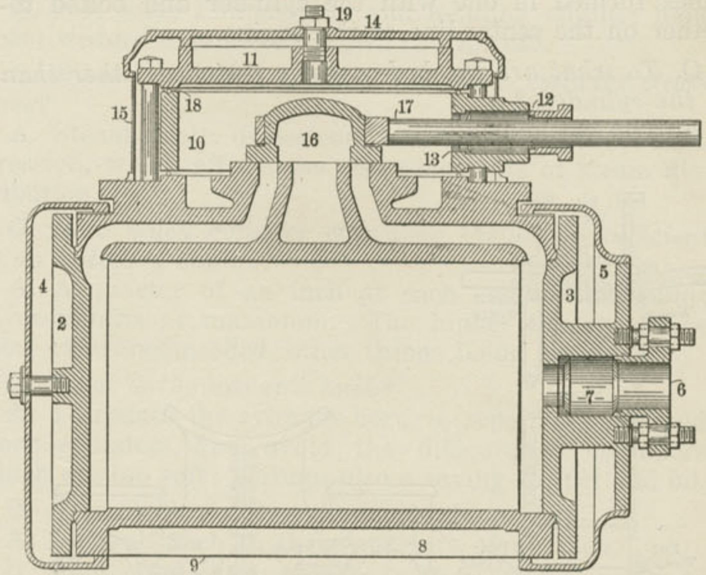


Fig. 128. Cylinder, Steam-chest and Attachments.

1. Cylinder. 2. Front Head. 3. Back Head. 4. Front Cover. 5. Back Cover. 6. Cylinder-gland, R. and L. 7. Cylinder-gland, Bottom-ring. 8. Wood Lagging. 9. Casing. 10. Steam-chest. 11. Steam-chest Cap. 12. Steam-chest Gland. 13. Steam-chest Gland, Bottom-ring. 14. Steam-chest Cover. 15. Steam-chest Casing. 16. Steam-chest Valve. 17. Steam-chest Valve-yoke. 18. Steam-chest Joint. 19. Steam-chest Oil-pipe Stem.

Q. How are the steam cylinders made?

A. Their convex walls are cast with the steam-chest bottom in one piece with them, and the passages from steam-chest to counterbores cored out; the front and the back heads are fastened on by bolts or studs, with steam-tight joints between the heads and the cylinder-end flanges. The steam-chest is sometimes in one piece with the cylinder, sometimes bolted thereto.

Q. To what are the cylinders fastened?

A. To bed-plates or bed-castings placed between them; these sometimes forming two separate pieces bolted together in the center of the engine, sometimes being in one piece, with the cylinders bolted to them, and sometimes formed in one with the cylinder and bolted together on the center-line of the engine.

Q. To what are the bed-castings fastened, other than to the cylinders?

A. The smoke-box.

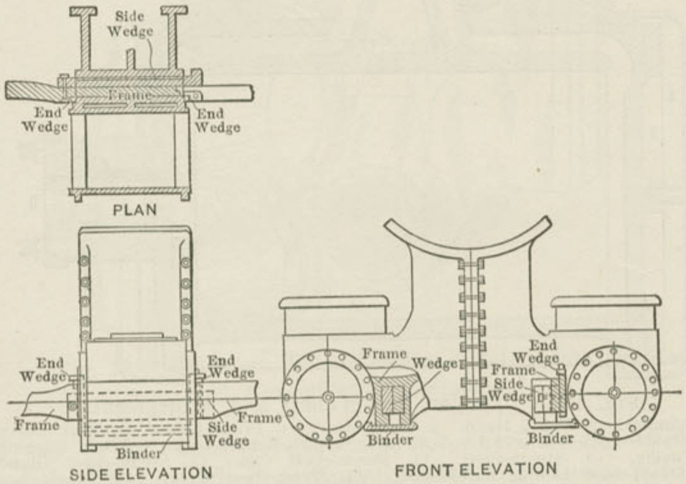


Fig. 129. Cylinder Fastening.

Q. To what are the cylinders fastened, other than to the bed-castings?

A. The frames.

Q. Which cylinder arrangement is the most popular in America for non-compound engines?

A. The cylinder and half-saddle cast in one. (See Fig. 129.)

Q. In this type, what is the difference between the cylinders for the two sides of a non-compound engine?

A. They are practically alike, to save expense in patterns and in keeping spare parts at various shops.

Q. Are cylinders and frames always bolted together?

A. No; some Philadelphia and Reading engines have them wedged together as shown in Fig. 129.

Q. What is the bad effect of too much cylinder clearance?

A. Steam waste, unless counteracted by excessive compression, which affects the other elements of steam distribution.

Q. How much cylinder clearance should be sufficient in an ordinary engine?

A. A quarter of an inch at each end as minimum; three-eighths as maximum. The higher the speed the more clearance needed, other things being equal.

Q. What is the use of a bush?

A. To reduce the cylinder bore, to repair cracked and worn cylinders, and avoid the difficulty of cylinders which are too soft; perhaps also a saving in fuel and oil.

Q. How thick should cylinder bushings be?

A. One-half inch to three-quarters of an inch.

Q. How should they be held in the cylinder casting?

A. Without any fastening except the pressure of the heads.

Q. Should cylinders be designed with the view of bushing when worn?

A. Many think so.

Q. Should new cylinders be bushed?

A. This seems the opinion of many.

Q. Show by sketches different methods of bushing cylinders.

A. Fig. 130 shows a bushing extending from the front head to the back; Fig. 131, one ending at the inside of the back port; Fig. 132, a proposed construction in which a collar in the front end of the bush is formed to bear the pressure of the front head and avoid the necessity of bridging the port.

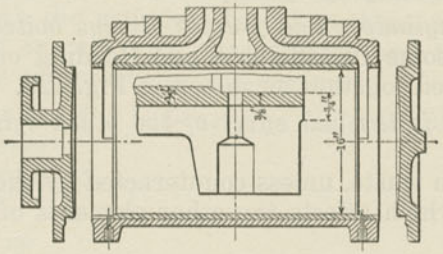


Fig. 130. Cylinder Bushing.

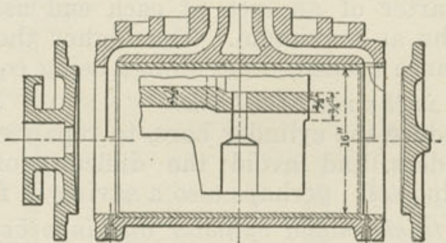


Fig. 131. Cylinder Bushing.

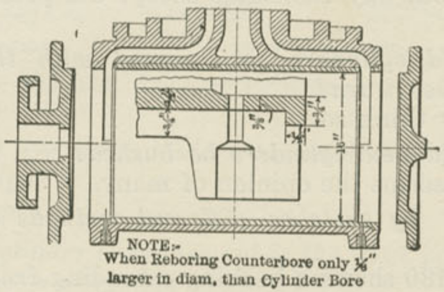


Fig. 132. Cylinder Bushing.

Q. *What is the questionable feature in this construction?*

A. The possibility of steam escaping between port and bushing.

Q. *What is the objection to bolts for fastening on the cylinder-heads?*

A. Breakage of the bolt calls for removal of the entire cylinder lagging, to replace that bolt; whereas a stud may be drilled out in place without unlagging.

Q. *Why is the cylinder counterbored at each end?*

A. To prevent the piston from wearing a shoulder at the end of its stroke.

Q. *What would be the disadvantage of such a shoulder?*

A. If the piston position with reference to the cylinder should be changed by any adjustment, there would be danger of breakage when the edge of the piston-head struck the shoulder at either end.

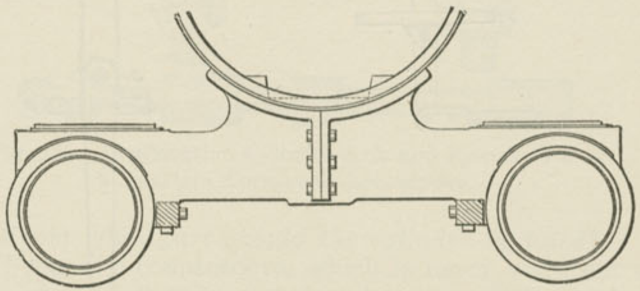


Fig. 133. Cylinder and Half-saddle.

Q. *How is the joint between steam-chest case and cylinder, between it and its cover, made steam-tight?*

A. One way is by an ordinary gasket; but a preferable one is by a ¼-inch soft copper rod of proper outline, the ends being scarfed and hard-soldered. This cannot be blown out, as is apt to be the case with ordinary gasket-stuff; and when the joint is broken the wire may be used again and again.

Q. What method or preparation is used in making joints between steam pipes and cylinders?

A. The faces of the steam pipes and the bearing on the saddle or cylinder should be as nearly parallel to each other as possible; the bearing on the pipe being flat and the saddle joint concave. Brass rings are carefully ground to both faces, and a very thin coating of white lead and oil may be put on the joints before tightening up.

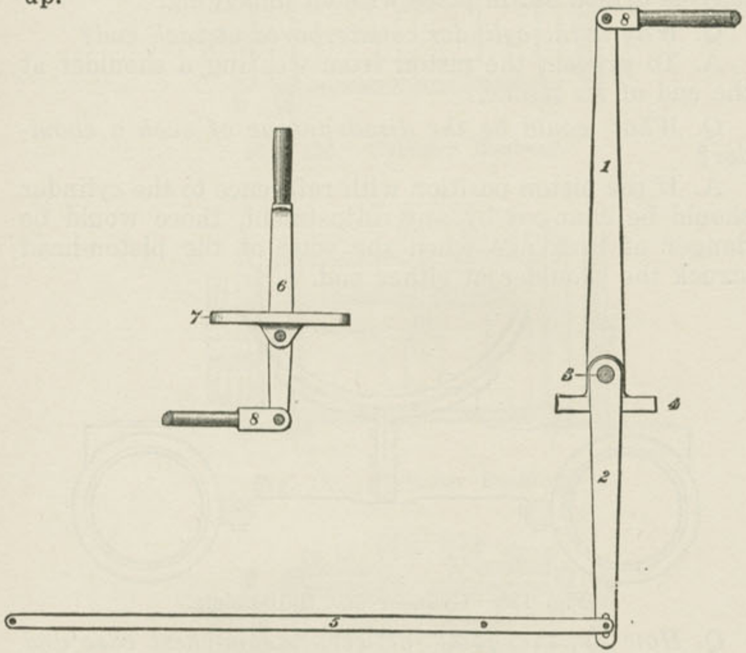


Fig. 134. Cylinder-cock Work.

1. Upper-arm. 2. Lower-arm. 3. Shaft. 4. Shaft-bearing. 5. Cock-strips. 6. Lever in Cab. 7. Lever-fulcrum. 8. Coupling-rod Jaws.

Q. How is the joint between cylinder and heads made steam-tight?

A. By sheet gasket, or by a soft copper wire as mentioned in connection with the steam-chest.

Q. How is the cylinder-casing held on?

A. It is best held out from the cylinder-walls by the flanges on the cylinder ends, and held on these by the front and back covers being slipped over it.

Q. How is the danger of knocking out a cylinder-head, by water carried over from the boiler or left by condensation, lessened?

A. By cocks at each cylinder end, controlled from the cab, and by which the cylinders may be bled from time to time if the engines work water or after starting. (See Figs. 134 and 135.)

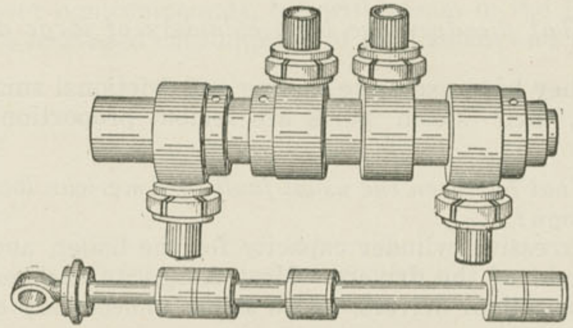


Fig. 135. Combination Cylinder-cock and By-pass Valve, Vauclain Compound Locomotive.

Q. From what part should the cylinder be lined?

A. From the counterbore, which is never worn out of size or shape. But it must first be scraped clean of oil crust, etc.

Q. What kind of a line should be used?

A. As fine as possible.

Q. If the back head is up, how is the back end of the cylinder to be lined?

A. By the stuffing-box.

Q. What is the cause of cylinder condensation?

A. The cylinder wall, which at admission has a lower temperature than that of the entering steam, condenses part of this latter, unless it is superheated, when it merely lowers its temperature without actual condensation.

Q. What influence has the thickness of the cylinder on the amount of temperature reduction?

A. The thicker the wall, the less this reduction; as the mass of iron acts somewhat as a reservoir of heat.

Q. What influence has relative cylinder diameter?

A. In so-called "square" engines there is more wall for a given volume than in those with stroke longer than the diameter.

Q. What disadvantage have cylinders of large diameter?

A. They have excessive cooling and frictional surface; further, their steam ports are seldom proportionately large.

Q. What has been the usual fault of American locomotive design?

A. Excessive cylinder capacity for the boiler, and for the weight of the drivers. Most American engines are able to slip their drivers, which shows unnecessary cylinder power.

Thus where diameter and stroke are each 10 inches, the head area is $78.54 \times 2 = 157.08$ square inches; the convex surface $31.416 \times 10 = 314.16$ square inches; total surface, 471.24 square inches; volume, $78.54 \times 10 = 785.4$ cubic inches; ratio of surface to volume, 1 to 1.67. With 10 inches diameter and 15 inches stroke the head area is 157.08 square inches, convex surface 471.24 square inches, total surface 628.32 square inches, volume 1,178.1 cubic inches; ratio of surface to volume, 1 to 1.88. With 10 inches diameter and 20 inches stroke we have the same head area as with 10 inches $\times$ 10 inches, but double the convex surface; hence total surface of 785.4 square inches, double the volume = 1,570.8 cubic inches; ratio of surface to volume, 1 to 2.

Q. What precaution is taken to lessen the loss of heat and lowering of pressure due to internal condensation by reason of radiation from steam-chest and cylinder walls?

A. They are lagged with a non-conducting substance, as wooden strips, and usually have an air-jacket or double wall; the cylinder-heads are in the same way double. Sometimes, instead of wooden strips, hair felt is used as a non-conductor.

Q. What are the results of tests as regards steam jacketing of compound locomotives?

A. According to Borodin, without steam in the jackets the economy of steam was 13 per cent, of fuel 24 per cent, over non-compounds, but with steam in the jackets there is increased consumption of both steam and fuel.

CHAPTER XLV

THE STEAM-CHEST

Q. In what position are the steam-chests?

A. In the American engines, on top (see Fig. 1); in British engines, or at least on those which have inside cylinders, on the sides next the center line of the machine.

Q. What are the advantages of top chests?

A. The engine is kept within less width than if they were on the side.

Q. What are the disadvantages?

A. The cylinder is more difficult to free from water than if the valve was on the side or beneath.

Q. What are the advantages of having the valve-chest and slide-valves on the cylinder side, as in English inside-connected engines?

A. The cylinders are more readily drained of water.

Q. Where is the valve-chamber of the Vauclain engine?

A. In the cylinder-saddle, as shown, between the boiler and the cylinders. (Figs. 126 and 127.)

Q. How are the steam-chests for flat D-valves made?

A. They usually consist of rectangular frames forming chests or boxes without either top or bottom, fastened to the cylinder-casting by a steam-tight joint, and having a cast-iron cover of considerable strength to resist the internal steam-pressure on its flat surface.

Q. How are the valve-seats made?

A. They are planed as true as the planer will make them, then filed and scraped until smooth and practically plane.

Q. What name is given to the plate covering the top of the steam-chest?

A. The steam-chest cap, as distinguished from the casing above it.

Q. What name is given to the other casing on top of the steam-chest?

A. The steam-chest cover, as distinguished from the cap which it covers.

Q. What is the disadvantage of the usual system of having the steam passages alongside of the exhaust-passages from the chest of the cylinder?

A. That the exhaust cools the live steam, unless there is considerable compression; also there is danger of cracking the saddle by unequal temperatures.

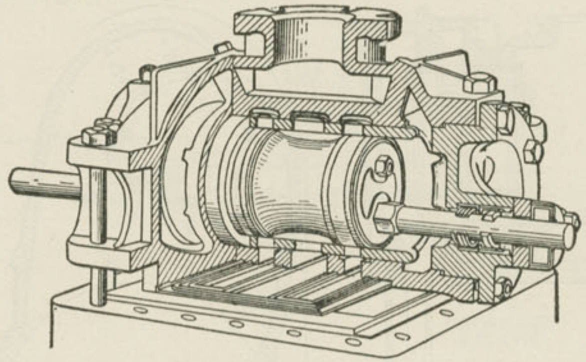


Fig. 136. Extra Piston-valve Seat.

Q. Describe the "Universal" valve chest.

A. This is a piston-valve arrangement for application to existing slide valve seats, saving the old valve-cylinders and frame ends. It is shown in Fig. 136, as adapted to either inside or outside admission. There is a supporting inner valve chamber jointed to the valve seat independent of the outer chest, that is seated on the cylinder apron in the usual way, thus utilizing the regular inlet port to the chest.

Q. What is its principal object?

A. To facilitate superheating by providing extra free steam flow; the passage area being equal to that of the old slide valve ports.

Q. How is increased steam efficiency in high-speed engines now obtained?

A. Among other ways, by so proportioning the openings for admission, and shaping the passages, as to guide the steam in stream lines to the working cylinders. This has the advantage of making a smaller valve effective, lessening the weight, and on locomotives, where this

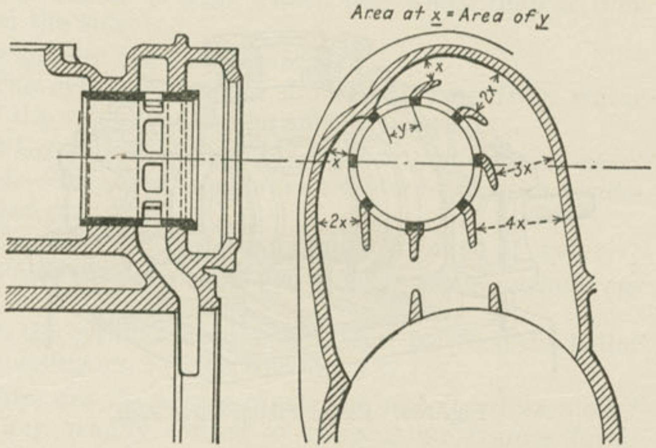


Fig. 137. Cylinder Port Arrangement.

method is particularly applicable, cutting down the valve-gear stresses, which on many engines are so great as to call for power reversing gear. This new method also reduces back pressure by giving a freer exhaust, and makes what the man in the cab calls a "smarter" engine.

Fig. 137 shows the "stream-line" system for new engines. For each bushing port Y the areas for the steam passage increase from 1x to 2x on one side and even 4x on the other.

CHAPTER XLVI

RELIEF VALVES

Q. What is a relief valve?

A. An outward opening safety-valve on the cylinder head or the end of the steam chest, which relieves any excessive pressure due to over-compression of steam, or the presence of water in the chest or cylinders to which it is applied.

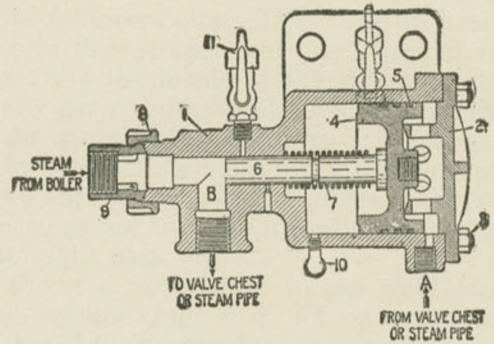


Fig. 138. Automatic Vacuum Breaker.

Q. What are the disadvantages of relief valves?

A. If they leak badly, they obscure the engineman's view.

Q. What prevents air and cinders being sucked into the steam chest through the exhaust pipes, when steam is off, and the piston working?

A. A relief valve in the end of the steam-chest, opening inward into the chest, and permitting air to enter the chest through it, instead of coming by way of the exhaust pipes and drawing cinders therewith.

Q. When the engine is drifting, what is the danger unless specially prevented?

A. That hot gases or cinders are drawn into the cylinder, the lubricating oil carbonized and the pistons caused to knock.

Q. How is this prevented?

A. By an automatic vacuum breaker, Fig. 138. When the pressure in chests or cylinders drops below ten pounds, the boiler pressure against the plunger 6 moves it and with it the piston 4 far enough to uncover the passage B and let live steam into the cylinders until ten pounds pressure is built up, when the plunger returns.

CHAPTER XLVII

THE PISTON

Q. What is the piston?

A. A reciprocating member formed of a piston-head and a piston-rod, playing together, lengthwise of the cylinder, freely but practically steam-tight.

Q. How is the piston-head made?

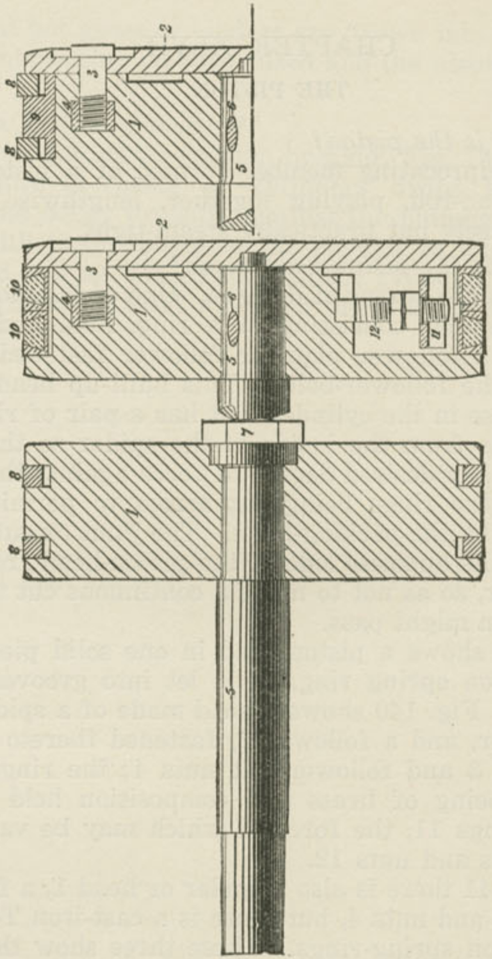
A. There are dozens of designs. One of the most common is a spider consisting of a ring, hub, and radial arms, and a follower plate or follower fastened to the spider by the follower-bolts. This built-up head works slightly loose in the cylinder, but has a pair of rings set out by bolts from the inside of the spider so that they press with any desired degree of force against the cylinder-walls; the rings being cut across to permit being opened out by the packing-bolts. The joint or cut in one ring is on the opposite side of the piston-head from that in the other, so as not to make a continuous cut through which steam might pass.

Fig. 139 shows a piston-head in one solid piece with two cast-iron spring rings 8, 8, let into grooves in its periphery. Fig. 140 shows a head made of a spider 1 or head proper, and a follower 2, fastened thereto by follower-bolts 3 and follower-bolt nuts 4; the rings 10 in this case being of brass and composition held out by piston-springs 11, the force of which may be varied by spring-studs and nuts 12.

In Fig. 141 there is also a spider or head 1, a follower 2 and bolts and nuts 4, but there is a cast-iron T-ring 9, and cast-iron spring-rings. These three show the principal kinds of packing used. In Fig. 139, the piston is fastened on with a nut 7; in Figs. 140 and 141, by a key.

Q. Of what material are these rings?

A. Of cast-iron, or of brass or gun-metal, or of either of these two with babbitt-metal run in to lessen friction.



Figs. 139, 140 and 141. Piston and Packing Rings.

1. Piston-head. 2. Piston-follower. 3. Piston-follower Bolts. 4. Pistol-follower Bolt-nuts. 5. Piston-Rod. 6. Piston-rod Key. 7. Piston-rod Nut. 8. Piston-spring Rings (Cast-iron). 9. Piston T-ring (Cast-iron). 10. Brass and Composition Piston-rings. 11. Piston-spring. 12. Piston-spring Studs and Nuts.

Q. What material is used for follower-bolt nuts?

A. Brass, to prevent the bolts being rusted tight therein, thus preventing adjustment.

Q. Is there any other way of packing pistons besides by setting out the packing-rings by bolts and nuts?

A. Yes, they may be steam-packed; that is, the rings may be set out by the steam-pressure in the cylinder, so that the greater this steam-pressure, tending to pass the piston, the greater the force by which the rings are

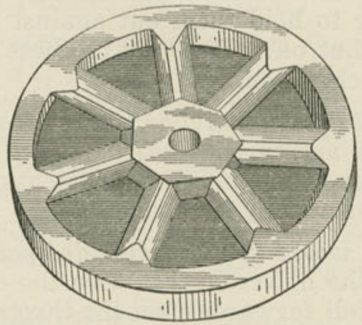


Fig. 142. Half of Vauclain Two-part Cast-iron Piston-head.

pressed against the cylinder-walls to prevent leakage past the head. Also, they are often held out solely by their own elasticity; being a trifle larger in diameter than the cylinder-bore and having cut out of their periphery a piece large enough to enable them to be sprung in.

Q. What section is given to such spring packings?

A. Their inner circle is eccentric with the outer, so that they are thicker at one side than at the other; the cut being made at the thin side, so as to give them the greatest possible spring, to tend to keep them open and against the cylinder-walls.

Q. Where a piston has split spring packing, on which side is the cut in the ring put?

A. On the bottom.

Q. What is the Dunbar piston-packing?

A. It is made of two cast-iron rings, one of them being shaped like the letter **L**, the other fitting into the side or recess of the **L** ring, so that both rings bear against the inner wall of the cylinder. These rings are generally cut in four sections, placed to break joints so the steam cannot get by and fastened so they will not work around and let the joints come opposite each other. When working steam it gets under the **L** ring and holds them both out steam-tight. There is a small spring steel ring put under the **L** ring to hold them out against the cylinder when steam is shut off. Two sets of these packing rings are used on each piston.

Q. What are the peculiarities of steam packing as compared with spring packing?

A. It runs longer without attention, but gives out more frequently by breakage.

Q. How would you test cylinder packing on the road?

A. Set the driver brake, close the cylinder cocks, put the lever full forward, open the throttle; open the cylinder cock on that end which should have no pressure in it. If steam shows, there is a leak in the packing.

Q. How much faster does the crank pin travel than the piston, and how is the ratio arrived at?

A. More than one-half faster, or in the ratio of 1 for the piston to 1.5708 for the crank pin; roughly as 7 to 11. The piston makes a full stroke both ways for one revolution of the pin. One piston stroke is equal to the diameter of the circle described by the crank pin, which, multiplied by 3.1416, gives the circumference of the circle.

Q. What method is there of making pistons which will permit of having them hollow, yet do away with the uncertainty of coring?

A. By casting them of two sections, and riveting them together; the sections being as shown in Fig. 142.

Q. How is the piston-rod fastened to the crosshead?

A. Usually it is tapered to fit a tapering-hole in the crosshead and keyed in place.

Q. What relieves the stuffing-box of the strain that would be put on it by the tendency of the connecting-rod to bend the piston-rod in a vertical plane?

A. The crosshead, which works in guides absolutely parallel with the cylinder-axis, thus protecting from undue wear the rod, the stuffing-box, and the cylinder and piston. (See Figs. 130 to 133 inclusive.)

Q. How is the piston-rod fastened to the piston-head?

A. It may be (1) passed clear through and riveted over, or (2) passed through and supplied with a nut on the front end, or (3) tapered and keyed, or (4) tapered and riveted, or (5) tapered, riveted and keyed. (See Figs. 139, 140 and 141.)

Q. Where the piston-rod passes through the back head, how is the steam prevented from passing out of the cylinder?

A. The rod passes through a stuffing-box, the annular space between it and the box being filled with an elastic material like hemp, India rubber and cotton, etc.; this material being pressed against the stuffing-box walls and the outside of the rod by the stuffing-box cover having a tube that partly projects inside the box and by which, when the cover or gland is screwed down more or less tightly, the packing is pressed more or less strongly against box and rod. There are also anti-friction metal split packing-rings which are pressed against rod and box by springs.

Q. What is the effect of excessive piston-clearance?

A. Waste of steam by preventing the exhaust being compressed up to the steam-chest pressure.

Q. What is an extension piston-rod?

A. A continuation of the piston-rod through the front head, having for its object to help keep the piston weight from the lower side of the cylinder bore. On a stationary engine it is called a back-rod.

Q. Where is it most used?

A. On the low-pressure cylinders of compound engines; also where the piston is very heavy.

Q. What is the disadvantage?

A. One more stuffing-box on each cylinder to adjust and keep tight and to make friction.

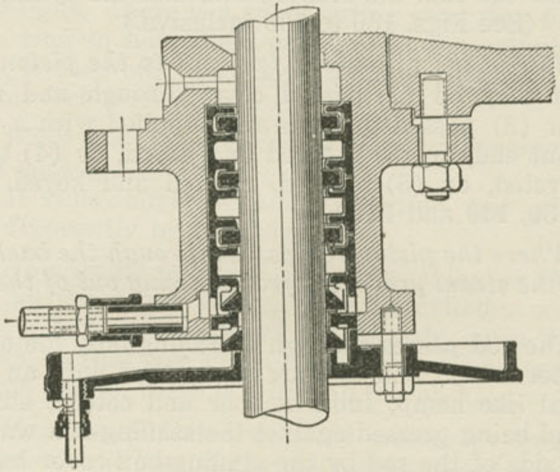


Fig. 143. Metallic Rod Packing.

Q. What is important as regards the weight of reciprocating parts?

A. It should be kept as low as is compatible with strength.

Q. So long as they are balanced, does it make any difference?

A. Yes. (1) No engine with unbalanced cylinder action can be balanced against both vertical and horizontal shocks; (2) these balance weights increase the centrifugal or tangential force, especially at high speed, thus causing hammering.

Q. Are European pistons generally lighter or heavier than American?

A. Much lighter.

Q. To what is the piston pressure necessary to produce acceleration of the reciprocating parts proportional?

A. (1) To the weight of those parts; (2) to the square of the rotation speed.

Q. How can this necessary pressure be kept down?

A. (1) By making the parts lighter; (2) by greater driver diameter.

Q. Have American engines lighter or heavier reciprocating parts than European of the same class?

A. Heavier; especially when we consider the use of cast-iron crossheads.

Q. Describe the Swiderski rod packing for high pressures and superheated steam.

A. The stuffing-box, as such, is absent. There are several metal rings, ground to fit the rod, and free to play radially between the lips of U-sectioned rings which closely fit the walls of the chamber; so that with any sidewise motion of the rod its rings, instead of pressing thereon, follow its movements and slide in the cavities of the inclosing box-rings. The steam pressure in the chambers of this packing varies with that in the cylinder itself. (Fig. 143.)

CHAPTER XLVIII

STEAM DISTRIBUTION

Q. What are the various occurrences and periods in the steam distribution in the cylinder?

A. Admission, full steam, cut-off, expansion, release, exhaust, compression or cushion, in the order named.

Q. Is not lead an occurrence?

A. No; lead is practically a time of occurrence. It is sometimes called pre-admission, but when the admission is hastened all other occurrences are correspondingly hastened also.

Q. In the full-steam period has the steam always full chest pressure?

A. No; it usually drops, owing to the great piston speed and diminishing port area.

ADMISSION

Q. What is admission?

A. Admission is the term given (1) to the act of entrance of live steam from the boiler, or of high-pressure exhaust directly from the H. P. cylinder or indirectly from the receiver into the L. P. cylinder; (2) to the time during which such entrance takes place.*

Q. Is it not simply the time between the beginning of the piston stroke and the cut-off?

A. No; because where there is lead or pre-admission, this takes place before stroke end, and where there is so-called "negative lead" admission does not take place until after the piston has started on the new stroke.

Q. Trace the steam from the boilers through the cylinders to the atmosphere, and explain how it transmits power.

A. The action of the direct radiation, conduction and

* Throughout this book the abbreviations "H. P." and "L. P." are used for "high pressure" and "low pressure" respectively.

convection of the heat in the fire-box changes the water fed into the boiler into water at 212 deg., and further into steam at that pressure, and at the highest pressure which the boiler can carry without blowing off at the safety valve, or to that pressure which may be attained if the boiler is using steam but has not yet reached the maximum. This steam passes through the dry pipe to the throttle valve and the steam chest; is there admitted to the cylinder, driving the piston before it at something less than boiler pressure, until the steam is cut off by the valve, when its pressure falls and its volume increases correspondingly until the exhaust passage is opened, when the momentum of the piston itself, aided by that of other reciprocating and rotating parts, and of the train itself as a whole, keeps the piston in motion, even against compressed steam caused by premature exhaust closure. Sometimes a superheating device adds heat to the saturated steam before it reaches the chest.

LEAD*

Q. With a lapped valve, suppose the piston is at beginning of the stroke, where is the valve?

A. Its steam edge is either just in line with the outer edge of the end port at the end at which the piston is, or slightly in advance thereof, in the direction in which both the piston and the valve are to move.

Q. Where it is slightly in advance of the "line-and-line" position—that is, where the port is slightly opened before the piston is at stroke beginning—what is said of the valve?

A. That it has positive lead (usually called simply "lead"), "advance," or "pre-admission."

Q. What is the measure of the linear lead (or simply the lead) of a valve?

A. The amount that the port is open at the moment the crank passes the center.

* See also under "Angular Advance of Eccentrics."

Q. What is lead angle, or angular advance?

A. The angular distance of the crank from its zero point when the steam port commences to open, or of the eccentric from a point 90° ahead of the crank.

Q. What may be said of expressing amount of lap and lead in inches?

A. It is nonsensical and misleading. A given lap or lead in inches of valve travel or of piston stroke might be right for one length or travel of valve, length of piston stroke, or steam pressure, and entirely wrong for another.

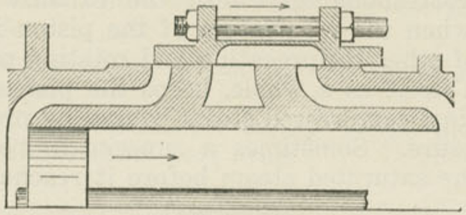


Fig. 144. Slide Valve showing Lead.*

Q. How should these elements be expressed?

A. Either in degrees of crank motion or in percentage of piston travel.

Q. Does lead have any effect upon the continuity of the crank motion?

A. No; because it is so small an angle that the lever arm is very short.

Q. What are the limits of lead angle for stationary engines?

A. Between zero and 8°.

Q. What are the objects (real or supposed) of lead?

A. To conceal and neutralize difficulty due to bad workmanship and to wear of boxes and pins, as well as to enable the cylinder space back of the piston to be filled with steam at full chest pressure at an early point in the stroke; also to ease the exhaust.

* See under "Slide Valve."

Q. What effect has lead upon the various elements of distribution: admission, cut-off, release, and cushion?

A. It causes all to take place earlier, other things being equal, than if there were no lead.

Q. How is a valve given lead: by its construction, or by its setting?

A. By the setting of the eccentric with relation to the crank.

Q. How is the valve given lead by the eccentric setting?

A. The eccentric is advanced still further beyond the point 90° from the crank, which it would have if there were no lead. Thus, if there is no rocker arm, the eccentric is run still further ahead of the crank in the direction in which it is to run the axle. If there is a rocker arm it is run still further back of the crank, or in the opposite direction to that in which the engine is to run the axle.

Q. Where no rocker is used, how may the linear lead be measured?

A. It will be exactly the amount of offset of the eccentric from a vertical line.

Q. If the valve has the same amount of lap at each end, will cut-off take place at the same point in both cylinder ends?

A. No; as the connecting rod introduces irregularities between the piston movement and that of the valve.

Q. What is the nature of these irregularities?

A. When the crosshead is at *C*, the out end of the stroke (see Fig. 145) the crank pin will be at *c*, on the outboard dead center. When the crosshead is at *B*, in the middle of its stroke, the crank-pin will not be at the quarter point of its path, but at *b*. When the crosshead is at *A* or inboard stroke end, the crank pin will be at *a*, or the half point of its path; and on the return stroke, when the crosshead is again at mid-stroke, at *B*, the crank pin will have made less than the quarter circle from *c* and will be at *b′*.

Q. What relation has the connecting rod (main rod) to the amount of this irregularity?

A. The shorter the connecting rod, the greater the irregularity.

Q. What would be the disadvantage of giving great main-rod length in order to lessen the irregularity?

A. It will increase the necessary length of the engine, and also the unbalanced weight.

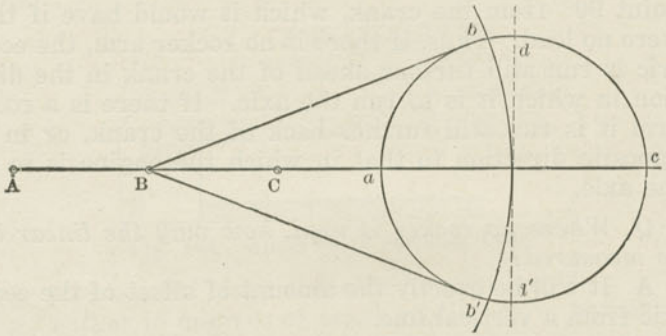


Fig. 145. Effect of Angularity of Connecting-rod.

Q. How may this irregularity of cut-off, caused by the angularity of the connecting rod, be done away with?

A. By giving the valve more lap upon that end at which the cut-off would be earliest if the laps were the same at both valve ends.

Q. How about the lead in the stationary-link motion?

A. It is constant for all gears; although the lead angle increases as much as with the shifting link.

Q. How about the lead with this motion, if the rods are crossed?

A. It has constant lead both with crossed and with uncrossed ends.

Q. Are engines with constant lead common in America?

A. No.

Q. Considering that engines with constant lead are the most common in Great Britain, where they average the fastest trains in the world, why is not constant lead good for high speed?

A. The mere fact of their having constant lead and making high speed does not prove that the constant lead causes the high speed. Those engines run on better tracks than those in America, and have larger drivers, admitting of slow piston speed.

Q. Does the shifting link change the angular advance of the eccentric?

A. No.

Q. Does the stationary link change the angular distance of the eccentric?

A. Yes.

Q. Can shifting-link motions be arranged with constant lead for various gears?

A. Yes; but only for various gears of one direction of the motion; thus, if the lead be constant for all forward gears from mid to full, it will vary on the backward gears.

Q. How may this be done with the ordinary open-rod shifting-link motion?

A. By giving the forward eccentric more angular advance than the backward eccentric; of course experimenting with the angular advance given, until the lead is constant at every position. In this case the lead-opening will be constant for all forward gear positions, and will diminish from mid-gear to full back gear.

Q. What would be the effect of giving the backing eccentric of this open-rod shifting-link motion more angular advance than the forward?

A. To give constant lead for all backward positions, and varying lead for all forward-gear positions—this, of course, implying that the proper excess of angular advance was given.

Q. How may the same effect as slight steam lead be given a valve, without in any way altering the gear?

A. By nicking its steam edge in one or more places so as to admit steam through the openings just made, before the valve edge has reached the port edge.

Q. What other elements does this affect?

A. It makes cut-off practically a trifle later, as it in one sense reduces the lap.

Q. Does it affect exhaust and compression?

A. No; these are not affected by the outside valve edge.

Q. Is it necessary to have lead to be able to start trains?

A. No.

Q. Is lead necessary in order to work smoothly at or near full gear?

A. No.

Q. With a slow-running locomotive, where the steam is admitted, say, half the stroke, is much lead necessary?

A. No; because with ordinary engines the exhaust will occur early enough to prevent back pressure during the return stroke; and compression will begin in sufficient time to provide the cushion required to bring the cranks smoothly over the centers, to reheat the cylinders, and to raise the pressure in the clearance spaces to the initial steam pressure.

Q. If you have a high-speed locomotive that has a valve gear which keeps the lead constant at all points of cut-off, how must the valve be set?

A. With what would be regarded as excessive lead at full gear in a shifting-link engine.

Q. Where would such excessive lead be detrimental?

A. When the engine was pulling on grades, or at places where the steam had to be worked at half stroke.

Q. What is the principal objection to increase of lead?

A. Increase of cushion or compression as the engine is hooked up, thus lessening the power, especially where the compression is greater than the initial pressure.

Q. What effect on lead has lost motion in the gear?

A. To decrease it.

Q. What will show this state of affairs if it exists?

A. The indicator.*

Q. On what class of engines is increased lead toward the center notch most injurious?

A. On slow, hard-pulling freight engines.

Q. How is it remedied?

A. By giving the back-up eccentric more angular advance, hence favoring the forward motion.

Q. To increase the lead of a standard engine with indirect motion, what is to be done?

A. Shift the eccentric belly toward the crank pin.

Q. With direct motion?

A. The reverse.

Q. Where the lead is the same for both motions, are the eccentrics equally distant from the crank pin?

A. No; even although the cut-offs may be equal at extreme notches.

Q. Give some examples, from a full-sized model, of effects of changing the lead.

Full gear lead	—1-16 in. F. M. & B. M.	0 F. M. —1/8 in. B. M.	—1/8 in. F. M. +1-16 in. B. M.
Cut-off	6 in.	6 in.	6 in.
Lead for cut-off	1/4 in.	1/4 in.	1/4 in.
Valve travel	2 11-32 in.	2 11-32 in.	2 11-32 in.
Maximum port opening	19-64 in.	19-64 in.	19-64 in.
Occurs in stroke at	11-32 in.	5-16 in.	9-32 in.
Exhaust opens at	16 1-16 in.	15 13-16 in.	15 3/4 in.
Exhaust opening, maxi'm.	1 5-32 in.	1 5-32 in.	1 5-32 in.
Exhaust closes at	16 1-16 in.	15 15-16 in.	15 13-16 in.
Lead opens at	23 3-16 in.	23 in.	23 1-32 in.

* See under "Indicator."

A. (In the case here cited the maximum valve travel was 5 3/16 inch; outside lap, 7/8 inch.)

Q. What lead should an Allen or Trick (double-ported) valve have, as compared with a plain D-slide?

A. The same.

Q. What is negative lead?

A. Retardation of all valve movements and functions with relation to the piston movements; principally seen and referred to in connection with admission, which commences after the crank has carried the piston past the center, instead of before, as with pre-admission or positive lead.

Q. What is an argument against the statement that positive lead is needed to cushion the reciprocating parts?

A. The fact that the engine rides most smoothly when the throttle is closed and the only cushion is that due to a slight air pressure and vacuum.

Q. Are cases known when reducing the lead lessened the jar?

A. Many such; and the steady tendency on American railways is to reduce the lead, thereby lessening the number of broken piston rods and deck bolts, and of hot crank pins.

Q. Where may negative lead give better results than positive?

A. With full travel; because of the slow speed, which gives plenty of time, anyhow, to fill the cylinder.

Q. What is the proper amount of lead for the running cut-off?

A. The greatest that is compatible with a full smooth cushion line not looped at the top.

Q. How may this be determined?

A. Only by the use of an indicator.

WIRE DRAWING

Q. What is the essential difference between the steam action in locomotive practice and that in other non-condensing engines?

A. With the usually-employed locomotive valve gear there is excessive wire drawing and cushion.

Q. What is wire drawing?

A. A reduction of pressure in the incoming steam, caused by too narrow ports or by insufficient port opening.

Q. Is wire drawing more injurious in compound or in non-compound engines?

A. In compounds, where high initial pressure is of main importance.

Q. What is gained by wire drawing?

A. Reheating or superheating of the steam; but this is more than balanced by "loss of potential" of steam pressure.

CUT-OFF AND EXPANSION

Q. What is the advantage of cut-off?

A. To permit the steam to expand from chest pressure, or nearly so, down to atmospheric pressure where the exhaust is free. In losing pressure and temperature, the steam is doing in the cylinder work which it would not be able to do if allowed to escape into the open air at high pressure and temperature.

Q. How is cut-off effected in a locomotive engine?

A. By constructing the valve longer than the distance between outside edges of steam ports, so that it stops the admission of chest-pressure steam before the piston has made a complete single stroke.

Q. Is perfectly "square" admission and cut-off in both gears possible with link motion?

A. No.

Q. What is usually sacrificed?

A. Squareness in the back motion, to get it in the front.

Q. Has the diameter of the eccentric disk any effect on the amount of valve motion?

A. No; the eccentricity alone effects this.

Q. Why are early cut-offs with shifting-link gears to be avoided?

A. Because they entail excessive cushion and wire drawing; the latter owing to the narrow port opening.

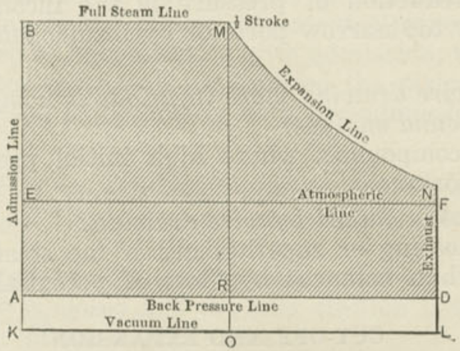


Fig. 146. Theoretical Indicator Diagram.

Q. With reverse lever at extreme notches, what may be said of the squareness of cut-off?

A. It is usually made later in forward than in backward motion.

Q. Where the exhaust is "square," is the cut-off so?

A. Not always.

Q. Which should be sacrificed?

A. Squareness of exhaust.

Q. In any engine, what effect has the point of cut-off on the uniformity of traction?

A. At slow speeds the later the cut-off the more uniform the traction. At high speeds not so much so, by reason of the momentum of the reciprocating parts. (See under "Traction.")

Q. What is isothermal or hyperbolic expansion?

A. That which assumes that with an unvarying temperature, the volume of the steam is exactly inversely proportionate to the pressure; the curve showing this being a hyperbola.

Q. Why does not the indicator diagram curve remain hyperbolic?

A. On account of (1) condensation up to the point (during expansion) in which the steam temperature is the same as that of the cylinder walls; (2) re-evaporation by heat radiated from the cylinder walls; the tendency always being for two bodies of unequal temperatures to equalize them.

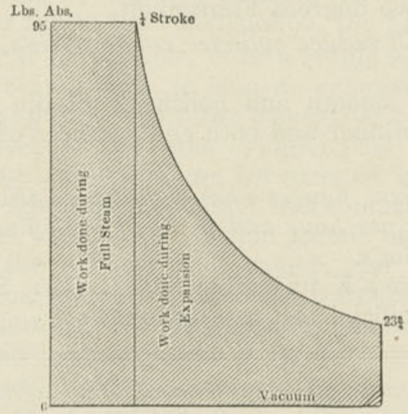


Fig. 147. Theoretical Indicator Diagram.*

Q. Of the three curves—actual, hyperbolic and adiabatic, which is the highest and which the lowest?

A. The actual is somewhat the highest and the adiabatic slightly the lowest.

Q. Does the indicator diagram enable calculation of water consumption?

A. No; it takes no account of condensation.

Q. If steam expands without either receiving or losing heat, what is that kind of expansion called?

A. Adiabatic.

* See under "Indicator."

Q. Where do we find such expansion?

A. In a steam turbine, approximately; never in a locomotive.

Q. If saturated steam from the boiler is superheated, what is the effect thereon if the pressure is kept constant?

A. Increase of volume.

Q. If the volume is kept constant?

A. Rise in pressure.

Q. How much does one therm (British heat unit) raise the temperature of one pound of superheated steam?

A. About two degrees Fahrenheit.

Q. What will reduce cylinder condensation, other than jacketing?

A. Turning smooth and polishing all the inside surfaces of the cylinder and both end surfaces of the piston head.

Q. Give some figures showing the relation between speed in miles per hour and point of cut-off under given normal conditions.

A. I will take a K 4 s engine (Pa. R. R.). Some of the figures of an official test are as follows:

Miles P. H.	Cut of %	Pressure, Lbs. by Gage		Superheat Deg. F. in Branch Pipe
		Boiler	Branch Pipe	
28.38	14.3	206.0	203.2	91.6
28.38	68.6	206.0	182.0	197.2
37.84	13.5	205.0	201.7	102.5
37.84	66.5	202.7	176.7	198.7
47.30	15.8	204.3	201.7	107.8
47.30	60.3	201.3	172.1	215.2
56.76	16.2	206.0	202.8	105.4
56.76	55.8	204.7	180.7	213.9
66.22	13.7	205.7	201.9	131.0
66.22	52.9	205.7	184.7	228.7
75.84	15.6	206.0	203.2	125.3
75.84	50.7	206.0	185.8	209.1
85.32	16.7	206.0	203.5	128.0
85.32	38.9	206.0	194.3	197.1

RELEASE AND EXHAUST

Q. Why should especial attention be paid to a free release or exhaust?

A. Because it is much less easy to get the steam out of the cylinder with the low pressure at end of expansion than to get it in at chest pressure; further, the exhaust passages are longer and more tortuous than those from the chest to the cylinder.

Q. How may free exhaust be facilitated?

A. (1) By exhaust lead, properly so called; (2) by inside clearance, or negative exhaust lap; the second being provided for in the construction, the first by setting.

Q. Would it be possible, with a single slide valve and the usual eccentric gear, to have an exhaust which would take place anywhere near the atmospheric pressure?

A. No; because the same cylinder-port opening must serve for both admission and for exhaust, and if there is insufficient admission opening there must be also too little exhaust opening, the piston speeds being the same. Increasing the exhaust lead would also increase the steam lead and produce difficulties in steam economy and in smooth running. Inside clearance seems to be the best practical help in most cases.

Q. Just what difference might be considered in the meaning of the two words "release" and "exhaust"?

A. Some consider release to be the action of opening the port for exhaust; others consider it as the time of exhaust; others as the exhaust itself.

Q. Where is inside clearance considered to be of value?

A. For fast-running engines, or for those with small wheels at moderate speed.

COMPRESSION OR CUSHION

Q. What is compression or cushion?

A. The confining of the exhaust in one end of the cylinder by closing the exhaust port, as by exhaust lap (inside lap) before stroke end, thereby lessening the space for the steam to occupy. The steam confined in what is temporarily the exhaust end of the cylinder is compressed by the advancing piston, to a pressure depending on (1) the exhaust pressure at the time of port closure, and (2) the relative volume of the cylinder-end space thus shut off and the cylinder clearance.

Q. What is the limit of compression?

A. Where the valve is an unbalanced flat slide which can lift from its seat, chest pressure. With balanced slides unprovided with a relief valve, and with piston valves, the limit is apt to be the strength of the cylinder heads.

Q. Why is it called "cushion"?

A. Because it is supposed to act as a buffer or spring to take up the shock of piston reversing, and thus save bearings.

Q. What other cause of cushion is there besides exhaust lap?

A. Lead.

Q. Is compression advantageous?

A. To a certain extent, because the compressed steam acts as an elastic cushion to absorb the shock of the reversal of motion of the reciprocating parts. It also does away with part or all of the loss which would otherwise occur by reason of the waste clearance space between the piston and the valve.

Q. What is the object of this clearance space?

A. To guard against the possibility of the piston—by reason of wear of parts or change of adjustment—overrunning its original course and striking the cylinder head; also to afford space for water which might get into the cylinder, and which — not being compressible as steam is—might knock out a cylinder head.

Q. Can compression in the cylinders give a pressure higher than that in the chest, or even in the boiler?

A. Yes; if the valve cannot lift.

Q. When is this likely to occur?

A. In cutting off very short where there is much midgear lead or inside lap, or both.

Q. How much compression should an engine have in order to make her pass her centers?

A. That depends on the amount of clearance. There should be enough to fill the clearance space at stroke end at boiler pressure. With 15 to 18 per cent clearance you must have high compression.

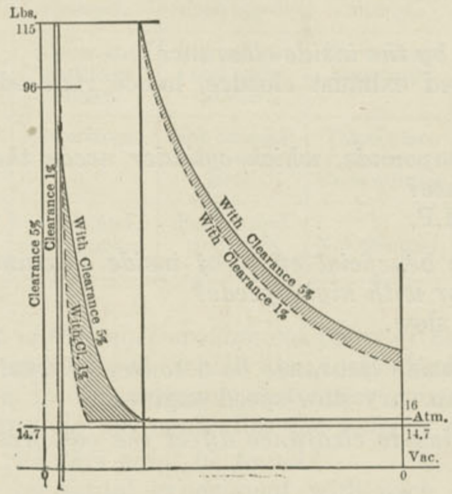


Fig. 148. Theoretical Indicator Diagram.

Q. As regards clearance space and compression, what is the essential difference between locomotive and stationary engine practice?

A. In the stationary engine the exhaust passages are of fixed dimensions, while in the locomotive they are likely to be clogged up by gum from the fuel, or have to be changed in size to accommodate some new fuel; and often if the exhaust nozzle could be kept of uniform size, the back pressure could not be so regulated as to give constant volume of steam in the cylinder with the valve closed for compression.

Q. How is over-compression best obviated?
A. By making the ports long, giving plenty of valve travel and outside lap, and some negative inside lap (inside clearance).

Q. What is gained by the increased travel and outside lap?
A. Good port opening at short cut-offs; later compression.

Q. What by the inside clearance?
A. Delayed exhaust closure, hence reduced compression.

Q. In compounds, which cylinder needs the most inside clearance?
A. The H.P.

Q. Is the beneficial effect of inside clearance greater with slow or with high speeds?
A. With slow.

Q. Can inside clearance be a source of waste?
A. Yes, on very slow-speed engines.

Q. Does inside clearance affect the compression after admission?
A. No.

Q. Has it the same value in freight as in passenger service, on the same engine?
A. No; less. It is, as a rule, of advantage only on high-speed engines.

Q. What is the principal cause of back pressure?
A. The exhaust nozzle, not the valve.

Q. What will back pressure average in non-compounds?
A. About four pounds per square inch.

Q. Can a table be made grouping the effects, upon each of the elements: admission, cut-off, release, and compression of increase in angular advance, valve travel, inside lap and outside lap?
A. Yes; such a table is here given:

	Admission	Cut-off	Exhaust Opening	Compression
Increase angular advance	Earlier, but period not changed.	Earlier. Period unchanged.	Earlier and period not altered.	Earlier and period the same.
Increase travel.	Sooner and continues longer.	Begins later and ends quicker.	Begins later. Ends later.	Begins later and ceases quicker.
Increase inside lap.	No change.	Not changed and ends later.	Takes place later. Ends quicker.	Begins sooner. Ends later.
Increase outside lap.	Later and ends quicker.	Earlier and continues longer.	Not changed.	Begins at same point.

Q. What is the most economical point of cut-off?
A. The earliest at which the condensation and re-evaporation in the cylinder and other causes, such as wire drawing, do not neutralize the gain by expansion.

Q. How can this point be found?
A. Only by actual experiment with each engine and each set of conditions of train, grade, piston speed, boiler pressure, external temperature, wind, etc.

CHAPTER XLIX

THE SLIDE VALVE

Q. By what means is the steam admitted to and allowed to escape from cylinders?

A. By a device called a slide valve, playing parallel with the cylinder length on a ported seat, driven by suitable mechanism, and controlling steam admission to and exhaust from both ends of the cylinder.

Q. What are the functions of a slide valve?

A. To let steam into only one end of the cylinder at a time; to cut off the supply at a certain point of the stroke; to let it escape from one cylinder end into the exhaust pipes as soon as it commences to enter the other (in some cases to close the exhaust before all the waste steam has been released); to prevent steam passing directly from the entrance ports into the exhaust passages.

Q. When and by whom was the slide valve invented?

A. Toward the end of the eighteenth century, by Matthew Murray, of Leeds, but in a crude form.

Q. In what forms does the slide valve exist?

A. In two principal types; the plain short D and the piston valve.

Q. Who invented the simple long D slide?

A. Murdock, Watt's assistant.

Q. What are the principal parts of the plain slide valve?

A. The body or arch, and the legs.

Q. What is the most simple and usual slide valve used for an American standard locomotive?

A. The valve consists in effect of a plate or block, as shown in section Fig. 128, having in its under surface a cavity which extends at right angles to the direction of the valve, and parallel with the ports in the valve-seat.

Crosswise projections from the top of the valve enable the valve-rod to be attached either by screws and nuts or by a collar or frame surrounding the projections, in such a manner that the valve is free to change its position with respect to the valve-rod, as its face and that of its seat wear away.

Q. Describe the seat upon which this type of plain slide valve or short D valve is placed?

A. As shown in Fig. 149, and in Figs. 150 and 151, it consists of a plain surface having three narrow ports, with parallel edges, all of which are at right angles to the direction of motion of the piston and of the valve. The central (and larger) one communicates only with the exhaust-passage, the end ones with the cylinder, at the counterbore, each serving alternately for admission and exhaust for its own cylinder end. There are usually shoulders at each end, so that the valve may in its travel extend beyond them, instead of cutting away material and wearing a low place in the seat.

Q. What would be the effect of omitting the shoulders in the seat?

A. If the valve were given short travel and wore itself a low place in the seat, there would, if the travel was increased or the valve adjusted so as to be brought nearer to or further from the crosshead end of the cylinder, be either a smash-up, or a leak between the steam-chest and cylinder.

Q. Why are the bridges made narrow?

A. To decrease friction, hence reduce the force needed to move the valve.

Q. What is the usual bridge width in American engines?

A. From 15/16 to $1\frac{1}{4}$ inch.

Q. What about the length of the valve seat for ordinary D valves?

A. Generally enough to leave the width of one bridge at each end with greatest valve travel—unless this would cause a shoulder to be worn when the gear is in the most usual position.

Q. What is the advantage of a false valve-seat?

A. It can be made harder and given a better finish than the seat in one piece with the cylinder.

Q. What effect do unequal steam ports on either side sometimes have?

A. To break crank-pins.

Q. Is there any usual rule for port area?

A. There is one, "more honored in the breach than in the observance"; to give each end port, for 600 feet piston speed, an area of 1/10 the piston area; for higher speeds, proportionately more port area is given.

Q. What is the proportion between port area and piston area in American locomotives?

A. There is no standard; it depends on the service required, and sometimes also on the whim or convenience of the designer. One 20 by 24-inch full-gage consolidation engine has 100 to 7; a 17 by 24 full-gage passenger engine, 100 to 8; a 15 by 18 narrow-gage consolidation, 100 to 9; a 12 by 6 narrow-gage passenger, 100 to 9; of 15.76 and 11.76 to 1 for full-gage and narrow-gage consolidations, and 12.6 and 11.3 to 1 for passenger engines.

Q. What may be said as to the effect of cylinder diameter on the port area, with ports of the same length compared with the cylinder diameter?

A. A port length of three quarters the cylinder diameter, for instance, gives comparatively less port area on a small cylinder than on a large one.

Q. By what means is a flat slide valve attached to and driven by the valve-rod or valve-stem?

A. Ordinarily by a yoke which embraces it so as to permit it and the chest to be worn or planed down without bringing the valve-rod too low in the stuffing-box.

Q. What other advantage has the yoke?

A. It lets the valve lift in case of excessive cushion, thus acting as a safety valve for the cylinder.

Q. What provision is made to prevent the valve from wearing shoulders in the seat at the points ending its most usual travel?

A. The seat is slightly raised above the bottom of the chest, so that the valve overruns it, as may be seen in the lengthwise section of the valve-seat (Fig. 139). Raising the valve-seat above the bottom of the chest also allows for wear and facilitates planing off.

Q. What would be the disadvantage of too short a valve-seat?

A. At full gear, steam would pass under the valve into the port which was being used for exhaust.

Q. What is the advantage of having the front and back sides of the slide valve extended above its arch?

A. It gives a good bearing for the valve-yoke, and enables the valve to be held on its back for planing.

Q. What is the disadvantage of the recesses on the valve-top?

A. Sometimes they hold oil that should go into the cylinder.

Q. By what means is the slide valve lubricated?

A. By oil let into the chest by a pipe running back to the cab, where it bears an oil-cup; the flow of oil from this to the chest being controlled by the cylinder oil-cock or cylinder-oiler.

Q. What would have to be the linear dimensions of a plain slide to effect admission at one stroke end, and exhaust at the other, for each single stroke of the piston?

A. Outside, equal to the extreme distance between outside edges of the end ports; inside, equal to the distance between inside edges of the same ports, as shown in Fig. 135, where the valve is in mid-position.

Q. What is the travel of a valve?

A. The entire distance that it moves along the valve seat, irrespective of whether its motion causes port opening or not; this being in locomotives a variable quantity, according to whether there is demand for early or for late cut-off.

Q. What is the relation between the travel of the valve and the throw of the eccentric?

A. If the rocker arms are of equal length, the valve travel is the same as the eccentric throw. If the rocker has arms of unequal length, then the valve travel will have the same relation to the eccentric throw as the rocker arm next the valve stem has to that below it.

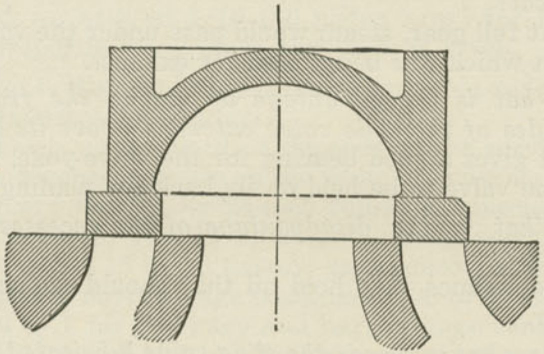


Fig. 149. D Slide Valve.

Q. What is the difference between the "throw" and the "eccentricity" of an eccentric?

A. The throw is twice the eccentricity; the latter being the distance between the center of the axle and that of the eccentric sheave.

Q. How is the admission of steam cut off before the piston has reached stroke-end?

A. By having the legs or lips of the valve longer than necessary to seal the end ports, and by so timing the position of the valve with respect to that of the piston, that after opening the end port for admission of steam the

valve shall return and close that port before the piston has reached stroke end.

Q. What name is given to the excess of length of leg or lip of the valve at each end, over what is barely required to cover the end port?

A. Steam lap, outside lap; or simply "lap."

Q. What is the relation between steam lap and the degree of expansion?

A. The greater the lap for a given valve travel, the earlier the steam is cut off, and the greater the expansion.

Q. What is the relation between valve travel and point of cut-off and degree of expansion?

A. The greater the travel for a given amount of lap, the later the cut-off and the less the expansion.

Q. If the valve had its lip just long enough to cover the end ports when in mid-position, were at mid-position when the piston was at stroke end, and given an equal degree of travel in each direction from its mid-position, what would be the effect upon the stream distribution?

A. If the valve had its travel so that it was back again at mid-position when the piston reached stroke end, there would be steam admission during full stroke, irrespective of the amount of valve travel and port opening.

Q. What effect would the amount of valve travel have upon the steam admission in this case, where the valve started from mid-position at beginning of stroke and reached mid-position again at stroke end?

A. The longer the travel the fuller the steam admission would be.

Q. How long should the travel be, to give the full degree of steam admission without choking?

A. That depends upon the length as well as the width of the port; also upon the piston speed. The narrower the port and the higher the piston speed, the greater should be the valve travel.

Q. When the piston starts out from one end of the cylinder, what is the direction of motion of the slide valve?

A. The same as that of the piston.

Q. When the piston is in the latter part of its stroke, what is the direction of the valve motion?

A. In the opposite direction to that of the piston.

Q. With a lapped valve, suppose the piston is at beginning of the stroke, where is the valve?

A. Its steam edge is either just in line with the outer edge of the end port at the end at which the piston is, or slightly in advance thereof in the direction in which both piston and valve are to move.

Q. Where it is slightly in advance of the "line and line" position, that is, where the port is slightly opened before the piston is at stroke beginning, what is said of the valve?

A. That it has "lead" or "advance."

Q. What is the reason for giving the valve lead?

A. To enable the steam to enter the cylinder more readily when the piston is at stroke beginning; also to enable the exhaust to open slightly before it would otherwise do, at or towards the stroke end.

Q. Is a valve given lead by its construction, or by its setting?

A. By the setting of the eccentric with relation to the crank pin.

Q. At what part of the valve travel does a slide valve move the fastest?

A. As its center line approaches that of the seat, that is, as it nears the middle of its travel.

Q. What is seal?

A. An overlapping of the valve edges when in central position, just enough to prevent leakage into or from the ports, without being sufficient to be noticeable as lap.

Q. Why will steam not enter the cylinder when the valve is on at mid-travel?

A. Because both steam ports are closed by the lap.

Q. What is lap?

A. Lap, properly called outside lap or steam lap, is in

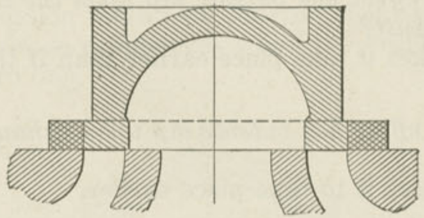


Fig. 150. Slide Valve with Lap Added.

the ordinary slide valve an excess of length over the amount necessary to just come line and line with the outside edges of the end ports. In Fig. 150, where the valve is in mid-position, the outside lap is represented by the extra heavily hatched portions at both ends. In Fig. 151 there is practically no lap.

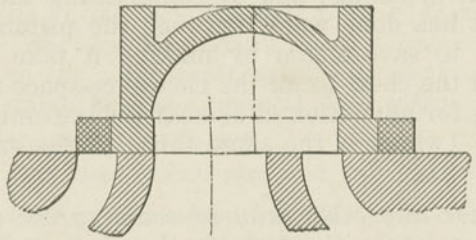


Fig. 151. Slide Valve with Lap Added.

Q. What is the object of outside lap?

A. To close the end ports to steam before the piston has completed its stroke, thereby permitting the steam to expand and do further work, independent of boiler pressure.

Q. When it is stated that a slide valve has a certain amount of lap, does that mean at each end, or at both together?

A. At each end, unless there is a different amount at each end, in which case it is so stated.

Q. What effect has outside lap upon the time of opening for exhaust?

A. It makes it take place earlier than if there were no lap.

Q. What effect has outside lap upon exhaust-release or opening?

A. It causes it to take place earlier.

Q. What is the effect of giving the valve legs or lips a certain lap inside the inside edges of the end ports? (See Fig. 152.)

A. To close the exhaust before the piston gets to stroke end, thereby giving cushion or compression.

Q. What are the advantages of compression or cushion?

A. To enable a fast-running engine to get over the centers without knocking; and by compressing the exhaust steam, that has done work, between the piston and the valve face, to save steam by making it take less new steam from the chest to fill the clearance-space when the valve opens for admission at or near the beginning of the new stroke (which is the same thing as the end of the old one).

Q. Is there any other way of enabling the piston to reverse its motion without shock, than by cushioning the exhaust steam?

A. Yes, giving "steam lead"; that is, causing the live steam to enter before the piston starts out on new stroke.

Q. What effect has inside lap upon the time of exhaust commencement?

A. It delays it.

Q. What is the effect, upon the steam distribution, of inside or exhaust lap?

A. To prolong expansion, and hasten compression or cushion.

Q. Where is inside lap usually employed?

A. In high-speed engines having very late cut-off, where compression takes place during about one-half the stroke and release commences when the crank is within 40° of the zero line.

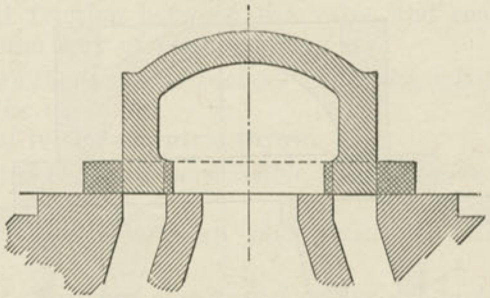


Fig. 152. Slide Valve with Outside and Inside Lap Added.

Q. In case of over-compression, that is, of compression in the cylinder clearance space up to a pressure greater than that in the valve chest, what happens?

A. The valve, if it is a plain D slide, rises.

Q. What permits it to rise?

A. The fact that it can rise and fall in the yoke.

Q. What other advantage has this yoke construction?

A. As the valve and seat wear, the former can follow the latter downward, without bringing the valve stem out of center with the stuffing box.

Q. What is clearance?

A. The reverse of inside lap; an excess of such width, to give the steam port greater opening at stroke commencement, permit early cut-off, increase compression, and aid in filling the cylinder clearance space. (See Fig. 153.)

Q. What is the effect, upon the steam distribution, of inside clearance or "negative inside lap"?

A. To shorten expansion and delay compression or cushion.

Q. What is inside lead?

A. There is neither outside nor inside lead. Lead is a position, not a dimension or proportion of the valve.

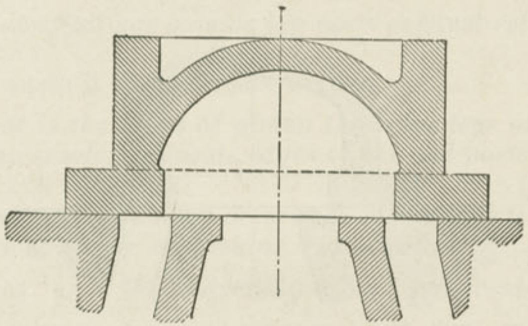


Fig. 153. Slide Valve with Exhaust Clearance.

Some might miscall exhaust clearance or inside clearance "inside lead," but it would be wrong.

Q. Would instantaneous steam-port opening increase speed and save fuel over the up-to-date valve gear now in use?

A. Experiments here and abroad with gears of the four-valve type have given affirmative results, as far at least as compared with the plain D slide.

Q. How is the valve position, with respect to the ports, the distances between the port-edges, the widths of the ports, and the dimensions of the valve itself, arranged so that it will do all that is required?

A. The arch of the valve must be of such width (in the direction of the valve travel) as about to reach from the inside edge of one steam port to the inside edge of the other; each leg or lip of the valve must, when the valve is in such a position that the arch will so reach (this being called its mid-position) be at least long or wide enough (in the direction of the valve travel) to entirely cover its end port.

Q. How about the amount of valve travel?

A. It may be more or less, according to the points at which it is desired to cut off steam admission and close the exhaust.

Q. What is the effect of great valve travel?

A. Great friction between the valve and seat, unless there is some way of counteracting it.

Q. Where there are no rockers and links, what will the travel of the valve be?

A. Equal to the eccentric throw.

Q. What is the least permissible travel to give full port opening?

A. Twice the steam lap plus twice the steam-port width.

Q. What effect has over-travel on the exhaust?

A. Chokes it.

Q. On the sharpness of cut-off?

A. Increases it.

Q. On the compression?

A. Retards it.

Q. On the release?

A. Retards it.

Q. Where is over-travel necessary?

A. When it is desired to give plenty of port opening at early cut-off, in which case other points have over-travel.

Q. How can the bed effects of over-travel on the cut-off be neutralized?

A. By giving more outside lap.

Q. How can delay in cushion, caused by over-travel, be neutralized?

A. By giving more inside lap.

Q. How can delay in exhaust, due to over-travel, be neutralized?

A. By reducing the exhaust lap.

Q. Suppose, however, that there is no exhaust lap?

A. Then by giving the valve exhaust clearance.

Q. To what is the distance that the valve travels, during expansion, equal?

A. To the sum of the outside and the inside lap.

Q. Is the proportionate effect of clearance greatest at high pressure or at low?

A. At low.

Q. Is it greatest with early or with late cut offs?

A. With early (other things being of course equal).

Q. What is the most usual valve travel for locomotives?

A. From 4½ to 5 inches maximum.

Q. The steam lap therefor?

A. About one-fourth the travel.

Q. The minimum?

A. About one-eighth the travel.

Q. The inside lap?

A. On account of the rapid exhaust it is seldom given; if at all, not more than 1/16 inch.

Q. How wide should the exhaust ports be?

A. Wide enough to have an opening at greatest travel equal to the steam port width.

Q. How may the valve travel be lessened without injuriously diminishing the port opening?

A. By providing supplementary ports and passages, as shown in what is known as the Allen or Trick valve, seen in Fig. 154. There is a step or shoulder on the valve-face, and a passage through the valve itself in such fashion that as the outside edge of the valve at either end commences to uncover the steam port at that end, the supplementary passage commences to receive steam at the other, and passes it over to be discharged into the

same port, beside the stream of steam coming by the outside edge of the valve.

Q. Where is this valve most needed, and where is it of most use?

A. It is most needed at high speed where the valve travel is shortest, and it is of most use here; also giving double the opening with a given valve travel.

Q. How may it be proved that it is economical of steam?

A. By the fact that some engines which have been unable to run past a certain water tank without taking water, when equipped with the ordinary plain D slide have been able to go on to the next one when the valve was changed to the Allen.

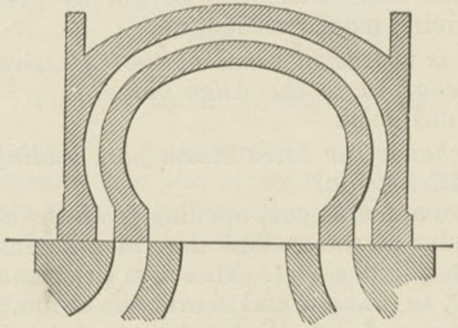


Fig. 154. Allen or Trick Valve.

Q. Can the Allen valve be used on the old seat?

A. Yes; but it is sometimes desirable that the steam ports be widened a trifle by chamfering their outside edges.

Q. What special precaution must be taken with the Allen valve, as regards its travel?

A. It should not travel so far as to bring the supplementary port over the exhaust port of the seat; in which case live steam would blow through.

Q. What precaution needs to be taken in designing the valve itself, independent of the travel?

A. That the walls of the passage through it be strong enough to stand the steam pressure.

Q. What precaution needs to be taken in the manufacture of the valve itself after it is designed?

A. That the coring is good, in order that the passage through it may be full size and have smooth walls.

Q. What is the disadvantage of the Allen extra port?

A. On long-travel valves under high pressures, the greater length necessitated by the extra port makes a greater area to be balanced.

Q. Can Allen ports be used to advantage with piston valves?

A. No; the same effect can be got by greater valve diameter, giving more port length.

Q. What is the usual cause of the excessive compression often charged to the Allen valve?

A. Too much lead.

Q. For what is the extra steam port leading over the top of the Allen valve?

A. To give a double port opening from the steam chest to the cylinder at the instant the valve begins to admit steam to the cylinder port. This port extends around exhaust cavity, so that one end is over the steam port at the time the other end is passing out beyond the edge of the valve seat at the opposite end. This lets steam pass into the steam port through two openings, one at the edge of the valve the other through the Allen port.

Q. What is the usual peculiarity of the compression line on indicator diagrams from an engine having Allen valves?

A. It is wavy.

Q. To what is this due?

A. Perhaps to the high-pressure steam confined in the extra channel or passage (often miscalled "port") being

admitted to the exhaust side of the piston as the valve moves over to admit steam at that end of the stroke.

BALANCED VALVES

Q. What is the principal objection to the ordinary slide valve?

A. That there is on its back a pressure tending to force it down against the valve seat and thus increase the friction and wear.

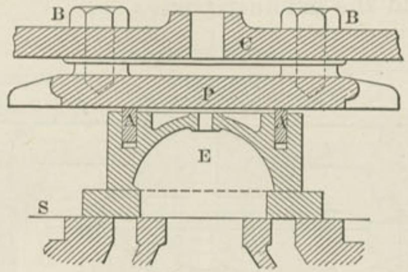


Fig. 155. Richardson Balanced Valve.

Q. How may this be remedied?

A. By causing it to play steam-tight but freely against a back plate parallel to the valve seat, thus removing a large part of the unbalanced pressure.

Q. How are such valves usually constructed?

A. In one of the most common types (the Richardson) there is a flat plate held out from the chest cover, parallel with the valve, the top of which latter is faced off plane; and packing strips are held against the plate by springs. There is a hole from the exhaust arch of the valve to the space included between the valve back and the balance plate, and bounded by the packing strips; the object of this hole being to let any steam, that might pass the packing strips, escape through the exhaust.

Q. Describe the plain Richardson balanced valve?

A. It is simply an ordinary D slide having in the top or back packing strip *A* bearing against a plate *P* that lies parallel with the valve seat *S*, and is fastened to the chest cover *C* by screws *B*. The central part of the valve back is recessed and is in communication with the exhaust arch *E* by a central hole. (Fig. 155.)

Q. Can the Allen valve be balanced?

A. Yes; in Figs. 156 and 157 such a valve is shown.

Q. What is the rule for area of a single balance for plain D valves?

A. 13/12 of the combined areas of one steam port, two bridges, and the exhaust port.

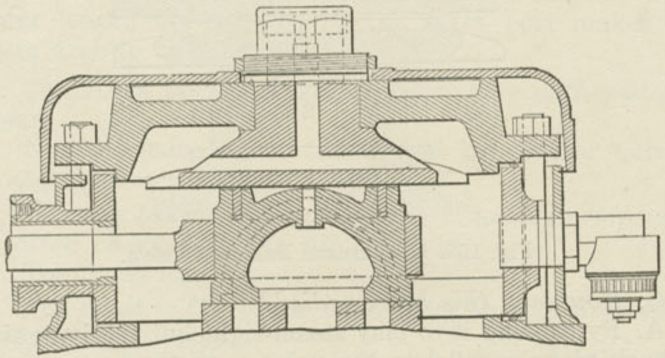


Fig. 156. Allen Balanced Valve, Pennsylvania Railroad Engine, Class "O." Central Lengthwise Vertical Section.

Q. For double balance?

A. 8/7 of the above combined areas.

Q. What is the rule for area of balance of an Allen (double-ported) valve?

A. Same as above, only minus the area of one side of the Allen port.

PISTON VALVES

Q. What is a plain piston valve?

A. A cylindrical sliding piece (usually an iron or steel casting) moving backward and forward in the cylindrical bore of a steam chest having the same relative ports as

for a flat slide for admitting steam to, and exhausting it from, an engine cylinder; this piston having a length practically equal to that of the slide for the same seat, and a circumferential depression corresponding in position and axial length equal to the arch of the flat slide. In other words, its axial section would look like two D valves back to back.

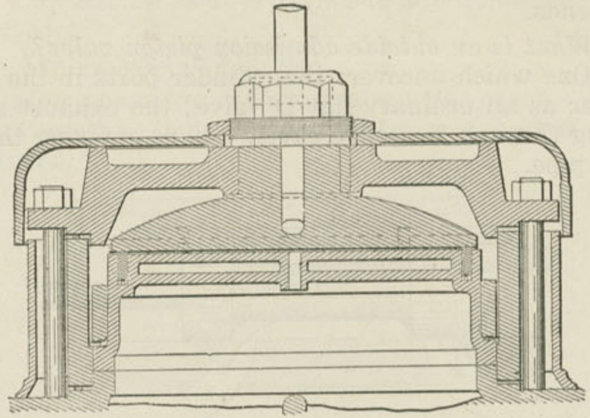


Fig. 157. Allen Balanced Valvé, Pennsylvania Railroad Engine, Class "O." Vertical Cross Section.

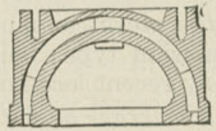


Fig. 158. Allen Balanced Valve, Pennsylvania Railroad, Class "O." Lengthwise Vertical Section to one side of Center.

Q. How is it operated?

A. In the same manner as a flat D valve.

Q. How is it packed?

A. Piston valves have disks or short cylindrical pieces secured to each end, with metal snap rings to insure a steam-tight fit in the valve-chamber bushing.

Q. What types thereof are there?

A. (1) Inside admission and (2) outside admission.

Q. What is an inside admission valve?

A. One which takes steam from the steam supply pipe into its central cavity, between the ends, and admits it to the steam passages leading to the cylinder ends; the exhaust steam from the cylinder being in contact with the valve ends.

Q. What is an outside admission piston valve?

A. One which uncovers the cylinder ports in the same manner as an ordinary flat D valve; the exhaust steam passing through the valve cavity before entering the exhaust pipe.

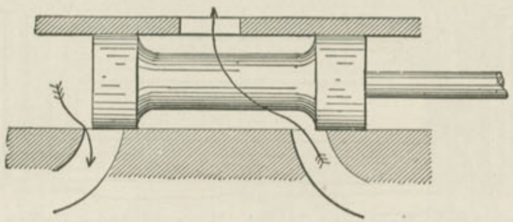


Fig. 159. Piston Valve.

Q. Which type is the more common?

A. The inside admission type; being used instead of the slide valve on many recent locomotives.

*Q. How can you tell whether or not the valves have inside admission?**

A. Watch the beginning of the stroke; if the valve stem moves in the same direction as the piston, the valve has inside admission.

Q. Is not this also shown if both rocker arms are turned down?

A. No; the eccentrics might be set in accordance; that is, the forward motion ahead of the pin.

* Not pre-admission.

Q. Can an outside admission piston valve be made to run without an exhaust cavity in the seat?

A. Yes; as shown in Fig. 159.

Q. What eccentric arrangement is here necessary?

A. The same as for the ordinary plain D.

Q. Can one be made with inside admission and no exhaust port?

A. Yes; as seen in Fig. 160.

Q. How about the valve motion in this case?

A. It must be the reverse of that where there is outside admission.

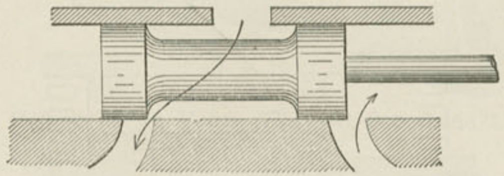


Fig. 160. Piston Valve.

Q. What would happen if either of the heads of this last piston-valve chamber were broken out?

A. The exhaust would escape into the air without going through the stack, hence the steaming would be affected; there would be only three exhausts per turn.

Q. Can a direct-acting locomotive have indirect-acting valves?

A. Yes; class "T" of the Pennsylvania Railroad is an instance.

Q. On these engines how are the eccentrics arranged?

A. As for an indirect-acting engine with direct-acting valves.

Q. How are the eccentrics arranged on a Baldwin compound freight engine?

A. The go-ahead sheave is ahead of the crank in running ahead.

Q. What about the port length necessary with a piston valve?

A. It should be longer than for a flat slide.

Q. At what point in their travel are piston valves most perfectly balanced?

A. When all ports are covered; that is, at mid-travel.

Q. What precautions must be taken in using piston valves?

A. Unless they have by-pass or special relief valves, not to work water into the cylinders; for, as this valve cannot raise its seat as a flat D valve can, the water would be liable to damage the cylinders and heads.

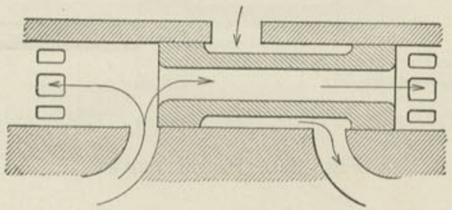


Fig. 161. Hollow Piston Valve.

Q. What are the advantages of the piston valve over the flat D valve?

A. (1) Better balancing, and consequently smaller resistance to being moved, (2) better distribution of steam at high piston speeds.

Q. Where is it specially desirable?

A. In four-cylinder compound locomotives, where one valve is employed for a high and a low pressure cylinder on each side of the engine, it is the only kind that experience has shown to be practicable.

Q. What is the principal disadvantage of piston valves?

A. As usually made, (1) the necessity of blowing through to warm them up before starting, to prevent the piston sticking in the bush—unless rings are used; (2)

the exhaust steam coming in contact with the valve throws it out of its normal position, wearing the valve gear and causing pounding of rods and boxes.

Q. Sketch a hollow piston valve and show how the exhaust escapes?

A. As in Fig. 161; the admission is between the valve ends, the exhaust at both chest ends.

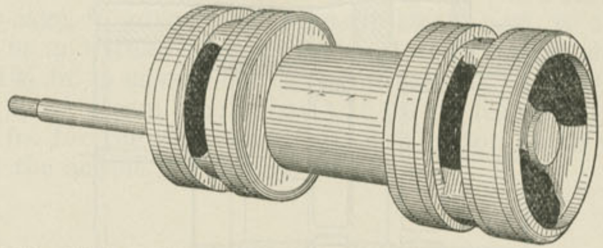


Fig. 162. Hollow Piston Valve, Vauclain Compound Locomotive.

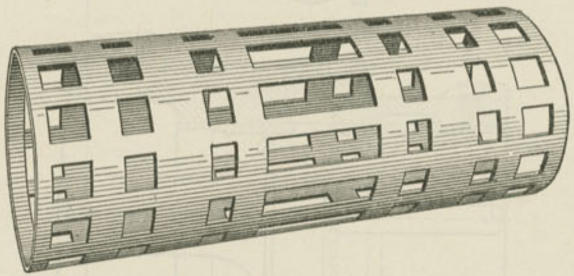


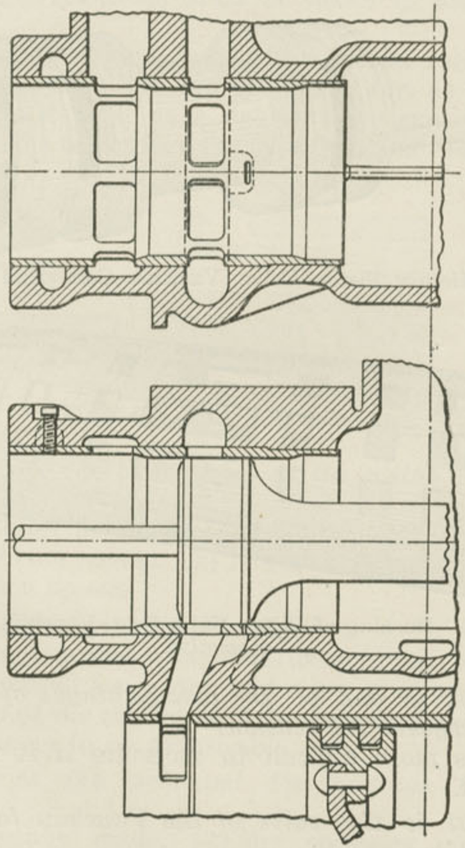
Fig. 163. Bushing of Piston-Valve Seat, Vauclain Compound Locomotive.

Q. What is one of the disadvantages of the piston valve as regards lubrication?

A. It is more difficult to ascertain if it is properly lubricated.

Q. What is the valve of the Vauclain four-cylinder compound engine?

A. It is a hollow piston having cast-iron rings sprung into place like ordinary piston rings. It is practically, in working, two D valves the two ends of which control admission and exhaust to and from the high-pressure cylinder, the inner rings doing same for the low. Fig. 162 shows the valve; Fig. 163 the ported seat or bushing in which it plays.



Figs. 164 and 165. Pilot Ports.

Q. How can we keep the cut-off the same when we give or increase lead?

A. By shortening the steam lap.

Q. How can compression or cushion be kept the same when we give or increase lead?

A. By shortening the exhaust lap.

Q. What is an auxiliary starting port?

A. As seen in Figs. 164 and 165, it is an extra port, the valve cage, in advance of the main steam port, to do the same as an excessive steam lead. In the example shown, it is 1¾ in. in advance of the main port; is ⅛ by 1½ in., with ¼ in. steam lap; it has 1 15/16 in. lead as against 3/16 in. for the main port. It is in action at all times when the engine is running.

CHAPTER L

VALVE DIAGRAMS*

Q. How may the relative positions of piston and valve, and the occurrences in cylinder and steam chest, be represented by a diagram?

A. According to Bilgram, by drawing a semicircle the diameter AB of which (Fig. 166) represents the piston stroke on one scale, the valve travel on another; drawing

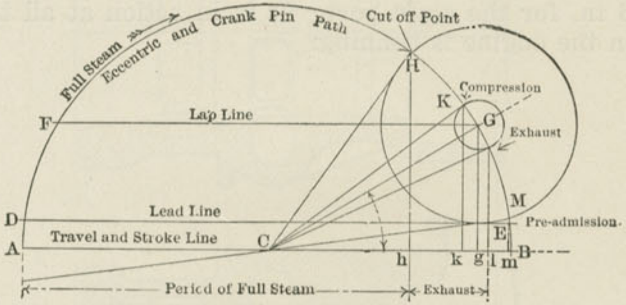


Fig. 166. Bilgram Valve Diagram.

parallel to this diagram a line DE, the distance of which from the latter represents the lineal valve lead; parallel to this again another line FG at a distance corresponding to the outside lap. Where this cuts the semicircle at G, strike one circle with the steam lap as radius (this will be tangent to the lead line) and another with either the exhaust lap or the inside clearance, as the case may be, as radius. From the center C of the semicircle draw two radii tangent to each of these lap circles, cutting the semicircle at points H, K, L. M. Where there is exhaust lap these cut the semicircle at points corresponding to crank-

* Not to be confused with indicator diagram or cards.

pin positions at cut-off, compression, release, and preadmission respectively. (Where there is exhaust clearance then compression and release will simply exchange places.) Perpendiculars Hh, Kk, Ll, Mm from these four cutting points to the semicircle diameter AB will cut the latter at points h, k, l, m, indicating the corresponding piston positions. The angle between the radius CG and the semicircle diameter is the amount in excess of 90° that the eccentric belly must be set ahead of the crank.

Q. Does the diagram thus made take any account of the irregularities caused by the angularity of the connecting rod?

A. No; it shows the occurrences as taking place in both ends of the cylinder exactly alike.

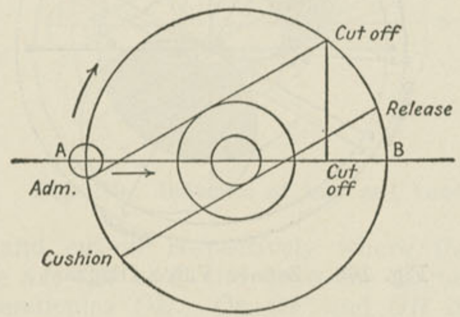


Fig. 167. Sweet Valve Diagram.

Q. How may the angularity of the connecting rod be taken account of?

A. By taking as radius the length of the connecting rod on the same scale as the piston stroke, and with centers on the semicircle produced in both directions drawing circular axes from H, K, L, M (instead of perpendiculars) to that diameter; the eight new cutting points will indicate the earlier and later piston positions due to the rod.

Q. Suppose there is so-called negative lead, how is the diagram made?

A. As before, only with the lead line *DE* below instead of above the semicircle diameter *AB;* the lap to be measured as before from the lead line and not from the diameter.

Q. How can this diagram be used to determine the desired amount of lap to cut-off, etc., at any desired piston position?

A. By working it backwards; assuming the points *h, k,*

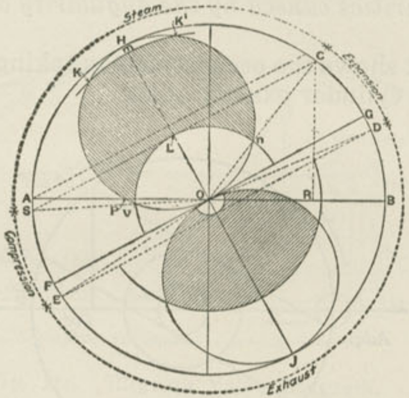


Fig. 168. Zeuner Valve Diagram.

l, and *m,* erecting the perpendiculars (or striking the arcs) and finding the middle positions where these last cut the semicircle.

Q. Show the Sweet slide valve diagram, as slightly modified by Grimshaw.

A. Referring to Fig. 167, the diameter *AB* of the large circle represents the valve travel; that of the small central one the exhaust lap, and of the larger central one the steam lap, that of the small one at the end of the diameter the lineal lead. Then tangents to the lead and steam-lap circles will cut the valve travel circle at a point corre-

sponding to crank-pin position at cut-off. A perpendicular from this to the diameter *AB* cuts it at a point corresponding to the wrist-pin position at cut-off. (Connecting-rod influence is neglected.)

Q. How does the Zeuner diagram represent the slide-valve movements and functions?

A. Referring to Fig. 168, *AB* represents the piston path and valve travel on different scales, the circle thereon the crank-pin path, and the eccentric-center path. Marking *M* and *C* as the crank position at points of ad-

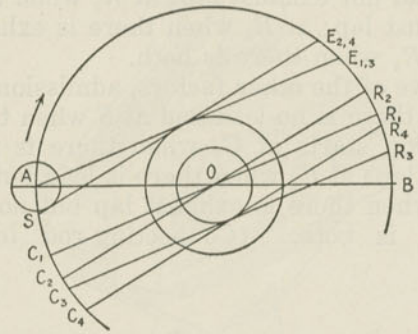


Fig. 169. Influence of Lap and Lead.

mission and cut-off respectively where there is lead, bisect the arc *CM* at *F* and draw the diameter *OH* and the perpendicular *OE*. On *OF* and *OH* draw circles, called the valve circles. Draw circles at the intersection of *OM* and *OR* respectively. Then *OD* or *OS* will be the required steam lap and *OI* or *OV* the exhaust lap. *AS* will be the maximum steam-port opening. *AOM* is the lead angle, *EOG* the lap angle; *EOF* the angular advance of the eccentric beyond 90° ahead of the crank. Making the arc *EX* equal to *EF, X* will be the position of the eccentric center when the crank is on the dead center *A*.

The piston or crosshead positions corresponding to the various angular positions are found by dropping perpendiculars from *C*, etc., to *AB*.

Q. Show on one diagram the influence of steam and exhaust lap, and lead.

A. In Fig. 169, AB represents valve travel and piston path. The radius of the small concentric circle is the exhaust (or inside) lap; that of the larger one the steam (or outside) lap; that of the small circle at the left, the linear lead. Then E, E_3, the end of the chord tangent to the steam-lap circle, is the wrist-pin position when there is no lead, irrespective of the other elements; E_1, E_4 when there is lead as shown. Release is at R_1 when there is neither lead nor exhaust lap; at R_2 when there is lead but no exhaust lap; at R_3 when there is exhaust lap but no lead; at R_4 when there is both.

Irrespective of the other factors, admission is at stroke end A when there is no lead and at S when there is lead.

Compression starts at C_1 when there is neither lead nor exhaust lap; at C_2 when there is lead but no exhaust lap; at C_3 when there is exhaust lap but no lead; at C_4 when there is both. (Connecting-rod influence not heeded.)

CHAPTER LI

THE CROSSHEAD AND GUIDES

Q. What are the essential parts of a crosshead?

A. A socket for the piston-rod end; a journal on which the connecting-rod may turn, and slides which may play between the guides.

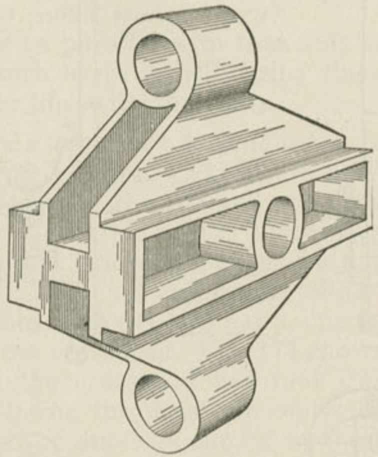


Fig. 170. Crosshead, Vauclain Compound Locomotive.

Q. Which is it best to have cut by wear—the slides or the guides?

A. The slides or gibs.

Q. What is the objection to a wrist-pin cast in one piece with the crosshead?

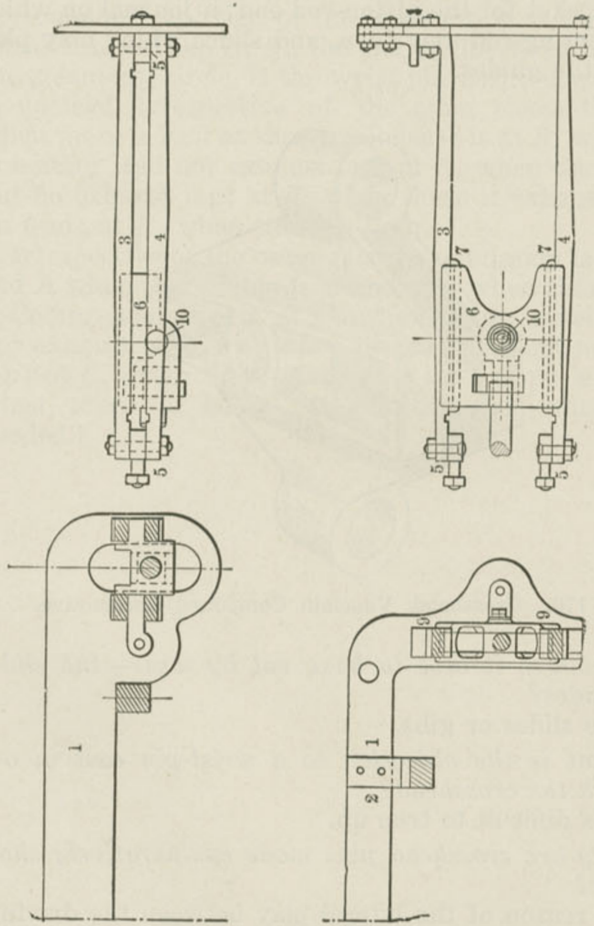
A. It is difficult to true up.

Q. Why are crosshead pins made comparatively short and thick?

A. By reason of the lateral play between the driving-wheel hubs and their boxes making a twisting stress on the pin, on curves.

Q. How is the wrist-pin attached to the crosshead?

A. It is usually cast solid therewith.



Figs. 171 and 172. Guide-bearer, Guides and Crossheads.

1. Guide-bearer. 2. Guide-bearer Knee. 3. Top Guide-bar. 4. Bottom Guide-bar. 5. Guide-fillings. 6. Crosshead. 7. Crosshead Gibs. 9. Crosshead Plate. 10. Crosshead Pin. 11. Crosshead Key.

Q. What class of crossheads may be used for compound engines having two cylinders on each side?

A. As shown in Fig. 170, having two sockets, one for each rod; the entire block being of cast steel in one piece and having its wearing-surfaces covered with block tin 1/16 inch thick.

Q. What is the purpose of crosshead guides?

A. To keep the piston in line with the cylinder axis.

Q. To do this, what is necessary?

A. That they be parallel with that axis and with each other, and at such hight as will bring the center of the crosshead pin in line with that axis.

Q. What forms are given to guides?

A. Their form is legion. (1) There may be only one guide-bar, above the piston rod and crosshead, and which is embraced by the latter, or (2) there may be two, one above and the other below, the crosshead having bearing surfaces on both, but not embracing either, or (3) two above the crosshead, or (4) two pairs, one pair above and one pair below the crosshead. Fig. 171 shows an arrangement in which the crosshead has four guide-bars, two upper and two lower, the wrist-pin center being about in line with the lower ones, as shown in the cross-section. Fig. 172 shows two, one upper and one lower guide, the wrist-pin coming about half way between them, as shown more clearly in the cross section. In Fig. 173 there is but one guide-bar, surrounded by plates bolted to the crosshead proper. In Fig. 174 there are two guides, having between them what is called the crosshead filling-piece, bolted between the two crosshead cheeks.

Q. What name is often given to the distance-piece between the guides?

A. Guide filling-pieces.

Q. What class of guides is used, where one of the driving-wheels is opposite the guide-bars, as with Mogul and consolidation engines?

A. There are two bars above the crosshead and none below or on the sides.

Q. What holds the guide-bars in place against the great vertical strains to which they are subjected?

A. They are bolted at the front end to the back cylinder-head and at the back to a guide-yoke attached to the frame of the engine, and usually, also, to the boiler.

Q. What is the guide-yoke?

A. A transverse plate or casting secured to the frames by angles or knees, holding and supporting the outer guide ends, and frequently having a brace to the boiler waist on each end, as well as an expansion plate for the boiler between the frames. It is also called spectacle-plate, motion plate, guide bearer, and guide cross-tie. The British call it a slide-bar bracket.

Q. What other name is often given to the guide-yoke?

A. The guide-bearer.

Q. What provision is there for reducing to a minimum the wear of guides and slides?

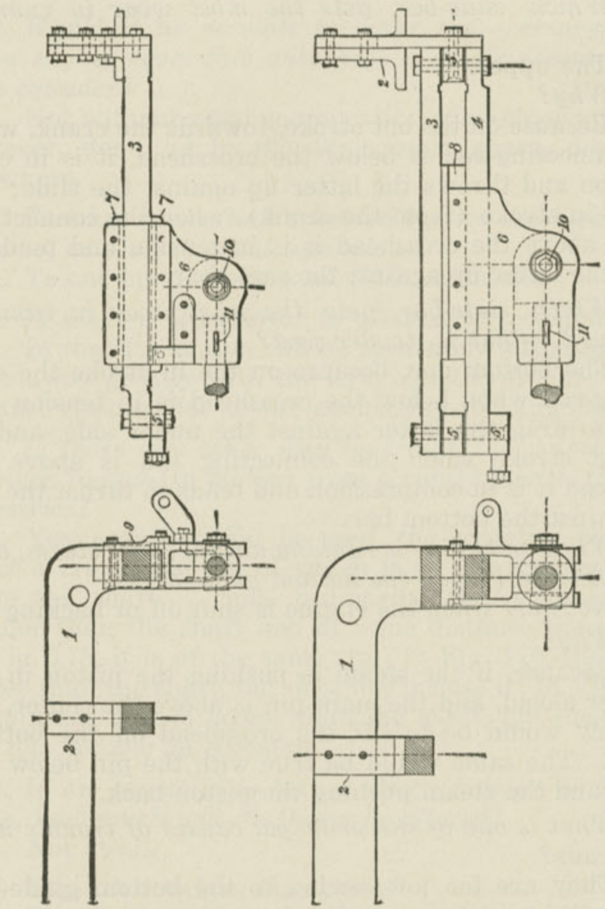
A. The guides are hard and finely finished, and the slides fitted with gibs of brass or bronze between them and the guides; these being adjustable so that as they wear they may be set out to take up the lost motion. The gibs or wearing-pieces being softer than the guides, get nearly all the wear, which is desirable, because they are cheaper to renew; and may be set out quite readily, by liners or otherwise.

Q. Is there any provision for bringing the guide-bars nearer together when worn, or for other reasons?

A. Where they are double, one above and one below, or one pair above and one pair below, they are held at a fixed distance apart by end-blocks or distance-pieces; and these latter being removed and planed off to any desired extent allow of this sort of adjustment. Another way is to provide liners at first and to have them removed from between the end-blocks and the guide bars, as the gibs wear.

Q. Is the wear on the guides uniform?

A. No; not where, as is usually the case, the engine runs more in one direction than in the other.



Figs. 173 and 174. Guide-bearers and Crossheads.

1. Guide-bearer. 2. Guide-bearer Knee. 3. Top Guide-bar. 4. Bottom Guide-bar. 5. Guide-fillings. 6. Crosshead. 7. Crosshead Gibs. 8. Crosshead Filling piece. 9. Crosshead Plate. 10. Crosshead Pin. 11. Crosshead Key.

Q. Where is there the greatest strain on a slide-bar?

A. At the center of length, by reason of its having less support there, and of the angularity of the connecting-rod being greatest there.

Q. Which slide-bar gets the most wear in running ahead?

A. The upper.

Q. Why?

A. Because on the out stroke, towards the crank, when the connecting-rod is below the crosshead, it is in compression and throws the latter up against the slide; and on the in stroke (from the crank), when the connecting-rod is above the crosshead it is in tension and tends to draw the latter up against the same bar.

Q. Which slide-bar gets the most wear in running backwards—that is, tender first?

A. The bottom one, because on the in stroke the connecting-rod when below the crosshead is in tension and tends to drag the latter against the under side, and on the out stroke when the connecting rod is above the crosshead it is in compression and tends to thrust the latter against the bottom bar.

Q. When an engine is running ahead, using steam, does the crosshead run on the bottom guide-bars?

A. No; only when the engine is shut off or backing up.

Q. Why?

A. Because, if the steam is pushing the piston in the cylinder ahead, and the main pin is above the center, the tendency would be to lift the crosshead off the bottom guides. The same would be true with the pin below the center and the steam pushing the piston back.

Q. What is one of the principal causes of trouble with crossheads?

A. They are too low, owing to the bottom guide-bar getting the most wear on down grades.

CHAPTER LII

THE ECCENTRIC MOTION

Q. Would it be possible to make the ordinary slide-valve engine reversible with only a single eccentric for each cylinder?

A. Not without great complication of mechanism; it is, however, done, as in the Walschaert gears, described elsewhere.

Q. To what does a link operated by two eccentrics correspond, as a mechanical equivalent?

A. To one operated by a movable eccentric.

Q. In what is it superior to a movable eccentric?

A. In that its motion can be accurately adjusted so as to do away greatly with the irregularities in cut-off and exhaust closure, due to the connecting-rod angularity.

Q. Is there any other way by which the valves could be given to-and-fro motion from a rotating axle, than by eccentrics?

A. Yes, cranks might be used, the eccentric being in effect a crank, the pin of which is so enlarged as to include the shaft. Thus, ordinarily, the crank-pin is smaller than the shaft and at some distance therefrom; in Fig. 175, it is of the same size; in Fig. 176, the pin is larger than the shaft, but does not inclose it; in Fig. 177, the pin not only is larger than the shaft, but incloses it and has become an eccentric.

Q. If an eccentric is turned down half an inch in a lathe, how much will its throw be altered?

A. Not at all.

Q. What determines the throw?

A. The distance from the center of the axle to that of the eccentric sheave.

Q. What is the effect of boring out and closing the eccentric strap?

A. To change the travel of the valve.

Q. What is the remedy?

A. Lengthening the eccentric rod.

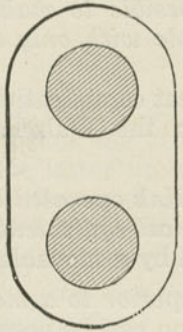


Fig. 175. Crank Axle.

Q. How tight should the keys of eccentric strap bolts be?

A. So tight that the nuts cannot work back more than a turn, else straps will probably break.

THE ROCKER ARM

Q. What would be the most simple way of getting the motion of the eccentric to the valve?

A. By an eccentric rod direct from the strap.

Q. Why cannot this be done in the case of a locomotive?

A. Because it is usually necessary to have two eccentrics so as to be able to reverse the engine, and to have a link to be able to alter the throw for the purpose of varying the period of admission and degree of expansion.

Q. With two eccentrics and a link motion, is the valve driven directly from the link?

A. No; there is a rocker arm to transfer the motion

from the lower plane to the higher one; also from the frames to outside.

Q. What other effect upon the motion has the rocker arm?

A. It reverses it, making it necessary to set the eccentrics differently from what would be the position were there no rocker arm.

Q. What is a direct-motion engine?

A. One without a rocker.

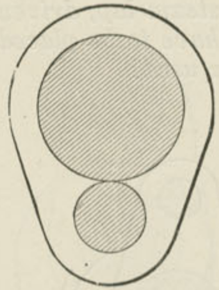


Fig. 176. Crank and Axle.

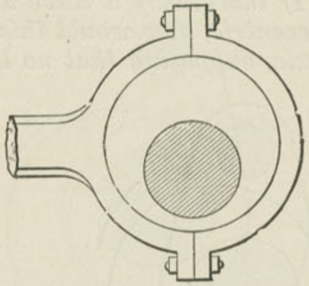


Fig. 177. Eccentric and Strap.

Q. In a direct-motion engine, when the engine is running ahead, which eccentric leads?

A. The forward one.

Q. Are most American locomotives direct or indirect motion engines?

A. Indirect.

Q. Where there is no rocker, will the eccentric be ahead of the crank, even with it, or back of it?

A. Ahead of it.

Q. What is the difference between the motion of an eccentric and that of a crank?

A. There is none, except that the eccentric rod cannot drive the sheave, while the crank may be driven by the connecting rod.

Q. What constitutes a "direct" or an "indirect" locomotive?

A. These terms apply to the valve motion only. If the valve moves with the eccentric rod, it is direct; if opposite thereto, indirect. The use of a rocker with its bearing between the eccentric rod or link connection and the valve rod makes an indirect valve motion. If a rocker is employed, with bearing at either end, it transmits the motion "directly."

ANGULAR ADVANCE

Q. If there were a valve without steam lap, driven by one eccentric, how would this latter have to be placed on the axle, supposing that no lead was used?

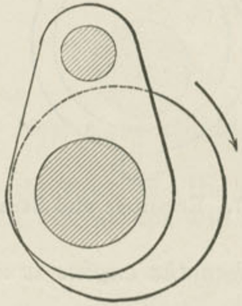


Fig. 178. Single Eccentric, Lapless Valve, no rocker.

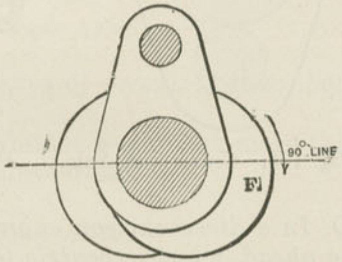


Fig. 179. Two Eccentrics, Lapless Valve, no rocker.

A. If there was no rocker arm it should be placed with its belly or high part 90° ahead of the crank pin, in the direction in which it was desired that the axle should turn; it would be as in Fig. 178.

Q. How should the eccentrics be set, where there are two with shifting link and uncrossed rods, driving a lapless valve without rocker arm (no lead being required)?

A. As shown in Fig. 180, each one 90° ahead of the crank pin in the direction in which the engine is to run. (The forward eccentric is marked *F*.)

Q. Suppose a single-eccentric engine having no rocker arm, driving a valve that had outside lap for the purpose of cutting off the steam before stroke end; how should the eccentric be set, if no lead was desired?

A. As shown in Fig. 180, in which the eccentric is more than 90° in advance of the crank pin, in the direction in which the axle is to turn; the excess being enough to enable the steam edge of the valve to be in line with the outside edge of the end port, when the piston is at beginning of stroke.

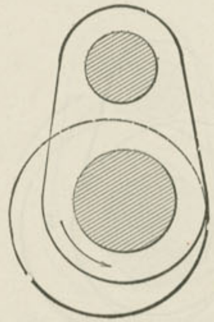


Fig. 180. One Eccentric, Lapped Valve, no rocker.

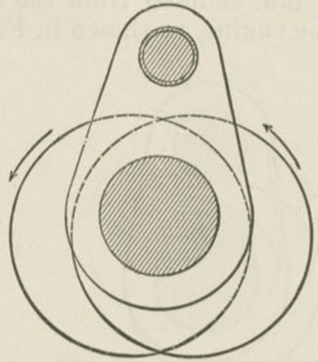


Fig. 181. Two Eccentrics, Lapped Valve, no rocker.

Q. How should the eccentrics be set where there are two driving a lapped valve, with shifting link, uncrossed rods and no rocker, and when no lead is desired?

A. As in Fig. 181, where the forward eccentric is ahead of the crank pin, in the direction in which the engine is to run ahead, 90° plus an amount enough to bring the valve line-and-line for steam admission, at stroke end; the eccentric bellies pointing from the crank.

Q. How can the amount ahead of the 90° position, necessary to make the steam edge of the valve lip line with the outside edge of the end port, be determined?

A. In two ways: first, on the engine itself, by turning the eccentric until the valve is in that position; second, on the drawings; the angle in excess of 90° being the angle which the crank makes with the central line of the engine, at the point of cut-off.*

Q. Where there is a rocker arm and one eccentric, with a lapless valve, what about setting the latter (*when no lead is desired*) *?*

A. As the rocker arm reverses the direction of valve motion with relation to the driving axle, the eccentric should be set, where there is no lap, just 90° back of the crank pin, counted from the direction in which it is to run the engine, as shown in Fig. 182.

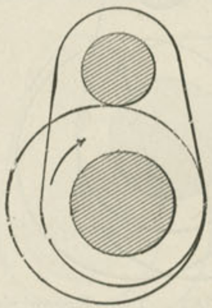


Fig. 182. One Eccentric, Lapless Valve, with rocker.

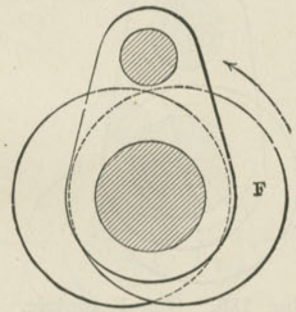


Fig. 183. Two Eccentrics, Lapless Valve, with rocker.

Q. Where there is a rocker arm and a lapless valve with two eccentrics, a shifting link and uncrossed rods, and no lead is required, how should the eccentrics be placed?

A. Each should be 90° back of the crank pin (in the opposite direction from that which it is required to run the engine). (See Fig. 183, in which the forward eccentric is marked *F*.)

Q. Where there is a rocker arm and a lapped valve,

* This is fully described and illustrated under the head of "Valve Setting."

with one eccentric, and no lead is desired, how should the eccentric be placed?

A. Back of the crank pin (in the opposite direction from which the engine is to run) 90°, less enough to bring the valve line-and-line for admission at stroke end; the eccentric belly being toward the crank. The more lap the more such excess. (See Fig. 184.)

Q. Where the valve has lap and there are two eccentrics and a rocker arm, with shifting link and uncrossed rods, and no lead is required, what should be the eccentric positions?

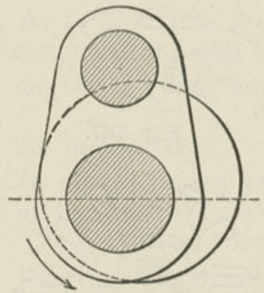


Fig. 184. One Eccentric, Lapped Valve, with rocker.

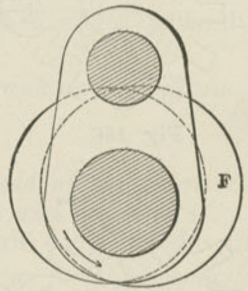


Fig. 185. Two Eccentrics, Lapped Valve, with rocker.

A. Each should be back of the crank pin (in the opposite direction to that in which it is intended to run the engine) 90°, less enough extra turn to bring the valve line-and-line for admission at stroke end; the eccentric bellies being toward the crank. (See Fig. 185, in which the forward eccentric is marked *F*.)

Q. Where lead is desired, what is the rule?

A. Turn the eccentric still further ahead of the crank pin, in the direction it is to run the engine, if there is no rocker. If there is a rocker, turn it still further in the opposite direction to that in which it is to run the engine.

Q. Is this rule good for either one or two eccentrics?

A. Yes.

Q. Suppose that you have two eccentrics of different throws, but the same angular advance, and that the valve laps are made so that both will have the same lead; how will the distribution be?

A. Admission and cut-off will occur at the same point

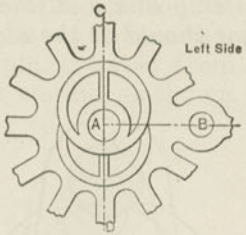


Fig. 186.

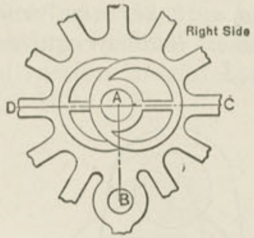


Fig. 187.

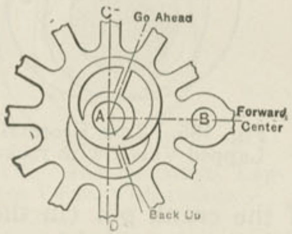


Fig. 188.

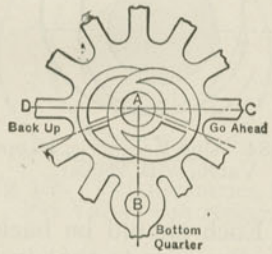


Fig. 189.

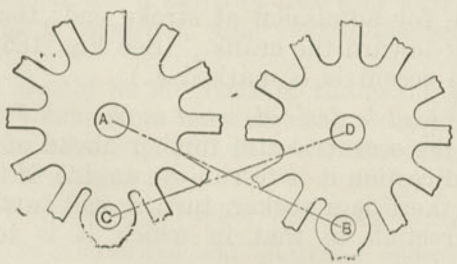


Fig. 190. Location of Eccentrics.

of the stroke, but there will be less width of port opening with the small throw.

Q. What would be the positions of the two eccentrics on the left-hand side if there were neither lap nor lead?

A. As seen in Fig. 186, where *A* is the axle, *B* the crank pin on the forward center, and *CD* the center line of eccentrics.

Q. On the right side at the same time?

A. As in Fig. 187, the lettering being the same.

Q. If there were lead or lap, or both, on the left side, with the crank on the forward quarter?

A. As in Fig. 186, the amount of angle depending on the amounts of lap and lead.

Q. On the left side, with the crank on the bottom quarter?

A. As in Fig. 189.

Q. In general what may be said of the relative positions of the center lines of crank and eccentrics?

A. The eccentrics form an angle enclosing the crank.

Q. What are the proper positions for the eccentrics, in relation to the crank pin on the same side?

A. The forward motion eccentric should follow the pin, at right angles, less the lap and lead of the valve. The back motion should lead the pin, at right angles, less the lap and lead of the valve.

Q. What are the positions of the eccentrics on the right side of a locomotive in relation to those on the left side?

A. The right forward motion eccentrics lead those on the left side by one-fourth turn. The same is so of the back motion.

THE SHEAVE AND STRAP

Q. In how many pieces is the eccentric sheave?

A. Sometimes in one; at others, for convenience of repairs, in two.

Q. How are these fastened together?

A. Sometimes by bolts or studs, at others by keys and cotters.

Q. What is the advantage of the latter?

A. There is less trouble in fastening the parts together in such a confined place.

Q. Where eccentrics are fastened together in halves by screws, as in English engines, what is done with the recesses at the screw heads?

A. They are filled up with babbitt metal to keep the screws from working out.

Q. How are the eccentrics fastened on the axle?

A. Sometimes by set screws only; sometimes by a key and keyway, and again, without cutting keyways, by two keys having teeth on their under sides so that they will grip the axle; these keys being held in place by set screws.

Q. What is the objection to a keyway?

A. It weakens the axle.

Q. Are the eccentrics always on the main driving axle?

A. No; in small engines they are often on the front axle.

Q. What difference does this usually make in the eccentric rods?

A. It puts the backing eccentric rod on the upper end of the link, and the forward eccentric rod on the lower; and the lifting-shaft will have to be in front instead of back of the link. The eccentric-strap is made in two halves, a front, shown in Fig. 155, and to which the eccentric rod is bolted, and a back, bolted to the front half.

Q. What is an eccentric strap?

A. A ring fitting on an eccentric, cast in two parts and usually with the inner surface grooved or channeled to fit a tongue surrounding the circumference of the eccentric, although sometimes the groove is in the circumference of the sheave and the projecting tongue on the

inside of the strap. The strap transforms the rotary motion of the eccentric to a reciprocating one at the end of the eccentric rod.

Q. Is the eccentric strap always divided in a line at right angles to the center line of the rod?

A. No; some builders make the parting at an angle of 45° or so with the rod.

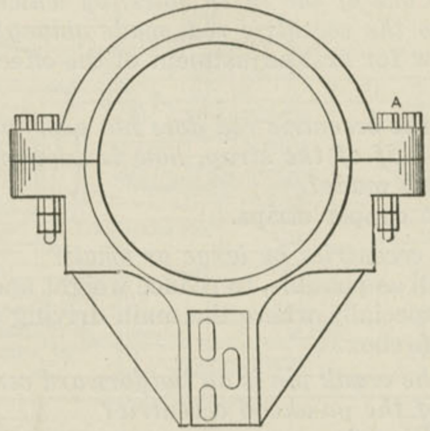


Fig. 191. Eccentric Straps.

Q. What is the advantage of having the parting at right angles to the center line of the rod?

A. That there will not be required one pattern for the right side, another for the left.

Q. What is the advantage of having the parting at more than a right angle to the center line of the strap?

A. Lessening the strain on the bolts and nuts connecting the two parts.

Q. Why has the eccentric strap two hubs cast thereon?

A. To avoid the necessity of having a right and a left-hand pattern.

Q. As between a grooved sheave and a grooved strap, which is better?

A. The grooved strap, as a grooved sheave would have to be wider, hence extra heavy.

Q. How can the breakage of eccentric straps be lessened?

A. By making the lugs or ears larger and putting in an extra screw bolt as at *A*, Fig. 191.

Q. Why is one of the three holes, by which the strap is attached to the eccentric rod, made oblong?

A. To allow for first adjustment of the effective length of the rod.

Q. Where the eccentric rod does not pass into a socket in the front half of the strap, how is adjustment of its effective length made?

A. By thin copper strips.

Q. Should eccentrics be large or small?

A. As small as possible, to reduce weight and wear and give room, especially where the main driving axle comes close to the firebox.

Q. When the crank pin is on the forward center, where is the body of the go-ahead eccentric?

A. Above the axle.

Q. When the crank pin is on the forward center, where is the body of the back-up eccentric?

A. Below the axle.

Q. Why is it that, other things being equal, the shorter the eccentric throw the earlier the cut-off?

A. Because the less the throw of the eccentric the greater the angle by which it leads the crank pin (or follows it, according as there is not, or is, a rocker arm).

Q. What relation has the size of the eccentric upon the length of valve travel?

A. Really none; a large eccentric may have a small throw and *vice versa*. The throw is determined by the distance between centers.

ECCENTRIC RODS

Q. Which type of engine has the proportionally longest eccentric blades?

A. The four-wheel connected.

Q. What are the disadvantages of long eccentric rods?

A. (1) Trying on the straps; (2) liable to spring and get the valves out of square, especially should the latter get dry.

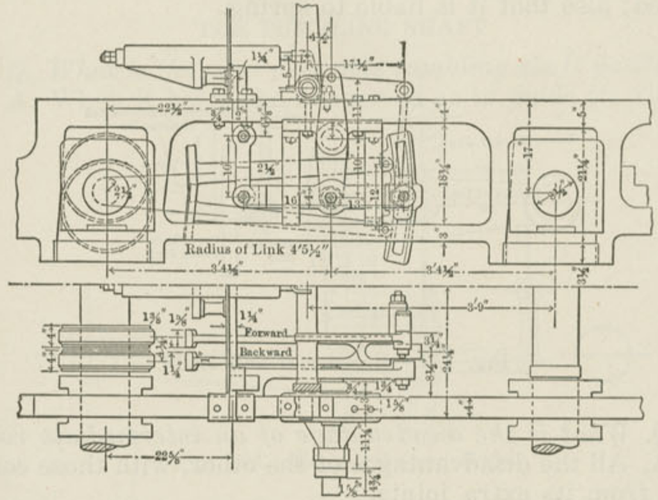


Fig. 192. Eccentrics and Valve Gear.

Q. In standard American engines, which eccentric blade is attached to the top of the link?

A. The forward.

Q. Which eccentric comes next to the box?

A. There is no rule; sometimes the forward, sometimes the back-up.

Q. What is the general rule as regards the lead of the cranks?

A. The right leads the left 90°.

Q. Why are short eccentric blades used?

A. To avoid a long curved rod around the forward driving axle, or an intermediate rod around the axle, hung on links or guides at the rear.

Q. Which of these two evils is the greater?

A. The latter.

Q. What is the disadvantage of a long curved rod?

A. Its weight, and its friction on the eccentric at high speed; also that it is liable to spring.

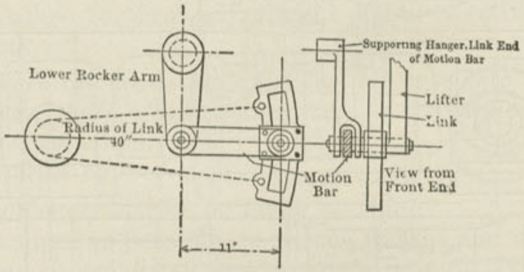


Fig. 193. Eccentrics and Rods.

Q. What is the disadvantage of an intermediate rod?

A. All the disadvantages of the other, with those coming from its extra joints.

Q. How can the evil of long eccentric rods, curved over the axle (as on many ten-wheelers) be remedied?

A. (1) By putting the link just back of the front axle, and using a curved transmission bar from the link to the rocker, just ahead of the leading axle—which gives two curved rods instead of one; (2) by using very short eccentric rods between main and forward axles; (3) as on the Southern Railway and the Plant System, by a straight direct transmission bar leading back to the rocker (Fig. 193); (4) as on some of the Brooks consolidated for the Long Island and the Lake Shore roads (Fig. 194).

Q. Why were eccentric blades formerly made adjustable, and why are they no longer so made?

A. It is no longer customary to make them adjustable by means of slotted holes at the eccentric end. They were formerly made adjustable so they could readily be moved to equalize the cut-off in case the engine became lame through wear or other causes. The practice was discontinued, as it was hard to keep the blades from slipping on the large modern engines.

THE TUMBLING SHAFT

Q. What is the most desirable tumbling shaft position?

A. When it holds the hanger so as to guide its vibra-

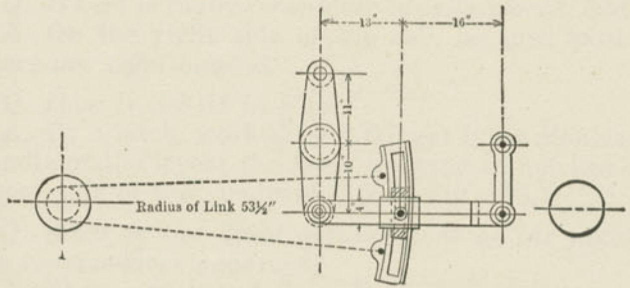


Fig. 194. Eccentrics and Rods.

tions in arcs practically parallel to the center line of motion. Also, it must be far enough above or below the central line of motion to keep it from being struck by the eccentric rods when the gear is moved from one motion to another.

Q. Why not curve the eccentric rods?

A. That would produce the desired results, but introduce into the design an element of weakness.

Q. What point must be noted in connection with the hanger?

A. It must be of such length that the link end will not strike the tumbling shaft in either forward or backward gear.

Q. What is the usual proportion between the tumbling shaft and hanger lengths?

A. The tumbling-shaft arm is usually at least as long as the hanger.

Q. Suppose that the boiler or other part prevents the tumbling-shaft arm from going far enough up to prevent the link being placed in full back gear, what will have to be done?

A. There are two remedies; one to put the tumbling shaft below the link motion, the other to lengthen the rocker so as to lower the entire motion.

CHAPTER LIII

THE REVERSING MECHANISM

Q. What is the reversing mechanism on British locomotives?

A. The reversing mechanism commonly consists of a hand wheel on a shaft having a worm gear which moves an arm attached to the reach rod.

Q. On American?

A. A lever.

Q. Where is the reverse lever usually placed, and why?

A. On the right side of the cab, because most engineers are right-handed.

Q. How is it held in place?

A. By a latch, worked by a trigger lying alongside the handle of the lever; the latch working in notches on the upper side of the quadrant. (See Fig. 195.)

Q. What is the usual arrangement of the notches in the reverse-lever quadrant?

A. They correspond to such positions of the gear as will cut off the steam at a given number of inches of piston stroke; as 6, 9, 12, etc., or 6, 8, 10, etc. Besides these, there is one notch corresponding to mid-gear.

Q. What will be necessary in the second case?

A. To change the relative rocker-arm positions in order to keep their motions proper.

Q. Which of these two methods is the better?

A. The second, as the greater the rocker-arm length the less the valve-stem vibration and the link-block slip.

Q. Of what material are the rocker arms usually made?

A. Wrought iron.

Q. Why are the holes in the rocker arms usually tapering?

A. To enable the pin to be driven out more readily.

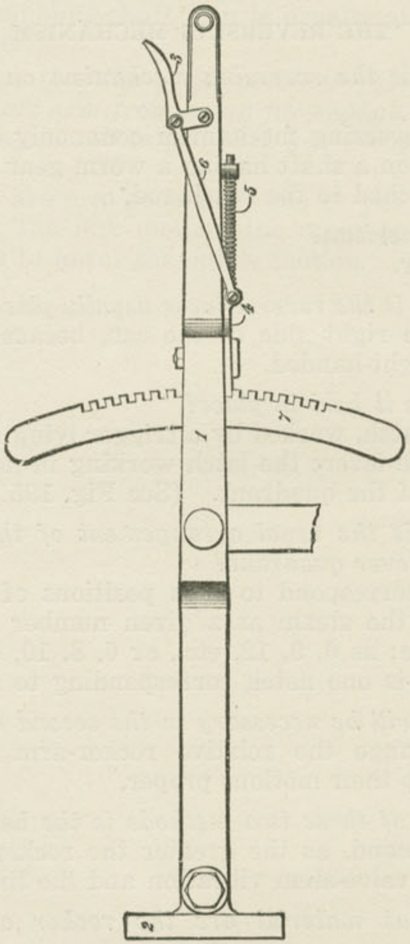


Fig. 195. Reverse-lever and Attachments.

1. Lever. 2. Fulcrum. 3. Handle. 4. Latch. 5. Latch-spring. 6. Latch-rod. 7. Catch.

Q. How long should the reverse lever be?

A. At least long enough to give the engineer a leverage of about four to one over the link; that is that one foot of lever motion should move the link not more than three inches. Six to one would be a better proportion.

Q. When the reverse lever is in the center notch, will the valves cover all the ports on each engine?

A. When the link is in its middle position and the crank on the center, the valve on that side is open by the amount of the mid-gear lead, which may be from $\frac{1}{4}$ to $\frac{1}{2}$ inch; that on the opposite side will be practically over the center of its seat, and therefore lapping both steam ports. For the central reverse lever position, the valve will be open when the crank is on the centers, and closed when on the quarters.

Q. If a reversing arm got lengthened, would it affect the valve travel; if so, in what way?

A. An increase in length of the lower reverse arm which supports the link would give increased valve travel if there was space enough between the link block and ends of link slot to allow the center of lower rocker pin, or that of the link block, to pass outside of the line of centers of the eccentric rod pins. This condition, however, seldom or never is found in locomotive practice; a link is usually designed so as to leave barely room for clearance for the maximum block slip—$\frac{3}{8}$ inch at these points is liberal clearance. Hence the travel would not be greatly disturbed with a lengthening of the arm.

Q. Are there many other varieties of reversing gear?

A. Yes; for instance, those shown in Figs. 196, 197, 198.

Q. What is the advantage of a screw reverse gear?

A. Permits shortening the cab.

Q. Describe the Franklin power reversing gear.

A. The piston and operating valve are directly connected by a grease-packed triple thread screw working in a trunk piston; cut-off adjustment being made by a

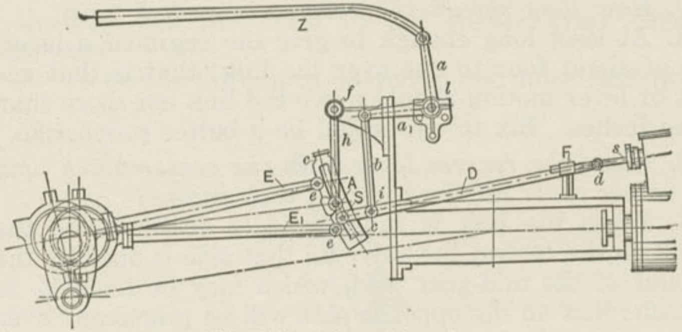


Fig. 196. Reversing Gear.

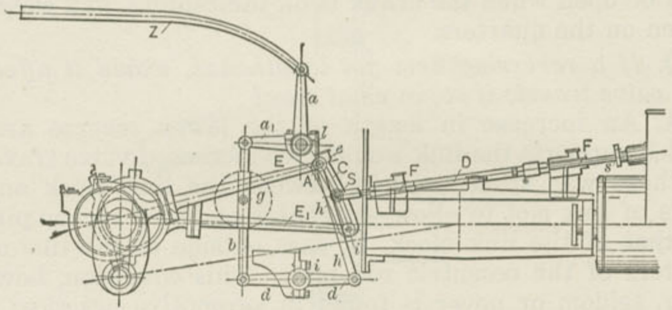


Fig. 197. Reversing Gear.

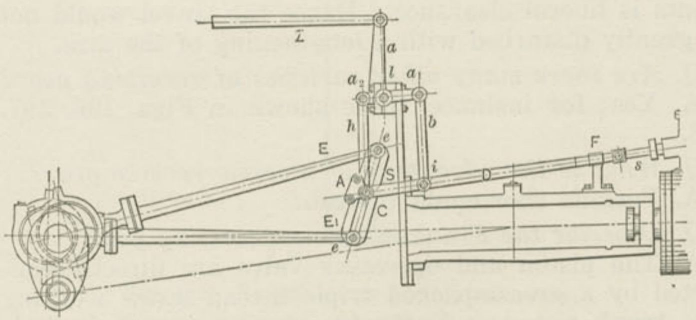


Fig. 198. Reversing Gear.

hand wheel in the cab and shown by an indicator there. When the valve is moved off center, air pressure is admitted to one side of the piston and air exhausted from the other. The piston then moves until the valve is again on center. The indicator shows the valve gear position, whether the air pressure is on or not.

Q. Describe the "Alco" power reversing rig.

A. There are two general types, one for steam, the other for air (see Fig. 199). There is a flat rotary valve operated by the reverse lever in the cab, and moving the

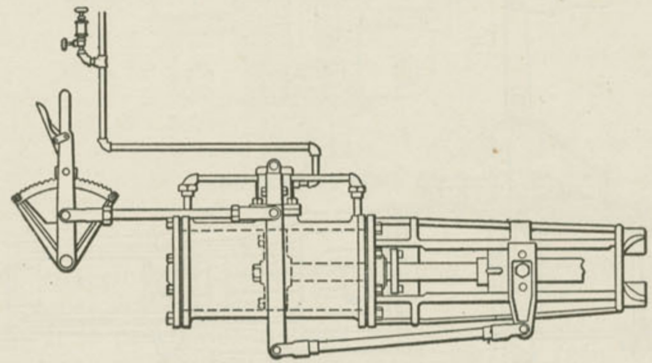


Fig. 199. Alco Reverse Gear.

piston to any desired point in its cylinder, corresponding to the notches in the quadrant, and moving the link (or block, as the case may be) to the position effecting the desired direction of motion and point of cut-off in the steam cylinders.

Q. Are any special precautions necessary in using it?

A. When the valve arm is against the stop, further movement of the reverse lever would result in straining the parts, and should be guarded against.

The pressure supply should never be shut off while the locomotive is moving. If there is no pressure in the reverse gear cylinder, the crosshead might move to a point where damage to the locomotive would result.

Q. Describe the Ragonnet power reverse gear.

A. As illustrated in Fig. 200, there is a cylinder with slide valve operated by the reverse lever in the cab; the piston in the cylinder controlling the position of the link or the block, as the case may be. Movement of the reverse lever opens the port at one end of the cylinder to air pressure, the other port to exhaust. The piston then moves until the cut off corresponds to that indicated

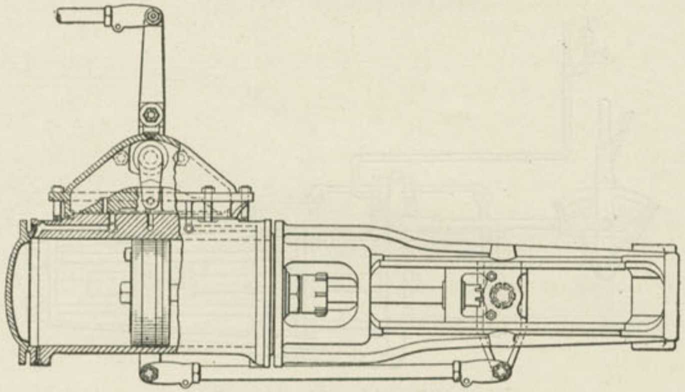


Fig. 200. Ragonnet Power Reverse Gear.

by the reverse lever position, when the combination lever again places the rocker arm that throws the valve in a vertical position and closes the cylinder ports of the device. Between the end of the valve and its chest there is only sufficient clearance to allow the valve to uncover the ports, and the reverse lever can be thrown only the desired distance until the gear moves a corresponding amount.

Q. What is the object of this construction?

A. To prevent the reverse lever moving more rapidly than the gear can respond.

Q. Suppose the gear showed a tendency to move, what would happen?

A. The slide valve would be displaced, admitting air to the cylinder and returning the crosshead of the device to the position shown by the reverse lever.

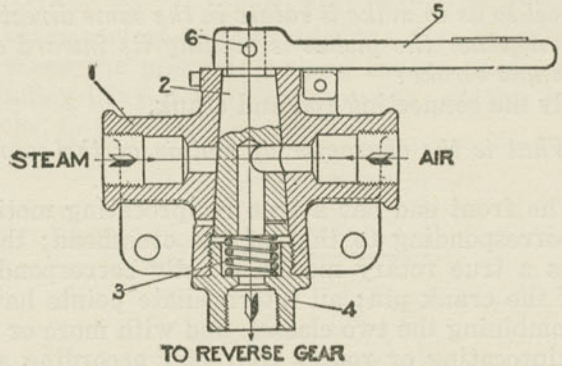


Fig. 201. Nathan Throttle Valve.

Q. Describe the Nathan steam and air throttle valve for power reverse gear.

A. It is practically a three-way cock. Under normal conditions it is in connection with the line from which the air is taken for the operation of the reverse gear and the operating handle is sealed. If anything should happen to make the air supply unavailable, the handle is turned to the opposite position (breaking the seal), the air line is cut out and the steam line cut in so as to operate the reverse gear by steam.

CHAPTER LIV

MAIN AND SIDE RODS

Q. How is the pressure on the piston communicated to the wheel so as to make it rotate in the same direction, no matter whether the piston is making its inward or outward single stroke?

A. By the connecting rod and crank.

Q. What is the character of motion of the connecting rod?

A. The front end has a true reciprocating motion exactly corresponding to that of the crosshead; the rear end has a true rotary motion exactly corresponding to that of the crank pin; all intermediate points have motions combining the two classes, and with more or less of the reciprocating or rotary character according as they are nearer the crosshead or the crank pin.

Q. Is there any loss of power by the use of the connecting rod and crank, by reason of the fact that the angle at which the connecting rod acts on the crank and that at which it receives the pressure of the piston, constantly vary in each half rotation of the crank pin?

A. None whatever, except that due to friction.

Q. At what point in the rotation have the piston and crosshead the most power to cause the crank to rotate?

A. At that point (about mid-stroke of the crosshead) where the crank pin is about at the uppermost or the lowermost point of its rotation.

Q. How much power have the piston and crosshead to turn the crank pin when the centers of the wrist pin, the crank pin and the main driving axle are in the same straight line?

A. None whatever.

Q. How then is the engine kept going?

A. The cranks are quartering, so that when one is on the dead center the other is about at its maximum power.

Q. Is there no means of preventing this difficulty of having dead centers?

A. Quartering the cranks gets around it well enough.

Q. What sort of a stress does the connecting rod get?

A. When the piston is making its out stroke (toward the stuffing box) it is in compression; on the return or in stroke, in tension.

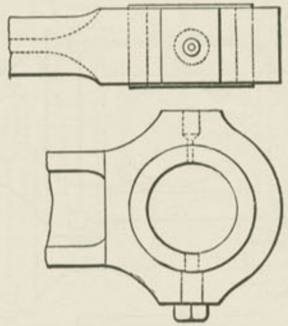


Fig. 202. Rod Ends.

Q. What is the most common shape of connecting rod?

A. They are flat wrought-iron bars, larger at the crank-pin than at the wrist-pin end, and having a cross section either rectangular, or modified from the rectangular by milling out wide flutes to remove material from the lengthwise center line, where material gives the least strength.

Q. Why are they larger at the crank-pin than at the wrist-pin end?

A. Partly because the crank-pin should be larger than the wrist pin, and partly because experience has shown that that end is the more liable to break.

Q. What class of bearing have the wrist-pin and crank pins, in the rod ends?

A. There are two classes. In one the rod is enlarged into a stub end having a ⊓-shaped strap by which half-brasses are held in place around the pin, and which may be set up as desired. In the other, the pins turn in bushes hydraulically pressed into the eyes in the rod ends, and which have no capability of adjustment; in fact cannot be taken out except at the shop.

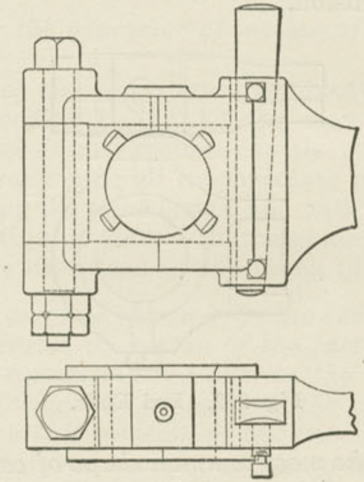


Fig. 203. Rod Ends.

Q. How is the adjustment of the brasses effected, with the ordinary stub end and strap?

A. There are keys by which the brasses may be closed up on the pins, up to that point where their faces touch; then to get any more adjustment they must be taken out and their faces filed off.

Q. In this latter case what is the shape of the hole in which the pin rotates, after the brasses have been thus planed off or filed off and set up?

A. Its outline is that formed by two circular arcs, each rather less than a semicircle.

Q. How are the crank-pin journals oiled?

A. By metal cups attached to the straps, where the stub-end type of rod is used, or to the enlarged head of the rod where solid bushings are employed. Sometimes also, in the stub-end type, there are on the under side of the straps recesses or "cellars" for oil, which is dashed up against the pins, through holes in the under strap leg.

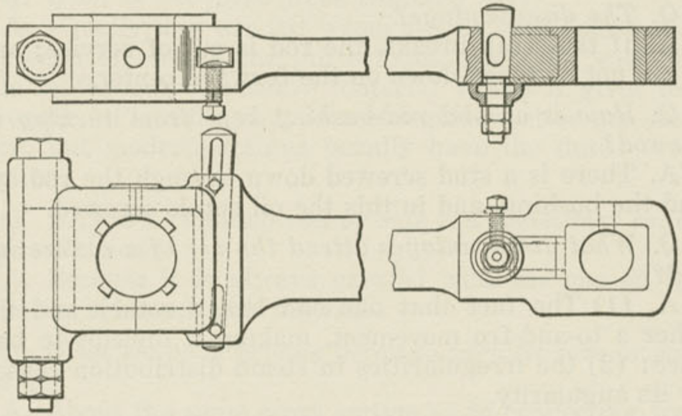


Fig. 204. Rod Ends.

Q. What material is employed for the brasses?

A. Sometimes brass, in other cases bronze; these being sometimes plain, but generally supplied with babbitt plugs or strips cast therein to lessen friction and wear.

Q. When a main rod has one key back of the crosshead pin and another back of the main crank pin, what is the effect on the effective rod length when both keys are tightened by reason of the brass-wear?

A. It will be left practically the same.

Q. Where one key is at the front of the crank pin and the other back of the wrist pin, what is the effect on the effective rod length when both are driven up?

A. To lengthen it.

Q. Which end or side of a main-rod brass gets the most wear?

A. The back one; this being frequently babbitted.

Q. What is the advantage of making a main rod with a fork and strap end?

A. Convenience.

Q. The disadvantage?

A. If the strap breaks, the rod is out of service; and it can not be taken down on the forward center.

Q. How is a solid rod-bushing kept from turning in the rod?

A. There is a stud screwed down through the rod eye and the bushing, and in this the oil cup is screwed.

Q. What disadvantages attend the use of a connecting rod?

A. (1) The fact that one end has a rotary and the other a to-and-fro movement, making it difficult to balance; (2) the irregularities in steam distribution caused by its angularity.

Q. Is this irregularity greatest with a proportionately long or a proportionately short rod?

A. Where the rod is proportionately short.

Q. What effect has the angularity of the connecting rod on the lead?

A. Decreases it in front, increases it behind.

Q. What effect on the cut-off?

A. Increases it in front, lessens it behind.

Q. What effect on the exhaust?

A. Increases it in front, lessens it behind.

Q. How can this be counteracted?

A. By back-setting the saddle pin.

Q. What is the use of coupling rods?

A. To enable the use of more than one pair of drivers, thus lessening the weight on any one axle, and on any one point of the rail.

Q. What is the disadvantage?

A. They lengthen the rigid wheel base and somewhat complicate the difficulties of balancing.

Q. What other names are given coupling rods?

A. Parallel rods, side rods.

Q. What is the form given coupling rods?

A. Usually they are flat wrought-iron bars enlarged at the ends to receive the pin brasses, generally with the side milled out to remove material where it gives less strength. Plain flat rods of rectangular section are common, but modern designs usually have the fluted or I-section.

Q. Why is a coupling rod or side rod sometimes called a parallel rod?

A. Because it is always parallel with the one on the opposite side and with the rails.

Q. What shape is usually given to parallel rods or side rods?

A. About the same cross section as to connecting rods or main rods, but of equal width at each end, or even slightly wider in the middle of length than at the ends.

Q. What classes of wear and stress do side rods get, that main rods do not?

A. There is play between the axle boxes and wedges, that lets the axles run out of adjustment. If the track is uneven the rods will be thrown out of parallel; if the tires wear unevenly, that changes the effective diameters of the wheels and makes one of them either slip or skid; and they also suffer on curves, when brakes are put on suddenly, when running on slippery rails, or when sand is used without judgment.

Q. What is the advantage of a coupling rod wider in the middle than at the ends?

A. Increased stiffness in the vertical plane.

Q. What is the advantage of a coupling rod thinner in the center than at the ends?

A. Lateral flexibility.

Q. In consolidation engines, which coupling rods have the most work to do?

A. The center ones.

Q. Why are the side rods of a Mogul engine in two pieces, forming a front and a rear side rod for each side of the engine?

A. To enable the driving axles to move up and down in their pedestals, independently of each other.

Q. Why is not the pin which connects the front and the rear side rod of a Mogul engine back of the main pin?

A. To keep it from being covered by the main rod, which in Mogul engines is usually outside of the coupling rods.

Q. Should the pin between the front and the back coupling rods be near to the main pin or far from it?

A. Near, to lessen the strain on the main-pin strap.

Q. Why are there three coupling rods on each side of a consolidation engine?

A. To enable its driving axles to rise and fall independently of each other.

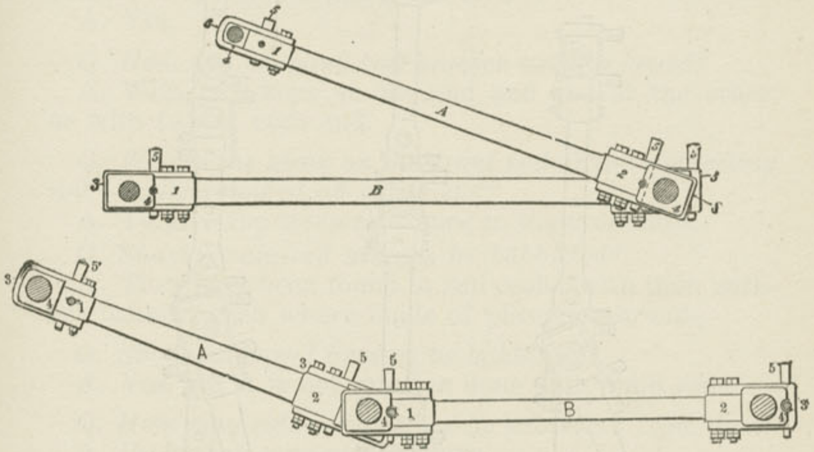
Q. What prevents the coupling rods of an engine which has more than two pairs of drivers from breaking on an uneven track?

A. They have knuckle joints permitting vertical motion; that is, at their forward ends they have a separate pin back of the crank pin on the big end of the rod immediately before them.

Q. What are the various relative positions of the rods on each side?

A. Fig. 205 shows the main rod outside the coupling

rod; in Fig. 206, it is inside. In Fig. 207, the crosshead is outside both the back and the second coupling rods. In Fig. 208, there are back, second, third and fourth, rod being outside of all of them and between the second and third. In Fig. 209, there are back, second, third and fourth coupling rods, the connecting rod being outside of all of them and between the second and third.



Figs. 205 and 206.

A. Main Rod. B. Parallel Bar or Coupling Pin. 1. Front Stub-end. 2. Back Stub-end. 3. Strap. 4. Brass. 5. Key.

Q. What is the usual way of connecting the coupling rods of a consolidation engine?

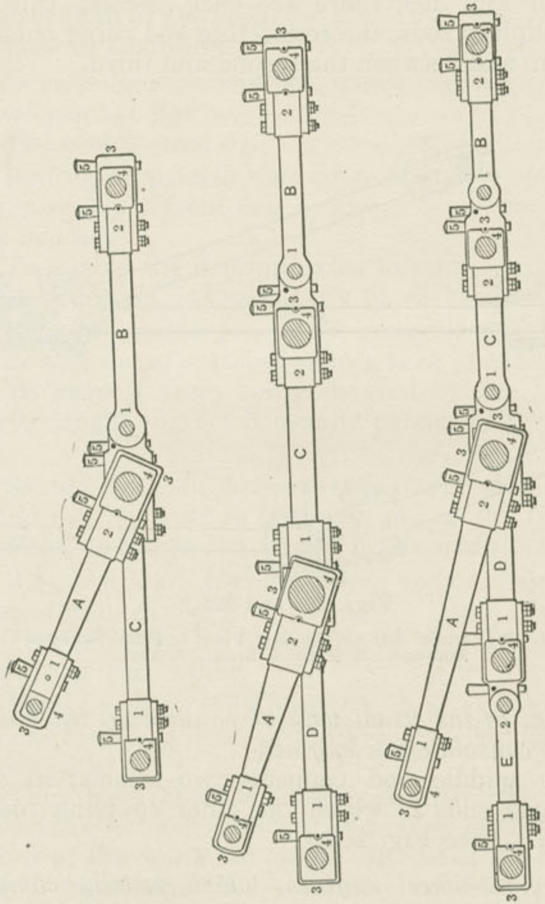
A. The middle rod connects two wheels; its straps have forged ends to which the other coupling rods are connected. (See Fig. 208.)

Q. In eight-wheel engines, which usually come outside: the main rods or the coupling rods?

A. The coupling rods; except on narrow-gage engines, where it is sometimes the other way.

Q. In consolidation engines what is the usage about knuckle joints?

A. There is one back of the main pin, another in front of the coupling rod pin; or back of and close to the pins



Figs. 207, 208 and 209. Rods, Straps and Brasses.

A. Main-rod. B. Back Parallel Rod. C. Second Parallel Rod. D. Third Parallel Rod. E. Fourth Parallel Rod. 1. Front Stub-end. 2. Back Stub-end. 3. Strap. 4. Brass. 5. Key.

in the third pair of drivers, and in front of and close to the pins in the second pair.

Q. Why are the coupling-rod pins in Mogul and ten-wheel engines smaller than on an eight-wheeler?

A. Because in the former there is greater distribution of the pressure.

Q. On this principle may consolidation engines have smaller coupling-rod pins than Moguls?

A. Yes.

Q. How are coupling-rod brasses usually keyed?

A. With two keys at one end and one at the other, or with two at each end.

Q. Why is the strap on the front end of the connecting rod usually rounded off at its end?

A. To give the strap clearance in the crosshead.

Q. Should main-rod brasses be babbitted?

A. They have been found to run cooler with than without babbitt, even where made of phosphor bronze.

Q. Should side-rod brasses be babbitted?

A. Yes, but it is not so often done with main rods.

Q. How may side-rod brasses be protected from dust?

A. By having caps cast on them.

Q. What is the disadvantage of such caps?

A. They hinder inspection of the pin.

Q. Should the brasses extend to the edges of the strap?

A. Yes, to exclude dust, and to prevent shouldering of the strap.

Q. Where does the knuckle joint in a sectional side rod come into play?

A. (1) Where the track is uneven, (2) on frogs, (3) in entering a turntable.

Q. How many knuckle joints on a side have six-wheel-connected engines?

A. One; usually back of the main pin.

Q. Are any engines made without parallel rods?

A. Yes; the Webb three-cylinder compounds shown elsewhere, in which the low-pressure cylinder drives one axle and the two high-pressure ones drive another.

Q. In ten-wheel, Mogul, and consolidation engines, which rod usually takes hold of the inner journal of the main crank pin?

A. The coupling rod.

Q. What is the advantage of solid pressed-in bushings in coupling rods?

A. There are fewer fitted parts, therefore less labor and expense in construction; fewer parts subject to breakage, and the only wear comes on the bush, thus enabling repairs to be effected more rapidly and cheaply than where bolts, keys, and straps require renewal; also there is insurance against being thrown out of adjustment by careless keying; prevention of too frequent adjustment where an engine is run by two or more crews in the same day.

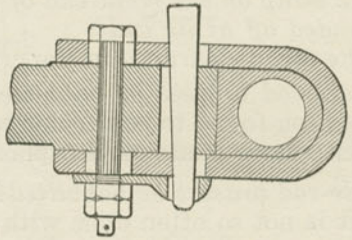


Fig. 210. Strap Joint.

Q. The disadvantage?

A. When worn it cannot be reduced to fit the pin, but must be scrapped, unless it can be bored out and used somewhere else on a larger pin where the same sized eye and external brass dimensions are used.

Q. How is the bush kept from turning?

A. By a hollow stud screwed clear through the rod at the eye and into which is screwed the oil cup.

Q. What is the advantage in fluting a rod?

A. The metal is put in the top and bottom flanges, where it will do more good than in the neutral axis.

Q. What is the reason that a loose brass will cause heating as well as a tight one?

A. Because of the pounding action.

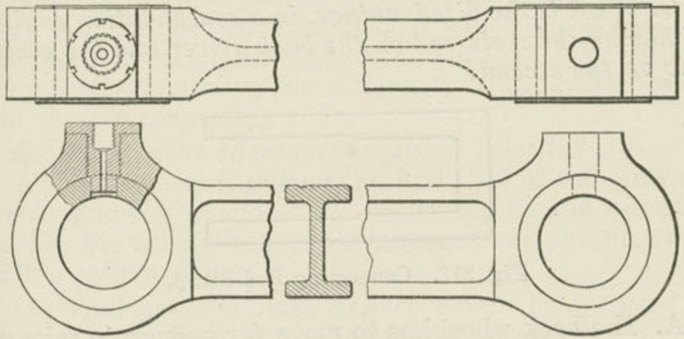


Fig. 211. Rod Ends.

Q. How much larger should the hole in the brass be than the pin?

A. Usually about 1/32 inch.

Q. How is an engine to be keyed up, when the front end rod-straps are as shown in Fig. 210?

A. The bolt must be loosened up first, else it cannot be keyed up.

Q. In what position and condition should the engine be for setting up the front end main-rod brasses?

A. On the lower quarter and no steam on, so that the rod hangs on the front section of the brass, and only the back brass section need be moved; further, the brass will be keyed to the largest part of the wrist pin.

Q. For both ends?
A. On the center, especially where the pins are out of round.

Q. How about keying up side-rod brasses where there are three keys?
A. They should be keyed while on the center.

Q. Where there are two keys, one behind each pin?
A. It makes no difference where the pins stand; both keys should be driven home to keep the brasses from working in the straps.

Q. What is the disadvantage, in a consolidation engine, of having the main rod on the back driver and the eccentric on the second?

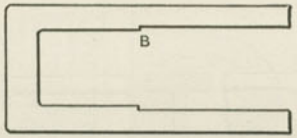


Fig. 212. Connecting Rod Strap.

A. The back wheel has to move far enough to take up lost motion in its axle box as well as the lost motion in the main connection, parallel rods, and the connection of the side rod to the second wheel, before the valve motion feels it.

Q. What is a disadvantage of solid-rod brasses?
A. After heating they are always loose and have to be shimmed or renewed.

Q. What is a common cause of trouble with rod straps?
A. The brass seat is planed off the same width as the stub end; and when it is worn, liners must be riveted in.

Q. How may this trouble be lessened?
A. By slotting the seat a little narrower than the stub end, so as to give plenty of metal for wear. (See Fig. 212.)

CHAPTER LV

CRANKS AND CRANK PINS

Q. What is a crank?
A. A "mechanical movement" designed to convert reciprocating motion into rotary, as in a steam engine, or the reverse, as in a crank-driven pump.

Q. Does the first half of an outward piston stroke correspond to the first quarter of the crank path?
A. No; as seen in Fig. 213, in which the crank pin gradually in each circle falls behind at first, then regains comparative velocity; the difference being greater with the shorter connecting rod.

Q. What is the effect on the piston velocity?
A. To increase it during the first half of the outward stroke and the second of the return stroke and retard it during the second half of the outward and the first half of the return stroke.

Q. What name is given to such cranks as are used on the ordinary English inside-cylinder locomotive?
A. Center cranks; inside cranks; full cranks.

Q. What name is given to such cranks as are used on the ordinary American standard outside-cylinder locomotive?
A. Half cranks.

Q. How are the inside cranks or full cranks of an English locomotive usually made?
A. By forging a large mass on the axle, at the place where there is to be a crank, and slotting it out to form the crank, then turning the pin in place; or by hydraulically bending the axle to the required throw, and turning the pins in place.

Q. What is the objection to the inside crank?
A. Frequent breakage of the crank axle.

Q. How are the cranks of a standard outside-cylinder American locomotive made?

A. Each one is a part of the driving wheel on that side; in the same way as what is known as a disk crank on a stationary engine.

Q. In the ordinary type, how are the cranks arranged?

A. One of them at right angles to the other, in order that when one of the two is on its dead center, the other can start the engine.

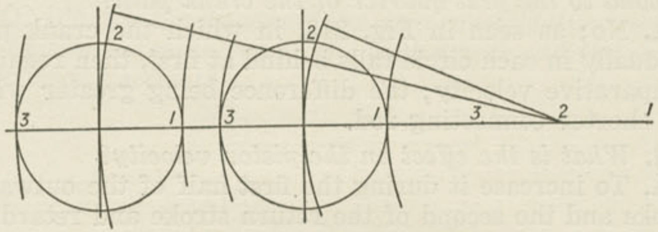


Fig. 213. Influence of Connecting Rod.

Q. Of what material are its crank pins?

A. Of tough wrought iron of the very best quality, or of low steel; turned and preferably ground to exact size and shape, and then either driven in or pressed into the holes bored therefor in the wheels.

Q. Are these holes usually cylindrical or tapering?

A. Cylindrical.

Q. How is the pin kept from coming out, in case the holes and the pin ends are tapering?

A. By a nut and key on the inside of the wheel.

Q. What is the advantage of steel crank pins?

A. They will stand more pressure than wrought iron, without abrasion.

Q. What is their disadvantage?

A. They are more apt to snap.

Q. What is the disadvantage of excessive crank-pin length?

A. The pins are liable to break off, especially on curves.

Q. What is the disadvantage of excessive crank-pin thickness?

A. Excessive friction.

Q. What sort of stress does the crank pin get?

A. In an outside-connected engine a bending stress and also one tending to shear it off at the point where inserted in the wheel. In one with inside cylinders the tendency, besides to bend it, is to shear it off where it enters the crank web.

Q. What is the advantage of having the inner journal of a main crank pin concave?

A. To make it less rigid and permit more flexibility on curves.

Q. Under what circumstances is the rotative effect of the pistons on the cranks the greatest?

A. When the two cranks are in front of the axle and at angles of 45° with the horizontal.

Q. When is it the least?

A. When both cranks are back of the axle and about 45° from the horizontal line.

Q. What is the reason of this?

A. Because when both cranks are in front of the axle, both connecting rods are in position to do maximum work; when one is in front and the other back of the axle, one is at best advantage and the other at poorest; when both are back of the axle, both are at minimum power.

Q. What other advantage is there in working steam with cut-off, besides saving steam?

A. There is a tendency to equalize the connecting-rod action on the crank all through the rotation, there being greatest steam pressure where the rod has least leverage on the crank pins, and *vice versâ.*

Q. *What is the dead center?*

A. That point when the crank pin is in the same horizontal line with the crosshead pin and the wheel center.

Q. *How can the dead center be found on an engine that has lost motion in the main rod?*

A. By marking a line on the guides and crosshead on the out stroke and then one on the in stroke; the correct dead center will be half way between the two marks.

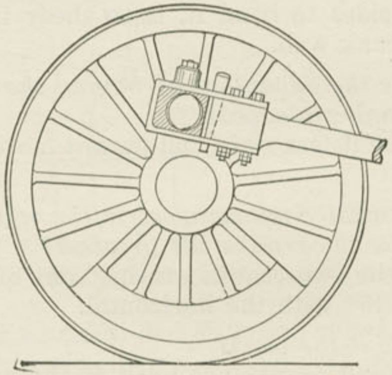


Fig. 214. Wheel and Crank.

Q. *What are the quarters?*

A. Those points at which the crank pin is 90° from the dead centers.

Q. *What determines the actual pressure on the crank pin at any given part of the stroke?*

A. The difference between the mean effective pressure and the inertia of all the reciprocating parts which act on the pin.

Q. *Given weight of reciprocating parts of 500 pounds, train speed 75 feet per second, 5-foot drivers, 20-inch stroke, effective piston pressure 30,000 pounds, crank position 35° above the center, in the first half stroke, what is the pressure on the pin?*

A. The horizontal distance of crank pin from axle can be calculated or measured. In this case it is 8.19 inches; that is, 0.819 the crank length. The velocity of the pin is $\frac{75 \times 2}{5} = 30$ feet a second. The square of 30 is 900; then the inertia of the reciprocating parts for that crank position is $0.031 \times 500 \times 900 \times 0.819 = 11{,}425$ pounds. Deducting this from the piston pressure at that position we have $30{,}000 = 11{,}425 = 18{,}575$ pounds as the actual pressure on the crank pin.

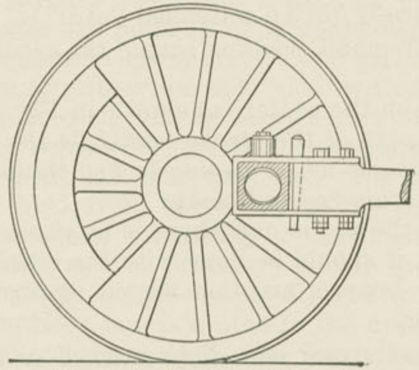


Fig. 215. Wheel and Crank.

Q. *What is the advantage of making crank pins hollow?*

A. Principally being able to judge from the borings whether or not the pins are free from internal flaws.

Q. *Is the tendency toward increasing or diminishing the diameter of crank pins?*

A. Towards increasing it.

Q. *What is likely to happen if the main-rod brasses are keyed up at the back end when the engine is on the center?*

A. The brasses will be closed on the small diameter of the pin, if the latter is worn out of round, and the "high" part will be crowded when running.

Q. *What is the usual shape of a much-worn crank pin?*

A. A cross between elliptic and D shaped; the longest diameter being near the horizontal one when the crank is on a center.

Q. *If an engine always runs in one direction, how will the crank pins wear?*

A. Heart shaped; flattened on one side when on the quarter.

Q. *If she runs in both directions equally?*

A. Elliptically (often miscalled "oval").

Q. *Then in which position should the crank-pin brasses be keyed?*

A. When on the center, as shown in Fig. 215.

Q. *What part of the stroke would be the proper place to stand an eight-wheel engine to key the brasses in the back end of main rod; and why?*

A. When the pin is new there is no choice of position; but if worn, it should be done with the crank on the center, for the brasses are then keyed against the largest pin diameter.

Q. *How are crank pins distinguished or classified?*

A. Crank pins are distinguished as main pins if on the driving pair turned directly by the main rod; front pins if on the forward coupled or driving wheels; back pins if on the rear drivers; and front intermediate or back intermediate pins if on front or back intermediate wheels between the main and the front or back drivers, as the case may be.

CHAPTER LVI

THE FRAME

Q. *What is the function of the frame?*

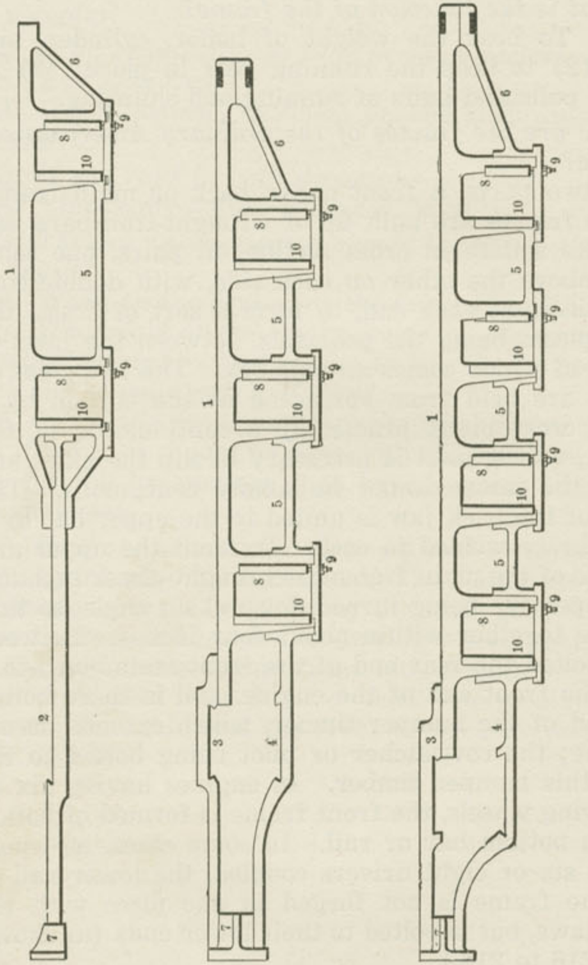
A. (1) To bear the weight of boiler, cylinder, and motion; (2) to keep the running gear in place; (3) to stand the pulls and buffs of running and shunting.

Q. *How are the frames of the ordinary American engine made?*

A. In two parts, a front and a back or main frame. The main frames are built up of wrought-iron bars, say four inches square in cross section, in pairs, one some distance above the other on each side, with double connecting pieces at each end, to form a sort of truss, the distance pieces being the pedestals, between the jaws of each pair of which comes an axle box. The two sides of each jaw are held from spreading at the bottom by a clamp or cross piece, practically a continuation of the lower bar, which, as it is necessary to slip the axles and boxes in the jaws, cannot be solidly continuous. The back leg of the back jaw is united to the upper bar by a diagonal brace welded to each. In front the upper and lower bars of the main frame are brought closer together by the upper one being turned down at an angle, so that they come together within about four inches. Between them is bolted the rear end of the front frame bar, that runs to the front end of the engine, and is there bolted to one end of the bumper timber, which extends across the engine; the cowcatcher or pilot being bolted to the front of this bumper timber. In engines having six or eight driving wheels, the front frame is formed of both a top and a bottom bar or rail. In some cases, as where there are six or eight drivers coupled, the lower rail or bar of the frame is not forged in one piece with the pedestal jaws, but is bolted to their lower ends (as shown in Figs. 216 to 218.)

Q. What is the use of the binding bars or caps at the bottom of the pedestal jaws?

A. To bind the jaws together and thus preserve their parallelism, and yet permit dropping out the axle boxes when the former are removed.



Figs. 216, 217 and 218. Built-up Frames and Pedestals.

1. Top Rail and Pedestals. 2. Front Rail. 3. Front Rail Top. 4. Front Rail Bottom. 5. Middle Brace. 6. Back Brace. 7. Frame Filling-piece. 8. Pedestal-wedge. 9. Pedestal-wedge Bolt. 10. Pedestal Gib.

Q. Are the frames strong enough to bear the weight of the boiler and all that is on it without yielding?

A. No.

Q. Why is the top rail of the rear part of the frame often dropped, back of the front driving box?

A. To get a deep or wide fire-box. For the same reason the equalizing bar is sometimes under the frame.

Q. How is the wear of the inside of the pedestal jaws lessened and horizontal lost motion taken up?

A. By shoes or wedges bolted to the inside jaw faces, and which can be adjusted by liners so as to grasp the axle boxes with just the desired degree of tightness.

Q. What is the usual arrangement of shoe and wedge?

A. The front liner is generally of equal thickness throughout; the back one tapered in thickness at the same angle as the face of the jaw itself, and supplied with an adjustment bolt, passing through the cap, so that wear of both jaw liners can be taken up by setting up the bolt.

Q. What is the effect of this on the position of the box and axle as regards the jaws?

A. They are driven backwards an amount corresponding to the wear of both liners and both sides of the box.

Q. What is the arrangement of wedge bolt on the Pennsylvania standard engines?

A. It is hollow; threaded outside through its entire length from the head upward; has a jam nut against the cap; through it passes a plain bolt, the head of which fits a T-slot in the under side of the box; this latter and the jam nut of the hollow one are first loosened, then the hollow bolt set up and jammed, and lastly the solid one jammed.

Q. What is the object of the solid bolt?

A. To lower the wedge.

Q. Are the strains on the front and the back pedestal jaws equal when the engine is working?

A. No; they are twice as much on the front jaws as on the back ones.

Q. How are the frames and boiler fastened together?

A. At the front end they are wedged and bolted to the cylinders, which in turn are fastened to the smoke-box; but further than this there are diagonal braces, the lower ends of which are bolted to the bumper-timber and to the frame, and the upper bolted to the smoke-box; and there are braces between the boiler barrel and the frames. At the fire-box end the frames pass through expansion clamps bolted to the side of the outer fire-box, so that as the boiler expands or contracts by rise or fall of temperature, the frames slip lengthwise in these clamps. In addition, there are usually diagonal braces bolted above to the back end of the outer fire-box sheet, at about the height of the crown sheet, their lower ends being bolted to the frames at their back ends. Cross braces attached to the lower bars each side of the engine unite the right and left-hand frames. Still further, the guide yoke is usually bolted both to the frames and the boiler, so that these two members are quite fairly bound together, although lengthwise expansion and contraction from changes in temperature is permitted.

Q. How much is this sliding of the frames through the expansion clamps in an ordinary engine?

A. About one-fourth of an inch; sometimes as much as five-sixteenths.

Q. Why not have the frames on each side all in one piece the whole length of the engines?

A. Because in repairing after a collision it would become necessary to take down the whole frame to repair only one end. The front being especially liable to accident, and the back part of the frame being especially difficult to take down by reason of the driving axles, common sense dictates to have the two parts separate.

Q. What is a built-up frame?

A. One in which the lower brace is fitted between, and bolted to, the pedestals. (Figs. 217 and 218.)

Q. What is a slab frame?

A. One in which the upper frame brace is reduced in width (horizontal thickness) and increased in vertical distance or depth; to give more width between the frames for the fire-box—the bottom of which, however, cannot come below the lower bar.

Q. Should frame bolts be straight or tapered?

A. Most builders make them straight; but if tapered they will hold the frame together better; this being particularly true if they are long.

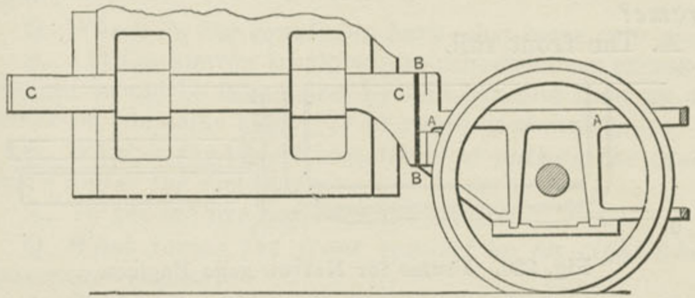


Fig. 219. Frame for Narrow-gage Engines.

Q. What different forms of pedestal legs are used?

A. There is one type that has both jaws tapering on the inside, and another and later that has only one tapering, the other being square with the frame.

Q. Where there is one straight and one tapering leg, to which one is the "long wedge" fitted?

A. To the straight one.

Q. What is one difficulty with narrow-gage engines?

A. That there is not enough room for the fire-box between the frames; and it must be made very narrow, unless the frames are made with an off-set or cross plate projecting outside of the wheels, as shown in Figs. 219

and 220, in which *B B* is the cross plate, bolted to the back ends of the arms. Two flat bars *C C* are bolted thereto and put far enough apart to give between them sufficient room for a fire-box as wide as desired.

Q. What name is given to the distance piece between the top and the bottom bars or rails of the front frame, as on engines having six or eight drivers coupled?

A. The filling piece.

Q. What name is often given to the upper bar of a bar frame?

A. The top rail.

Q. What name is given to the bar or frame forming the front part of the frame, and connected to the main frame?

A. The front rail.

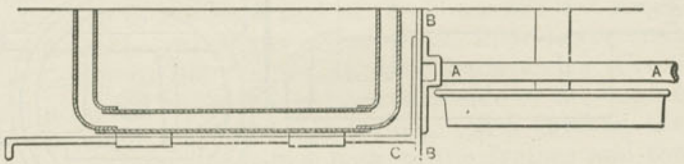


Fig. 220. Frame for Narrow-gage Engines.

EQUALIZING BARS

Q. What is the tendency of the connecting rods on an engine, as regards the smooth running of the engine?

A. To cause pitching and rolling.

Q. How is this neutralized in great part?

A. By springs and equalizing levers.

Q. How do equalizing bars distribute the weight of the engine equally on all drivers?

A. Because if there were more weight put on the rear of the engine, back of the rear driving axle, tending to depress only the rear ends of the back springs, they would raise the rear ends of the equalizing bars, put a corresponding extra weight on those of the forward

springs, and carry part of the extra weight to the front driving axle. The same principle applies to weight put anywhere on the engine; it will be distributed to both or all the driving axles.

Q. What is the general effect of the system of supporting the weight of the back of the engine on equalizing bars?

A. To suspend all that part from two points, thus hanging the entire weight of the engine from three points: the fulcrums of the equalizing bars, and the center pin. Three-point suspension is the most suitable way that is known; as witness the greater steadiness of a three-legged over a four-legged stool on an uneven floor.

Q. Where do the equalizing bars most come into play?

A. (1) On uneven track, where otherwise an excess of weight would be taken first by one box and then by another on the same side; (2) in running switches.

Q. What is the object sometimes of putting the equalizers under the frames?

A. To get the fire-box over the latter.

Q. What forms the front support in an eight-wheel passenger engine?

A. The center pin.

Q. What is the front support in a Mogul?

A. The fulcrum of that equalizing bar which joins the front springs and the pony truck.

Q. How many points of support has a consolidation engine?

A. Five; the fulcrum of the equalizing lever connecting the pony truck and the front driving-wheel springs being the front point, the fulcrums of the equalizing levers between the driving wheels forming the other four.

Q. How many points of support has a ten-wheel engine?

A. Five; the truck center pin in front, and the fulcrums of the equalizing bars between the drivers.

Q. What is the advantage of having Mogul engines equalized between the truck and the front drivers?

A. If the truck goes over a rough part of the track, some of the strain is taken off its springs and thrown on the front driving springs.

Q. What is to prevent irregularity of rail joints, and the effect of the unbalanced weight of the connecting rod, etc., lifting the entire engine up in a bouncing manner, thus giving it a chance to leave the rails, to say nothing of injury to the parts by the ensuing pounding and vibration?

A. There are springs between the axle boxes and the frames, so that as the engine rises on one side the axle boxes on that side, and their axles and wheels remain in the proper position; and when the weight comes down on that side, the springs lessen the shock which would tend to injure axle box, axle, wheel, and rail; to say nothing of the substructure, as on a bridge.

Q. What is the usual method of connection between the springs and the axle boxes and frames?

A. There are U-shaped saddle pieces which bear on the tops of the axle boxes and surround the upper frame bars; these are attached to the centers of the two bottoms of compound leaf springs, running lengthwise of the engine and frames. From one end of each of these springs is a hanger, to the lower end of which is attached the frame, there being a spiral spring interposed at the fire-box end. From the other end of the spring there is a hanger, to the lower end of which is attached one end of an equalizing bar, the center of which is bolted to the upper frame bar, between driving axles. Thus most of the engine weight (that part borne by the driving axles) is hung from both ends of each spring on each side of the engine; and the equalizing bar which joins the rear end of the front driving axle spring to the front of the rear driving axle spring, aids in distributing the weight, so that neither spring gets an excess; any excess that would

otherwise go on the rear driving axle spring on either side, being partly carried forward to the front driving axle spring on the same side. (Fig. 221.)

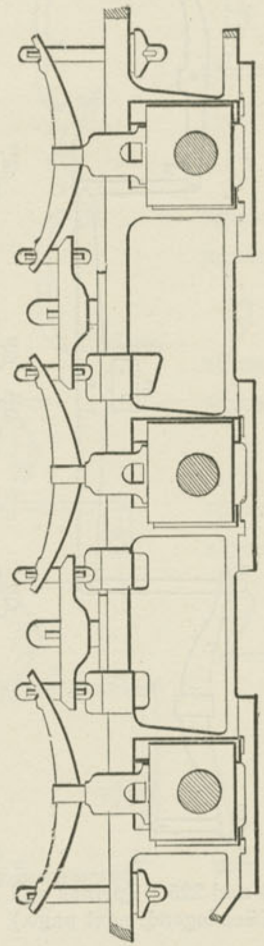
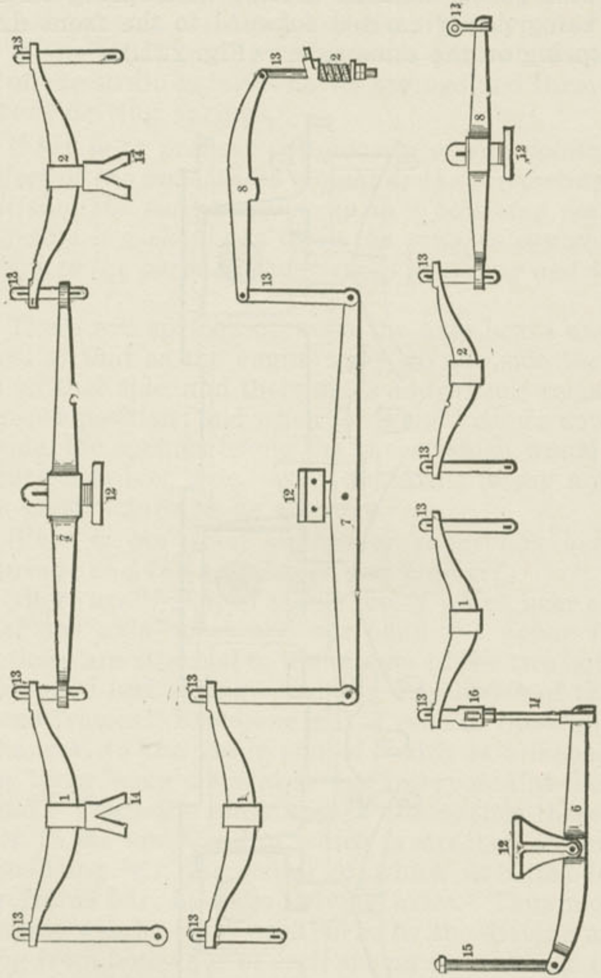
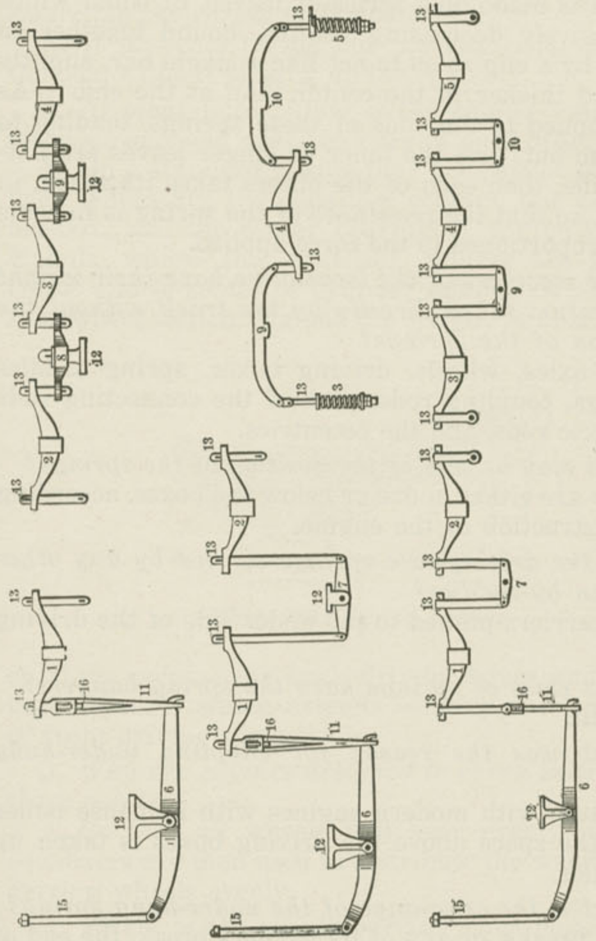


Fig. 221. Spring Arrangement for Consolidation Engines.



Figs. 222, 223, 224 and 225. Springs and Equalizer Work.
(See legend, next page.)



Figs. 226, 227, 228, 229, 230 and 231. Springs and Equalizer Work.

1. Forward Driving-spring. 2. Second Driving-spring. 3. Third Driving-spring. 4. Fourth Driving-spring. 5. Fifth Driving-spring. 6. Forward Truck Equalizing-beam. 7. Driving Equalizing-beam, First. 8. Driving Equalizing-beam, Second. 9. Driving Equalizing-beam, Third. 10. Driving Equalizing-beam, Fourth. 11. Forward Equalizing-beam, Link. 12. Equalizing-beam, Fulcrum. 13. Driving-spring Link. 14. Driving-spring Staple. 15. Forward Truck Center-pin Bolt. 16. Transverse Equalizing-beam.

THE SPRINGS

Q. What is the character of the driving-axle springs?

A. Each is made of a series of leaves, of equal width but successively decreasing lengths, bound together in the center by a clip so as to act like a single bar, slightly curved, and thicker in the center than at the ends. As force is applied to the ends of these springs, tending to flatten them out, first the inner or longer leaves are flattened a trifle, then each of the others takes its share, in succession, so that the resistance of the spring is in some measure proportioned to the force applied.

Q. What members of the locomotive have their weight and momentum taken directly by the track without the intervention of the springs?

A. The axles, wheels, driving boxes, spring saddles and springs, coupling rods, part of the connecting rods and eccentric rods, and the eccentrics.

Q. What may be said of the position of the springs?

A. They are either above or below the boxes, according to the construction of the engine.

Q. Are the driving-axle springs carried by any other means than by saddles?

A. By carriers pinned to the under side of the driving boxes.

Q. What class of springs have the spring hangers?

A. Spiral.

Q. What was the reason for adopting under-hung springs?

A. Because with modern engines with immense boiler diameter the space above the driving boxes is taken up by the boiler.

Q. What is the advantage of the under-hung spring?

A. If it breaks, or any of its hangers break, the end of the spring is not likely to get far out of place, and there is no danger of the equalizer flying up so far as to be difficult to replace.

Q. What is the disadvantage of the under-hung spring saddle attached to driving box extending downward and encircling the spring at the band?

A. It prevents taking out the box cellar for packing the box, without jacking up the engine.

Q. At what fixed points is the engine weight carried when springs and equalizers are in good order?

A. On a standard engine the "permanent bearings" or fixed points are the equalizer centers, one each side of fire-box, and the center bearing of engine truck; with Moguls, where the equalizer centers are fastened to frame and to center of cylinder saddle. With almost all four-wheel switch engines the weight is also distributed

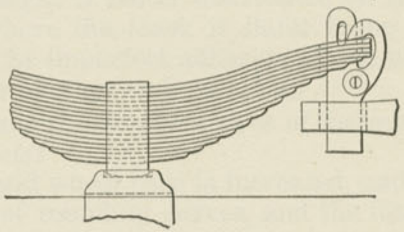


Fig. 232. Spring Hanger.

on three points; the back driving boxes and middle of that equalizer which extends between the forward ends of front driving springs.

Q. Why are engines designed to carry their weight on three points?

A. So that all wheels will bear evenly on the rail; equalizers are then used to distribute the weight to all the driving wheels evenly.

Q. Where is the weight carried when blocked up over the forward driving box?

A. If blocked up over forward driving box solid, this takes all the weight that was carried on both boxes on that side, and a little more, as the block comes more nearly under the engine center than the equalizer post does. If the block over driving box carries the weight which was before carried by equalizer, it will have a double load. When blocked up solid over a driving box, as with a broken tire, the weight of the entire engine comes on the engine-truck center, the equalizer post on the good side of engine and the block over driving box on the disabled side.

Q. Where are ordinary spring hangers weakest?

A. In the keyhole.

Q. How may this be remedied?

A. By the arrangement shown in Fig. 232, as on the L. N. A. and C. R. R.

CHAPTER LVII

WHEELS AND AXLES

Q. How many driving axles has the ordinary English passenger locomotive?

A. One only, having of course but two driving wheels.

Q. How many has the ordinary standard American passenger locomotive?

A. Two, with four driving wheels.

Q. What is the advantage of having more than one pair of driving wheels?

A. The weight is better distributed on rails and journals; and where the track is liable to be imperfect, if there should be imperfect adhesion of one pair of wheels, there will be another to help along.

Q. What are the disadvantages of having two pairs of driving wheels?

A. The rigid wheel base is increased, and the difficulty and danger of rounding curves, and the loss of power in doing so, increased.

Q. What will tend to make an engine free running?

A. Having the driving axles exactly at right angles to the center line of the cylinder and parallel with all the other axles.

Q. What is the effect of not having the driving axle true with respect to the cylinder center lines and the other axles?

A. A snaky motion, tending to make the engine weave more to one side of the track than the other, and thus wear the flanges on that side more than on the other.

Q. What is the advantage of large driving wheels?

A. They reduce the rotation speed and thus enable high speeds to be attained and keep down the piston speed, thus enabling the steam to be properly exhausted.

They also reduce the injurious effects of the counterbalance weights, and lessen wire drawing and cushion.

Q. What are their disadvantages?

A. They set the engine too high; are more liable to jump the track at high speeds and on curves or by reason of obstructions.

Q. Which of the wheels slip in going around a curve —the inner or the outer?

A. If the wheels are coned to allow the outer wheel to travel around its path in the same time that the inner one measures off its circumference on the rail, there will be no slip in either wheel; but this is never found in practice, and slip does occur, for the reason that the outer wheel has a greater distance to cover than its mate on the same axle, and the slip of the wheels will therefore be measured by the difference in the distance they will travel in rounding the curve.

Q. Has the size of driving wheel any effect on the mean effective pressure?

A. At high speed it does. The larger the driver the better the result, especially with speeds of 40 to 60 miles, above which figure the smaller wheels catch up somewhat proportionately.

Q. Does loss of power due to decreased mean effective pressure imply loss of efficiency?

A. No; at any rate seldom or never in the same degree.

Q. What is a common driving-wheel diameter of a British engine?

A. Seven feet.

Q. How many revolutions per minute would such engine make at 40 miles an hour?

A. 160.

Q. How many revolutions per minute would an American engine with five-foot drivers make at the same train speed?

A. 233.

Q. What is the disadvantage of the small-wheeled American engine in this particular?

A. It not only has to make its stroke much more rapidly than the large-wheeled engine, but has to reduce the

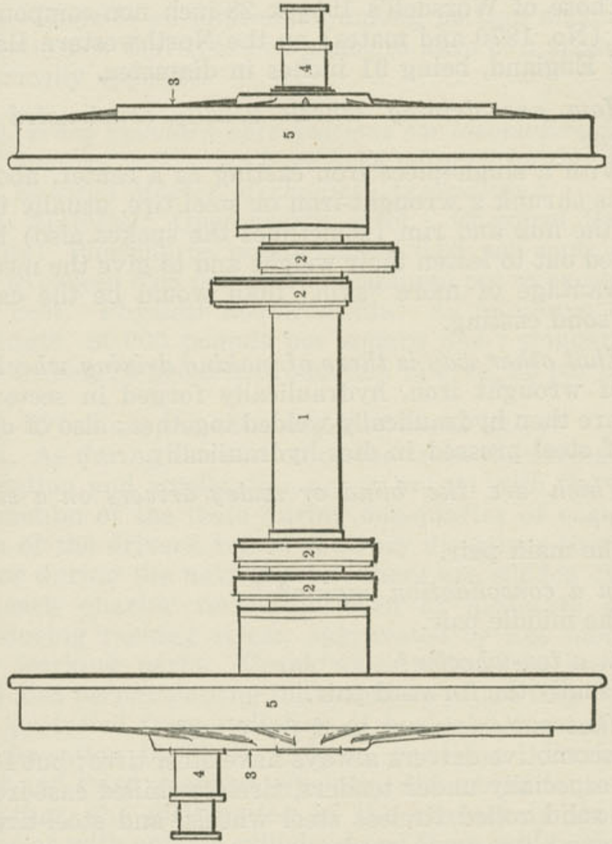


Fig. 233. Wheels, Axle and Tires.
1. Axle. 2. Eccentrics. 3. Wheel-centers. 4. Wrist-pin. 5. Tires.

speed of the reciprocating parts from a much greater velocity; therefore it requires greater compression to transfer part of the work represented by the piston momentum to the succeeding stroke.

Q. *What is the largest four-coupled drivers yet tried?*
A. 99-inch; tried some years ago on the Continent.

Q. *The largest four-coupled drivers in regular active service?*
A. Those of Worsdell's 19½ x 28-inch non-compound engine (No. 1870 and mates) on the Northwestern Railway of England, being 91 inches in diameter.

Q. *How are driving wheels usually constructed in America?*
A. With a single-piece iron casting as a center, about which is shrunk a wrought-iron or steel tire, usually the latter, the hub and rim (sometimes the spokes also) being cored out to lessen their weight and to give the metal the advantage of more "skin" than would be the case with a solid casting.

Q. *What other way is there of making driving wheels?*
A. Of wrought iron, hydraulically forged in sectors, which are then hydraulically welded together; also of one piece of steel pressed in dies hydraulically.

Q. *Which are the blind or muley drivers on a six-wheeler?*
A. The main pair.

Q. *On a consolidation engine?*
A. The middle pair.

Q. *On a ten-wheeler?*
A. Usually the forward pair.

Q. *What materials are used for tires?*
A. Locomotive drivers always have steel tires; but for trucks, especially under tenders, tireless chilled cast-iron wheels, solid rolled tireless steel wheels, and steel-tired wheels are extensively used.

Q. *What is the rule for number of spokes in locomotive drivers?*
A. The diameter of the center in inches divided by four; if the remainder is one-half or over, one more

spoke; that is a 44-inch center should have 11 spokes, an 80-inch 20.

Q. *What is the advantage of having an odd number of spokes?*
A. There is an impression among pattern makers and foundrymen that it is better not to have two spokes diametrically opposite.

Q. *What standard specifications for locomotive driving and engine-truck axles have been adopted by the American Railway Master Mechanics' Association?*
A. Material: Open-hearth steel. Chemical Requirements: Phosphorus not to exceed 0.05 per cent; sulfur not to exceed 0.05 per cent; manganese not to exceed 0.60 per cent. Physical Requirements: As minimum tensile strength, 80,000 pounds per square inch; elongation in two inches, 20 per cent; reduction in area, 25 per cent.

Q. *What are the advantages of crank axles?*
A. As during the motion of the train the forces of retardation and acceleration act in unison with the course of motion of the train during one-quarter of each rotation of the drivers, but in contrary directions to one another during the next quarter, there are sudden changes at each quarter revolution, even at moderate speeds, producing racking stress, aggravated by lost motion in the working parts. Crank axles centralize the stress, and also permit putting the cylinders where they are better protected from radiation of heat and from cylinder condensation by their inclosed positions. During the first and third quarters, when the disturbing forces work together, the distribution of the stresses is about the same as with outside cylinders, and there will be no racking stress; but during the other quarters the disturbing forces are practically balanced; and only light counter weights are needed to balance the coupling rods and wrist pins.

Q. What are the advantages of a built-up crank axle as against a solid one?

A. All its parts are forged and machined separately, which reduces the possibility of hidden flaws, as in a solid casting; if any part wears excessively or is broken, it can be replaced by another.

THE TIRES

Q. What is to prevent a broken tire coming off the wheel?

A. There is often a series of bolts holding it to the wheel rim from within the latter; or what is better, grooves are turned in its flat sides and in these are placed the projecting fillets of retaining-rings, bolted to the rims; so that if the tire should break the parts will be clamped to the wheel center by these rings.

Q. How are the driving wheels fastened to their axles?

A. Their hubs are bored out a trifle smaller than the diameter of the axles in the "fit" and they are then pressed on hydraulically, or by a powerful screw press.

Q. What is to prevent the wheels turning on, instead of with their axles, by reason of there being two connecting rods acting at points 90° apart, on two wheels, at opposite ends of the same axle?

A. Square keys are driven in grooves or keyways in hubs and axles.

Q. How should driving wheels be made for engines that are to run on roads which are to have their gage narrowed?

A. The wheel center should be made wider than necessary, and the tire set to conform to the present gage; then when it is desired to narrow the gage the tire may be moved further in, and the projection thus left on the outside of the wheel center turned off. This is shown in Fig. 234.

Q. What is flange friction?

A. The friction of the flanges against the inside edges of the rail heads, due partly to slewing.

Q. How may it be lessened?

A. By lubrication, as is practised on some of the European railways; usually by a block of tallow pressed

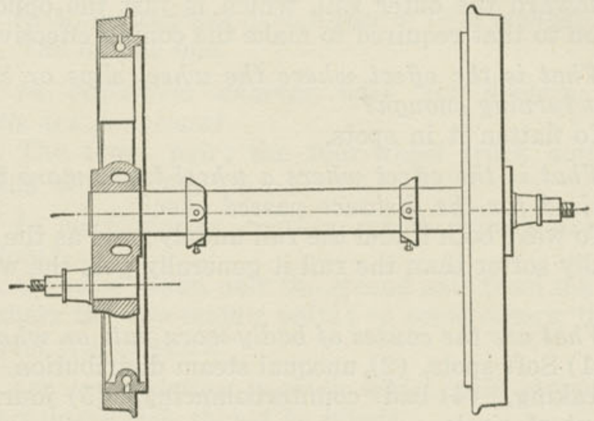


Fig. 234. Wheel-centering to permit Gage-narrowing.

against the flanges, care being taken not to let it get on the wheel treads.

Q. In running around a curve, what is the tendency of any wheel pair which does not turn with its axle?

A. As the outer rail is longer than the inner on the curve, and as both wheels must make the same number of rotations, either the outer wheel must skid on the outer rail, without turning as often as it should for the distance passed over, or the inner one must slip on the inner rail, making more turns than the distance passed over requires, or both.

Q. Can this be prevented by coning the wheel treads so that the pair may slide away from the outer rail and *thus give the outer one a larger effective diameter than it had, and the inner one a smaller?*

A. This will be effective only in case the amount of taper or cone given the treads is directly proportionate to the curve radius. Each degree of curvature requires a different taper; furthermore, the action in passing around a curve at high speed is to throw the entire machine toward the outer rail, which is just the opposite direction to that required to make the coning effective.

Q. *What is the effect where the wheel slips or skids without turning enough?*

A. To flatten it in spots.

Q. *What is the effect where a wheel turns more than is required for the distance passed over?*

A. To wear both it and the rail unduly; and as the tire is usually softer than the rail it generally gets the worst of it.

Q. *What are the causes of badly-worn flats on wheels?*

A. (1) Soft spots, (2) unequal steam distribution, (3) bad braking, (4) bad counterbalancing, (5) journals worn out of circle.

Q. *What are the causes of driver flanges on one side of the engine cutting more than on the other?*

A. (1) The pull on the division being heavier in one direction than on the other, (2) one wheel larger than the other, (3) journals of unequal diameter.

Q. *Why have standard gage car wheels and locomotive wheels inside (instead of outside) flanges?*

A. The inside flange helps hold the wheel on the axle, whereas the outside one would aid the "weaving" motion to pull it off lengthwise. Every little helps.

Q. *Then why is not this the case on "industrial" railways and very narrow-gage lines?*

A. Because in rounding very sharp curves the outside flange helps increase the radius of the outside wheel.

Q. *Are all the driving wheels always supplied with tires?*

A. No, some builders leave the front pair without.

Q. *What name is given to a flangeless driving-wheel tire?*

A. It is variously called plain, muley, and blind.

Q. *In Mogul engines, which pair of tires is made blind?*

A. The middle one.

Q. *In ten-wheel engines, with six drivers, which wheels are flangeless?*

A. The front pair; the four-wheel truck doing the guiding at that end.

Q. *In consolidation engines, which drivers are plain or blind?*

A. On some roads, only the second pair from the front, on others the two middle pairs; on some others, the second and fourth pairs.

Q. *On consolidation engines, which pair should have flanges and which should be blind?*

A. The front and rear pairs should have flanges, because the pony truck is not always a safe guide, and the rear of the engine should have flanges anyway; then the two center pairs may be left without flanges.

Q. *What is the object of blind or plain tires?*

A. To enable an engine with a long rigid wheel base to round sharp curves without undue flange friction.

Q. *What is the object, in some wheels, of the shoulder on the wheel-center rim, against which the tire is pressed?*

A. To prevent the tire from slipping inward when the flange is working against the rail.

Q. *Where only is this desirable, and why?*

A. Where driver brakes are used, as their frequent use tends to expand and hence loosen the tire.

Q. How thin can a tire be worn with safety before it is necessary to remove it?

A. Thinner in warm than in cold climates; thinner in summer than in winter; thinner with light engines than with heavy; say, as a minimum, one and one-fourth inches for light engines in warm climates and summer.

Q. Which is desirable, a thick or a thin tire?

A. A thick one, because stronger, and enabling the wheel to run longer without renewal; because also, there is less percentage of material thrown away without use, when the tire is removed.

Q. What is the disadvantage of excessive tire thickness, say over four inches?

A. It puts on the rails and their joints too much weight without the intervention of springs.

Q. What is the minimum permissible thickness to which steel tires of wheels are allowed to be worn?

A. For tender wheels, one inch, measured normal to the tread and radial to the curved portion of the flange through the thinnest part, within 4¼ inches from the flange back, the thickness from the latter point to the outer edge of tread to be not less than one-half inch. To facilitate inspection the practice has been adopted of cutting a small groove in the outer face of all tires when the wheels are new, at a radius of one-fourth inch less than that of the tread when worn to the prescribed limit.

Q. Is the influence of cone or taper on the wheel treads increased or lessened with the distance between axles?

A. Diminished.

Q. What are the causes of tire wear?

A. Slipping at high speeds, due to centrifugal force in the counterbalance (wheels having too little counterbalance showing less wear than those overbalanced), the almost inappreciable slip at starting, and the catching of wheels on the rails after a violent slip through one or more revolutions.

Q. Should driving-wheel tires be softer than the rails, or harder, or of the same hardness?

A. Softer, because their renewal is more readily effected when worn down, and inequality is more readily detected.

Q. Which can be worn the longer—hard or soft tires?

A. Soft.

Q. What is about the limit at which hard tires break in service?

A. About 1¾ inches in thickness seems about to be the experience.

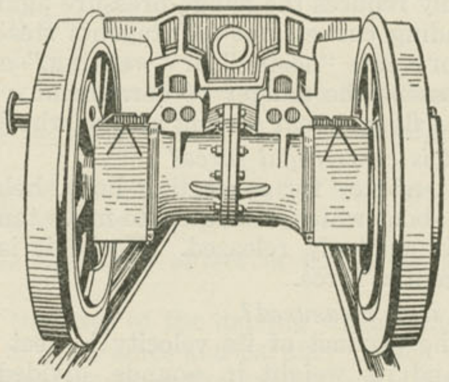


Fig. 235. Truck with Lateral Motion Box.

Q. Why do they break?

A. Probably by reason both of the battering on the rails and the high tensile strain to which they are subjected in shrinking on.

Q. What connection have high steam pressure and flat tires?

A. High pressures generally mean early cut-off and plenty of lead and cushion; at each stroke end the piston stands still until all lost motion on that side is taken up; and during this period the wheel on that side slides, hence wears a flat place on the tire.

Q. Does the right-hand tire flatten at the corresponding point with the left?

A. No.

*Q. How are very long engines enabled to round short curves easily and safely, other than by making some of the driving wheels flangeless, or by building them "articulated"?**

A. One way is by giving that portion of each crank pin which is embraced by its scoring a spherical surface.

Another method, particularly applicable to narrow-gage railways, is the use of a lateral motion driving box, that not only reduces the flange pressure against the rail when rounding curves, but on tangents steadies the engine and prevents "nosing" or "weaving," and in some measure lessens the danger of derailment. It also distributes the flange wear among all the wheels.

Q. What is centrifugal force?

A. The tendency for a rotating body, held rigidly to the center about which it rotates, to move tangentially to its path, if suddenly released. Hence it is sometimes called tangential force.

Q. How is it measured?

A. By the product of its velocity in feet per second, squared, and its weight in pounds, divided by 32.174 times its radius in feet. That is, with twice the velocity it is four times as great, and so on, according to the velocity square.

* See under "Articulated."

CHAPTER LVIII

WEDGES AND SHOES

Q. What is the usual arrangement of driving-box wedges on modern engines?

A. With a wedge behind the box and a stationary shoe in front.

Q. How is the box got back where the shoe is in front?

A. The shoe must be removed and "shims" or liners put between it and the jaw.

Q. How is it got ahead?

A. The shoe must be planed off the desired amount.

Q. What is the advantage of the single wedge arrangement?

A. The engine cannot be put out of trim by enginemen setting up the wedges at haphazard.

Q. What is the main object in lining up shoes and wedges?

A. To get the axes of the driving wheels and axles at right angles to the frames and parallel to each other, and to keep the distance from the axis of one driving wheel pair to that of the next the same as the length of their coupling rod.

Q. What must be the condition of driving shoes and wedges?

A. The faces must be parallel with the axle and at right angles to the top of the frame; the main ones must be just so thick as to bring the axle center in the pedestal mid-line on one side of the engine at least; on the other, just so thick as to hold the axle at right angles to the cylinder axis. The other shoes should give the proper distance between driving-axle centers. All should be parallel with the wedges.

Q. How can the driving axles be got at right angles to the cylinder axis?

A. Lines are to be drawn through the cylinder axes and extended three feet back of the back heads. A sliding double square such as is shown in Fig. 236 is to be clamped across the frames about six inches back of the heads and slid out until the arms (which are vertical) touch the cylinder lines. By means of an adjustable tram such as is shown in Fig. 237 a point is found on the saddle casting half way between the center cylinders and

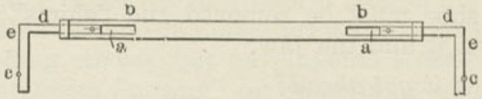


Fig. 236. Sliding Square.

as low as possible. Its point *a* being put against the vertical part of the double square at one of two marks *e*, at equal distances above the cylinder lines, with the point *b* an arc is to be scribed on the saddle casting as nearly as possible to the center. The same is to be done on the other side of the engine; the tram arcs should intersect

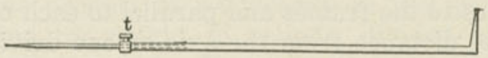


Fig. 237. Adjustable Tram.

near the bottom of the saddle casting. The center is marked with a punch; we will call it *a*.

On the outside of the frame, lines *b b c c* are to be drawn parallel with its upper edge, and all at equal distances therefrom; on the front jaw of each front pedestal *c c* is to be drawn parallel with *b b*, the same distance therefrom on both sides.

With the point *a* an arc *l*, Fig. 238, is to be scribed on each front jaw, across *c c;* the crossings prick-punched; we will call them *c*. A line joining *x* and *x* will be at

right angles to the cylinder axes. With a T-square a line is to be drawn through *x* at right angles to each frame top, and the crossing *d* of this line with *C C* prick-punched. A line *d d* will be parallel to *x x*, hence at right angles to the cylinder axes.

To get the point *h*, through which a line at right angles to the frame top will cut the center of the pedestal, a line is drawn from the upper end of the front pedestal jaw

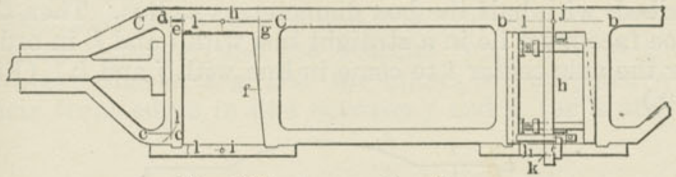


Fig. 238. Locomotive Frame.

at right angles to *b b;* the crossing *e* is pricked. A similar line is drawn from *f*, half way between the back pedestal-jaw ends; where it cuts *C C* we will call *g*. Point *h* is midway between *c* and *g*. With the distance *d h* from *d* as center on the opposite frame, an arc is scribed across *C C;* the intersection *h* is the point for that frame.

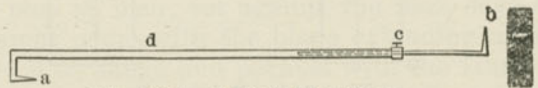


Fig. 239. Adjustable Tram.

With a T-square a line is scribed through *h*, across each pedestal binder. A center-punch mark *i* being made thereon, an arc is scribed with *h* on the opposite frame as center, across the line previously scribed across the binder edge; this gives *i* for the opposite side.

The distance *h j* should be 1/32 inch less than the side-rod length (measured between rod-brass centers) and is to allow for influence of temperature.

To find *j*, Fig. 238, in each brass is put a piece of wood on which to mark the center; the "effective length" of the rod is trammed, and the tram then shortened 1/32 inch. From center *h* an arc is scribed, crossing *b b* in *j j*, and from center *i*, one across the edge of the back binder. With *j* as center and distance *h i*, an arc is scribed on the back binder, cutting the first one in *k*. The points for the other side are similarly found.

The driving box being calipered with *j* and *k* as centers, the arc *l* on the frame and l_1 on the binder are scribed, with half the box diameter as radius. Then the shoe face must lie in a straight line with *l* and l_1 in order for the axle center *t* to come in line with *j* and *k*. (Fig. 240.)

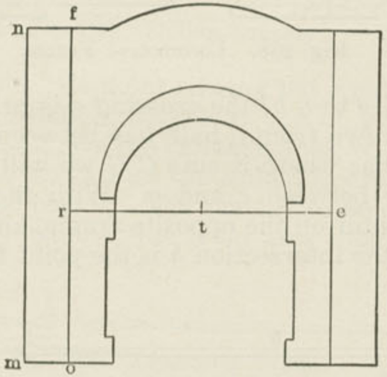


Fig. 240. Driving Box.

Q. In case the box is bored out of center, what should be done?

A. A wooden flush center put in the brass, and the center *t* be found; a line *e r* scribed, at right angles to *m n* and through *t*, and a line *o f* parallel to *m n* and exactly opposite the box face. With radius *r t* the arcs *l* l_1 are scribed.

Q. How long should the shoes be?

A. 1/32 inch shorter than the clear pedestal opening.

Q. How long should the wedges be?

A. About two inches shorter than the shoes.

Q. To what should the shoes and wedges be faced?

A. To the pedestal jaws.

Q. How would you lay out the shoes for planing?

A. Each being in its proper place, a 5/16 inch block is put between their lower ends and the binder; they are held apart by "spreaders," Fig. 241 top and bottom; a 5-foot straight edge is wedged between the binders and the bottom spreader as shown at *o*, Fig. 238, and one between the top spreader and the pedestal top. With a small straight edge *h*, Fig. 238, the others are adjusted with their front edges in line between *j* and *k* (or *h* and *i*).

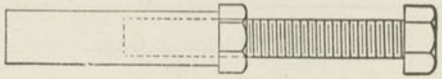


Fig. 241. Spreader.

This will bring them in line with the axle center. An adjustable square is set to half an inch more than the driving-box width (if the box is not bored centrally) to *r t*, Fig. 239, plus ½ inch; set against the back edge of the short straight edge, with the blade extending along the side of the shoe flange and parallel with the frame as in Fig. 238. Lines are scribed along the blade end on each shoe flange; one on the outside flange near the end, one inside near the middle. After planing, the shoe faces should be just ½ inch from the flange lines.

Q. How can the wedges be laid out?

A. The shoes being held in place by spreaders, the square is set to the box width plus ½ inch, and with its head against the shoe face lines scribed on the wedge flanges as with the shoes; the wedges are then planed by these lines.

Q. How is the flange thickness determined?

A. By marking on a smooth slat, Fig. 242, the distance *a b* between wheel hubs and that *a c* between outside frame faces; drawing a line *d* across the stick, at a distance from *b* equal to the desired lateral motion of the engine—say 3/32 inch for the front wheels, 1/8 inch for the back. The distance *d e* must be double the thickness of the outside driving-box flange; half *e c* will be the outside flange thickness of shoes and wedges.

The inside flanges should be planed off to bring the width of shoes and wedges 3/32 inch less than the distance between driving-box flanges; all corners to clear the box fillets.

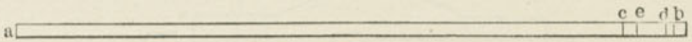


Fig. 242. Thickness Gage.

Q. What ways are recommended for "setting up" wedges?

A. (1) Set tank brake as a precaution; place on the back center the crank pins of the side you wish to adjust; put reverse lever in or near center notch. You will then have a lead opening in the back steam port of the side on which you are working, while on the opposite side the ports will be covered. Open throttle, and the driving boxes will be drawn against the dead wedges. Loosen set screws in side of jaws and nuts under binder brace, and wedges may be easily pried up with a short steel bar. Run the nuts on top of binders down with the fingers, then tighten the nuts under binder, and the side is finished. Place the crank pins of the opposite side on back center, and proceed in the same way. (2) With the engine near the top quarter on the right side, lever front, driver brake cut out, tender brake set or drivers blocked, throttle partly open, so that the steam will pull the crank pin ahead a bit as in Fig. 243. Pull the driver box

against the shoe and leave a space between the back of the box and the jaw. Then with the engine a quarter of a turn ahead, the same operation as the left side.

Q. How tight should main wedges be set?

A. Tight enough to prevent pounding of the box, but loose enough to let oil between them and the shoes.

Q. When should wedges be set?

A. Before pounding commences; that is they should be "felt" regularly and set up as per the answer to the last question.

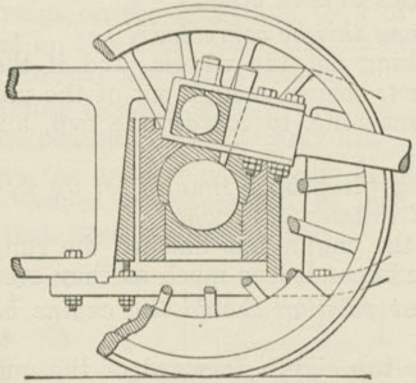


Fig. 243. Crank Pin and Driving Axle.

Q. How tight should other wedges than the main ones be set?

A. A trifle more loosely than the main ones.

Q. How should a key be driven?

A. With a lead or copper hammer, or with a block of wood between it and an ordinary hammer.

Q. What should be done to a key, in order to know just how far it is driven?

A. It should be marked on the under side flush with the strap, so that the amount which it is driven in at each blow may be noticed; and also, that if it is slacked up it may be put back in exactly the same position.

Q. What is meant by "out of tram"?

A. An engine may be "out of tram" in several ways, and any of them remedied without taking wheels from under her. (1) The distance from the saddle center to the main journals may not be the same; (2) the distance between axle centers on each side may not be the same; or (3) if both of the above points were right, the side rods might be too long or too short.

Q. When is an engine "out of quarter"?

A. When the crank pins on the opposite sides are not at right angles to each other.

Q. How may this be corrected?

A. By taking out the wheels, and if the axle is too good to reject, boring enough out of the pinholes, in the quartering machine, to correct the evil, and putting in new pins.

Q. When is the proper time to set up wedges and key up main-rod brasses; and why?

A. After the engine has finished the run, because the bearings are expanded as much as they ever should be.

Q. In what position should the engine be for setting up wedges?

A. On the top eighth forward of the quarter, on the right side; lever in front notch to carry the brass forward off the wedges, the truck wheels being well chocked.

Q. What should be seen to before setting up the wedges?

A. That the side rods do not bind, and the wedge is well oiled or graphited.

Q. Should one wedge be set up at a time?

A. No; that might change the tread.

Q. Should wedges be adjusted when the engine is cold, or when steam is up?

A. When steam is up, by reason of the expansion that would take place and throw the whole thing out after the boiler was filled, if the wedging was done on a cold engine.

Q. Should brasses be lined or keyed when the engine is cold, or with steam up?

A. With steam up, by reason of the expansion that takes place when the engine is fired.

Q. Should valves be set with the engine cold or hot?

A. Hot, and not only that, but with steam on, because that makes it easier to turn over the engine.*

Q. When an engine is running ahead and pulling a train, on which pedestal jaw is the most strain, on the front or the back; or is it equal?

A. The strains on the front and back of the jaw are equal, exerted on the front when the crank is above the axle, and on the rear when it is below.

Q. In adjusting wedges, what is the first thing to see?

A. That the pedestal bolts are snug up.

Q. How can the amount of slack-up be calculated?

A. If the wedges are tapered 1/16 inch per inch = ¾ inch per foot, then pull down for—

	Consolidations, Moguls, 10-wheelers.	8-wheelers.
Main Wedges	1-16 in.	1-16 in.
Front Wedges	⅛ in.	——
Back Wedges	3-16 in.	⅛ in.

Where the taper is 1/32 inch per inch or ⅜ inch per foot, pull down half that amount.

Q. How would you tram an old engine having worn boxes?

A. Exactly as when in good condition, but taking up lost motion all in one direction; that is, keeping the boxes against the shoes, by blocking the truck and pinching the wheels ahead in all cases.

* See chapter: "Valve Setting."

CHAPTER LIX

THE TRUCK

Q. What is a truck?

A. A frame bearing one or more pairs of non-driving wheels and attached to the engine frame (one end of which it supports) by a vertical center pin about which it turns.

Q. What is the use of the truck?

A. Partly to guide the engine around curves and about switches, and partly to take from the drivers some of the excess of weight that would not be good for their bearings or for the rail joints.

Q. What is the use of two wheel pairs in the front truck, instead of one?

A. That one may guide the other; as it is more difficult to guide a single pair of front wheels when pushed, than a pair that is pulled.

Q. Where there are two truck-wheel pairs, where is the center pin placed?

A. Equidistant from each axle.

Q. Where there is but one truck wheel pair, as in the so-called pony or Bissel truck, where is the center pin?

A. Back of the axle; the further back the more easily the truck will turn, and the better it will guide the engine.

Q. How is the truck usually made?

A. With two axles running in boxes playing between jaws (which, however, have no wedges to take up lost motion, as have those of the driving-axle boxes) attached to the lower side of a rectangular frame forged in one piece. On each side is a leaf spring, convex side up. On each axle box rests the ends of a pair of equalizing levers (one inside and the other outside the frame, on each side), and to these the spring ends are hung by hangers.

On the spring strap rests the truck frame; so that it is supported on two points, and the front end of the engine is borne on one point of the same frame, at the center plate. (See Figs. 244 and 245.)

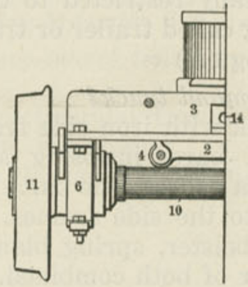


Fig. 244. Engine Truck

Q. How are engine trucks designated?

A. (1) As "four-wheel" or "bogie" trucks, (2) as "two-wheel" or "pony" trucks when ahead of the drivers, and (3) as "two-wheel" or "four-wheel" trailing trucks respectively, when back of the drivers.

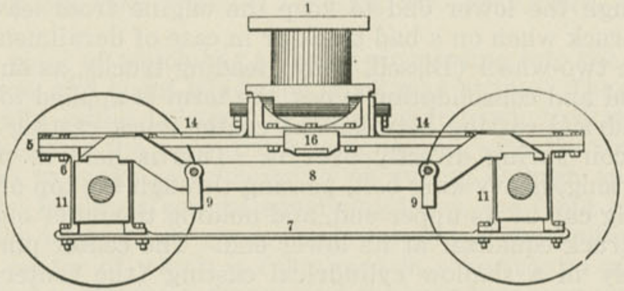


Fig. 245. Four-Wheel Truck

1. Center-pin. 2. Swing Bolster. 3. Swing-bolster Cross-tie. 4. Swing-bolster Link. 5. Truck Frame. 6. Truck Pedestal. 7. Truck-pedestal Cap. 8. Equalizing-beam. 9. Spring Link. 10. Axle. 11. Wheel. 12. Radius-bar. 13. Radius-bar Brace. 14. Longitudinal Brace. 15. Spring-staple. 16. Spring-seat. 17. Safety-strap.

Q. Are engine trucks rigid or adjustable?

A. With exception of a few designs of rigid trailers, all engine trucks turn about a central pivot or allow for side displacement to enable rounding sharp curves. The term engine truck is usually restricted to the forward truck, the rear truck being called trailer or trailing truck. (The British name is "bogie.")

Q. What is a diamond truck?

A. A tender truck with iron side frames consisting of two or more arch bars, inclosing so-called diamond-shaped spaces, and a pedestal tie bar. The journal boxes are rigidly bolted to the side frames. The cross members of the truck, bolster, spring blank, etc., are either of wood or metal or of both combined. Metal transoms, bolsters, and spring blanks are in general use and increasing in favor.

Q. What is the center pin?

A. A large bolt or pivot passing through the center casting of an engine truck, or the center plates of the body and truck bolsters of a tender. There is usually a washer below, where the head bears on the center plate. With engine trucks, a key is commonly put through the lower end to keep the engine from leaving the truck when on a bad track or in case of derailment.

On two-wheel (Bissell, pony) leading trucks, as on the Mogul and consolidation types, the term is applied to the cylindrical casting between the center truck casting and the coil spring directly over it. This is held in place by a long, heavy king bolt, passing through the top of the spring cap at its upper end, and holding the outer end of the truck equalizer at its lower end. The center pin fits loosely in a shallow cylindrical casting (the center-pin guide) bolted to transverse braces.

With four-wheel trucks, the casting bolted to the cylinder saddle bottom and fitting in the center plate or casting is called a center pin.

Q. How is the center plate fastened to the truck?

A. Sometimes it is bolted thereto; sometimes it is hung by swing links, permitting it to vibrate crosswise of the track.

Q. What keeps the engine from being jolted off the center pin in case of a very rough track or a derailment?

A. A key passing through the pin.

Q. How is a two-wheel truck (pony truck or Bissell truck) made?

A. There is a rectangular frame having below it jaws in which the axle boxes play, as in the four-wheeled truck. Bolted to the back of this is a V-shaped frame,

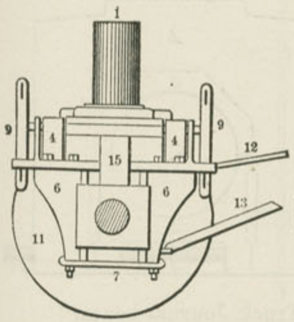


Fig. 246. Pony Truck.

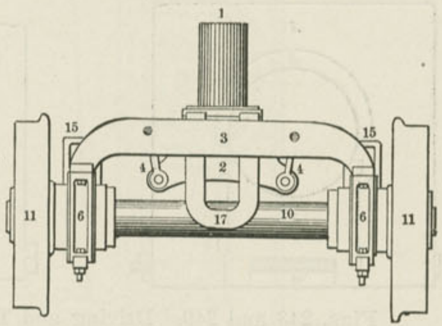


Fig. 247. Pony Truck.

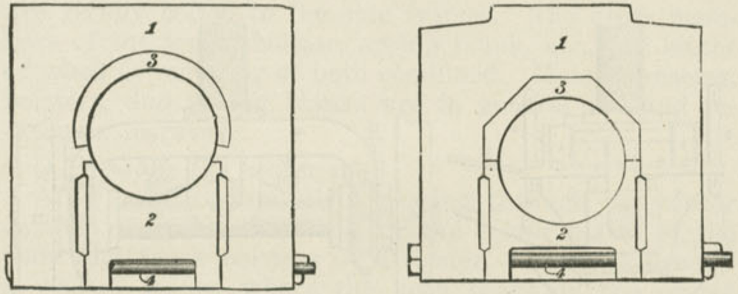
the point of which has a center pin passing into the main frame, and about which the truck may swing. There are usually swing bolsters, as on some four-wheeled trucks. Sometimes the pony truck is equalized with the driving axles to make safer running on curves at high speeds; as by having a central equalizing lever, the front end of which bears in an eye in the lower end of the center pin, the center of which is fulcrumed in a horizontal pin attached to the main frame, and the rear borne by a crossbar suspended from the front ends of the front driving-axle springs. This rig gives the truck a share of any excessive downward thrust or weight that is put over the driving wheels, and *vice versa*. (See Figs. 246 and 247.)

Q. What is the advantage of the pony truck over one with four wheels?

A. It lets the front drivers come closer to the cylinders; thus permitting more drivers to be used, or, other things being equal, giving the drivers more weight (hence more tractive power) for the same cylinder power.

Q. Of what are truck wheels usually made?

A. Of cast iron in a single piece, often in practically the same manner as ordinary cast-iron car wheels; their treads being chilled. Sometimes, cast-iron centers are



Figs. 248 and 249. Driving and Truck Journal-boxes.

1. Box. 2. Cellar. 3. Brass. 4. Cellar-bolt.

used and given wrought-iron or steel tires, as driving wheels are made; sometimes again there are two webs or wrought-iron plates between hub and rim, the space between them being filled with compressed paper.

Q. Which is better for high-speed passenger service—a four-wheel or a pony truck?

A. A four-wheel truck, if the weight can be spared from the driving wheels, which is not always the case.

Q. What character of bearings and journal boxes have the truck axles?

A. About the same as those of the drivers, but they are smaller.

Q. What keeps the trucks from getting across the track in case of derailment?

A. Check chains or safety chains.

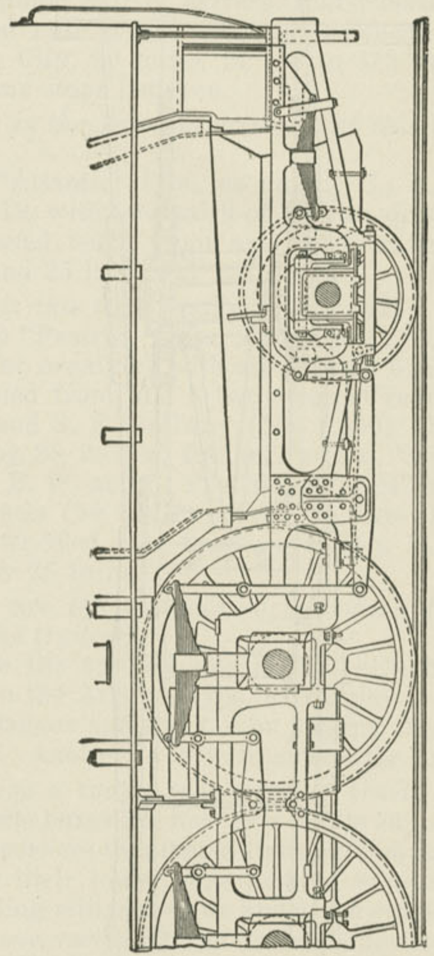


Fig. 250. Trailer Truck Elevation

Q. What class of running gear is required under boilers such as are shown in Fig. 250?

A. With trailing wheels to support the great weight of the overhang.

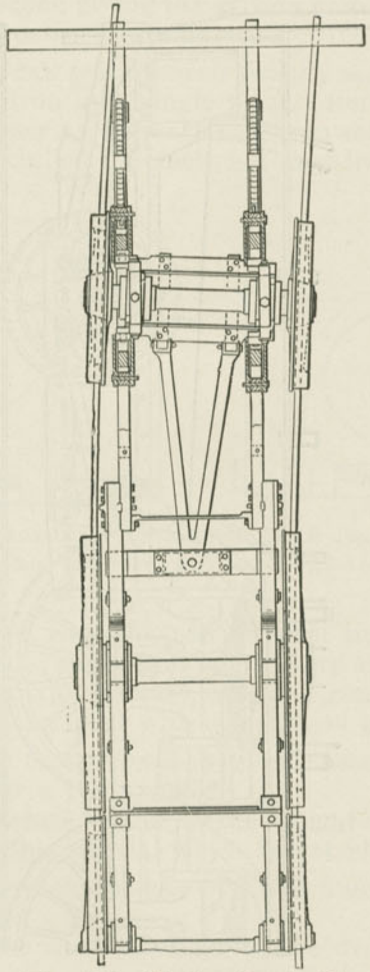


Fig. 251. Trailer Truck **Plan.**

Q. What were among the first engines with such supporting trailing wheels?

A. Those like the Philadelphia and Reading road's No. 378, with single pair of drivers, four-wheeled front and two-wheeled rear truck; running between Philadelphia and Jersey City, 90 miles, in 108 to 113 minutes, with three or four stops between.

Q. What is the first development of this type of running gear?

A. The "Atlantic" type, as on the C., M. and St. P. Ry.'s No. 919, with two pairs of 84-inch drivers coupled, a four-wheeled truck front and pony trailers (engines 15 inches and 25 inches by 28 inches).

Q. How is this type further developed?

A. In the "Prairie" types, as on the C., B. and Q. Ry. (No. 687, for example) with six coupled 64-inch drivers, a two-wheeled front and a two-wheeled rear truck; and the A., T. and S. F. Railway (No. 1,000) 17 inches and 28 inches by 28 inches; further, in the "Mikado" type, such as the B. W. and G. F.'s "Great Falls" engine, eight coupled wheels (50 inches outside) a two-wheeled front and a two-wheeled rear truck; cylinders 14 inches and 24 inches by 26 inches.

Q. What are the methods of providing for sidewise motion of the trailers?

A. Where the trailers are rigidly held between the frames as in the Atlantic type, extra play is allowed between the flanges and the rail or making the front drivers "blind." Another way is to swivel the axle radially.

Q. Describe a radial swing trailer truck.

A. The axle boxes are held in a cradle supported at the four upper corners by pivoted links extending downward and having their lower ends secured at each side to a yoke extending either over or under the cradle ends. The yoke can move vertically, but is held sidewise rigid with the frame. The links allow the wheels, boxes, and axles free sidewise movement. The yoke may be connected by springs with the frame or equalized with the driving springs. A radius bar pivoted to a cross piece on the frame gives the required curved motion. On a curve the cradle links raise the suspension point, insuring centrality on a straight track.

Q. Describe the boltless cast-steel freight trucks in use on the Plant system.

A. Referring to the illustration, Fig. 253, the side frame, of cast steel, is formed in one piece; journal box

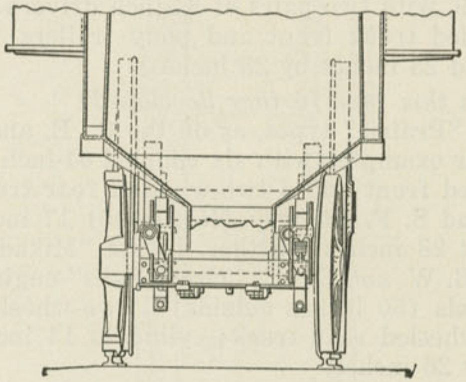
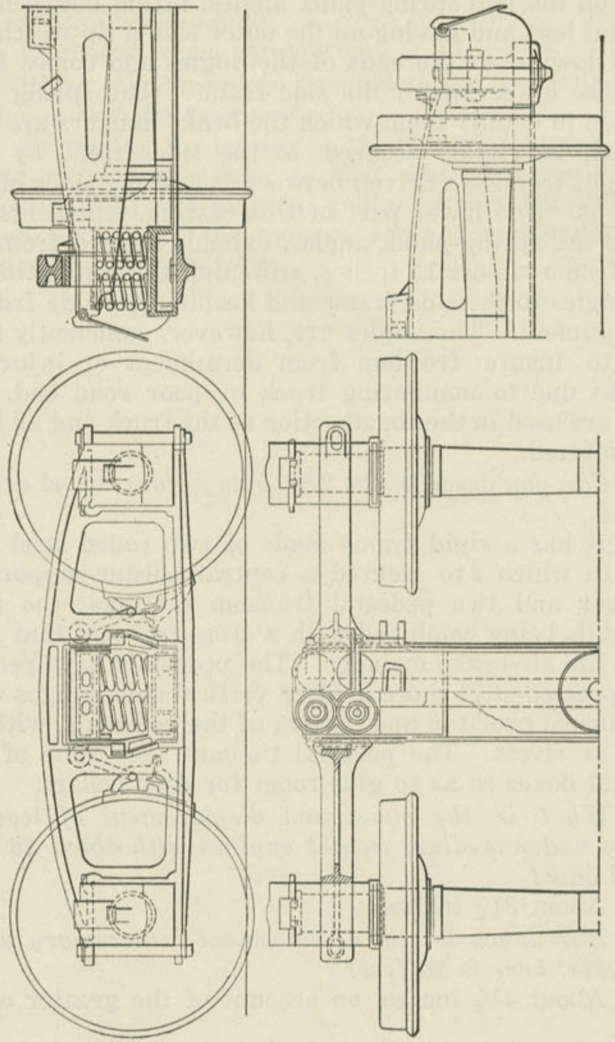


Fig. 252. Radial Swing Trailer Truck.

jaws are horizontal, and the boxes are retained by heavy wrought iron, semi-circular keys, as shown. Provision has been made for using standard M. C. B. journal boxes, although this is not shown on the drawing. On the earlier design of trucks a one-piece cast-steel spring plank was used, but it was found advisable, both because of the reduced weight and the greater flexibility, to use two $5 \times 3 \times 3/8$ inch 9.8-pound angles, with the shorter legs up. The longer or horizontal leg has $4\frac{1}{2}$ inches from each end a $1\frac{3}{8}$-inch hole which fits over bosses on the lower side frame bars. The spring seat is of cast steel, slipped in place from the inside of the frame, and



Figs. 253 and 254. Cast-steel Freight Truck.

rests on the two spring-plank angles, fitting between the vertical legs and having on the outer side a lip which extends down over the ends of the angles and comes flush with the lower bar of the side frame. The spring seat (shown in detail) from which the brake hangers are suspended, is rigidly secured to the side frame by two wrought iron keys driven between it and the sides of the columns. The lower part of this casting, which fits between the spring-plank angles, extends inward from the side frame almost 14 inches, stiffening the connection of the angles to the side frame and keeping the side frames in alignment. The angles are, however, sufficiently flexible to insure freedom from derailment or injurious strains due to undulating track or poor road bed. No bolts are used in the construction of the truck and all keys are cottered.

Q. Can you describe the "Economy" four-wheel engine truck?

A. It has a rigid frame made of two rolled steel side bars to which are secured a central bolster-supporting member and two pedestal transom castings; the four pedestals being combined with a cross transom that supports the air-brake cylinder. The pedestals have renewable pressed-steel shoes held by vertical side flanges with lips turned over top and bottom of the pedestals, without bolts or rivets. The pedestal tie-bars are inside of the journal boxes so as to give room for deep cellars.

Q. What is the maximum displacement of leading trucks under medium weight engines with about 26 feet wheel base?

A. About 3½ inches.

Q. How much lateral displacement is necessary when the wheel base is 30 feet?

A. About 4½ inches, on account of the greater overhang.

Q. How is this attained with three-point hangers?

A. By longer hangers.

Q. What is the result?

A. Increased wheel-flange wear.

Q. What other way can be used to get swing without weakness and flange wear?

A. By resting the bolster on the points of curved rockers in tangent position; so that when the center pin moves laterally the point of contact comes between the curved surfaces of the rockers, and inclined under surfaces of the bolsters.

CHAPTER LX

WHEEL BASE

Q. What name is given to the distance between axle centers?

A. Spread.

Q. What name is given to the total distance between the centers of the front and back wheels?

A. Total wheel base.

Q. What name is given to the distance between front and back driving-wheel centers?

A. Rigid wheel base.

Q. What is the effect, on the resistance to rolling, of lessening the distance between truck axles?

A. Up to a certain point to diminish it.

Q. What is the advantage of placing the driving axles between furnace and smoke box?

A. That the overhanging weight of the furnace in the rear balances that of the cylinders, smoke box, etc., in front, thus distributing the engine weight.

Q. What is the disadvantage of having over nine feet between any two drivers?

A. It makes a coupling rod which is too heavy and too liable to break.

Q. In ordinary ten-wheel engines is the distance greater between the front and the middle pair of driving axles, or between the middle and the rear pairs?

A. Between the middle and the rear.

Q. What is the objection to the six-wheel connected engine with an axle back of the fire-box, as is sometimes built?

A. The overhanging weight of cylinder, smoke box, etc., brings undue weight on the front pair of wheels.

Q. What is one of the principal objects in inclining the cylinders?

A. To get the leading wheels well forward.

Q. What is the advantage of getting the driving wheels well back?

A. To give the greatest weight where it will cause adhesion, and to lessen to some extent the tendency of the connecting rod to cause pitching and rolling.

Q. What is the measure of the wheel base?

A. The distance from the center of the trailing axle to that of the leading axle.

Q. What measures the rigid wheel base of an engine?

A. The length between pin centers of the parallel rod; or where there are more than one on each side, the total lengths of such rods on one side.

CHAPTER LXI

WEIGHT DISTRIBUTION*

Q. How much weight is it safe, as far as the rails are concerned, to put on each axle, with rails weighing 30 pounds per yard?

A. About 8,000 pounds.

Q. How much is it safe, for heavy steel rails, to place on each driving axle?

A. About 30,000 pounds.

Q. What enabled the Mogul engine to be possible?

A. The invention of the pony truck (see Fig. 272), which permits the front driving wheels to be placed further forward than on a ten-wheel engine with a four-wheel truck one axle of which is in front and the other back of the cylinders.

Q. What may be said of the tractive power of the Mogul as compared with the ten-wheeler?

A. It has greater hauling power, by reason of having a greater proportion of weight on the drivers.

Q. At what point is an engine's weight supported when it is in working order?

A. At the spring hanger and equalizer fulcrums, transferred by means of spring saddles and equalizers to drivers, lead and trailer wheels, except in case of four-wheel trucks, in which part of the weight is supported by the center casting resting on the truck frame, and transferred to the truck wheels by the springs and equalizers.

Q. What is an equalizer, equalizing beam, or equalizing lever?

A. A beam connected at each end to a driving or truck spring, or to the end of another similar beam, to distrib-

* See also chapter on "Frames."

ute the weight of an engine or tender to two or more axles, and prevent excessive load upon one axle by reason of inequalities of track or bed. Locomotives having two driving axles have these two equalized together; those with three or more commonly have the forward driving axle equalized with the leading truck. Equalizers are always used for four-wheeled engine trucks, and frequently with tender trucks. The British name is compensating beam. They are designated "transverse" when they connect the equalizing systems on the two sides of the locomotive. They are also designated by their position as equalizer, top of box; equalizer between drivers, etc.

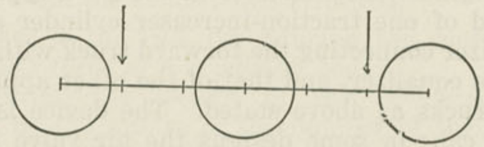


Fig. 255. Equalizing Weight on Drivers.

Q. If there are three pairs of drivers with two pairs of equalizers, and a weight of 96,000 pounds is applied vertically at the center of each lever, how much comes on each wheel?

A. On each center wheel 24,000 pounds, on each of the others 12,000.

Q. How must the load be applied so as to give each wheel the same load?

A. At points two-thirds away from the center wheel pair; this will put 16,000 pounds on each wheel of the first and third pairs and twice 8,000 = 16,000 on each one of the center pair. (Fig. 255.)

Q. In equalizing an engine, should the spring hanger length be changed?

A. No; if the spring is weak, liners should be put under the gib in the hanger; when it has full set the liners should be taken out.

Q. Why should the change be made in the spring and not in the hanger?

A. Because the hanger never changes, while the spring constantly does so.

Q. What is a traction increaser?

A. An arrangement for transferring a portion of the weight from the leading or traveling truck to the drivers, to increase the tractive power in starting. It consists of a cylinder supplied with compressed air and containing a piston the rod of which, by operating a set of levers, shifts the fulcrum of the equalizing beam that connects the driving and trailing truck springs on a 4-4-2 type of engines. Locomotives of the 2-6-2 type have the piston rod of one traction-increaser cylinder applied to the equalizer connecting the forward truck with the front transverse equalizer, and that of the other applied to the trailing trucks as above stated. The device is operated from the cab; in some designs the air valve is so connected with the reverse lever that it is closed and the normal distribution of weight on the drivers restored as soon as the reverse lever is moved back to a certain point; say when cutting off at about 60 per cent.

Q. What is the average weight of an American steam passenger locomotive?

A. About 60 tons without tender.

Q. How much of this is on drivers?

A. About 38 tons.

Q. Of freight engines?

A. About 68 tons on drivers.

CHAPTER LXII

COUNTERBALANCE

Q. What is the object of counterbalancing?

A. To equalize the centrifugal force of those reciprocating parts which also have a rotating motion at one end.

Q. What is centrifugal force?

A. The tendency of a revolving body to fly off at a tangent if the restraining force that keeps it at a certain distance from the center, was removed.

Q. What is the rule for figuring the centrifugal (or tangential) force of a revolving body?

A. Multiply the weight of the revolving body (in pounds) by the square of the number of turns per minute, the radius in feet of the center of weight from the center of revolution, and 0.00034; that will give the centrifugal or tangential force in pounds. Thus supposing a weight of 600 lbs., making 200 turns a minute, concentrated at a point 5 ft. from the center of revolution, we have $600 \times 5 \times 40{,}000 \times 0.00034 = 40{,}800$ lbs. (Practically the same result will be obtained by dividing by 2,934, as by multiplying by 0.00034.)

Q. Illustrate by a diagram the force tending to accelerate or to retard the piston during a full stroke.

A. Fig. 256 shows in *A B* the length of the stroke on any convenient scale, and in *A C, B D,* the centrifugal force. The distance of a diagonal line from *C* to *D* from *A B* represents the accelerating or the retarding force at various points; being zero at mid-stroke, *E*.

Q. How would you show the effect of the momentum and inertia of the reciprocating parts, in modifying the effect of centrifugal force?

A. As in Fig. 257, in which the centrifugal force is accelerated at one end of the stroke and retarded at another; the straight line $C\ D$ being replaced by a curve $F\ H$, cutting the stroke line at G, before mid-stroke E.

Q. In a two-cylinder locomotive at high speed, what is the tendency of the heavy end of each connecting rod as it rotates?

A. To raise the entire engine on that side when the rod goes up, and to hammer the track as it goes down; one side lifting the engine and the other hammering the track, at the same time; thus also causing a "wee-wawing" or swinging of the entire engine from side to side of the track.

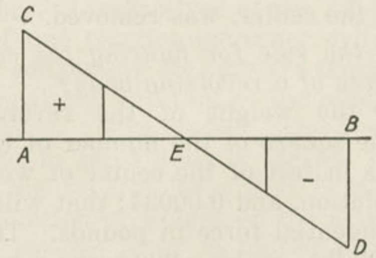


Fig. 256. Acceleration Diagram.

Q. How is this counteracted?

A. It cannot be entirely counteracted on a two-cylinder engine; but the moving weight of the connecting rod may be partly counterbalanced so as to lessen the hammer blow on the track, while increasing the tendency to jerk the train back and forth.

Q. Where are the counterbalance weights placed?

A. In the driving wheels, opposite each crank pin.

Q. How much counterbalance weight should be thus placed opposite each crank pin?

A. Such a weight as, multiplied by the distance of its center of gravity from the axle center, will equal the weight at the crank pin multiplied by half the piston stroke.

Q. Can the lack of balance in the reciprocating parts be counteracted by giving either lead or compression?

A. No; nothing but weight will remedy it even in part; and the only way by which weight may be made to do it effectually is to have for each crank pin another one connected to rods and parts of equal weight, going in exactly the opposite direction; so that for every pound that goes up there will be another pound coming down at the same time and speed; and for every pound going forward there shall be another coming back at the same time and speed.

Q. Suppose that you have a segment-shaped counterweight; how can its center of gravity be found?

A. By cutting out a wood or cardboard templet of even

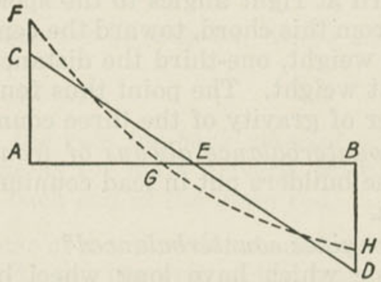


Fig. 257. Acceleration Diagram.

thickness, of the same size and shape as the weight, and suspending it from several points in its surface, near its rim, by a bradawl thrust through it at right angles to its face; dropping plumb-lines from this awl in the several positions, and marking where they cross the templet face. Where two of these lines intersect will be the center of gravity of the templet, and should be that of the piece of regular thickness which it was made to match.

Q. Where there are two segment-shaped counterweights separated by a spoke, will their common center of gravity be at the same distance from the axle center as that of either one of them?

A. No; it will be nearer the axle.

Q. How can it be determined just how much nearer?

A. By laying down the segments in full size and proper position in a drawing, and connecting the two centers of gravity by a chord at right angles to the radius or spoke. Where this cuts the center line of the spoke will be the common center of gravity of the two segments.

Q. Suppose that there are three segment-shaped counterweights of the same size, shape and weight, separated by spokes; how can their common center of gravity be found?

A. By laying them down as directed for two segments, connecting the centers of gravity of the two outside ones by a chord at right angles to the spoke radius, and stepping off from this chord, toward the center of gravity of the middle weight, one-third the distance between the chord and that weight. The point thus found will be the common center of gravity of the three counterweights.

Q. Is the counterbalance always of iron?

A. No; some builders put in lead counterbalancing for heavy engines.

Q. Are all engines counterbalanced?

A. No; some which have long wheel base and four cylinders are left without counterbalance.

Q. How is the weight for driving-wheel counterbalance, where there are no side rods, calculated?

A. Weigh (1) piston and rod, (2) crosshead and wrist pin, (3) small end of connecting rod; take 2/3 of their sum. Thus:

	Pounds.
Piston head and rod	300
Crosshead and pin	150
Small end of connecting rod	175
	625
2/3 of 625 = say	417

This is the approximate weight to be hung to each crank pin. This being done, the wheel pair is to be placed with axle in a level position and journals resting on smooth flat level strips. If with the calculated weights hung to the pins the wheels hold equally well any crank position given them, the "standing balance" is right; if not, the weights can be decreased or increased until the desired weight is attained.

Q. How do you get the weight of the small end of the rod?

A. By slinging it in a level position, by rope passed through the pin holes, the big end being hung to a fixed point, and the small end to a steelyard.

Q. If the tires are already on, where will the point of suspension be?

A. Outside the tire.

Q. What is the rule for back wheels?

A. The same as for main drivers, omitting to use the weight of the back end of the main rod.

Q. In the case of a consolidated engine?

A. Weigh (1) the big end of the main rod, (2) each end of each coupling rod as explained for the main rod. Divide 2/3 the sum of the weights as mentioned in the foregoing answer for single driver engines by the number of drivers on one side; to this quotient add, for each wheel, the weight of the side rod or side rods connected thereto. Thus:

	Pounds.
Piston head and rod	500
Crosshead and wrist pin	200
Small end of main rod	200
	900
2/3 of 900 =	600

$600 \div 4 = 150$ pounds per wheel; call this A.	
Side rod $90 + A = 150 =$	240
Side rod $225 + A = 150 =$	375
Side rod 250 + big end of main rod..... } $450 + A = 150 =$ .... }	850
Side rod $95 + A = 150 =$	245

Q. In figuring the centrifugal force of a driver counterweight, from where is the radius reckoned?

A. From its center of gravity.

Q. How is this determined?

A. By taking a templet exactly the shape of the weight, hanging it freely from two points from which a plumb-line is let fall; where the trace of the lines cross is the center of gravity, no matter how irregular the shape of the body, so long as it is of even thickness and uniform density.

Q. Where there are two counterweights with a spoke between?

A. Find the center of gravity of each, when in place, and connect the two by a line; where this cuts the centre line of the spoke is the common center of gravity.

Q. Where there are three?

A. Find the center of gravity of one; draw an arc (with the center of revolution as a center), through this and the others' centers of gravity; connect the outer ones by a chord, and draw a radius through the center of the middle weight. Mark where this radius, one-third of the distance from the chord to the arc, cuts the radius; there is the common center of gravity of all three weights.

Q. When there are four counterweights?

A. Draw an arc through all four centers of gravity. Connect those of the two adjacent weights by a chord; the same with the centers of the outside weights. Bisect that part of the center line of the spoke between the two chords; there is the common center of gravity.

Q. What is the rule for the weight of the counterbalance on each side?

A. From the weight of the reciprocating parts on one side (including the front end of the main rod), subtract 1/400 the total weight of the engine. Divide the remainder by the number of driving axles; for each wheel add to the quotient the weight of the revolving parts.

Q. At what distance from the wheel center should the center of gravity of this counterweight come?

A. In the same center as the crank pin center.

Q. How is the weight of the reciprocating parts found?

A. Add the weights of piston (complete), piston rod, crosshead (complete,) and front main rod end (complete).

Q. How do you get the weight of each end of the main rod?

A. Balance one end on a knife edge at the pin center and let the other end bear (through knife edges) on a platform scale. Having got that weight, reverse the ends to get the other.

CHAPTER LXIII

JOURNALS AND BEARINGS

Q. What name is given to those parts of the axle which bear against the brasses?

A. The journals; this being the common name for the bearing portion of a rotating piece.

Q. What character of bearing do these journals have?

A. Usually brasses with semicircular bearing surfaces, and held in cast-iron or cast-steel journal boxes which have also, below the axle, an oil box or cellar, held up to the axle by two bolts. These journal boxes slide vertically in the pedestals or horn pieces, so that the entire engine may rise and fall with rapid running, without the wheels being raised from the track.

Q. What are the two principal classes of driving brasses used?

A. (1) Octagonal, (2) cylindrical.

Q. What are the objections to octagonal brasses?

A. They are more difficult to fit than the cylindrical, and more liable to close on the axle.

Q. What is the disadvantage of babbitting brasses?

A. The dust gets into the babbitt and cuts the axle; so that what would be very good practice where dust was not liable to get in, would be bad usage here.

Q. What is the most common usage as regards material for bearings?

A. Soft metal for engine and tender journals, and babbitted strips in rod and driving-box brasses. Soft metal cannot be relied on under all circumstances, as in case of a hot journal the metal or bearing is apt to crush or break in pieces.

Q. What is the advantage of a cast-steel driving box with a bronze shell or lining?

A. Cheapness and convenience of renewal after wear of the contacting surfaces.

Q. What may be said of malleable-iron driving boxes?

A. They are good if the side next the hub is spotted with babbitt; else, they cut the cast-iron hubs.

Q. Should oil cellars be straight or tapering?

A. Tapering, to facilitate removal.

Q. What per cent of the surface of a bearing, such as a driving box, is figured as supporting the load, and what is the usual pressure allowed per square inch?

A. It is now customary to figure the "vertically projected" area from the journal diameter and the length of the bearing as the supporting surface. Given driver bearings 9 x 13 inches, 9 x 13 = 117 square inches is the projected area. If the load on each wheel is 24,750 pounds, dividing this by 117 gives 211.5 pounds per square inch.

Q. What is the advantage of a cast-steel box with a shell, over a solid one?

A. That it may be renewed more cheaply; also it does not close up so readily when worn part way through.

Q. What effect will an engine being low on one side be apt to have on the bearings?

A. The back end of the connecting-rod brasses, or the crosshead, may heat on that side.

Q. What is Babbitt metal properly?

A. An alloy of 9 parts of tin and 1 part of copper, for journal bearings; so called from its inventor, Isaac Babbitt, of Boston. Some variations have been made; among the published compositions are:

Copper	1	1
Antimony	1	5
Tin	10	50

(Another formula substitutes zinc for antimony.)

The term is commonly but falsely applied to any white bearing alloy, as distinguished from those in which copper predominates.

Q. What is a lead-lined journal bearing?

A. One having its inner surface covered with a thin layer of lead, so that it may fit itself to the journal when worn. They are often called Hopkins bearings. (A variety of others are more or less similar, but a greater quantity of lead or Babbitt metal is frequently used.)

Q. What is the proper method of packing a journal box?

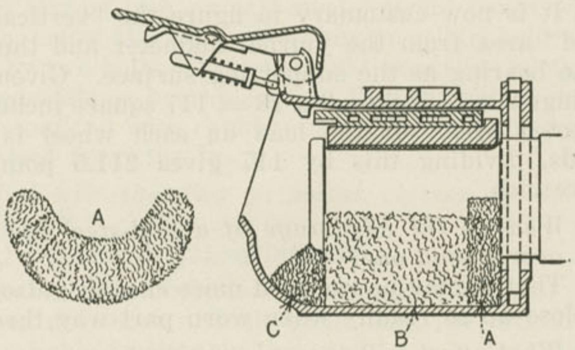


Fig. 258. Proper Packing.

A. As clearly shown in Fig. 258* the first packing should be made into a tightly twisted roll or pad *A* and firmly packed in the back of the box against the journal shoulder and dust guard, to keep the oil in and the dust out. Then the lubricating space should be packed with good-sized balls, firmly enough to resist being shaken down by shocks. The side packing should be loose and the strands on the sides where the journal leaves, carefully turned down under the mass to prevent its being pinched between journal and brass. None should be put above the axial line of the journal. The journal should

* This and the other cuts in this connection are from "Baldwin Locomotives" for July, 1922.

be well behind the collars and on the ends in order that the lateral movement of the journals will not cause the collars to loosen the packing and work it up into the front

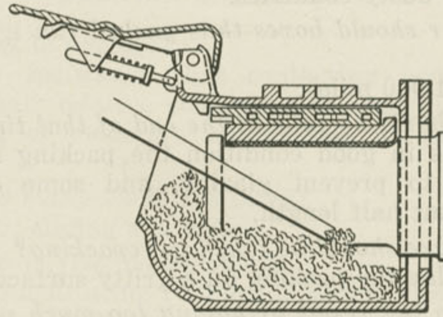


Fig. 259. Improper Packing.

part of the box. When the packing is thus applied behind the collars, a wedge *C* of packing should be placed against the end of the journals and the end of the box

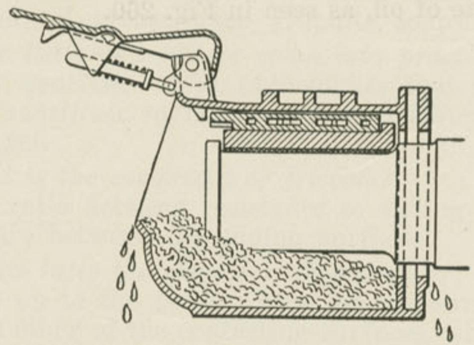


Fig. 260. Improper Packing.

to aid in holding it in position. It should not extend above the bottom collar.

Q. What precautions should be taken after this has been done?

A. To see that no strand is left hanging out; and to close the box tightly.

Q. Where is this last especially necessary?

A. In dry, dusty countries.

Q. How far should boxes thus packed run without renewal?

A. About 1,000 miles.

Q. What should be done at the end of that time?

A. If all is in good condition the packing should be loosened up to prevent glazing, and some oil added each side about half length.

Q. What care should be taken in repacking?

A. Not to lay the packing on a gritty surface.

Q. What is the result of having too much packing in front and not enough at the rear of the box?

A. Irregular lubrication; possible heating of the journal at the rear. (Fig. 259.)

Q. What is the effect of putting too much packing at the front and not enough at the rear?

A. Waste of oil, as seen in Fig. 260.

CHAPTER LXIV

FRICTION AND LUBRICATION

Q. What is friction?

A. The resistance that contacting bodies have, to change their relative position; principally caused by interlocking of moderate roughnesses on their opposing surfaces.

Q. How many kinds are there?

A. Two; sliding and rolling.

Q. How is friction lessened?

A. By substituting rolling for sliding friction; by suitable choice of contacting surfaces; by reducing their mutual pressure, and by interposing between them a layer or film of minute particles, which have less friction among each other than exists between the otherwise contacting bodies.

Q. What are the principal lubricating materials?

A. Water, oil, grease, mica, graphite, soapstone.

Q. Have balls and rollers come into practical use in locomotive practise, as in automobiles and other machines, to substitute rolling for sliding friction?

A. Not yet.

Q. What is the coefficient of friction?

A. The ratio between resistance to sliding motion to the pressure between the sliding surfaces.

Q. Is this ratio the same for all pressures?

A. Yes, up to the point where the pressure deforms one or the other of the contacting surfaces, when it may either increase or decrease, according to the change in the surfaces or up to the point where the lubricant is squeezed out.

Q. Is the friction between a journal and its bearing "sliding" friction?

A. Yes, because only one of the contacting surfaces moves in such a way that each point in its circumference passes any given point in the bearing.

Q. What, then, is rolling friction?

A. That between two bodies, one or both of which move in such a way that no one point in either is rubbed by consecutive points in the other; as where a wheel rolls on a rail, or a journal rolls on the circumference of two rollers.

Q. Is the coefficient of friction the same for continuous as for intermittent lubrication?

A. No; it is less where lubrication is continuous.

Q. As regards journal friction what is the advantage of large drivers?

A. For a given train speed there is less velocity of journal surface than with small drivers having the same journal diameter.

Q. What is the principal advantage of large journals?

A. Their ability to be more regularly lubricated, on account of the lesser pressure per square inch.

Q. How much power is lost by the internal resistance (friction of its own parts) in an engine?

A. That depends on the speed (the higher the speed the greater the loss), the type of engine, and the number of coupled axles (the more, the greater the loss). On an average, 8 to 10 per cent.

Q. Show the relation between machine friction and draw-bar pull.

A. Reliable recent figures are as follows:

Drawbar Pull, lbs.	Frictional Loss, Per Cent.
1076	3.01
2041	14.06
3399	29.01

Q. Can you give reliable data as to the frictional loss of the high speed passenger engine at various m. e. p.'s?

A. As a sample, those here given:

M. E. P. lbs. per sq. in.	Frictional Loss, Per Cent.
4.31	3.61
5.32	5.26
6.56	5.31
7.72	12.50
8.92	24.09
10.63	19.92
11.91	31.76

Q. Can you give some concrete figures concerning engine friction in terms of horse-power, etc.?

A. In one series of tests they were as under:

H. P.	Loss in Friction, Per Cent.
108.6	4.61
203.7	10.61
305.4	11.32
411.8	14.06
525.7	31.22
771.7	29.01

Q. Are the laws of friction for locomotive and train lubricants the same as with most machinery?

A. No, because the railway lubricants operate under entirely different conditions when starting and when running; being most unfavorable just when friction is least desirable, namely, at starting.

Q. What is the use of lubrication?

A. To interpose between the comparatively rough rubbing surfaces a film of material which will fill up the hollows and prevent the projections catching in each other.

Q. What are the necessary qualities of a good lubricant?

A. Fluidity, to enable it to reach the rubbing surfaces, with sufficient "body" to prevent its being easily squeezed out; capacity to withstand great heat without being disintegrated; at the same time resistance to stiffening at low temperatures; freedom from acid which would corrode the rubbing surfaces.

Q. What are the best all-around lubricants for ordinary working conditions?
A. Fats and oils.

Q. What solid substance is a good lubricant, where the pressures and temperatures are great?
A. Flake graphite, where it can be properly introduced between the rubbing surfaces.

Q. What is the disadvantage of animal oil for cylinder lubrication?
A. At high temperatures it is decomposed and forms "fatty acids" which honeycomb the cylinder.

Q. What is a fault of mineral oil for cylinder lubrication?
A. Lack of "body."

Q. What is the effect of the introduction of oil or other lubricant between rubbing parts?
A. Unless the space between them is too small, to substitute for the friction of the metal against metal that of metal against lubricant or of lubricant against lubricant. If, however, the parts are held immovably very close together, as is the case with the plug-and-ring gages used in shops, oil will prevent their coming together or moving.

Q. Upon what does the amount of friction depend?
A. On the character of the rubbing surface (that is, their material and condition), the speed at which they are rubbing, and the pressure between them.

Q. What is the viscosity of a lubricating oil?
A. Its resistance to being squeezed out from between the lubricated surfaces.

Q. How may it be judged?
A. Comparatively, by letting a drop slide down an inclined glass plate, of known temperature. Also by filling a glass tube just half full, inverting it and noting the time required for the oil to meet the half mark.

Q. What is the relation between temperature and oil viscosity?
A. The higher the temperature the lower the viscosity (other things being equal).

Q. For what classes of bearings is a highly viscous oil best?
A. Heavy and slow-running.

Q. What oils do not contain acids, if pure?
A. Mineral hydrocarbons.

Q. What is the effect of high steam temperatures on tallow and animal oils?
A. To disintegrate them chemically and produce fatty acids that pit cylinder walls, etc.

Q. What is the effect of gum in an oil?
A. To prevent its entering between the surfaces to be lubricated, and to produce a deposit that increases friction.

Q. How may its presence be detected?
A. By evaporating the oil in a watch crystal.

Q. What is the effect of dirt in a lubricating oil?
A. To reduce its anti-friction quality; also to clog the oil passages.

Q. What is the flash-point of mineral oil?
A. That temperature at which the more volatile components are driven off by heat and may be ignited.

Q. Is it the same as the burning point?
A. No; below that.

Q. What oils should have a high flash point?
A. Cylinder oils.

Q. Is the flash point the same under all steam pressures?
A. No; the higher the pressure, the higher the flash point.

Q. What oils should resist thickening by cold?
A. Those for the framing.

Q. What are the disadvantages of animal oils as lubricants?

A. Especially at high temperatures they decompose and form so-called fatty acids, that attack metal surfaces.

Q. What are the advantages of solid lubricants, such as dry graphite, soapstone and mica?

A. Their resistance to pressure; once in or on, they stay there.

Q. The disadvantages?

A. Their coefficient of friction is comparatively high; although pure flake graphite gives good results, once in place, for very high pressures.

Q. At what temperature should a good lubricating grease melt, without separation of its components?

A. 105° F.

Q. As a rule, which trains start most readily, those with grease-lubricated axle boxes, or those using oil?

A. Those with grease, because it is not so readily squeezed out while the train is standing.

Q. Are tests with cylinder oils, made on rotating journals, of any practical value?

A. None whatever.

Q. What is the action of graphite (black-lead, plumbago) as a lubricant?

A. To fill up any low places. It also has great value in that it is unaffected by either heat or cold, and in resisting pressure.

Q. What is its disadvantage?

A. Difficulty in getting it between the surfaces to be lubricated.

Q. What is a good mix for journal lubrication?

A. Four per cent of graphite to 96 of sperm oil.

Q. What is the reason that a trifle of draw filing will often cure a crank-pin brass from heating?

A. It makes minute oil grooves.

Q. Does the shape of the oil groove influence the efficiency of lubrication?

A. Yes; in many cases the groove breaks the oil film and lets the brass touch the bearing.

Q. What does this suggest?

A. Oiling by a pad from below.

Q. Is a small or a large arc of contact between journal and brass desirable?

A. Small; at any rate much less than 180°.

Q. Which edge of a brass wears most?

A. That in the direction of train motion; the "off" edge.

Q. What bearing surfaces have a higher speed than those of the crank pin?

A. Those of the eccentrics.

Q. What is the compensating advantage?

A. Smoother movement, and alternation of pressure and relief.

Q. What is the disadvantage of a very long slide?

A. The advancing end sweeps the oil away from the other end.

Q. Which guide bar of a forward-running engine needs the best lubrication?

A. The top one.

Q. With superheater engines, what type of valve is most favorable for lubrication?

A. Piston.

Q. What is the advantage of lubricating driver flanges?

A. To reduce their wear.

Q. What method is best?

A. Grease blocks, to keep oil off the rail top.

Q. For high speeds, should bearings be long or short?

A. Long; which also helps keep the lubricant in place when the train is standing.

Q. Explain how the oil gets from the lubricator cup to steam-chest and cylinders.

A. When the steam, water, and feed valves are open, and the "sight-feed" glasses full of water, oil will pass upwards through the water, which is heavier than oil, until the steam current from the equalizing-tubes takes it and delivers it as fine spray through the small nozzle in the side of the cup, and thence to the steam-chest.

Q. What about the small check valves over sight-feed glasses—for what are they?

A. They act by reason of the steam pressure from the equalizing valves, in case the sight-feed glass breaks.

Q. Are there any other valves between lubricator and steam chest?

A. No. They would prevent the oil spray from reaching the steam chest.

Q. After filling the oil cup, what valve do you open first? Why?

A. The water valve, to let the oil expand.

Q. If you should fill the cup with cold oil while in the house, would you open the water valve or leave it closed?

A. Open it.

Q. How often should lubricators be cleaned out? Why?

A. That depends on the kind of oil being fed; from one to twelve weeks; the poorer the oil the oftener cleaning is needed.

Q. How often should all rod and guide cups be taken out and cleaned?

A. Weekly.

Q. What does "cross-feeding" of a sight-feed cup mean?

A. The feeds on each side of a locomotive cup are intended to be independent of each other, each to feed on its own side only. If, however, the oil can get from one side to cross over to the oil pipe on the other side of the cup, permitting all the oil to go to one side of the engine, it is said to "cross-feed," or feed across the cup to the opposite side. In such cases one side of the engine gets no oil at all, and as the drops are rising regularly through both glasses it gives no warning until too late. Some of the old style cups will do this when the oil pipe becomes stopped so oil cannot get out of the cup, through the pipe to the steam chest; modern lubricators are arranged to overcome this defect.

Q. What is positive lubrication?

A. Forced feed of the oil to the rubbing parts, as distinguished from gravity lubrication or gravity feed.

Q. Where is it practised?

A. In modern European engines, where the oil is pumped through the oil pipes to the bearings at a rate dependent on the speed of the engine.

Q. Should the sight-feed glass or feed valve on one side become broken or inoperative, can that on the other side be used?

A. That depends on the style of lubricator used; some will "cross-feed," some will not.

Q. Explain the "cross-feeding" difficulty as experienced in some of the lubricators in service.

A. There are two equalizing tubes, one for each side; and in case one gets stopped up the other cannot send oil to that side.

Q. Is there a possibility of losing all the oil out of the lubricator after shutting off both bottom feeds to steam chest, when engine is allowed to cool down?

A. Yes. It may be drawn through when the steam in the boiler condenses and the external air pressure tends to force oil from the lubricator into the vacuum thus formed; but this can only take place if the steam, the water, and the feed valves of the lubricator are left open, which should not be the case.

Q. Does the draft from the open cab windows affect the working of the lubricators?

A. Yes.

Q. Why?

A. It chills them.

Q. Suppose the lubricator on one side chokes between stations on a fast run, what is to be done?

A. (1) Blow out the obstruction from the choke plug or (2) oil by hand through the auxiliary.

Q. How is the obstruction to be blown out?

A. Shut off the feed plugs and condenser plug and take the boiler pressure from the top of the lubricator; with a wrench loosen the feed plug where it screws into the bottom arm of the sight-feed glass, and blow the glass clean, if the apparatus permits; if not, open up and go on.

Q. What is to be noted in connection with heavy oil in sight-feed lubricators?

A. If it is so heavy that it gets near the specific gravity of water, it is apt to lie on the nipple of the sight-feed tube, and instead of rising in drops through the center, to run up the side of the cup.

Q. What should be done with oil that is in this condition?

A. It should be thinned with a lighter grade.

Q. Of what kind of metal are lubricators made?

A. Usually of brass or of gun metal, tested to twenty atmospheres.

Q. How much will cylinder oil increase in bulk when heated from normal temperature of 70° F. to 390° to 400° F.?

A. Nearly one-fifth.

Q. What then is the effect of filling lubricators that have no expansion chambers, with cold oil, and not at once opening the water valves and steam valves?

A. A burst cup is likely to result.

Q. What is another cause of bursting or bulging lubricator cups?

A. Neglecting to drain the water from them when from any cause the boiler gets cold in a freezing temperature.

Q. Where are the principal causes of lubricator trouble?

A. In the choke plugs, equalizing tubes, and check valves.

Q. To keep the sight-feed lubricator working well, what is necessary?

A. To have full boiler pressure always in the steam chamber.

Q. What facilitates this?

A. The choke plug.

Q. What is the size of the hole in the choke plug?

A. From 1/32 to nearly 1/8 inch in diameter, according to the size, style, and make of the lubricator.

Q. What is the effect of the hole wearing larger or the plug getting smaller?

A. The pressure in the cup will vary with the steam-chest pressure.

Q. What are the usual causes of irregular working of a lubricator?

A. (1) Too small an opening in the steam supply valve, or too small a pipe; (2) stopping up of the equalizing tubes; (3) closeness of the choke plugs in the hole.

Q. What is the effect of throttling or wire-drawing the steam in the pipe from the boiler to the sight-feed cup?

A. To make the cup feed irregularly.

Q. What is the use of the equalizing tubes?

A. To overcome the back pressure from the steam chest, and furnish condensed water to the sight-feed glass.

Q. What is the remedy for choke plugs filling up?

A. To remove them and clean out the hole.

Q. What is the remedy where choke plugs are worn so as to be loose, or the hole through them is too large?

A. To replace them by new plugs.

Q. What is apt to happen if the pipes from the lubricator to the steam chests are not straight and of gradual fall?

A. They may trap the oil and cause irregular lubrication; especially where the engine is working slowly with full open throttle.

Q. Can oil be blown out from the cup?

A. It sometimes takes place when the boiler is cooling down, the feed valves shut, and the water and steam valves open.

Q. What should be done when the sight-feed gets clogged?

A. The water valve should be closed and the drain cock opened, then the steam valve opened, so that the steam blowing down through the equalizing tubes will force the obstructions out of the feed tube into the body of the cup.

Q. What is the best way to close the oil feeds?

A. Usually by closing the water valve, so as to cut off pressure from the body of the lubricator.

Q. Will the feed start up at the same number of drops per minute when the valve is again opened as before it was closed?

A. Yes.

Q. When the locomotive is working very light and it is desired to restrict the amount of oil feed to the cylinders, how may this be done?

A. By completely closing the water valve.

Q. What objection is there to the practice of closing the water valve to shut off or lessen the feed?

A. It shuts off the oil from the air pump.

Q. Should lubricators be filled quite full?

A. No.

Q. In what order should the valves be opened in putting them into service?

A. First the steam valve, then the water valve, then the feed.

Q. In shutting off, what should be the order of handling the valves?

A. First the feed, next the water valve, last the steam valve.

Q. If steam is turned into the lubricator, what care should be exercised before the feed is started?

A. To see if the side glasses have condensed full of water.

Q. When the feeding glasses have an inside coating of oil, and a drop from the feed tube runs up the side of the glass, of what is that a sign?

A. Either of too thick oil, or that the feed has been turned on before the glass had condensed fully.

Q. What causes discoloration of the water in the glass?

A. Failing to open the steam valve before the throttle.

Q. What is a hindrance to perfect lubrication in the case of the sight-feed lubricator?

A. The formation of a "water seal" in the oil pipes.

Q. There is a lubricator that cannot be oiled through one of the cups while the engine is drifting, on account of steam escaping. The one opposite is all right. What causes the trouble?

A. An obstruction in the tallow pipe, preventing the steam from blowing down the pipe with sufficient freedom, and causing a back pressure which sends the steam through the auxiliary hand oiler whenever the latter is opened.

Q. What is the cause of sight-feed glass on lubricator filling with oil?

A. A general cause applying to all makes is, the glass and passages above it to the steam passages get gummed up, so that the oil sticks there, and has not enough buoyancy to rise higher.

Q. What causes discoloration of the water in the oil-feed glasses?

A. Mixed water and oil, and sometimes air from the cup, forced back by over-compression.

Q. At what cut-offs do engines give the least trouble with valves running dry?

A. At short ones, as the varying chest pressures give the oil no chance to flow down; and especially at high speeds.

Q. Describe the automatic steam chest plug?

A. It is between the tallow pipe and the steam chest, and has therein a choke with a ball valve, which when

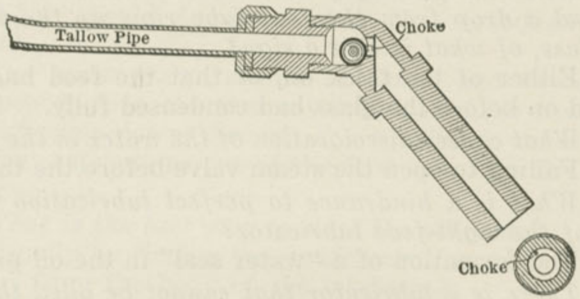


Fig. 261. Automatic Chest Plug.

the throttle is open lies to one side as shown in Fig. 261. When, however, the throttle is shut the ball covers the choke, with the exception of a small hole through which but a limited amount of oil can pass.

Q. With such a device, what is the remedy for a dry valve?

A. Pulling the throttle wide open, so as to unseat the ball and let more oil flow into the chest.

Q. How many drops are there in a pint of oil?

A. That depends on the density of the oil and the size of the hole in the feed tubes; 3,600 may be said to be a fair average.

Q. Assuming 3,600 drops to the pint, and five drops per minute to the steam chest and one drop to the air pump, how long would a pint last?

A. $3{,}600 \div (60 \times 6) = 10$ hours.

Q. How many drops are there in a pint of Galena valve oil, and how long should it last?

A. For Galena oil, average 6,500 to 6,600 drops; at five drops per minute for each cylinder and one for the air pump we have nearly ten hours. At 15 miles an hour, 150 miles per pint; at 25 miles, 250 miles; but really the high speeds call for more oil.

Q. What about the quantity of oil required for bearing surfaces?

A. No general rule can be laid down as regards drops per mile, as some oil has more drops per pint than others; also the condition of the bearings, speed at which the train is run, the load that is being hauled, the regularity of speed, the condition of the rails, the temperature of the surrounding air, and other things tend to cause variation.

Q. What is a good way to get the oil on the valve seat in making long runs, without shutting off steam?

A. To ease off on the throttle for a minute to lessen the pressure in the chest, and thus let that in the lubricator force in the oil.

Q. What will empty a lubricator of oil after the steam and expansion valves of both feeders are closed?

A. Condensation of the steam in the condenser and pipe connections, causing a vacuum in the oil cup.

Q. How does the oil get from the cup to the steam chest?

A. The condenser at the top of the cup is full of condensed steam from the boiler connection at its top. Boiler steam passes down steam pipes to top arms over the sight-feed glasses, thence through oil pipes to the chest. From the bottom of the condenser to that of the oil tank there is a pipe down which water can pass, driving the oil out into the sight-feed glass, in which it rises to where it mixes with the steam passing to the chest.

Q. Why are there check valves over the sight-feed glasses?

A. To be closed in case a glass bursts.

Q. Is there boiler pressure in the lubricator, condenser and oil chamber?

A. Yes.

Q. While working full throttle, are the tallow pipes from steam chest to lubricator full of condensed water, or of steam?

A. It is generally a mixture of both; but with the most improved lubricators means are provided for preventing water forming in the pipes.

Q. What is the first requisite of lubrication?

A. Good oil or other lubricant.

Q. What care should be taken with oil cans?

A. That no waste threads get in them; such threads could get around a main-rod cup spindle and stop the feed.

Q. With what lubricating arrangement should eccentric straps be provided?

A. With oil cellars below, to catch the oil and throw it up again.

Q. What precaution should be taken with regard to the lower strap joint in the matter of lubrication?

A. To have it oil tight.

Q. How should eccentric-strap oil cups be made?

A. As part of the strap itself.

Q. What is a faulty construction of driving boxes in relation to lubrication?

A. Where there are holes drilled to the wedges at such a point that the latter get the oil meant for the journals.

Q. Which driving boxes require the more oil—steel or cast iron?

A. Steel.

Q. Which wheel hubs require the more oil—steel or iron?

A. Steel.

Q. What bearings give about the most trouble?

A. Those of the trucks.

Q. What is apt to cause this?

A. Equalizers bearing unequally on the two ends of the brass; the brass being longer than the box; the oil recess in the top being clogged; cellar bolts not filling the holes.

Q. How can the trouble with oval cellar-bolt holes be cured?

A. By making the bolts out of correspondingly flatted rod.

Q. Which is better for truck cellars—woolen waste or cotton.

A. Woolen, because elastic.

Q. What is a good "home-made" truck cellar packing?

A. Tight small rolls of ingrain carpet as long as the cellar is long inside, and laid lengthwise of the journal.

Q. What is "wick trimming"?

A. An English feeder for engine-axle brass, made by passing yarn or wicking through a loop of copper wire, so that when the yarn is doubled back along the wire it will loosely fill the oil hole.

Q. What is the use of the wire loop?

A. As a handle.

Q. How is such wick feed adjusted?

A. By varying the number of yarn strands; the more strands the less feed.

Q. How can an eccentric strap be oiled, that has the oil hole out of sight when the sheave belly is below the axle?

A. By having a short piece of pipe screwed into the hole.

Q. How can oiling truck boxes be facilitated?

A. By having oil pipes as high up as the frame.

Q. *Why is it that sometimes after having stirred the cellar packing up against the journal the latter runs hot?*
A. Because gritty waste has been brought up against the journal.

Q. *What rule should be observed on oiling up?*
A. To fill all cups before starting out, and adjust the feed just so that the oil will keep the pins, etc., cool, but not splash out.

Q. *What facilitates getting the oil to the wedges?*
A. Putting the engine on the forward center with the lever in the back notch.

Q. *On which side is oiling the axle boxes most important—inside or out?*
A. Inside, on account of the cinders from the ash pit.

Q. *Which guide requires the most oil?*
A. The upper one, because the engine runs more ahead than backwards.

Q. *What part of some classes of engines is it apt to be difficult to oil with the lever in the back motion?*
A. The lower end of the link.

Q. *What is a good way to keep the waste up against the truck journals?*
A. To twist up a bunch of waste like a rope and push it hard against the back of the box so as to act as a dust guard and oil holder, and then pack under the journal as high up as the middle line of the axle.

Q. *What kind of packing should be used in replenishing or repacking?*
A. Drained and saturated.

Q. *What is the effect of carrying oil cans next the boiler heads in warm weather?*
A. The oil is made unnecessarily thin, thus having less body, and causing hot bearings.

Q. *What is sometimes the result of poking at or lifting packing on top of driver boxes?*

A. Heating, as cinders are apt to get underneath the packing.

Q. *What should be done when the oil on top of the boxes becomes liver-like?*
A. A little petroleum should be used to cut it out of the packing.

Q. *What about the use of saturated packing?*
A. It should be used in replenishing or new packing, not thrown away, even if a little seared over.

Q. *What about the use of bottom waste as against wool?*
A. It is closer and saves oil in warm weather if put on top of the boxes.

Q. *What kind of a spout should the oil-can have?*
A. One made with a spiral "reinforce" of metal strip so as to prevent bending, flattening, or breaking, and with a check valve to prevent oil flowing out when the spout is being changed from one oil hole to another.

Q. *Should water be used on a hot crank pin where the babbitt has started?*
A. No; it is apt to crack the brass or spring it so it cannot be straightened or cannot run cool.

Q. *What are the principal causes of heating engine-truck brasses?*
A. (1) Uneven distribution of weight on the top of the brass, through the equalizers not being in proper adjustment, (2) brasses (second hand) that are thicker at one end than at the other, (3) truck frames not high enough from the box, (4) waste packing settling from the journals.

Q. *What may be said in general in the matter of oiling?*
A. It should be frequent, regular, and not excessive; every wearing surface should receive oil at every station, where there is time enough, and every one should have

the hand laid on it to notice whether or not it is getting warm.

Q. How are the slides oiled?

A. By oil cups on the top guides or on the crosshead.

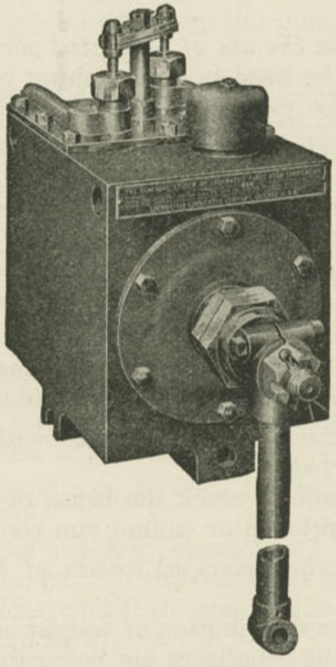


Fig. 262. Schlacks Lubricator.

Q. What special precaution should be taken in oiling the engine?

A. To oil the sides of all boxes and bearings.

Q. Why not put the truck-axle bearings outside the wheels, where they could be more readily oiled and inspected, and where renewal would be easier?

A. Because they would be in the way of the cylinders.

Q. Name an often-neglected cause of the back rod end heating?

A. A forward-end brass keyed too tight.

Q. When should the preliminary oiling before leaving take place?

A. Immediately before pulling out.

Q. When should special attention be paid to oiling?

A. Just after the engine comes from the repair shop.

Q. Describe the Schlacks system of forced lubrication.

A. As shown in Fig. 262, there is attached to either valve chamber a reservoir casting containing two oil pumps, one for each side of the engine, and forcing oil to all desired points at every rotation of the drivers. There is a lever operated by a link connected to a part of the valve gear, and which operates a ratchet that turns a cam shaft in the oil reservoir, which operates the pumps. A steam pipe with a check valve to control the pressure of the steam that heats the oil, keeps it at constant temperature, and a drop of oil enters the steam at each pump stroke and is carried to the valve chest, eventually lubricating the cylinders.

Q. What causes carbonization in the cylinders?

A. Admission of air when the cylinder temperature is higher than the flash point of the oil, or by unconsumed gases drawn in through the exhaust.

Q. What is the remedy?

A. Drifting with slightly open throttle; also, using an oil of very high flash point.

CHAPTER LXV

TRACTION*

Q. What is meant by traction?

A. Two things; one the amount of grip or drawing power that a locomotive or other similar engine has, and the other the percentage or proportion of the amount of drawing power that is wasted or absorbed by friction between the rolling body and the road upon which it is drawn, and also the amount of axle friction of the vehicle being drawn, where such vehicle has wheels.

Q. Where is traction the greatest?

A. Of course upon up grades the traction is greater than upon levels; and upon down grades it is less. Upon grades the friction of the axles remains the same as upon levels, but going down grade there may be very little retardation between the vehicle and the road. Upon curves there is more retardation or waste traction than upon straight tracks or, as the engineer of permanent way calls them, "tangents."

Q. What name is given to the percentage or proportion of force required upon railways and other different roads?

A. The traction co-efficient.

Q. How great is it?

A. It runs about as follows under ordinary average conditions:

Upon railroads in good condition, with well lubricated axles, 4 pounds per ton of load; upon railroads under ordinary, but not very good conditions, 8; upon a very smooth pavement, 12; on ordinary street pavements in good condition, 20; on street pavements and turnpikes, 30; on turnpikes new laid with coarse gravel and broken stone, 50; on common roads in bad condition, 150; on entirely loose ground or sand, 560. Of course where the load stalls in mud the traction is 2,240 pounds per gross ton.

* See chapter on "Starting."

Q. What increases this adhesion or traction in the case of a self-propelled vehicle, as a locomotive or an automobile?

A. Weight on the drivers. Other things being equal, the greater the weight thereon the greater the tractive effort.

Q. Why not make all the wheels of a locomotive drivers and thus have all the engine weight utilized in giving traction, instead of having one-fourth to one-third of it on the trucks?

A. That would necessarily lengthen the rigid wheel base. While it would do for slow speeds on straight roads it would not do at all on curves, by reason of the long wheel base, or for high speeds, on account of the greater tendency of large wheels to leave the track.

Q. Can a locomotive have too much cylinder power?

A. Yes; it may have cylinder power in excess of tractive power, and thus slip its wheels instead of driving the whole machine ahead.

Q. How can tractive force be best measured?

A. By a traction dynamometer: an instrument applied between the motor and the train and by or through which it is hauled; the compression or expansion of a spring therein or the amount of pressure exerted by a piston in a cylinder of oil as registered on a gage, showing the force passing through it.

Q. How much pull can an ordinary engine exert?

A. According to the speed; say from 2,500 pounds at sixty miles an hour up to 12,000 at ten miles.

Q. What are principal causes of slipping?

A. Half-wet rails; over-hard tires or over-soft rails; too little weight on drivers; sometimes too short wheelbase or too light springs.

Q. What precaution should be taken as regards the condition of the rails in making an up grade?

A. Care should be taken that there are no drops of water or of oil on the rails to lessen the traction.

Q. How should sand be used?

A. Very sparingly; only enough to give the drivers a grip, without unduly covering the rails with a sand crust so as to increase the resistance.

Q. What kind of sand is necessary?

A. Clean, dry, and sharp.

Q. How should it be used?

A. Sparingly; that is, sprinkled on.

Q. What is the evil effect of thick sanding?

A. (1) Stalling on up grades; (2) sanding of axle boxes, rod brasses, and guides.

Q. What is the evil effect of sanding one rail more than the other?

A. Unequal traction, hence risk of breaking crank-pins and side rods.

Q. What is the relation between driver diameter and tractive power?

A. Other things being the same, small drivers have the best pulling power, but the weight on drivers and the cylinder diameter and stroke have also influence. It makes a difference (1) where the main rod takes hold, (2) how much of a pull or push it can give, and (3) how much of this pull can be utilized without slipping.

Q. About how many pounds pull should it take to move an ordinary train of 500 tons on a level track?

A. From 3,000 to 4,500 pounds, according to the wheel-diameter, journal-diameter, character of track, kind and quantity of lubricant supplied, etc., say, 3,750 pounds for average conditions.

Q. If the entire weight of an engine could be put on two wheels instead of on six or ten, without injuring the track, could she be started as well?

A. Yes.

Q. How may the starting and hauling power of non-compound engines be figured?

A. By multiplying the square of the cylinder diameter in inches by the mean effective pressure in pounds per square inch and the stroke in inches, and dividing by the actual wheel diameter at the rail in inches. This gives the gross power at the rail in pounds, not allowing for engine friction.

Q. At what piston positions has the engine the weakest starting power?

A. At latest cut-off.

Q. Figure up the tractive power of a 20 x 24-inch non-compound engine with 60-inch drivers and mean effective pressure of 170 pounds?

A. $$\frac{314.16 \times 2 \times 24 \times 2 \times 170}{3.1416 \times 60} = 27{,}200 \text{ pounds.}$$

Q. At what may we take the mean effective pressure for starting?

A. At 85 per cent of the boiler pressure.

Q. What is the formula for the gross tractive power of a two-cylinder compound, when the mean effective pressure is known?

A. $\dfrac{d^2 Ps}{2D}$; where d is the diameter of the L. P. cylinder, P the mean effective pressure therein in pounds per square inch, s the stroke, and D the driver diameter (all measurements in inches).

Q. Express this formula in words instead of letters.

A. Multiply the diameter of the L. P. cylinder by itself, by the mean effective pressure in that cylinder and by the stroke and divide the product by double the driver diameter (all measurements being in inches) to get the tractive power in pounds.

Q. Suppose there are no indicator diagrams?

A. Call the M. E. P. 70 per cent of the boiler pressure.

Q. How much should be deducted for internal friction?

A. Say 7 per cent.

Q. How may the tractive power of a four-cylinder compound be calculated?

A. Roughly, by considering the M. E. P. in both cylinders at 45 per cent of the boiler pressure, then dividing 45 by the cylinder-area ratio; and multiplying 0.45, plus the quotient just found, by the boiler pressure, gives the mean effective pressure in the L. P. cylinders. Then the formula for gross tractive power is

$$\frac{d^2 P s}{D}$$

the letters having the same meaning as in the preceding answer.

Q. Express this formula in words instead of in letters?

A. Multiply the diameter of the L. P. cylinder by itself, by the mean effective pressure in pounds per square inch in that cylinder and by the stroke, and divide by the driver diameter (all measurements being in inches) to get the tractive power in pounds.

Q. What is the formula for calculating the tractive effort of a Vauclain four-cylinder compound when working as a simple engine?

A. $$T = 0.85\left(\frac{C^2 \times S}{D}\right) + \left(\frac{c^2 \times s}{D}\right) \times \frac{P}{2}$$

where T is the tractive effort, C the diameter in inches of the H. P. cylinder; c the diameter in inches of the

L. P. cylinder; P is the boiler pressure in pounds per square inch, and D is the diameter in inches of the drivers. The formula, however, reduces to this simpler form:

$$T = \frac{(C^2 + c^2) \times 0.425\, P \times S}{D}$$

The constant 0.425 is obtained by cancellation, which eliminates the figure 2 from the denominator. The constant 0.85 is the percentage of boiler pressure allowed by the Master Mechanics' rule for the mean effective pressure in the cylinders.

Q. Give the adhesion of various types of engine, summer and winter.

A. According to Haswell, they are as follows, the coefficient of friction being 0.222 in summer, 0.2 in winter.

	Weight.	Lbs. on drivers.	Adhesion. Summer.	Adhesion. Winter.
American	64,000	42,000	9,350	8,400
Ten-wheel	78,000	58,000	13,000	11,600
Mogul	88,000	72,000	16,000	14,000
Consolidation ..	100,000	88,000	19,550	17,600
Tank switcher..	68,000	68,000	15,100	13,600

Q. Suppose that we have an engine with 50,000 pounds on the drivers; how much of this will be available for traction?

A. That depends on the condition of the rails. If they are fairly dry but not sanded, or wet and sanded, about 10,000 pounds will be available for traction. If perfectly dry but unsanded, about 12,500; if both dry and sanded, about 17,000; if wet or frosty (or what engine runners call "greasy") only about 8,300 pounds; with snow or ice on them, less yet.

Q. How is an engine given increased tractive power in case the rails are wet or frosty?

A. By sharp, clean sand led by pipes directly in front of the drivers, a few inches above the rail; a lever from the cab controlling the supply as desired.

Q. Where is the sand box?

A. Usually on top of the boiler; but in recent practice one has been put lower down, each side, between the

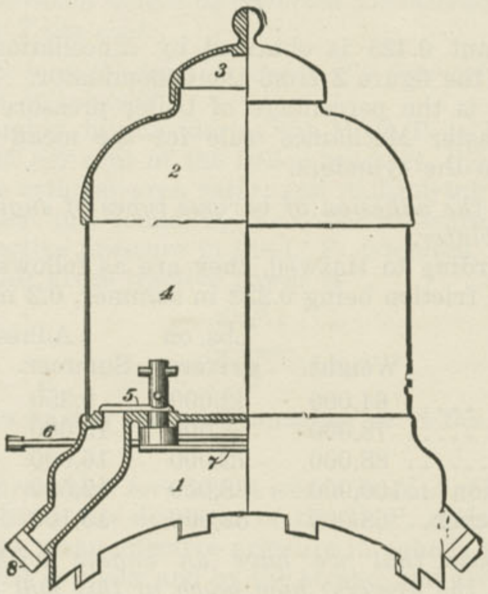


Fig. 263. Sand-box Work.

1. Base. 2. Top. 3. Lid. 4. Body. 5. Valve. 6. Lever. 7. Valve Connecting-rod. 8. Pipe-flange.

drivers, so that the sand may be nearer where wanted and have less chance to stick in the pipe in case it gets frozen. (See Fig. 263.)

Q. Is increase in weight per wheel attended by increased wear of tires and rails?

A. No; on the contrary.

Q. Why?

A. Perhaps because a heavy engine does not respond so quickly as a light one to shocks from an uneven track; perhaps the lower the center of gravity (in the case of small boilers and less wheel weights) the more disadvantageous the angle at which the flanges strike the rail heads.

Q. What are the tensile draw-bar stresses of an engine coupling onto its train?

A. From 65,000 to 142,000 pounds.

Q. What are the buffing stresses?

A. Thirty loaded cars moving 6½ miles per hour and coupling on to ten loaded ones with brakes set gave a buffing shock of over 375,000 pounds. The Westinghouse dynomometer car striking a loaded 60,000-pound furniture car (standing) at a speed of 13½ miles an hour gave a shock of over 380,000 pounds.

Q. Describe the "auxiliary driver" system.

A. This is a German idea:

The engine runs, under ordinary conditions, on five axles, viz., a four-wheeled bogie in front, two coupled axles, and a trailing carrying axle situated in a Bissell truck. Besides that it is fitted with an auxiliary driving axle, between the two bogie axles, but not forming part of the bogie, having its bearings guided by horn plates extending down from the main frame plates outside the bogie frames. The center bogie pin, on the casting forming the main cylinders, is just before the auxiliary axle. The latter takes its motion from two equal-sized outside cylinders on the main frames in front of the leading wheels. The auxiliary valve gear is a modification of Joy's.

The auxiliary engine is used for starting and climbing; when not in use the auxiliary drivers are held off the rails by springs, and are held down, when in use, by two 7-inch steam cylinders.

Q. What is the traction increaser?

A. On the "Atlantic" type, with four wheels coupled, a trailer under the firebox and a double truck in front, there is usually only 54 per cent of the weight on the drivers, so that in starting it is usually necessary to have two levers (one on each side) extending from immediately under the back ends of the back driving springs and connected to the driving-spring hangers back under the fire-box, where the back ends are made secure. Then slightly behind the attachment at the front ends two 8-inch air cylinders are coupled to these levers, being fastened vertically to the frame (push rods down) and coupled to the main levers in the usual manner. To transfer part of the weight from the trailer to the driver, air from the main reservoir is admitted to the 8-inch cylinders, with the result that about 8 per cent more weight pulls down on the back spring hanger of the main driving spring.

The device for operating the traction increaser from the cab is a two-way cock, one way making a direct channel for air from the main reservoir to the brake cylinders, the other to block such channel and open the exhaust from the cylinder to the atmosphere.

Q. What are the advantages of traction increasers?

A. They save sand, and enable the train to be pulled out of a hole when otherwise they might not.

Q. What are their disadvantages?

A. They are hard on springs, the sand wears the rails on curves and grades, and wears the tires, which are generally softer than the rails.

Q. What is the booster truck, or simply "booster"?

A. This is a special trailing pony truck equipped with twin steam cylinders with three-point suspension, driving its axle through 3-to-1 gearing, and intended to aid the main cylinders in starting a heavy train or climbing steep grades. The cylinders are 10-inch diameter, 12-inch stroke, and cut off at three-fourths stroke; receiving superheater steam where this is furnished the main cylinders. The weight of the engines proper is about 6,000 lbs.; of engines, truck and all attachments, about 15,000 lbs. (See Fig. 264.)

Q. How is it supplied with steam?

A. By an auxiliary throttle in the cab.

Q. How is it thrown in and out of gear?

A. By an idle gear between the piston on the engine shaft and the truck ends, that can be thrown in by a bell crank operated by a piston actuated by air pressure.

Q. How much extra starting power does the booster accord?

A. Boosters now in service are claimed by the makers to show an addition in starting power to the 2-10-2 type of 10 per cent or more, Mikado type of 23 per cent; Pacific type of 27 per cent; Atlantic type of 40 per cent.

A new 2-10-2 type locomotive of 75,150 lbs. tractive effort and weighing 385,000 lbs., may be increased (the makers say) by the booster to a tractive effort of 84,050 lbs. with an addition of weight of only 5,300 lbs. as compared with one of the same class weighing 420,000 lbs. and having a tractive effort of only 83,000 lbs., yet has 35,000 lbs. less to haul around all the time.

Q. Considered as a motor, is it not wasteful of steam?

A. Certainly, cutting off as it does at three-fourths; but it is steam well spent, as it enables a faster start, more rapid acceleration to road speed, and in many cases reduction of over-time wages and car rental. Also, boosters, if on all engines, would eliminate the necessity of "pushers."

Q. What facilitates the action of the booster?

A. The fact that in starting there is always surplus steam.

Q. How much additional traction is claimed therefor?

A. The equivalent of about 50,000 lbs. of locomotive weight; but it does away with the necessity of heavier rails to carry that weight.

Q. In how many ways may grades be expressed, and what are they?

A. Four: (1) per cent of grade; (2) rise in feet per mile; (3) length of grade to a foot rise; (4) angle with the horizontal. For instance, a 2 per cent grade is 105.6 feet per mile, or fifty to one, or 1 degree 9 minutes = 1 3-20 degree from the horizontal.

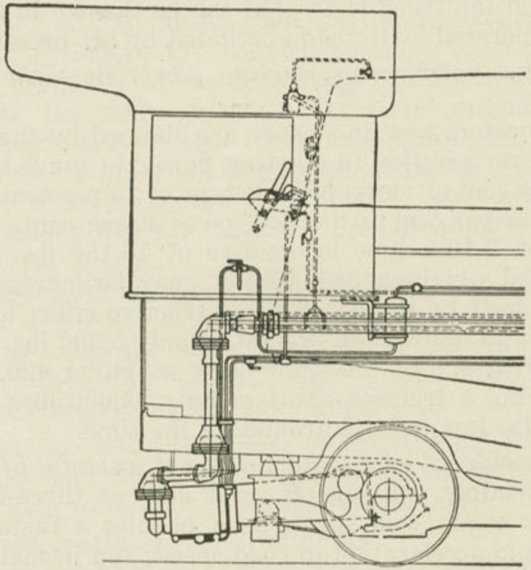


Fig. 264. Locomotive Booster Truck.

Q. What makes an engine "slippy"?

A. (1) Too much cylinder power for the weight on drivers; (2) very hard steel tires on hard steel rails; (3) badly-worn tires; (4) too short wheel base; (5) too limber driving springs.

Q. How may slipping often be diminished?

A. By throttling and working nearly full stroke.

Q. What is the reason for this?

A. The steam pressure (hence also the work on the crank pins) is more uniform during the stroke.

Q. What is the disadvantage?

A. Losing the benefits of expansion in steam consumption.

Q. What is the effect of sanding the rail while engine is slipping, without first shutting off the steam?

A. To strain rods and pins up to the danger point.

Q. Is it good policy to allow sand to run from the pipe only?

A. No. It wrenches the pins and connections.

Q. Does it hurt an engine to slip her, after you get her out of the roundhouse, in order to get the condensed steam out of the ports and steam ways?

A. The best way is to start back slowly, with cylinder cocks open, until the water is worked pretty well out of the passage-ways and cylinders. This should suffice, but it does not, always; thus making it desirable to slip the engine two or three turns to get out all the condensed steam. Of course, there is always danger of blowing out a cylinder head if much water is in the cylinders. Opening the throttle wide and excessive slipping is unwise, even dangerous. Sometimes the slipping, caused by a wide-open throttle, draws water from the boiler into the cylinders and throws it out through the stack. Some roads object to the practice; others tolerate it. It protects a polished jacket and clean front end.

Q. What causes an engine to slip at high speed, with steam shut off?

A. Centrifugal force of the counterbalance weights, slightly lifting the wheels from the rails.

Q. Where is this most noticeable?

A. In engines having heavy reciprocating parts which are partly counterbalanced.

Q. Then why should these be counterbalanced?

A. For slow speeds it gives smooth riding.

Q. What is the effect of this counterbalance of reciprocating parts (which are the piston, crosshead, and from one-fourth to two-thirds of the weight of main rod)?

A. To balance those parts while passing the centers. Such balance is productive of smooth riding at slow speed; but at high speeds becomes a disturbing element.

Q. If an engine slips when shut off, drifting on a damp or wet rail, of what is that a sign?

A. That the main wheels are out of quarter, either originally or by reason of axle springing.

Q. What is the effect of catching an engine on sand when slipping?

A. Injurious to the engine generally; puts a breaking stress on axles, pins, and rod straps, especially if the sand does not run even on both sides.

Q. In using sand on a bad rail, is it necessary to let a continuous stream run?

A. No. When moving, say, twenty miles per hour, a little sand every telegraph pole will keep the engine to the rail.

Q. Why would it not be better to let it run all the time and save the trouble of working the sander or sand lever?

A. Sand makes a train pull hard; and much will make it pull harder than only a little.

Q. Is it right to use sand on one side only?

A. No; that puts a bad torsional strain on the axles.

Q. What effect is that liable to have?

A. To twist the axles and throw the engine out of quarter; if followed up, no doubt start a fracture.

Q. What is the effect of continually sanding the rail in taking the run for a hill?

A. To impede the wheels when the hard pull comes.

Q. Will an engine do herself more damage, slipping when running fast than when running slow?

A. When an engine, pulling a full load, is just moving, and slips, with throttle wide open, the rotations of the driving wheels are numerous compared to the distance moved over, and energy is rapidly accumulated by the slipping wheels. When they catch, nearly all this energy is converted into work, which appears either in the form of a sudden acceleration of the train speed, a sprung side rod or a damaged part; or if it results in a jerk, the train will very likely be broken in two. Suppose, however, that this engine slips when moving 20 or 30 miles per hour. The increase in the number of turns, above those which the speed requires, is not so great in proportion as in the former case, and when the wheels catch, there is not relatively so much rotating energy to be dissipated as at slow speeds, and consequently less jar or jerk takes place.

Q. What is the difference between slipping, sliding, and skidding?

A. To slip the wheels is to make them turn without advancing, or advancing less than the wheel-run movement would measure. To slide is to block the wheels by the brake shoes or otherwise and permit them to move along the rail without turning. To skid is the same as to slide, and is generally used by British writers.

Q. At what speeds is uniformity of traction most important?

A. At slow ones; still more especially in starting.

Q. Where one cylinder has a larger bore than the other, how may the difference in pressure be equalized, at least partially?

A. By giving the smaller one the later cut-off, so as to make the mean effective pressure the same at the most usual cut-off.

Q. Can inequality of cylinder diameter be discovered by the indicator?

A. No.

Q. Is the resistance of cars to traction proportionate to their weight?

A. No; light ones have proportionately more resistance than heavy ones.

Q. What rule can you give for resistance, based on this fact?

A. The total resistance of the train (exclusive of engine and tender) is equal to 1.8 times the weight in tons, plus 100 times the number of cars. This is correct for five miles per hour; from that up to 30 miles, add two per cent for each mile over five.

Q. Does the drawbar pull increase or diminish with the speed?

A. It decreases; for instance in one test it was 33,800 lbs. at 30 m.p.h., 22,700 at 50 m.p.h., and only 14,600 at 70 m.p.h.; being about in inverse ratio to the speed.

Q. How far can the maximum tractive effort obtainable by the adhesive weight on drivers, only, be counted upon?

A. Only up to a certain well determined speed for each engine.

Q. Beyond that, on what does it depend?

A. On the maximum power developable by the engine, independent of adhesive weight.

Q. Of an engine weighing 200,000 lbs. and over, how much is usually on drivers?

A. About 55 per cent.

Q. What would be its adhesion?

A. About 20 per cent; giving a draw-bar pull of, say, 22,000 lbs.

Q. What mean effective pressure is necessary to overcome the frictional loss?

A. For nearly all speeds and cut-offs, 3.8 lbs. per sq. inch.

Q. What then will be the maximum tractive effort?

A. As expressed by the relation (161 times heating

surface in sq. ft. ÷ speed in miles an hour) minus (3.8 × square of cylinder diameter in inches, times stroke in feet, divided by driver diameter in feet).*

Q. Can you give a table showing the calculated tractive force of engines of various driver diameters at some stated boiler pressure?

A. The following table is good for 100 gage lbs. per square inch boiler pressure:

Cylinder		Wheel Diameter, Inches			
Dia.	Str.	36	48	54	60
12	20	6,800	5,100	4,550	4,080
16	20	12,100	9,050	8,100	7,250
18	20	15,300	11,500	10,200	9,200
		48	54	60	72
14	22	7,650	6,800	6,100	5,100
16	22	10,000	8,850	8,000	6,650
16	24	10,900	9,650	8,700	7,250
18	24	13,800	12,250	11,000	9,200
20	24	16,950	15,100	13,600	11,350
18	26		13,300	11,900	9,950
28	30			33,400	27,800

Q. Describe the "A" type of Leach pneumatic track sander.

A. In the double form, as shown in Fig. 265, there is a casting attached outside of and communicating with the sand box and having independent outlets for the sand which is led through hand-lever controlled pipes to the rail. The sand may be forced through the pipes by compressed air; or if that should fail, the pitch of the pipes is steep enough to permit it to flow by gravity.

Q. Apropos of the pull required to start a train, have you any idea of the money cost of stopping one?

A. Yes. Reckoning the engine runner's time at $1.00 an hour, the fireman's 77 cents, the conductor's 80 cents,

* Goss.

and two brakemen's at 69 cents; and counting in all other expenses, it costs a railway company 24 cents to stop an average size freight train running at a speed of five miles an hour, 69 cents to stop a train running ten miles an hour, and $1.44 to stop a train traveling at fifteen miles an hour, according to computations made by operating officials. (These figures refer to stoppages on a straight level reach.)

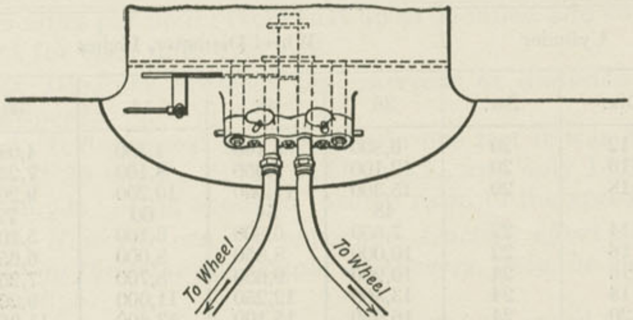


Fig. 265. Leach Sanding Device.

Q. How would it be on grades?

A. If the grade were descending, the distance required to stop would be increased, but the time and distance required to accelerate would be so diminished that the total cost would probably be lessened. On the other hand, if the grade were changed to an ascending one, the time and distance required to accelerate would be so increased as to probably increase the cost. This would also, probably, be increased still more if any curve resistances were introduced into the calculation.

CHAPTER LXVI

RESISTANCES

Q. What are the resistances which an engine has to overcome?

A. The rolling friction of the train on the track, and the sliding friction of its own parts, including that of its journals in their bearings, which is really sliding friction.

Q. What may be said about the resistances due to journal friction and pressure of wind?

A. They increase with the speed, except that there are cases where journal friction has been shown to be rather less per ton per mile at one certain speed than at others either lower or higher.

Q. Can you give some figures showing train resistances in pounds per ton of load?

A. On the P. R. R. it has been shown to be equal to the square of the speed in miles per hour, divided by 217, and plus 3; that is, for 15 miles per hour it would be $(225 \div 217) + 3 =$ about 4 pounds; at 20 miles, $(400 \div 217) + 4 =$ about 4.8 pounds; at 60 miles, $(3{,}600 \div 217) + 3 =$ about 19.5 pounds.

Q. What is the resistance due to curvature of the road?

A. About one-half pound per ton per degree of curvature.

Q. Give some idea of the resistance to train due to the wind?

A. On the U. P., with a ten-mile head wind, the coal consumption was 7,800 pounds; with the same train, distance and track, and a 20-mile wind, 11,300 pounds; being 45 per cent increase.

Q. Supposing the resistance to be in direct proportion to the wind-speed, that would have made only 4,300 if *there had been no wind; and if the wind had been from behind, no coal would have been needed. What must we conclude?*

A. Either (1) that the resistance increases with the wind velocity, or (2) that the figures are wrong.

Q. What is the resistance of a train at different speeds?

A. There are too many factors to enable a rule to be laid down. One set of experiments with a passenger train gave 12 pounds per ton at 30 miles and 16 at 60 miles an hour.

Q. About how many square feet of end surface does an ordinary engine expose to the resistance of the wind?

A. We will say for the area of the cab from 30 square feet, the boiler front 28, saddle front 5, valve front ends 5, cylinder front ends 7; total, 75 square feet.

Q. Can you give some figures concerning the resistance of trains on a straight level track on a calm day, at different speeds?

A. The experiments of Wellington, Stroudley, and Vauclain give about as follows:

RESISTANCE PER TON OF 2,000 POUNDS

Miles per hour	10	20	30	40	50	60	70
Resistance in pounds per ton of heavy passenger train (Wellington)	4.5	6	9.5	12	14	17	19
Vauclain	..	..	..	..	11	13	15
Loaded freight cars	4	5.8	9.2	11.3	12.5	..	..
Empty freight cars	6	7.5	11	14	17	..	..

Q. What may be said about the train resistance due to grades alone?

A. They can be very exactly calculated. The grade in feet per mile, times 0.38, gives the resistance in pounds per net ton.

Q. What about the resistance due to curves alone?

A. This varies greatly with train length and with the condition of the curve. Generally ½ pound per ton is allowed for each degree of curvature.

Q. What is the Barbier formula for resistance of locomotives and tenders?

A. $R = 3.8 + 0.9\ V \dfrac{v + 30}{1{,}000}$.

Q. What is the corresponding formula for resistance of cars?

A. $R = 1.6 + 0.456\ V \dfrac{v + 10}{1{,}000}$.

Q. How many horse-power would be needed for a train of 400 tons on a 3.6 grade (190 feet per mile), at 20 miles an hour?

A. For train resistance about 190 H. P.; for grade resistance about 1,340 H. P.; in all 1,530 H. P. (independent of internal friction of engine).

Q. How many H. P. for the same train at 10 miles, same grade?

A. For train resistance about 50, for grade resistance about 770; total, 820 H. P.

Q. For the same train at 10 miles on a 300-foot grade?

A. For train resistance 50; for grade resistance 1,215; total, 1,265 H. P.

Q. With what does train resistance due to speed vary?

A. With track condition, load pulled as such, number of cars in the train, independent of load, and other conditions.

Q. To what is the resistance of the engine and tender due?

A. To engine friction, head air resistance, that due to weight on engine trucks and trailing wheels, grade resistance and curve resistance.

Q. About how much is the average engine friction?

A. According to the American Locomotive Co., 22.2 lbs. per ton, or 1.11 per cent of weight on drivers.

Q. How much is the head air resistance?

A. It is equal to the cross sectional area (say 120 sq. ft.) times 0.002 of the speed in miles per hour.

Q. How much is the resistance due to the weight on trucks, trailers, and tenders?

A. The same per ton as that due to the cars.

Q. How much engine and tender resistance does the grade make?

A. 20 lbs. a ton for each per cent of grade.

Q. With what does the curve resistance to engine and tender vary, and how much is it?

A. With the engine wheel base; for each ton it is—

0.4 plus the product of the degree of the curve by the following constants:

Wheel base, ft...	5	6	7	8	9	12	13	15	16	20
Constant	0.380	.415	.460	.485	.520	.625	.660	.730	.765	.905

Q. What is the resistance of freight cars?

A. The Penna. R. R. figured it as follows:

Tons, per car..........	10	20	25	30	40	50	60	70	72
Resistance, lbs. per ton.	13.10	7.84	6.62	5.78	4.66	3.94	3.44	3.06	3.

CHAPTER LXVII

TRAIN SPEED

Q. How can the speed be calculated where the distance between points, and the time consumed, are known?

A. Multiply the miles by 60 and divide by the minutes. Thus 5 miles in 6 minutes $= 5 \times 60 \div 6 = 50$ miles an hour.

Q. What is the distance between telegraph poles in the U. S. and Canada?

A. 55 yards or 32 per mile, so that the number of poles passed in 19 seconds gives nearly the speed in miles per hour.

Q. How many rail lengths to a mile?

A. Usually $5{,}280 \div 30 = 176$.

Q. What is the quick method of approximating the speed of the train on which you ride?

A. If the rails are 30 feet long, count the number you pass in 20 seconds and you will come very near the speed in miles per hour, as $5{,}280 \div 30 = 176$, and $3{,}600 \div 20 = 180$, which is not so far out. A trifle nearer would be to count the number of rails in 41 seconds and multiply by two; thus $3{,}600 \div 41 = 87.8$; which is practically the half of 176.

Q. How else than as shown on page 457 can you determine the speed of a train in miles per hour?

A. By multiplying the driver circumference in inches by the turns per minute, and either multiplying by 0.00947 or dividing by 1,056. Thus if the drivers are 194 inches in circumference and the driver makes 150 turns a minute, the speed will be $194 \times 150 \times 0.00947 = 27.56$ miles an hour; or $194 \times 150 \div 1{,}056$ gives the same result.

Q. How do you get the circumference of the drivers?

A. Either by using a tape measure or by multiplying the measured diameter by 3.1416.

Q. Is there any other way of estimating train speed?

A. Yes; half the number of 30-foot rails passed in 41 seconds, or of 33-foot rails in 45 seconds, will give a close approximation to speed in miles an hour.

Thus, sixty 30-foot rails in 41 seconds makes 60 × 30 × 60 × 60 divided by 41 × 5,280 = 29.9 miles, practically half of 60; and sixty 33-foot rails in 45 seconds makes 60 × 33 × 60 × 60 divided by 45 × 5,280 = 30 miles (exactly half of 60).

Q. Give a table showing how many turns a minute are necessary for various train speeds and driver diameters.

A. As under:

Wheel Diam., Inches	Miles an Hour			
	10	20	25	30
50	67	134	118	201
56	60	120	150	180
60	56	112	140	168
62	54	108	136	162
66	51	102	128	153
68	49	99	124	148
72	47	93	117	140
78	43	86	108	129
80	42	84	105	126
84	40	80	100	120
90	37	75	93	112
96	34	67	84	101

Wheel Diam., Inches	Miles an Hour					
	40	50	60	70	75	80
50	268	336	403	470	504	538
56	240	300	360	420	450	480
60	224	280	336	392	420	448
62	217	271	325	379	407	433
66	204	255	306	357	383	408
68	198	247	296	346	371	395
72	187	233	279	326	400	373
78	172	215	258	301	323	344
80	168	210	252	294	315	336
84	160	200	240	280	300	320
90	150	186	224	261	279	299
96	133	168	202	235	252	269

Q. How would you get such figures for other wheel diameters and train speeds?

A. Multiply the miles per hour by 5,280; divide the product by 60 times the wheel circumference in feet (equal to the circumference in inches multiplied by 0.2618).

Q. Can you give a table showing the number of wheel turns that are necessary for various wheel diameters in making a mile run, not allowing for sliding?

A. Here is such a table, the figures rounded off to the nearest whole number:

Diam., Inches	Rev. Per Mile	Diam., Inches	Rev. Per Mile
50	403	78	258
56	360	80	244
60	336	84	240
62	325	90	224
66	306	96	210
68	297	100	201.6
72	280		

Q. Why do you give 100 when there are no 100-inch drivers?

A. To facilitate finding the turns needed for wheels of other diameters than those in the table.

Q. How do you find the needed driver speed for various wheel diameters and train speeds?

A. To get the turns per mile (5,280 feet) divide 1,680 by the wheel diameter in feet. To get turns per minute multiply the miles per hour by 28 and divide the product by wheel diameter in feet.

Thus an engine with five-foot drivers, at 40 miles an hour, would make 1,680 ÷ 5 = 336 turns a mile or 40 × 28 ÷ 5 = 224 turns a minute.

Q. Can you make a table showing piston speed in feet *per minute for an engine speed of ten miles per hour (880 feet a minute), with various wheel diameters?*

A. I give it for 24-inch piston stroke. For any other stroke, wheel diameter or train speed, the necessary piston speed will be proportionate (use 100 inches as basis):

Wheel Diam., Inches	Piston Speed, Ft. per Min.	Wheel Diam., Inches	Piston Speed, Ft. per Min.
30	443	60	222
33	403	66	201
36	369	72	185
39	341	78	170
42	317	84	158
45	295	90	148
48	278	100	132.93
51	259		
54	246		
57	233		

CHAPTER LXVIII

EXPANSION*

Q. *What is the principal advantage of steam over hot air as a motive fluid?*

A. The fact that it continually tends to expand until it attains the tension or pressure of the least resistance, without any extraneous force being expended.

Q. *In a locomotive what is the least resistance?*

A. That of the atmosphere, plus the friction in exhaust passages and stack.

Q. *What would be the minimum theoretical attainable resistance to expansion?*

A. That of a perfect vacuum, about 14.7 lbs. per square inch below that of the atmosphere, at sea level.

Q. *Why do you add "at sea level"?*

A. Because at high altitudes the atmospheric pressure is less, as proved by the barometer column or indication falling as the height increases.

Q. *Does the locomotive runner have anything to do with pressures in vacuo?*

A. Certainly; because all the functions of expansion are referred to absolute pressures; that is, those above vacuum.

Q. *When steam at 50 lbs. gage pressure is permitted to expand into double its volume, what would its gage pressure be?*

A. About $(50 + 14.7) \div 2$, above vacuum, or 32.35 lbs. absolute or 47.05 by the gage.

Q. *Is it advisable to use a high grade of expansion?*

A. Certainly, when it does not cost more to get it than it is worth.

* See also under "Horse-Power" and "Indicator."

Q. Explain that remark.

A. The higher the grade of expansion with a given initial pressure, the greater the cylinder volume required to get a given average pressure; that adds to the weight, size and cost of the engine and the trouble with cylinder condensation and shocks of reversal of stroke.

Q. Why not increase the initial pressure?

A. That has already been done; but that calls for stronger, hence heavier boilers, and increased fuel consumption, to haul the extra boiler weight and get the higher steam pressure and temperature.

Also interposes difficulties with valve and piston lubrication.

Q. About where is the best paying limit found, these days?

A. With average cut-off at about half stroke, and initial pressure of 250 lbs. by the gage.

Q. What is the usual average maximum cylinder pressure as compared with boiler pressure?

A. About 90 per cent of the latter.

Q. When is this attained?

A. In full gear only.

Q. In order to get the advantage of great power with economical cut-off, what means are possible?

A. To use either three cylinders instead of two, with maximum cut-off at half stroke, or greater cylinder diameter.

Q. What is the objection to three cylinders?

A. Mechanical complication.

Q. To increased cylinder diameter?

A. Excessive width, where there are bridges and tunnels; also, decreased traction, owing to lessening ratio of m. e. p. to boiler pressure, due to earlier cut-off; and the necessity of having extra starting ports. (See under Slide Valve.)

Q. At what points of cut-off are the best coal rates obtained?

A. At early cut-off. Thus in recent tests the best were 1.68, 1.52, 1.54, and 1.70 lbs. per i. h. p. hour, at 15 per cent cut-off (at speeds of 240, 280, 320, 360 r. p. m. respectively), while at 25 per cent cut-off they were 240 and 320 r. p. m., 1.80 lbs.

Q. To what does this point?

A. To desirability of longer cylinders to develop as much power at 15 per cent as with former 25 per cent.

Q. What is the nominal expansion ratio?

A. The quotient of the stroke length by the time of full steam.

Q. What is the actual expansion ratio?

A. The quotient of the sum of the cylinder volume and the clearance volume, by the sum of the volume filled up to the point of cut-off, and the clearance volume (all volumes in cubic inches).

Thus if the clearance is 7 per cent of the cylinder volume, the actual expansion rate for cut-off at half stroke is $1.07 \div 0.57 = 1.877$.

Q. How do you find the net work done by the steam for one piston stroke, with a given cut-off?

A. Find the actual expansion rate, allowing for clearance. Get its hyperbolic logarithm from the table. Add one thereto. Multiply the sum by the time of full steam plus the clearance in feet. From the product take the clearance. Multiply the remainder by the total initial pressure in pounds per square inch. That gives the total work done in foot pounds per square inch, on the piston. To get the negative work per square inch of back pressure in foot pounds per square inch, multiply the average back pressure in pounds per square inch by the stroke in feet. Take this produce from the total work per square inch, to get net work per square inch. Multiply the remainder by the net average piston area (deducting half the rod cross section); this will give the net foot pounds per single stroke.

TABLE OF HYPERBOLIC LOGARITHMS

No.	Hyp. Log.	No.	Hyp. Log.
1	0.00000	5	1.60944
1.2	0.18213	5.5	1.70475
1.4	0.33646	6	1.79175
1.6	0.46998	6.5	1.87180
1.8	0.58776	7.	1.94591
2.	0.69315	7.5	2.01490
2.5	0.91629	8.	2.07944
3.	1.09861	8.5	2.14007
3.5	1.25276	9.	2.19722
4	1.38629	9.5	2.25129
4.5	1.50408	10	2.30258

Q. How do you find the admission period needed for any given actual expansion ratio?

A. Multiply the clearance proportion by one less than the actual expansion ratio; take this from one; divide by the actual expansion ratio.

CHAPTER LXIX

THE INDICATOR

Q. What is a steam-engine indicator?

A. An appliance enabling one to ascertain clearly, among other things, the pressure at each point of the stroke for each end of the cylinder.

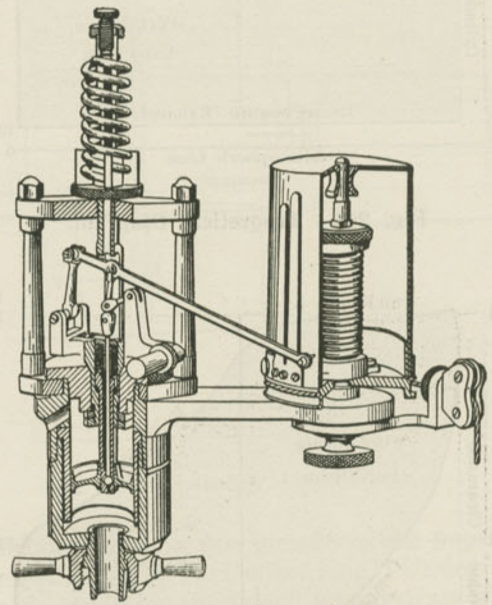


Fig. 266. Crosby Indicator.

Q. How is it constructed?

A. There is a small cylinder (see Fig. 266) which can be put in steam communication with the counterbore at either end of the cylinder (it is better to use one for each end). In this there plays accurately, but

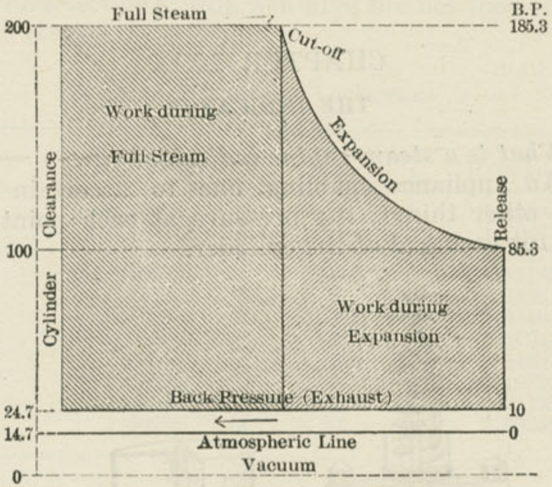


Fig. 268. Theoretical Diagram.

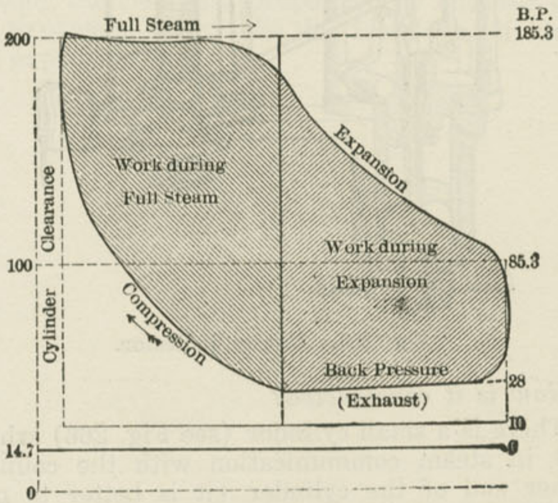


Fig. 269. Indicator Diagram.

with little friction, a very light piston, which gives vertical motion to a pencil bearing lightly on a paper strip wrapped about a barrel parallel to the indicator cylinder, and which gets an almost complete to-and-fro rotation from the crosshead. This piston is forced up by the steam pressure in the engine cylinder against a spiral spring of known resistance, away from the influence of the steam. If there were no pressure in the cylinder, this

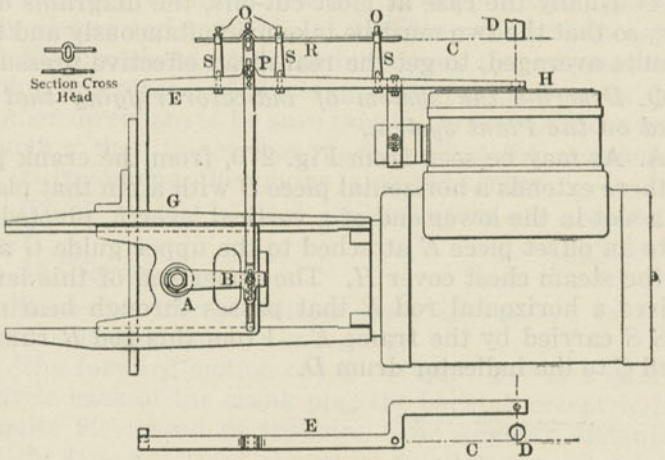


Fig. 270. Indicator Attachments.

pencil would describe on the reciprocating paper on the paper drum, a straight horizontal line. Under constant pressure in the cylinder the pencil would draw a straight line, the hight of which from the first line would represent that pressure. Under constant pressure during the entire out stroke and constant back pressure during the back stroke it would describe a rectangle slightly above, and parallel to, the first or atmospheric line, and the hight of which would represent the effective pressure. Under varying pressure, however, it describes a more or less irregular figure, called a "card" or "diagram," the hight of which at various points represents the pressure at the corresponding stroke points, while the vertical distance of the under side from the straight horizontal atmospheric line measures the back pressure. (See Figs. 268 and 269.) Where expansion begins, the upper line falls toward out-stroke end; where compression begins, it rises toward back-stroke end.

Where the two cylinder ends have different pressures, as is usually the case at most cut-offs, the diagrams differ; so that the two must be taken simultaneously and the results averaged, to get the real mean effective pressure.

Q. *Describe the system of indicator rigging that is used on the Plant system.*

A. As may be seen from Fig. 270, from the crank pin *A* there extends a horizontal piece *B* with a pin that plays in a slot in the lower end of a vertical lever *L*, pivoted at *P* to an offset piece *E* attached to the upper guide *G* and to the steam chest cover *H*. The upper end of this lever drives a horizontal rod *R* that passes through bearings *S S S* carried by the frame *E*. From this rod *R* runs a cord *C* to the indicator drum *D*.

CHAPTER LXX

VALVE SETTING

Q. *How do you get the engine on the exact center?*

A. In the case of an old engine with worn guides, by moving the wheels until the crosshead reaches the end of the travel marks on the guides. Where there are no such marks—as with a new engine or one with guides newly planed and scraped—by pinching the wheels over until the crosshead stops and reverses its movements; scribing this place and pinching again past the center, in the other direction, to be sure that the crosshead does not go further than the scriber mark. When the crosshead is at its travel end, the engine is on the center.

Q. *Which center is most convenient to set eccentric from?*

A. The forward.

Q. *Where do the eccentrics come in relation to the crank pin on that side of the engine?*

A. The forward-motion one is not quite 90° or a quarter circle back of the crank pin; the backing eccentric is not quite 90° ahead of the pin. The angular distance from the true 90° point is enough to allow for valve lap and for valve lead, and varies with the amount of lap on the valve and with the lead desired.

Q. *Where do they come in relation to the eccentrics for the same motion on the other side of the engine?*

A. Just 90° from them.

Q. *From what point are the eccentrics permanently set?*

A. From the center line of motion; not from the crank pin.

Q. *In temporary setting?*

A. From the crank pin.

Q. What are the so-called "danger marks"?

A. Marks on the guides to show extreme crosshead position at each end of stroke.

Q. Describe in detail the process of ascertaining leads with steam on.

A. All lost motion having been taken up while the engine is hot, the reverse lever is put in full forward position. The chest covers are removed and the valve placed first with one steam edge, then with the other, in exact line with the outer end-port edges. Commence on the left side. With a short ┌─┐ shaped tram lay out on the valve stem the points *A* and *B*, Fig. 271, corresponding to front and back admission, and also one for the central valve position, measuring from a prick-punch mark *C* on the cylinder top. (The distance of the two extreme points on the valve stem will be the sum of the two outside laps. Replace the chest covers. Running the engine (under steam) until the crosshead is near the back center, take a long tram *H* and from a prick point *K* on the frame, scribe an arc *E* on the main driver; at the same time, with a short tram on a prick point on the guides, making a prick point on the crosshead. Move the engine ahead until the crosshead has passed the dead point and the crosshead and guide marks again "tram." Scribe on the driver a second arc *F*, tramming with the prick mark on the frame. With dividers step off the ex-

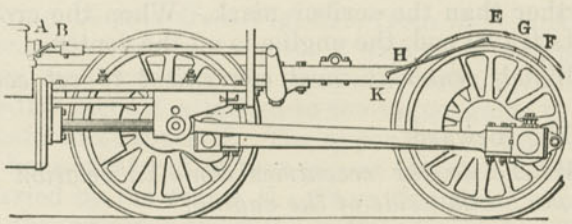


Fig. 271. Tramming a Locomotive.

act central point *G* between *E* and *F*. Putting the reverse lever in the back notch, move the engine back until the point *G* trams with *K;* the engine will then be on the back dead center. The short tram is then used to indicate on the valve stem the valve position for this center. The distance between this point and that indicating the opening position will be the lineal lead (either positive or negative) at that end.

Have a "lead card" so ruled (Fig. 272):

Gear	Center	Right	Left
F.	F.		
	B.		
B.	F.		
	B.		

Fig. 272. Lead Card.

In the space corresponding to back-up motion, left side, back center, enter the amount of lineal lead first found. With lever in full forward position, move the engine back a trifle (to take up lost motion), then ahead until *G* trams with *K*. Mark on the valve stem where the valve stem stands on the back center in forward motion; the distance between this and the "line and line" position is the lineal lead, positive or negative as the case may be. In this way, ascertain the leads (positive or negative) for both centers, both sides, in both full motions—eight lineal leads in all. Some may be positive, some negative.

Q. How may the leads thus ascertained be equalized, where one end has negative lineal lead and the other positive, in the same motion?

A. Subtract the negative lineal lead from the positive and divide the difference equally between the two ends.

Q. What is the procedure where both sides have either positive or negative lead, but in different amount?

A. Take half the sum of the two similar leads as the average for each end.

Q. What is to be done if in forward motion the valve has 1/8 inch lead on front end, 1/16 inch on back, and it is desired to equalize the two?

A. The valve must be removed back 1/16 inch, by lengthening the top eccentric blade that amount (a trifle less if the engine is new).

Q. Why this difference for a new engine?

A. Because at first there is considerable wear, and the wheels usually wear ahead in the brass.

Q. When the crank pin is on the forward center, from which port mark is the valve tram mark to be reckoned?

A. From the front.

Q. With standard (indirect) rocker arm, which eccentric follows the crank pin in forward running?

A. The forward or go-ahead.

Q. What is the general tendency of taking up lost motion on the position of the main axle?

A. As the wedge is usually behind the brasses, the effect is gradually to bring the main axle forward, hence increasing the front port opening.

Q. After an engine has been set up on her springs, with her slide valve properly set, if she went down either front or back, what effect would it have on the valves?

A. That depends on how much the engine settles. With ordinary deflection it will be difficult to note any distortion in the valve motion.

Q. Can valves be set correctly without coupling up connecting rods?

A. No.

Q. How can valves be tested for "squareness"?

A. By applying the brake and working with a good throttle in each notch of the quadrant.

Q. In setting valves, what will facilitate turning over?

A. Running the main drivers up on rollers, so that the engine need not be pinched ahead on the track to shift the valve position.

Q. When an engine has got lame after running some time, are the valve travels alike on both sides?

A. In length, yes; in position, no. One or both has got shifted so that the travel on one side of the exhaust-port center is greater than that on the other.

Q. When both valves have their travel center shifted the same amount and in the same direction from the exhaust-port center, what is the character of the exhaust coughs?

A. Both forward coughs are alike, and both rear ones, but the exhausts on the back stroke are not like those on the front.

Q. When only one valve has shifted, how are the exhaust coughs?

A. On the normal or unchanged side, front and back alike; on the other, different both from those on the normal side and from each other.

Q. Should the engine carry full steam much later on one side than on the other, what should be looked into?

A. The tumbling shaft, to see if one arm is not sprung either up or down.

Q. How can you avoid changing the length of eccentric rods?

A. By changing that of the valve stem by means of the right and left nuts. But if the stem length is already just right, it should not be altered.

Q. In changing lead by altering reach-rod length or link-hanger length, what is the effect on the squareness?

A. What is put on the go-aheads is lost on the back-ups, and *vice versa*.

Q. What is one cause of a valve getting too much travel after being rightly set?

A. Opening out of an eccentric strap by reason of one of the bolts losing a nut.

Q. Is it possible to make the valves square as regards both cut-off and admission?

A. It is possible, but not very easy with most valve motions.

Q. Suppose that it entails too much difficulty to square the valves both for lead and for cut-off, which way should they be squared?

A. For cut-off, because it is the amount of steam that is used in the cylinder up to the point of cut-off that causes the draft and makes the sound of the exhaust.

Q. How can the cut-off be equalized in the ordinary slide valves and eccentric?

A. By varying the angular advance of the eccentric, or the length of the eccentric rod.

Q. Where the cause of unequal cut-off front and back is found to be in the link saddle, what should be done?

A. An adjustable link saddle should be used; or temporary saddle bolts used and the saddle moved forwards and backwards until the cut-off is square.

Q. Suppose that when the engine is moved ahead slowly with the cylinder cocks open, steam is let into the front end of the cylinder before the piston has reached the center, or that the back cylinder cock shows steam too late, of what is that the sign?

A. That the eccentric rod is too long.

Q. Suppose that with the engine moving ahead slowly with the cylinder cocks open, steam is found to be too late on the front end and too soon on the back; of what is that a sign?

A. That the eccentric rod is too short.

Q. Will changing the length of one eccentric blade effect the other motion?

A. Yes.

Q. At what cut-off will this be most noticeable?

A. At short ones.

Q. If there is any difference in the lateness of cut-off in the two ends of the cylinder, in which should it be the later?

A. In the crank end, on account of (1) the smaller effective piston area; (2) the angularity of the connecting rod.

Q. What effect has the boiler expansion on the valve gear?

A. To pull back the quadrant and raise the links, hence increasing the lead on the forward and decreasing it on the back-up eccentrics.

Q. In setting an engine cold how is allowance made for boiler expansion?

A. The back-up eccentrics are given more lead than the go-ahead.

Q. What does it mean when one says that the valves of an engine are set "line and line" forward and "7/32 of an inch blind" on the back motion?

A. Valves are "line and line" when in full forward gear they have no lead; that is, at the beginning of the stroke the valve edge coincides with the steam-port edge. "Back motion 7/32 inch blind" means that in full throw in back gear, the valve must travel 7/32 of an inch after the piston stroke has begun, before the steam port begins to open.

Q. What is the object of such setting?

A. To favor the forward motion at the expense of the backward.

Q. What is the "clock" rule for setting valves?

A. For valves with outside admission with a rocker, or for valves with inside admission without a rocker, put the crank pin at a point corresponding to "3 o'clock" and the eccentrics at "1 and 5 o'clock" with the rods uncrossed.

For inside admission valves with a reversing rocker, the eccentrics are to be set with the crank pin at a point corresponding to "3 o'clock," the eccentrics at 7 and 11 with rods crossed.

Q. How may the rocker arm be brought into an exactly vertical position in valve setting?
A. By scribing on the end of the shaft, with the same center as the shaft itself, a circle of exactly the same diameter as the hole of the pin in the top of the arm; hanging a thin cord by two weights over the pin, and bringing the arm into such a position that this cord, acting as a double plumb line, will just touch both sides of the circle on the shaft end.

Q. Is it best to set the forward motion eccentric or the backward?
A. Usually the forward is the most easy to get at, hence should be the first one set; as it can be more readily reset in case the backward one has been so set as to affect the lead in the forward motion.

Q. When is it not practical to equalize the cut-off of each end of the cylinder by changing the position of the saddle stud?
A. Where the links are case-hardened and the saddle bolted rigidly to the link.

Q. What other way is there to equalize the forward motion?
A. To change the length of the backing motion rods, thus affecting the equality of the lead as well as the cut-off in back gear.

Q. In any other way?
A. By giving up equality of lead in both forward and backward motion for equality of cut-off.

Q. Should a piston valve be long or short?
A. As long as possible, in order to give short steam passages.

Q. What is one of the advantages of the piston valve?
A. It does not require balancing, as does the flat D valve.

Q. Is steam most usually admitted at the center or the ends of a piston valve?
A. At the center.

Q. What are the advantages of this?
A. That most of the cooling surface and the valve chamber come in contact with exhaust steam only; and the stems need be protected against exhaust pressure only; also, the joints with the valve-chest heads are more readily kept tight.

Q. Does it make any difference in the setting of the valve whether the steam is taken in at the center or at the ends?
A. Yes; the movement is just the reverse.

Q. How may the opposite motion be obtained?
A. Either by placing the eccentrics on the axle opposite from the usual position, or by doing away with the rocker arm and connecting the valve rod direct to the link block or a connection from this latter.

Q. If the eccentrics and crank pin are together and there is a rocker arm to reverse the motion, has the piston valve inside or outside admission?
A. Outside.

Q. If the eccentrics and the crank pin are together and there is no rocker arm, or the motion is direct, has the valve inside or outside admission?
A. Inside.

Q. If there is a rocker arm to reverse the motion, or the eccentrics of the crank pin are opposite, which kind of admission has the valve?
A. Inside.

Q. Is valve setting on the road a usual occurrence?
A. No.

EXHAUST COUGHS

Q. Of what is it a sign when both exhausts on one side are heavier than those on the other?

A. That that side has longer valve travel than the other.

Q. What is the remedy?

A. To shim up the tumbling-shaft box on the "heavy" side, or lower that on the "light" side; or both.

Q. What would cause this difference in the cough?

A. Among other causes (1) unequal length of link hangers, (2) tumbling-shaft arms sprung, (3) engine low on one side, (4) truck spring broken, (5) loose bolt in eccentric strap, allowing it to open.

Q. If there are three loud and one light cough when hooked up in forward motion, but all are alike when in the corner, what is probably wrong?

A. A back-up eccentric has slipped.

Q. Which eccentrics are usually the hardest to get at?

A. The back-up.

Q. If the exhausts run one loud and one light alternating, what may be looked for?

A. Broken link lifter, slipped eccentric, loose rocker-arm pin, loose rocker box, loose nuts on eccentric-strap bolt.

Q. If you had three ordinary exhausts followed by one loud one?

A. Slipped eccentric blade, loose or cut blade pin, loose valve-rod key.

Q. In the first instance, how can you determine which eccentric has slipped, if you think this is the case?

A. If hooked up in forward motion, it would probably be the back-up eccentric that caused the light coughs.

Q. What may suddenly cause an irregular exhaust?

A. A loose eccentric-strap bolt or blade bolt; loose valve-stem key; slipped eccentric, or broken valve yoke.

Q. If the exhaust gets out of square on the trip, what does it indicate?

A. Slipped eccentric, loose strap bolt or strap rods, broken valve yoke, or bent rocker arm.

Q. Is there anything else not mentioned that would affect the sound of the exhaust?

A. Loose exhaust pipe, one exhaust tip gone (where there are by rights two), bent lifter arm, loose rocker box.

*Q. Where forward motion is taken from the lower link half of a Walschaert gear, how would you move the valve ahead in forward motion?**

A. Lengthen the eccentric rod.

Q. In backward motion?

A. Shorten it.

Q. Where forward motion is from the upper link half, how would you move the valve ahead in forward motion?

A. Shorten the eccentric rod.

Q. In backward motion?

A. Lengthen it.

Q. How can the lead of the Walschaert gear be increased?

A. By either reducing the lap or altering the distance between the connecting points of the lap-and-lead lever (making the upper arm proportionately longer).

* See under "Valve Gears."

CHAPTER LXXI

VALVE GEARS

Q. What is the valve gear?

A. The mechanism by which the slide valves are operated by the driving axle (usually the main one).

Q. Under what two principal classes may locomotive driving gears, such as are now used, be divided?

A. Into (1) link motion gears and (2) radial gears.

Q. What is a link-motion gear?

A. One in which the valve receives motion from a piece driven by a strap, the two ends of which are actuated by eccentrics on the driving axle.

Q. What is a radial gear?

A. One in which the valve stem receives its motion (1) from a vibrating member, as the connecting rod, or (2) from a reciprocating one, as the piston rod, instead of from a rotating one, as an eccentric.

Q. Do radial gears employ links?

A. Some do; some do not.

Q. Why is the link in the ordinary valve gear made curved?

A. Because if straight it would throw the valve out in its travel.

Q. What are the requisites of a locomotive valve gear?

A. It must be capable of driving the engine in either direction, forward or backward, of changing the direction of motion in a moment from full speed one way to full speed the other; and of giving all shades of power from nothing to maximum, in either direction; besides which it must be able to work steam with great economy by expansion, where this is required, and with great power without regard to economy where occasion calls for this.

Q. Which of the two classes of valve gears—link or radial — is the more common with American locomotives?

A. The link motion is almost universal in this country, and the principal one employed in other countries also.

Q. What was the drop-hook motion?

A. As seen in one form in Fig. 273, an arrangement in which throwing the lever forward held the backing hook out of reach of the rocker pin and let the forward one drop in. There was a starting bar to move the valve

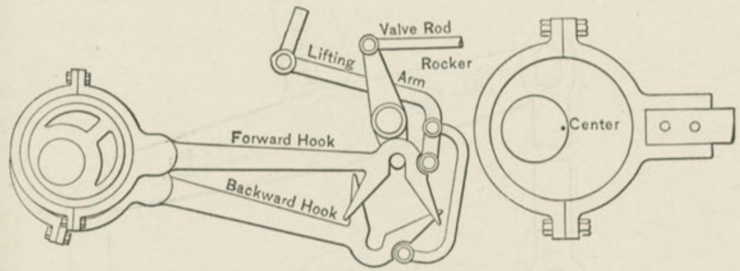


Fig. 273. Hook Valve Motion.

until the hook dropped in, or to enable working the engine entirely by hand.

Q. What was the V hook?

A. A reversed arrangement of Stephenson's fork motion; no starting bar being necessary, the V's settling on the pin and resting in the center. (See Fig. 274.)

Q. What was the immediate forerunner of the link?

A. The combined hook, Fig. 275, being two V hooks joined at the points.

Q. What is its principal disadvantage?

A. It could be worked only in full gear.

Q. Its advantages?

A. Few parts; only one rocker pin for both motions.

Q. What is one essential fault of valve gears operated by eccentrics or cranks?

A. The steam distribution is disturbed by the eccentric or crank being attached to the driving axles, that do not remain in line with the valve mechanism, which latter is attached to the frames vibrating on springs.

THE SHIFTING LINK

Q. In the most common form of American locomotive, what is the character of the link?

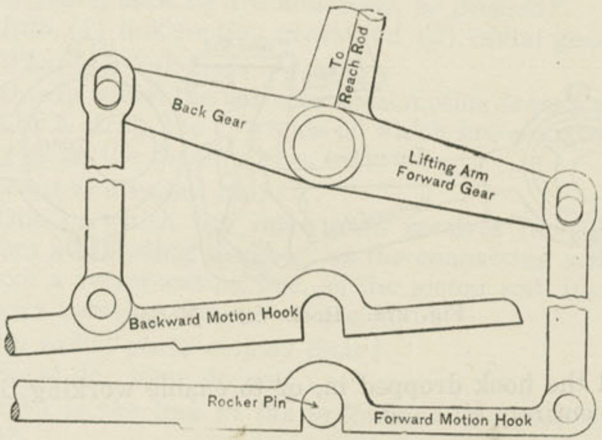


Fig. 274. Hook Valve Motion.

A. It is a curved piece of metal, having in it a slot of circular curvature, with its concavity toward the eccentric. In this slot plays accurately a block, which may pass from one end to the other thereof. This block is attached to the lower arm by a pin which serves as a pivot. The two eccentric-rods are attached to the ends of the link by pins serving also as pivots. The link itself has across it, as shown in Fig. 276, a plate to which is attached a pin, by which the link is hung by a nearly vertical link hanger to the lower end of a lifting arm borne

on a horizontal shaft parallel with the axle. This lifting-arm, carrying with it the link, may be raised and lowered by a nearly vertical arm, connected by a nearly horizontal reverse rod to a nearly vertical reverse lever in the cab. Moving the upper end of the reverse lever forwards

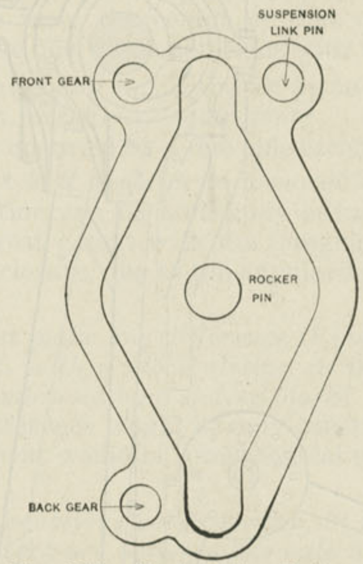


Fig. 275. Hook Valve Motion.

and backwards lowers and raises the link. The weight of the link and of otherwise unbalanced parts of the gear is counteracted by a spring. In England these same otherwise unbalanced parts are counteracted by a weight.

Q. What name is given to this link motion?

A. The Stephenson or shifting-link gear.

THE STEPHENSON MOTION

Q. How long has this motion been used on locomotives?

A. Since 1843, at which time it was invented by Howe, and applied to the locomotives of Robert Stephenson & Co.

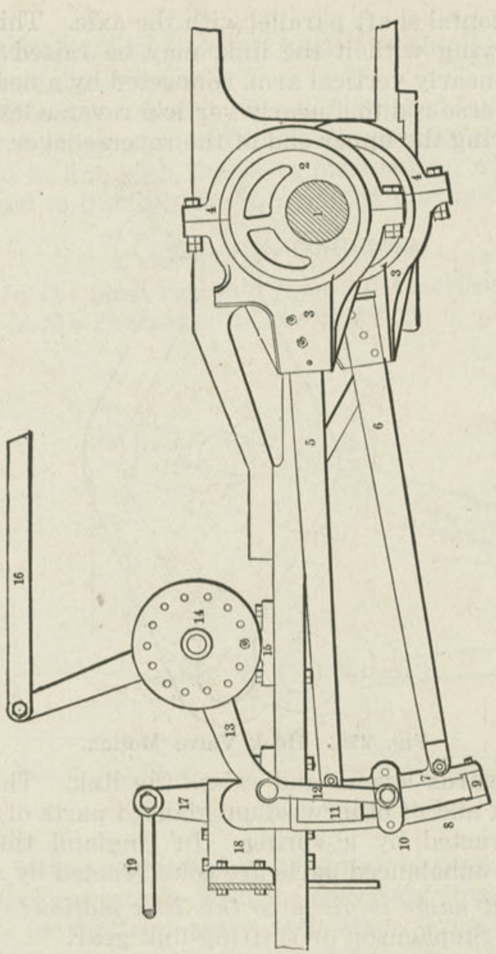


Fig. 276. Valve Motion Work, Shifting Link.

1. Axle. 2. Eccentric. 3. Eccentric-strap, Front Half. 4. Eccentric-strap, Back Half. 5. Eccentric-rod, Inside (Forward Motion). 6. Eccentric-rod, Outside (Back Motion). 7. Reverse-link, Back Half. 8. Reverse-link, Front Half. 9. Reverse-link, Filling-piece. 10. Reverse-link Saddle. 11. Sliding-block. 12. Link-lifter. 13. Reverse-shaft. 14. Counterbalance-spring. 15. Reverse-shaft Bearing. 16. Reverse-lever Rod. 17. Rock-shaft. 18. Rock-shaft Box. 19. Valve-rod.

Q. *Has it been much changed since its original invention and application?*

A. No.

Q. *What is the radius of a link?*

A. A link is usually a segment of a circle. Its radius is the distance from the center of that circle to the periphery of the one which coincides with the link curve.

Q. *To what does a link operated by two eccentrics correspond, as a mechanical equivalent?*

A. To one operated by a movable eccentric.

Q. *In what is it superior to a movable eccentric?*

A. Its motion can be accurately adjusted so as to do away to a great extent with the irregularities in cut-off and exhaust closure, due to the angularity of the connecting rod.

Q. *Would it make any difference if instead of the link being slotted, with a block sliding in its slot, it was a simple bar, embraced by a sliding block?*

A. The difference would be only constructive; the latter arrangement would be a mechanical equivalent of the former.

Q. *Are link-motions very common, in which, when the eccentric centers are between the axle and the link, the rods are crossed?*

A. No; except with independent cut-off motions.

Q. *What special advantage would there be in a crossed-rod link motion?*

A. That the engine might be stopped with the link in mid-gear, which is never possible with the ordinary open-link motion; in which the valve is of necessity open a slight amount at mid-gear.

Q. *Are the eccentric rods of the Stephenson valve gear ever so arranged as to be crossed instead of "open" or uncrossed, when both eccentrics are on the same side of the axle as the link?*

A. Yes; in some engines they are arranged so as to be as shown in Fig. 277, in which *F* is the center of the forward eccentric sheave, and *B* the center of the backing eccentric sheave; *A* being the axle center, and *M* the

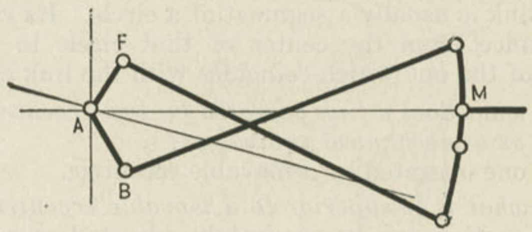


Fig. 277. Stephenson Link, Crossed Rods.

lower rocker pin. In Fig. 278, the ordinary method of arrangement in American locomotives, it will be seen that when both eccentrics are on the same side of the axle as the link, the rods are not crossed.

Q. What is the effect of raising the link so that the link block and rocker pin will be below both the eccentric rods?

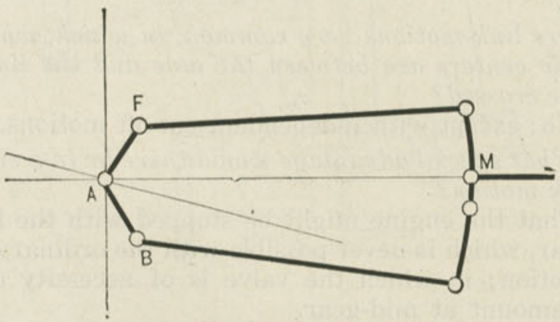


Fig. 278. Stephenson Link, Open Rods.

A. If the links are uncrossed, the effect will be to drive the block almost entirely with the lower eccentric rod.

Q. What is the effect of lowering the link so that the block and rocker pin will be above both the eccentric rods?

A. If the links are not crossed, the effect will be to drive the block almost entirely with the upper eccentric rod.

Q. What is the effect upon the valve motion of placing the reverse lever in such a position as to bring the block at the center of the link?

A. The motion of one eccentric and its rod will counteract that of the other, and either at or near the center of the link-slot or at "mid-gear," the block will have no motion either way, no matter which way the eccentrics run; or to put it another way, the valve will be in such a position as to run the engine either way.

Q. What name is applied to that position of the gear when the rocker pin is half way between the end of the eccentric rod and the center of the link slot?

A. Half gear.

Q. What name is given to that position of the gear when the rocker pin is at the center of the link slot?

A. Mid-gear.

Q. What name is given to that position of the gear when the block and rocker pin are at the end of the link slot?

A. Full gear.

Q. With this ordinary link motion, how late can steam be cut off the cylinder?

A. The admission is fairly good up to about seven-eighths stroke, although after five-eighths it is such as to give best duty; this depending of course on the lap of the valve as well as on the travel given it by the gear; the less lap giving the later possible cut-off.

Q. What is the earliest cut-off at which a locomotive can be worked by this motion?

A. There is poor admission as early as one-sixth, but fairly good admission as early as one-fourth stroke; although even that early there is wire-drawing.

Q. How does this motion affect the point at which release or exhaust takes place?

A. The greater the valve travel the later the release or exhaust.

Q. With this motion, and open rods, how does the lead vary with the link position?

A. The lead increases with the expansion; that is, the earlier the cut-off the greater the lead.

Q. With this motion, as ordinarily made, but with crossed rods, how does the link position affect the lead?

A. The greater the expansion, or the earlier the cut-off, the less the lead.

Q. Can this motion be so constructed that the lead will be constant with varying grades of expansion?

A. Yes; if the link be short, the eccentric rods long, and the two eccentrics properly set with different angles of advance, the lead variations become practically nothing.

Q. In this motion, what must be the link-slot radius?

A. Equal to the eccentric-rod length.

Q. At which end does the angularity of the connecting rod end to make cut-off later than the average or desired amount?

A. At the forward end.

Q. How then can the link be arranged to equalize the gear?

A. By giving greater travel for the forward stroke.

Q. What practical difficulty is there in the way?

A. That as the link block moves upon a fixed arc while the link rises and falls, for each crank rotation the link will slip backward and forward a certain distance upon its block. Should this slip be very great with the engine linked up in any particular position, and should the engine run a long time in that gear, the link faces would

be worn, and there would be lost motion and irregular distribution owing to this wear and lost motion.

Q. At what point is the slip the least?

A. Near the point of suspension.

Q. To what does this point in designing a link motion?

A. To the fact that if desired to have a minimum of slip at a certain point of suspension, the saddle stud should be as nearly as possible over that point.

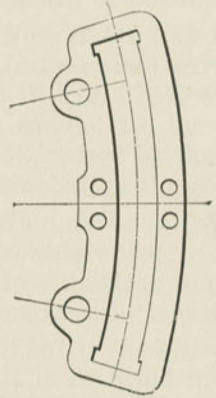


Fig. 279. Usual Link.

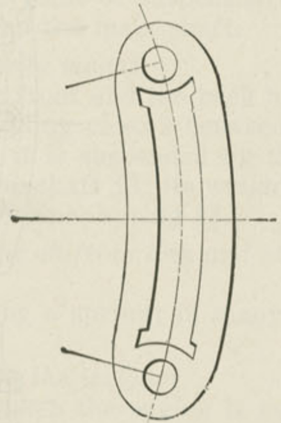


Fig. 280. Open Link.

Q. What is an "open link"?

A. One in which the eccentric pins instead of being back of the link as in Fig. 279, are as in Fig. 280.

Q. What are the peculiarities of the open as compared with the ordinary link?

A. The eccentric pins move a greater distance than the greatest travel of the link-block, and for this reason there must be a larger eccentric circle to get a given valve travel.

Q. To what class of locomotives is this adapted?

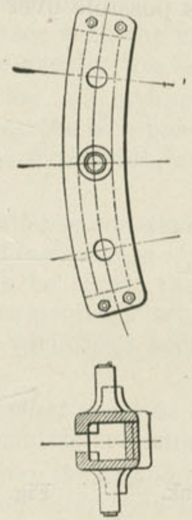
A. To those where there is no rocker, as in British practice.

Q. How is the open link usually hung?

A. From the upper eccentric-rod pin; and with the tumbling shaft below the central line of motion.

Q. What is a box link?

A. One in which, as in Fig. 281, the pins are in the line of the slot itself.



Figs. 281 & 282.
Box Link

Q. What are the disadvantages of the box link?

A. It is mechanically difficult to construct.

Q. Where is the box link best adapted?

A. Where short eccentric throw is desired.

Q. Why?

A. The valve travel is always about the same as the eccentric-circle diameter.

Q. Can the box link be used with advantage in places where the ordinary link with points of suspension back of the link is now used?

A. Very seldom, by reason of the excessive slip which it gives in such positions; and in such cases it is usually made a box in construction, but with the stud beyond the link arc.

Q. How about the use of the box link in place of the open link?

A. It is usually given the point of suspension within the link arc or between it and the main shaft.

Q. How is the link ordinarily made?

A. In two main parts, the front and the back half (as shown in Fig. 276), with a filling piece 9 between them, and a saddle, 10, by which it is suspended by the link lifter 12, raised by the reverse-shaft 13; its weight being counteracted by the counterbalance spring 14.

Q. How is the weight of the shifting link and attached parts counteracted?

A. In American engines, by a spring; in many European engines, by a weight.

Q. What is the objection to the weight?

A. It is in rapid motion when the engine is running, and sometimes is slung from its position, damaging the valve-gear or other parts.

Q. Where a flat spiral spring is used to balance the link weight, how is its tension regulated?

A. By turning the case and adjusting the bolt in any one of the holes shown in a circle in the illustration, Fig. 276.

Q. Suppose that we have a shifting-link motion in which the greatest slip comes in full gear, and it is desired to reduce the slip; how may this be done?

A. In four ways; (1) by increasing the angular advance; (2) by reducing the valve-travel; (3) by increasing the length of the link; (4) by shortening the eccentric-rods.

Q. Are link motions very common in which, when the centers of the eccentric are between the axle and the link, the rods are crossed?

A. No, except with independent cut-off motions.

Q. What is the result of increasing link length?

A. To lessen increase of lead toward full gear, and increase slip toward mid-gear.

Q. What end of the link is generally connected to the go-ahead rod?

A. The upper end.

Q. What is the character of the motion that the link gets?

A. Not only a rocking but a reciprocating or to-and-fro motion; the latter being what moves the slide valve.

Q. What is the disadvantage of heating links and putting them in cold water to close them?

A. It is apt to set up injurious strains therein.

Q. How can the reversing action of the link be shown by simple skeleton sketches?

A. As in Fig. 283, where the link is down and the engine in forward motion, and in Fig. 284, where it is in back-up gear. In Fig. 283 the forward port is uncovered, and the piston driven backward for running ahead; in Fig. 284 the back port is open and the piston driven forward for backing.

In both figures *R* is the rock-shaft center, *U* the upper rocker-pin center, *B* center of the lower rocker pin and of the link block, and the heavy curve *L* the center arc of the link. The vertical lines through the rocker pins and the shaft center aid in showing relative centers and center-line positions.

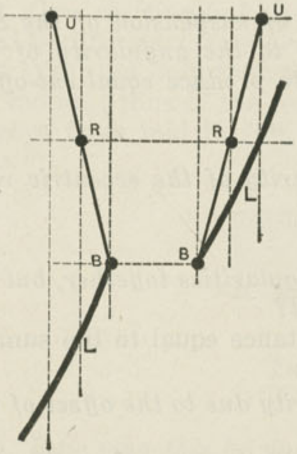
Q. How does raising the link from central block position give more valve-travel?

A. This is best seen from the skeleton sketch, Fig 285, in which *L* is the link, *B* the block, and the various dots show successive relative block positions with relation to

the link in forward motion. The proportionate amounts of travel may be indicated by the distance *AB*, *AC*, etc. With the block in the link center the valve gets no motion; in successively removed block positions the travel is greater and greater.

Q. Why is the Stephenson link saddle offset?

A. To get as nearly as possible equal cut-off and lead at both ends.



Figs. 283 and 284.
Reversing Action of Link.

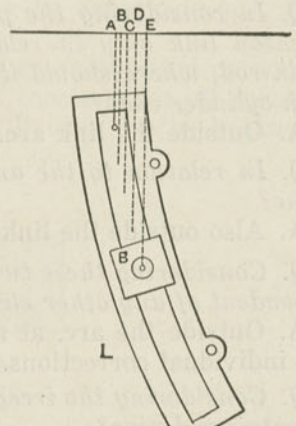


Fig. 285
Stephenson Link.

Q. How else could the valve motion be equalized?

A. By raising the saddle above the link center.

Q. Is this ever done?

A. No; there are practical objections thereto.

Q. When does a link slip most?

A. In full gear.

Q. What are the principal means of lessening slip?

A. Giving more angular lead; lessening travel; lengthening the link; shortening the eccentric rods.

Q. How does setting the link-hanger stud back of the link arc equalize cut-off?

A. It causes late cut-off at the forward port. This is brought about by locating the stud so that it causes the link to occupy a different position for the two cylinder ends; being lower down on the rocker pin for the backward stroke, thus effecting later cut-off. The effect is precisely the same as if the reverse lever lowered and raised the links at the proper time to cause an equalized cut-off.

Q. In considering the point of suspension of the Stephenson link only in relation to the angularity of the main rod, where should it be to produce equal cut-off in both cylinder ends?

A. Outside the link arc.

Q. In relation to the angularity of the eccentric rods alone?

A. Also outside the link arc.

Q. Considering these two angularities together, but independent of any other element?

A. Outside the arc, at a distance equal to the sum of the individual corrections.

Q. Considering the irregularity due to the offset of the eccentric-rod pins?

A. Inside the arc, at a distance greater than the sum of the two distances just mentioned.

Q. Taking all three into consideration?

A. Where we now find it—somewhat back of the link arc.

Q. What is the reason that with the ordinary link motion the valve lead is increased as the reverse lever is brought toward the center?

A. The straps being moved back on the eccentric produces the same effect as though the latter were moved ahead on the shaft—which is well known to increase the lead.

Q. What influence has the length of the eccentric blades on the increase of lead in hooking up?

A. The longer the blades, the less the increase in lead in hooking up.

Q. How may the eccentric be moved on the shaft a very trifle without the difficulty of having it draw back in the old key-marks?

A. By having a key with an offset; its cross-section being as shown in Fig. 286.

Q. Can shifting-link motions be arranged with constant lead for various gears?

A. Yes; but only for various gears of one direction of the motion; thus if the lead is constant for all forward notches from mid to full, it will vary on the backward ones.

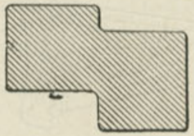


Fig. 286.
Offset Key.

Q. How may this be done with the ordinary open-rod shifting-link motion?

A. By giving the forward eccentric more angular advance than the backing one, of course experimenting with the angular advance given until the lead is constant at every position. In this case the lead opening will be constant for all forward gear positions, and will diminish from mid-gear to full back gear.

Q. What would be the effect of giving the backing eccentric of this open-rod shifting-link motion more angular advance than the forward?

A. To give constant lead for all backward gear positions, and varying lead for all forward—this of course implying that the proper excess of angular advance was given.

Q. Is it possible to design a link motion which will reduce lead as the links are drawn up?

A. Yes. With all indirect motion engines the eccentric rods are open when the pin is on the forward center. If they are crossed when the pin is in that position, lead will decrease as the links are drawn up.

Q. Under what circumstances is the Stephenson link motion gear satisfactory?

A. Where the eccentric rods are fairly long and straight, particularly in the old-type eight-wheel engines.

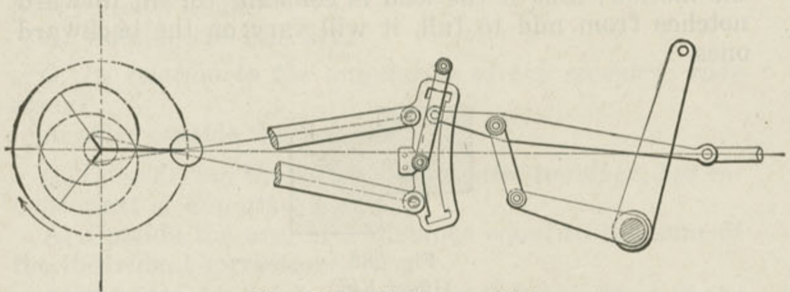


Fig. 287. Stationary Link.

Q. What is the result of having a very large sheave in the Stephenson gear?

A. This, together with the lateral play that accumulates in the boxes and with the shortness of the rods, produces a binding effect on the straps and the eccentrics; there is also trouble with breakage of the supports for hanging the links.

STATIONARY LINKS

Q. Would the same effect as with a shifting link be produced if the link block were raised and lowered and the hight of suspension of the link remained the same?

A. Valve motions are made, in which the link is not

raised and lowered, but the block is; but in this case the convexity of the link-slot curvature is toward the axle and eccentric, instead of the concavity being so turned. One such motion, known as the Gooch gear, is outlined in Fig. 288, with the links uncrossed. In *B* is the center of the backing eccentric; *F* that of the forward eccentric; *S* being the saddle and the point of suspension of the link; *P* the block attached to the radius-rod *PV*, that is

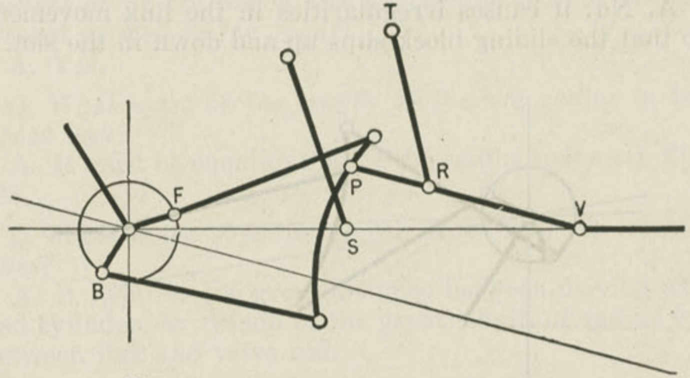


Fig. 288. Gooch Valve Gear, Open Rods.

raised and lowered by the hanger *RT*, which is carried by a bell-crank lever moved by a hand lever in the same way as with the Stephenson gear.

THE GOOCH GEAR

Q. Can the links of the Gooch or stationary-link motion be crossed?

A. Yes; they are so shown in Fig. 289 (in which the hangers of both the link and the radius rod are omitted).

Q. How about the lead in this stationary-link motion?

A. It is constant for all gears; although the lead angle increases just as much as with the shifting link.

Q. How about the lead with this motion, if the rods are crossed?

A. It has constant lead both with crossed and with uncrossed rods.

Q. In the Gooch motion, where is the point of connection of the suspension rod which carries the link itself, usually placed?

A. Back of the curve, toward the axle.

Q. Is this desirable?

A. No; it causes irregularities in the link movement, so that the sliding block slips up and down in the slot.

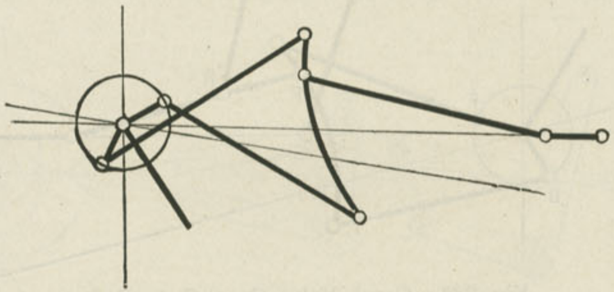


Fig. 289. Gooch Valve Gear, Crossed Rods.

Q. May this trouble be removed?

A. Partly by placing the suspension point of the link near the center of the chord or straight line joining the slot ends.

Q. To what class is the stationary-link motion, Fig. 287, best adapted?

A. To those having no rocker.

Q. Is the stationary link common in American practice?

A. No; because our engines are built with steam chests on top of the cylinders instead of on the side as in Europe.

Q. In the Gooch gear, how should the suspension of the radius rod be placed, to permit the least slip of the block in the link slot?

A. So that the vertical movement of the point at which this suspension rod is attached to the radius rod, shall be as little as possible; best effected, in practice, by a suspension rod having a radius equal to the radius rod length.

Q. Are the facts concerning the points and manner of suspension of the Gooch link and radius rod correct for crossed as well as for open?

A. Yes.

Q. What must be the length of the slot radius in the Gooch link?

A. It must be equal to that of the radius rod, as in Fig. 288.

Q. What is the objection to the Gooch gear for locomotives?

A. It requires too great distance between driving axle and cylinder, by reason of the great length of radius rod between link and valve rod.

Q. How long has the Gooch motion been known?

A. About as long as the Howe or Stephenson shifting link.

Q. Has it met with much favor?

A. Yes; throughout Great Britain and the continent of Europe.

Q. What is the objection to both the Stephenson and the Gooch gears?

A. That as the center of motion of the valve moves farther and farther from the center of the driving axle, as the Stephenson link or the Gooch radius rod is raised or lowered, the steam distribution is different in the forward stroke from what it is in the return or backward stroke.

Q. What difference does crossing the rods of the Gooch link make?

A. None.

Q. What is the advantage of not crossing rods in the Stephenson and the Allan motions?

A. There will be no reduction of lead in linking up, as crossed rods reduce the part opening at the earlier cut-off and cause unfavorable wire-drawing.

Q. What is the advantage of the Gooch link motion over the Stephenson?

A. The link block and radius bar are lighter to lift in reversing than the link.

Q. What is the disadvantage?

A. The sweep of the radius bar in its raising and lowering is obstructed by the front driving axle when the main connection is made to the second or third pair of wheels.

THE ALLAN GEAR

Q. By what style of valve motion may this difference in steam distribution in forward or backward motion be obviated?

A. By one having a straight link slot, and in which there is a link and a radius rod, the former being raised as the latter is lowered.

Q. What name is given to such a gear?

A. The Allan or the Trick; Allan and Trick having invented it independently, the former slightly before the latter. It is shown in outline in Fig. 290, with open rods.

Q. Can this link motion or gear be used with crossed rods?

A. Yes.

Q. What is the effect of the link position upon the lead, with the Allan gear?

A. With crossed rods, the lead decreases with increase of expansion; that is, the earlier the cut-off the less the lead.

Q. Is the variation of the lead greatest in the Allan or in the Stephenson gear?

A. In the Stephenson.

Q. What is one peculiar advantage of the Allan motion?

A. Its parts are more perfectly balanced than those of the Stephenson, and it dispenses with the counterweight or spring peculiar to the latter.

Q. What is the objection to the Allan gear?

A. The great distance between the steam chest and the driving axle, by reason of the long radius rod required.

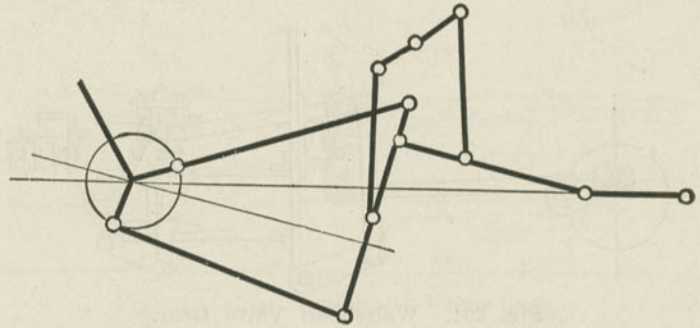


Fig. 290. Allan Valve Gear, Open Rods.

Q. What is the advantage of the Allan valve motion as compared with the Stephenson and the Gooch gears?

A. As the link and valve rod are both moved in opposite directions, the angularities and distances in either direction are reduced to one-half those in either of the other motions, with an increase of lead amounting to about one-half of that obtained by the Stephenson gear in linking up.

Q. What common point have the Stephenson, Gooch, and Allan motions?

A. All are based on the two eccentrics being set in symmetrical relations to the line of motion, one governing the forward and the other the backward movement of the engine; the three differing principally from one another only in the matter of lead.

SINGLE ECCENTRIC GEARS

Q. Are two eccentrics necessary to produce the backing as well as the forward motion?

A. No; there are many engines which have but one for each valve.

THE WALSCHAERT GEAR

Q. What is the Walschaert link motion?

A. One in which there are two distinct movements; one from a single eccentric, and the other from the crosshead; the eccentric usually being a return crank from the main crank pin as shown in Fig. 291, with its center at right angles to the crank arm. The link swings from a fixed axis, and its arc has a radius equal to the radius-rod link. From the end of a short arm and bolted to the crosshead pin, is a union bar, pinned to one end of the "combination-lever," by the aid of which the eccentric and crosshead motions are so combined that the crosshead motion gives the angular advance which the eccentric would not, and thus gives the valve constant lead.

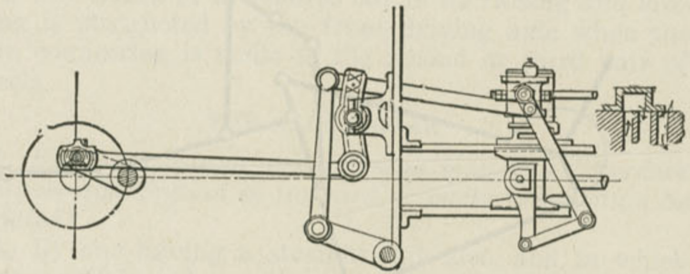


Fig. 291. Walschaert Valve Gear.

Q. What does the crosshead connection impart?

A. The motion for lap and lead at stroke end, when the link is in central position.

Q. In mid-gear with the reverse lever in its central notch, what motion do the valve and the radius bar get with the Walschaert gear?

A. None.

Q. What is the action of the eccentric in the Walschaert gear?

A. Practically the same as though it were two eccentrics, one for the forward and one for the backward motion, diametrically opposite each other. The angle of advance in the Stephenson motion is taken care of by the main crank in the crosshead connection. The latter motion being constant, the lead remains the same at all points of cut-off.

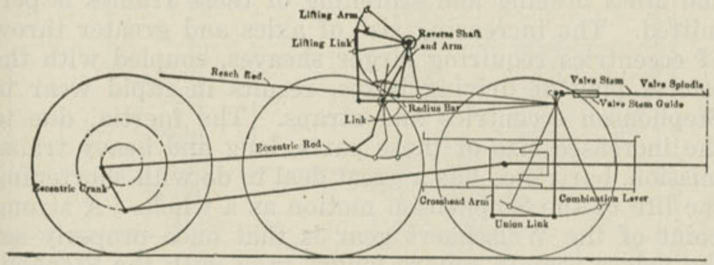


Fig. 292. The Walschaert Valve Gear.

Q. In setting the eccentric crank of the Walschaert gear, from which end of the link should the forward motion be taken?

A. From the lower end; the eccentric crank will follow the main crank for an inside admission valve, and lead it for an outside valve.

Q. Where should the connecting point of the radius bar and the combination lever be?

A. Above that of the valve-stem connection, for inside admission, and below it for outside admission valves.

Q. Name the principal parts of the Walschaert gear?

A. Referring to Fig. 292, the eccentric crank, the eccentric rod from this to the link, the radius bar from the lifting link to the combination lever, the crosshead arm, union link between this and the combination lever, the radius bar connecting this latter with the lifting link, the lifting frame connecting this with the reverse shaft and arm and the reach rod from the reverse arm to the cab.

Q. State some of the reasons for employing Walschaert gear?

A. It is lighter and more accessible for adjusting, cleaning, and oiling than the Stephenson gear must necessarily be on a large engine. By removal of the valve motion parts from between the main frames more substantial cross bracing and stiffening of these frames is permitted. The increasing size of axles and greater throw of eccentrics requiring larger sheaves, coupled with the lateral play of driving boxes, results in rapid wear to Stephenson eccentrics and straps. The inertia, due to the increased size of these parts, long and heavy transmission, bars, etc., has a great deal to do with shortening the life of the Stephenson motion as a whole. A strong point of the Walschaert gear is that once properly set the valves remain square longer than with the Stephenson. This goes far to offset the probable better general steam distribution obtained by the latter motion, for if the valves do not remain as set, the economy from that setting is lost. Theoretically, the constant lead of the Walschaert gear is a distinct disadvantage when applied to a locomotive which is to be operated at any considerable range of speed; but in practice this objection is more than offset by the greater ease with which the reverse lever can be handled. Occasionally, on very large locomotives equipped with Stephenson gear, engineers are afraid to handle the reverse lever while the engine is running, for fear of being pulled through the front of the cab, with the result that the reverse lever once set, stays in that position until the next stop. When adjustments of this importance are neglected the variable lead

advantage favoring the Stephenson gear is relatively of no consequence. With the Walschaert gear there is no excuse for not carrying the lever in the most economical position.

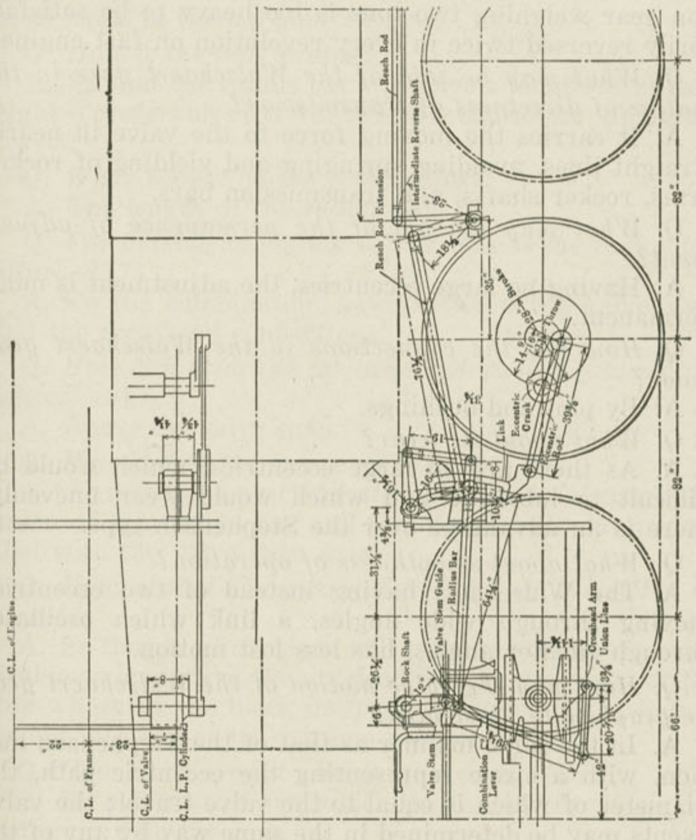


Fig. 293. Walschaert Valve Gear.

Q. What can you say of the number of Walschaert gear engines in Europe?

A. About nine-tenths of those on the continent are equipped with it.

Q. What can you say of the reduction in weight by the use of the Walschaert over the Stephenson gear in a heavy passenger locomotive?

A. In one case there is 1,745 pounds saved. A Stephenson gear weighing two tons is too heavy to be satisfactorily reversed twice in every revolution on fast engines.

Q. What may be said of the Walschaert gear in the matter of directness of transmission?

A. It carries the moving force to the valve in nearly straight lines, avoiding springing and yielding of rocker arms, rocker shafts, and transmission bars.

Q. What may be said of the permanence of adjustment?

A. Having no large eccentrics, the adjustment is more permanent.

Q. How are the connections in the Walschaert gear made?

A. By pins and bushings.

Q. What about its wear?

A. As there are no large eccentrics, which would be difficult to lubricate and which would wear unevenly, there is an advantage over the Stephenson type.

Q. What about smoothness of operation?

A. The Walschaert having instead of two eccentrics moving through wide angles, a link which oscillates through smaller angles, has less lost motion.

Q. How may the valve motion of the Walschaert gear be graphically illustrated?

A. In the same manner as that of the Stephenson motion, with a circle representing the eccentric path, the diameter of which is equal to the valve travel; the valve events may be determined in the same way by any of the methods (Zeuner, Bilgram, Sweet, Reuleaux, etc.).

Q. In designing a Walschaert gear, what elements are taken up first?

A. The valve travel, the lead and the maximum cut-off, which determines the valve lap.

Q. How is the combination lever proportioned?

A. The piston stroke being given, it is so proportioned that there is given to the valve, when the crosshead is moved from one end of the stroke to the other, a movement equal to the lap plus the lead.

Q. How is the link located?

A. So that the radius bar will have a length of at least eight (preferably ten to twelve) times the link-block travel.

Q. What should be the link radius?

A. The length of the radius bar.

Q. For outside admission valves, how is the radius bar attached?

A. To the combination lever between the valve stem and the crosshead connections.

Q. How is it attached for inside admission valves (piston valves)?

A. Above the valve stem.

Q. How should the fulcrum of the link lie?

A. As nearly as practical on a line drawn through the union of the radius bar and the combination lever, parallel with the valve-stem axis.

Q. How should the suspension point of the lifter be placed?

A. So that the link block will travel as nearly as practicable on a chord of the arc described by any point of the link wherever the block happens to be, when the link is swung into one of its extreme positions.

Q. How is this most closely approximated?

A. By a lifter through which the radius bar slides, not swinging with the link.

Q. What will accomplish practically the same results?

A. Properly suspended hanger, although the link-bar slip will be more in the back than in the forward motion.

Q. In placing the lengthwise position of the link fulcrum, to what should consideration be given?

A. To the eccentric-rod length, which should be at least $3\frac{1}{2}$ times the eccentric throw and be as long as possible, with an approximately equal length of the radius and eccentric rods.

Q. Where should the point of connection between the eccentric rod and the link motion be?

A. As near to the center line of motion of the main rod as this correction for rod angularities will permit.

Q. With what requirement is this often coupled?

A. Excessive eccentric throw.

Q. What is to be done in such a case?

A. Compromise.

Q. How about the fore-and-aft position of the point of connection between the eccentric rod and the link relative to the tangent of the link arc?

A. This must be determined with reference to the angularity of the eccentric and main rods, so that the link is exactly in its central position when the piston is at either end of the stroke.

Q. What about the angles through which the Walschaert link swings on both sides of its central position?

A. They should be as nearly as practicable equal.

Q. What about the effect of the angularity of the connecting rod on the cut-off?

A. It should be reduced to a minimum, this having an effect upon determining the locus of the suspension point of the lifting link, as well as that of the eccentric-rod connection to the link.

Q. How may the lap and lead of a valve with the Walschaert gear be measured?

A. By turning the engine from one dead center to the other in any cut-off position.

Q. How must the Walschaert gear be adjusted?

A. With the cranks on the dead centers, by lengthening or shortening the eccentric rods until the link takes such a position as to give the valve no motion when the link block is moved from extreme forward to extreme backward position.

Q. What should be done before this change in the eccentric rod length is made?

A. The valve-stem length should be examined, as it may be desirable either to plane off or to line under the foot of the link support, which might correct the lengths of both rods; or at least only one of these should need to be changed.

Q. What about the difference between the two positions of the valve on the forward and back centers?

A. This is twice the sum of the lap and lead, and cannot be altered except by changing the leverage relations of the combination lever.

Q. What about the relation between lead and lap?

A. The lap is determined by the lead, or *vice versa.*

Q. How can it be divided for both ends?

A. By lengthening or shortening the valve spindle.

Q. How else may this adjustment be made?

A. Within certain limits only, by shortening or lengthening the radius bar.

Q. Why not do this?

A. Because it is desirable to keep the length of the radius bar equal to that of the links, to meet other requirements.

Q. How may the lead be increased?

A. By reducing the lap, which would, however, also slightly advance the cut-off point.

Q. What is the effect of increasing the lap?

A. To shorten the cut-off.

Q. Give a diagram of the motion of the Walschaert gear.

A. Fig. 168 is a combination of a Reuleaux and a Zeuner diagram; *AB* is the valve travel and engine stroke (on different scales), *AR* the minimum desired cut-off. Drawing a perpendicular *RC* from *AB*, cutting the arc

ACB, decides the lead; with this latter as a radius and on the same scale as the valve motion, draw an arc with *A* as the center. From *C* draw a line tangent to the lead circle around *A*; then the lap of the valve will be equal to the perpendicular distance from *CS* to *O*. The crank will be at *OS* when the valve commences to open, on the angle *AOS* in advance of the dead center, and on *OC* at cut-off. The valve will be in this middle position when the crank is at *OG*, parallel to *SC* through *O*. Extending this line to *F*, and with the exhaust lap as radius, draw the exhaust lap circle on the opposite side *GF* and make *DE* tangent to this circle; then *OD* will be the crank position at release. The exhaust will remain open from crank position *OD* until *OE*, when it closes, and compression takes place until the crank again reaches *OS* for admission; this completing one revolution. Placing the Zeuner diagram upon this, draw from *H* a diameter perpendicular to *FG*, and with the radius *OH* of the eccentric circle as a diameter, draw the admission valve circle *OVHnO* and the lap circle with the steam lap as a radius; the intersection occurs at *V* both with the circles and the radial lead down admission line *O S* to the cut-off point at the intersection at *n*. On the line *OH* set off the steam port width from *L* toward *H* equal to *Lm*; and with *Om* as radius draw the arc *KmK*. Then the shaded figure inclosed by the letters*VKK'nL* represents the steam-port opening during admission. The width of the port opening at any desired crank position is found by measuring the radial distance from *O* between the lap to the valve circles and the port line.

The exhaust openings, determined in the same manner, are shown on the opposite side of *FG*, where the crank passes through arc *DJE* during exhaust with a positive exhaust lap equal to *EF*. When the exhaust edge of the valve lines with the port, this arc becomes *GJF*, 180°; when there is negative lap (clearance) the exhaust will last during more than half a crank rotation.

Q. Which has the fewer working joints, the Stephenson or the Walschaert valve motion?

A. The Stephenson.

Q. What is by many considered a second disadvantage of the Walschaert gear as compared with the Stephenson?

A. A constant lead.

Q. Is there any reason why the Walschaert gear should

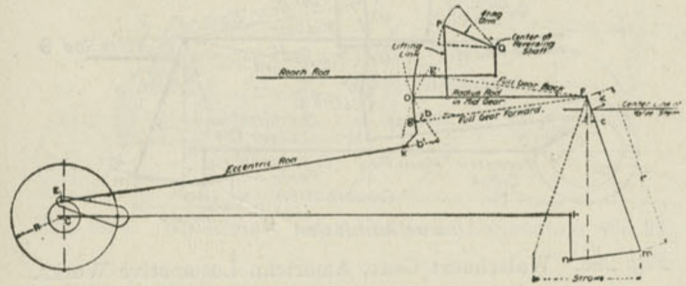


Fig. 294. Walschaert Valve Gear.

produce economy in steam consumption over the Stephenson?

A. Not when they are both in the best condition.

Q. Which gear remains secure longer, the Walschaert or the Stephenson?

A. The Walschaert.

Q. Which gives the best steam distribution at first?

A. The Stephenson.

Q. What is one advantage resulting from the absence of the link motion in the Walschaert gear?

A. It is easier to give attention to the driving boxes.

Q. What is the most inherent feature of the Walschaert gear?

A. Constant lead at all cut-offs.

Q. For what classes of engines is the Walschaert motion desirable?

A. Narrow-gage engines, or others in which it is desirable to place the valve motion wholly outside the frames; and very large engines.

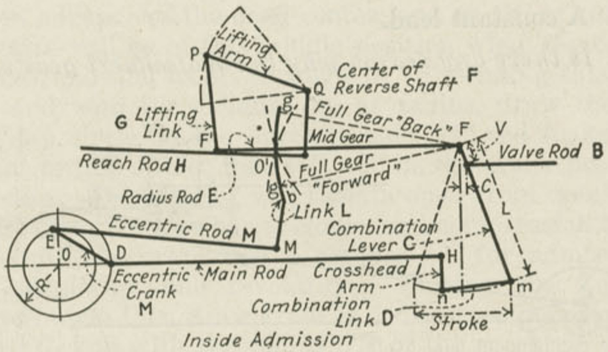


Fig. 295. Walschaert Gear, American Locomotive Works.

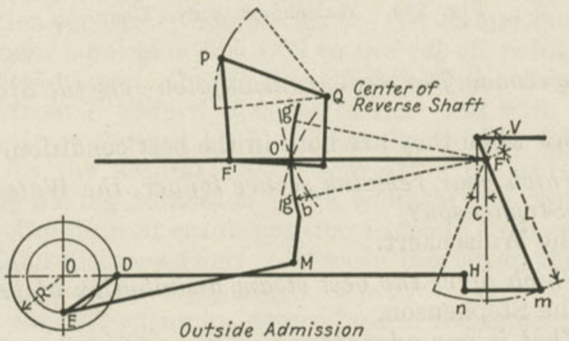


Fig. 296. Walschaert Gear, American Locomotive Works.

Q. What is the arrangement of the Walschaert gear as applied by the American Locomotive Works?

A. Fig. 295 shows it for inside admission, Fig. 296 for outside. The principal difference between this arrangement and the one just described is in the position of the lifting arm and link. The cuts show mid positions in full, those for full forward and backward gears, in dotted lines.

Q. Describe the action of the Walschaert gear with constant lead.

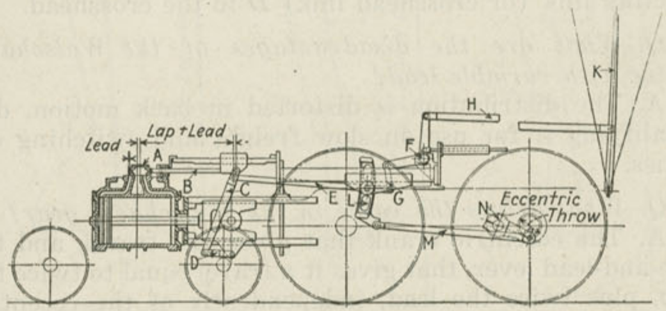


Fig. 297. Walschaert Gear, Baldwin Locomotive Works.

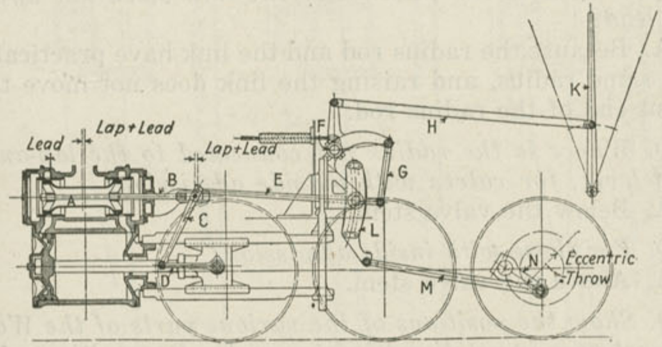


Fig. 298. Walschaert Gear, Baldwin Locomotive Works.

A. Referring to Fig. 297, showing it as applied by the Baldwin Works to outside admission slide valves, and Fig. 298, as applied by them to inside-admission piston valves:—the return crank (or eccentric crank) *N*, on the main pin, is so set that, if the radius rod *E* were attached directly to the valve stem *B,* at stroke, and both the link *L* and the valve *A* would be in mid position. But at stroke end the valve should have advanced by an amount equal to lap plus lead. To get this advance, it is given lead by the combination lever *C,* attached directly to the valve stem *B,* and the radius rod *E;* and through the connecting link (or crosshead link) *D* to the crosshead.

Q. What are the disadvantages of the Walschaert valve with variable lead?

A. The distribution is distorted in back motion, disqualifying it for use on slow freight and switching engines.

Q. What drives the valve in the Walschaert gear?

A. The eccentric crank that gives full travel, and the lap-and-lead lever, that gives it a travel equal to twice the lap, plus twice the lead, independently of the eccentric crank.

Q. Why does the position of the link block not affect the lead?

A. Because the radius rod and the link have practically the same radius, and raising the link does not move the front end of the radius rod.

Q. Where is the radius rod connected to the lap-and-lead lever, for valves with outside admission?

A. Below the valve stem.

Q. For those with inside admission?

A. Above the valve stem.

Q. Show the positions of the various parts of the Walschaert gear in relation to piston and valve positions, for late and early cut-off and for outside and inside admission valves.

A. Figs. 299 and 300 show them for outside admission, for late and early cut-off respectively. Figs. 301 and 302 the same things for inside admission, American Locomotive Company usage.

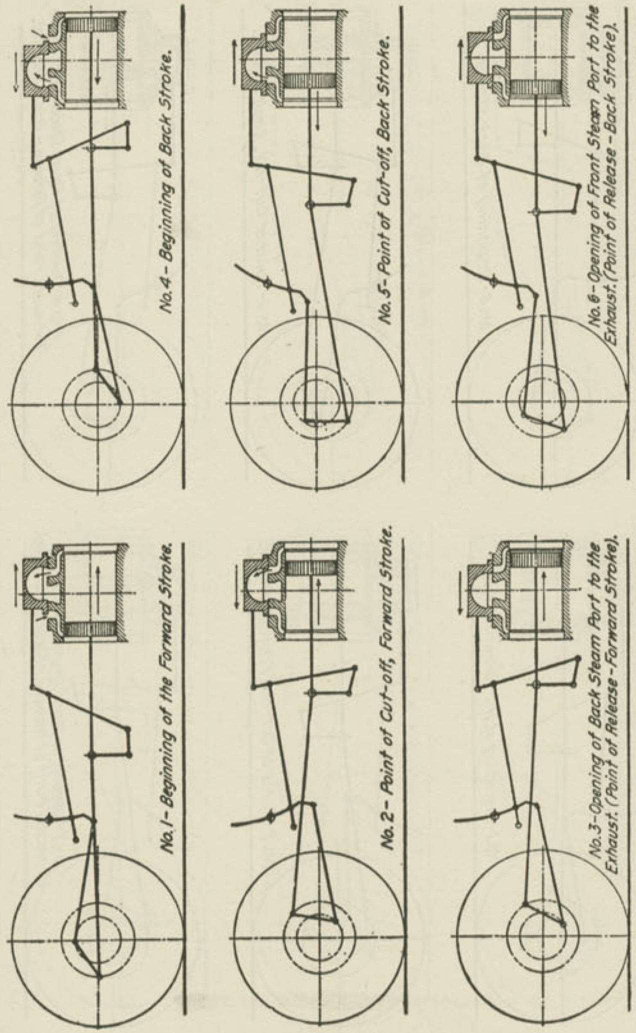


Fig. 299. Walschaert Gear, American Locomotive Works (Outside Admission).

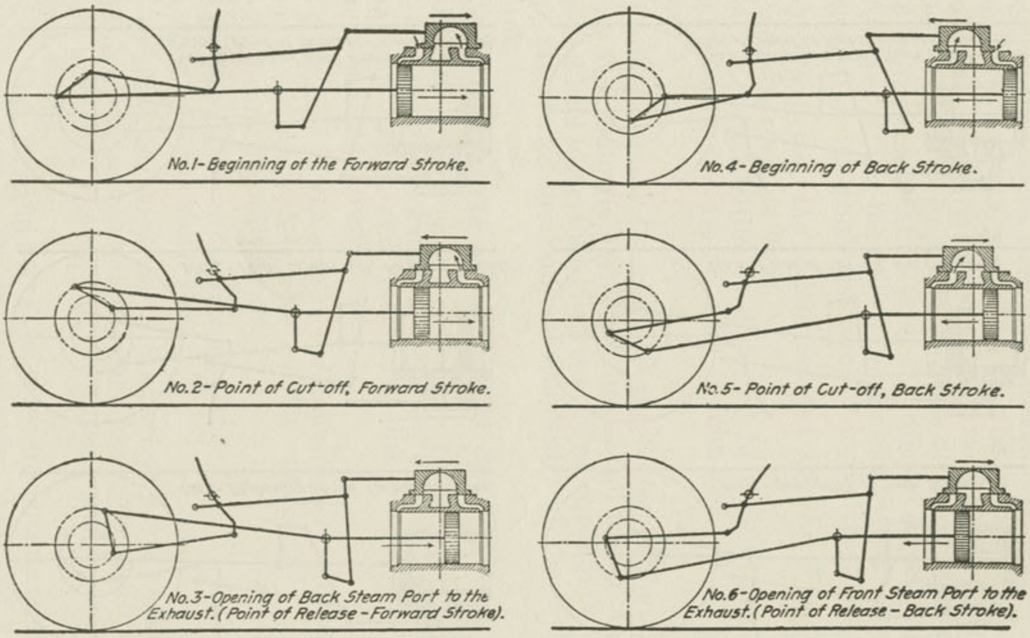


Fig. 300. Walschaert Gear, American Locomotive Works (Outside Admission).

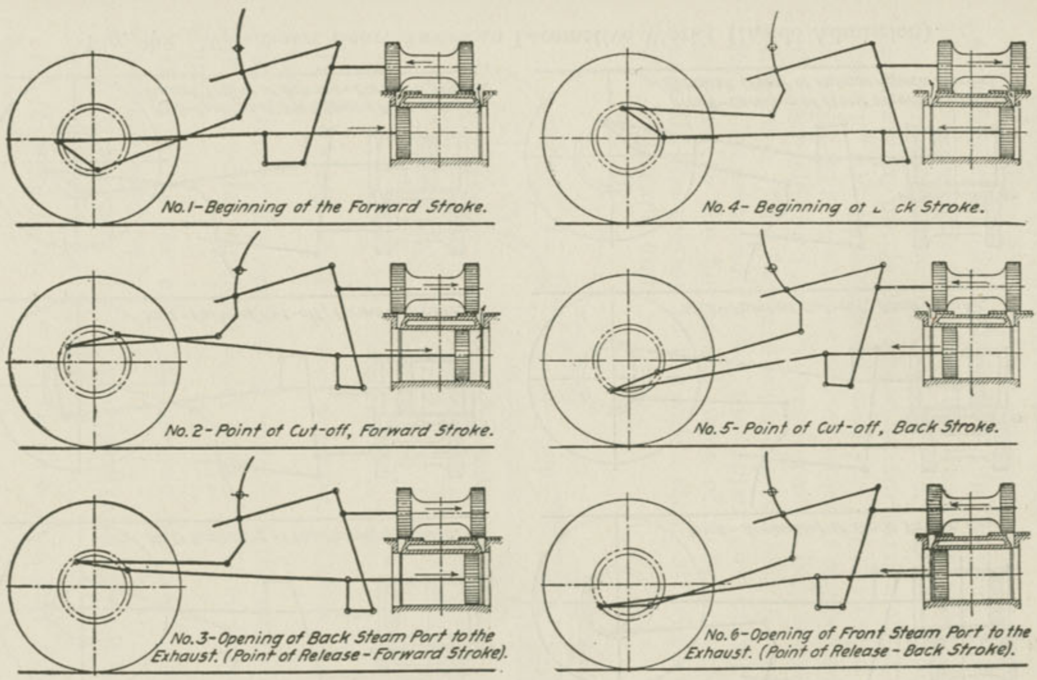


Fig. 301. Walschaert Gear, American Locomotive Works (Inside Admission).

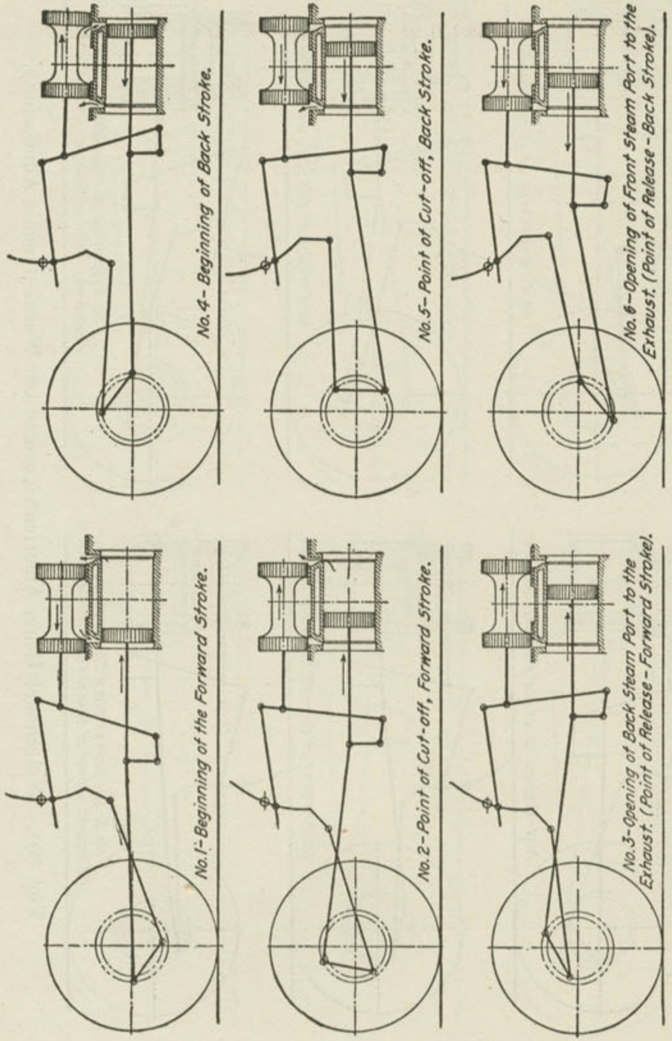


Fig. 302. Walschaert Gear, American Locomotive Works (Inside Admission).

Q. Describe the Southern valve gear.

A. As seen in Fig. 303, an extension arm is secured to an extension of the main crank pin, so that on inside-admission engines the eccentric crank pin is 90° behind the former in forward motion. For outside admission the eccentric pin is 90° ahead in forward motion. The eccentric rod is supported near its forward end by a radius hanger, the upper end of which is supported by a link block sliding in a link resting on a link support on the frames. The forward eccentric-rod end is connected with a transmission yoke, the upper end of which is connected to the horizontal arms of a bell crank that transmits the motion to the valve stem, attached to the lower bell-crank end.

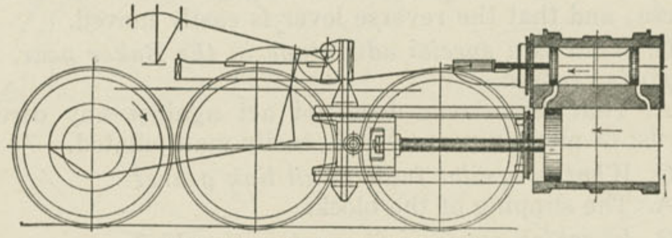


Fig. 303. Southern Valve Gear.

Q. With the block in mid position, what is the valve stroke?

A. That of the vertical movement of the outer eccentric rod; which amounts to lap plus lead (lead being constant).

Q. What is the effect of moving the block forward from mid position?

A. To increase the valve travel and give it proper movement for forward motion.

Q. How early in the stroke does this give full port opening?

A. At from 2 to 2⅞ inches on an engine with 28-inch stroke.

Q. What is the advantage of the link being stationary?

A. The valve can be squared without the parts being removed, by merely slipping a liner under one end or the other of the link, and there is practically no wear between block and link, as the block is moved only to reverse or to change cut-off.

Q. What are the valve units shown in Fig. 303?

A. The main crank pin is moved 180° off the front dead center, the piston being at the back end of the stroke and the valve opened to 3/16-inch lead (back gears).

Q. What are specially good points in the Southern gear?

A. That the link does not move with the valve; its only motion being when shifted to change cut-off or to reverse; and that the reverse lever is easily moved.

Q. What is a special advantage in the Baker gear, as regards reversing?

A. That the lever does not act against any direct thrust of moving parts, but is easily manipulated.

Q. What is a vital fault in all link gears?

A. The slipping of the block.

Q. In which types is it most noticeable?

A. The shifting-link.

Q. What would be demanded of the theoretically perfect valve gear?

A. To give the same lead for each cylinder end and in either gear, at all cut-offs; never choke either admission or exhaust; and to give sharp cut-off and quick exhaust release.

Q. How can a valve motion be tested for these points?

A. On a full-sized scale drawing; better yet with a skeleton model, preferably full-size, or double-size.

Q. Can all the foregoing points be obtained?

A. Not with a single slide valve.

Q. Can it be done so as to equalize all functions in forward gear only?

A. No; the best that can be done is to "square" them for half gear.

Q. Will an eccentric with a short throw give the same cut-off with the same valve, as one giving more travel?

A. No; not if the linear lead is to be maintained.

Q. Why not give the eccentric with small throw the same angular advance as the other and cut down the lap?

A. The port openings would be less. This is shown in Figs. 304 and 305, in which the valve travels are unequal,

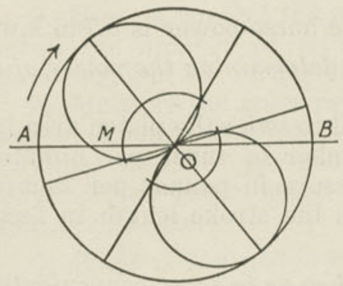


Fig. 304. Effect of Travel.

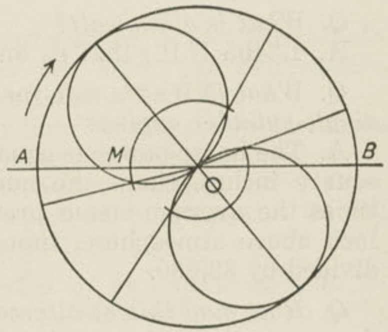


Fig. 305. Effect of Travel.

but although the steam lap *OM* in the one is shorter than in the other, the maximum port opening *AM* is also less.

Q. Under what circumstances is variable lead desirable?

A. Where a late cut-off in starting is desirable, so long as the steam distribution is not distorted in back motion; hence, only for passenger and fast freight work.

Q. How can this result be attained with the Walschaert gear?

A. By designing the combination lever *C*, Fig. 295, for maximum lead in mid gear, reducing it to a desired minimum at full gear by shifting the eccentric crank *M* in the right direction, the proper amount.

CHAPTER LXXII

HORSE-POWER*

Q. What is a horse-power?

A. An amount of power sufficient to raise a weight of 33,000 pounds one foot high in a minute, or 550 pounds that high in a second, or 1,980,000 pounds that high in an hour.

Q. What is a kilowatt?

A. 1.3405 H.P.; that is, one horse-power is 0.746 k.w.

Q. What is Watt's rule for determining the power of a single-cylinder engine?

A. The horse-power is equal to twice the piston area in square inches, times the number of turns per minute, times the average steam pressure in pounds per square inch above atmosphere, times the stroke length in feet, divided by 33,000.

Q. How may this be altered so as to serve conveniently for two-cylinder locomotives?

A. Multiply the square of the cylinder diameter in inches by the speed in miles per hour, by the average steam pressure in pounds per square inch above the atmosphere throughout the stroke, and by the length of stroke in inches, and divide the result by the driver diameter in feet and by 4,500. If the stroke is in feet, divide by 375.

Q. By this rule, find the horse-power of an engine with cylinders 18 inches in diameter, stroke 24 inches, driver diameter 6 feet, and average steam pressure 80 pounds, at 40 miles per hour?

A. It is equal to (324 $\times$ 40 $\times$ 80 $\times$ 24) divided by 6 $\times$ 4,500; or 921.6 horse-power.

* See also under "Expansion" and "Indicator"; also consult Alphabetical Index at end of book.

Q. What is the "Grimshaw formula" for calculating gross horse-power?

A. One which comes "pat" to the memory, being:

$$\text{H.P.} = \frac{PAT}{33{,}000}$$

; in which P is the mean effective pressure in pounds per square inch, A the mean piston area in square inches, and T the piston travel in feet per minute. Thus for m.e.p. 60 pounds, area 200 square inches, travel 660 feet per minute, the gross H.P. is 60 $\times$ 200 $\times$ 660 $\div$ 33,000 = 240.

*Q. How do you get the piston speed in feet per minute when the number of miles per hour, the driving-tire diameter, and the stroke are known?**

A. Multiply the miles per hour by the stroke in inches and by 4,669, and divide by the tire diameter in feet.

Thus: 45 miles per hour, 6-foot drivers, and 24-inch stroke; then piston speed 45 $\times$ 24 $\times$ 4 $\div$ 6 = 840.42 feet per minute.

Q. What is the piston speed of an engine having 18-inch stroke and four pairs of 54-inch drivers, at 60 miles an hour?

A. Sixty miles an hour equals 5,280 feet a minute. The tire circumference is 4.5 $\times$ 3.1416 = 14.1372 feet, and the wheel makes 5,280 $\div$ 14.1372 = 372.8 turns per minute. Consequently the piston makes 372.8 double strokes per minute and its speed per minute equals 372.8 $\times$ 20 $\times$ 2 $\div$ 12 = 1,243 feet.*

Q. In an engine having 24-inch stroke and making 250 turns a minute, what is the average piston speed per second?

A. 1,000 $\div$ 60 = 16 $^2/_3$ feet.

Q. Is the power of a locomotive directly proportional to the speed?

A. No; because there is at high speeds imperfect steam

* See chapter: "Train Speeds."

admission and distribution, so that there is a point of speed which gives the maximum of economy.

Q. What is the horse-power of a boiler?

A. Boilers have no horse-power, as one engine might get twice as much power out of the steam as another. But the so-called commercial horse-power in America is the evaporation of 34½ pounds of water per hour from feed at 212° F. = 100° C. into dry steam at the same temperature.

Q. How is the piston speed calculated?

A. By multiplying twice the stroke in feet by the number of wheel turns (double strokes) per minute.

Q. How do you ascertain the average pressure in the cylinder?

A. By the indicator, that makes, upon a given scale, a closed diagram the average height of which may be measured by a planimeter or other means; each unit of hight representing one pound per square inch. Or, by dividing the diagram into, say, ten or more strips of equal width and measuring their average hight (at the center of width of each strip).*

Q. What determines the horse-power that a steam locomotive can develop?

A. The evaporative capacity (independent of duty) of the boiler, and the capacity and duty of the cylinders.

Q. What is the hourly average evaporation of locomotive boilers, per square foot of heating surface?

A. From 8 to 16 lbs., according to type.

Q. What is the average steam consumption per indicated H.P. hour?

A. From 23.7 to 29 lbs.

Q. The average evaporation per square foot of heating surface in service?

A. Twelve pounds per hour.

Q. The average economy under service conditions?

A. About 27 lbs. of water per indicated H.P. hour.

* See chapter: "Indicator."

Q. In every horse-power developed in the average locomotive's cylinders, how much heating surface must the boiler have?

A. 2.25 sq. ft.

Q. What formula can you give for cylinder H.P. compared with heating surface?

A. Cylinder H.P. = 0.43 × heating surface in square feet.

Q. What formula for tractive effort?

A. Tractive effort equals (375 times cylinder H. P. divided by speed in miles an hour) minus frictional tractive effort, or (161 times heating surface in sq. ft. divided by miles an hour) minus frictional tractive effort.

Q. What can you say about the relation between indicated horse-power and back pressure?

A. On the same engine the back pressure increases rapidly with the horse-power. On one engine it ran 0.5 lb. at 800 i. h. p. and 18 at 3,200 i. h. p.; on another, 1.25 lbs at 1,000 i. h. p. and 17.5 at 2,600 i. h. p.

Q. How can you ascertain the gross horse-power from the piston area, quickly?

A. By having a table of multiples for various speeds and pressures, as here given:

M. E. P. Lbs. per Sq. In.	Piston Speed, Ft. per Min.			
	250	500	750	1000
10	0.075758	0.151515	0.227273	0.303030
20	0.151515	0.303030	0.454545	0.606061
30	0.227273	0.454545	0.681818	0.909090
40	0.303030	0.606061	0.909091	1.212121
50	0.378788	0.757576	1.136363	1.515152
100	0.454545	0.909090	2.272727	3.030303

For pressures not here given, use 100 as a basis; thus 35 lbs. would give 35 per cent as much power as 100 lbs.

For other speeds take 1,000 as a basis.

CHAPTER LXXIII

STEAM CONSUMPTION

Q. What is the relation between steam consumption per hour per horse-power and train speed?

A. It increases with the speed. Prof. Goss's tests show it as a minimum at 35 miles an hour (188 revolutions or 752 feet piston speed a minute on the engine tested by him).

Q. What is the relation between steam consumption per hour per horse-power and point of cut-off?

A. The former varies with the point of cut-off; and according to Goss is not minimum at shortest cut-off, except at 55 miles an hour. (296 revolutions or 1,184 feet piston speed a minute.)

Q. How high does the back pressure sometimes reach in locomotives?

A. 15 lbs. above atmosphere.

Q. What effect has this on the value of or gain by expansion?

A. It occasions a loss.

Q. How can such a loss be overcome?

A. By increase in initial admission pressure.

Q. What prevents utilization of this method?

A. The difference between the increased boiler weight and cost and the permissible decrease in weight and cost of cylinders and some moving parts.

Q. With 240 lbs. boiler pressure and open throttle, what would be the minimum consumption of saturated steam?

A. Goss found it to be 24 lbs. per H. P. hour.

Q. What would be the maximum?

A. 26.3 lbs.

Q. With 120 lbs. gage pressure what should be the minimum and maximum steam consumption per H. P. hour?

A. 27.5 and 33.8 lbs. respectively.

Q. Where did Goss find the most effective cut-off for the 120-lb. pressure?

A. At the eighth notch, or 35 per cent of the stroke.

Q. What did he find the best notch with 200 lbs.?

A. The sixth.

Q. For pressures above 160 lbs., what speed was found the most economical of steam?

A. Forty miles an hour.

Q. Is the increase in saving proportionate to the increase in pressure?

A. No, the successive percentages of saving decrease.

Q. From the mechanical point of view, what are the disadvantages of high initial pressures and expansion rates?

A. They cause such varying pressures on the piston as to produce wheel slip; also racking of the moving parts.

Q. In how many ways can the efficiency of a steam engine be expressed?

A. In steam per hour, steam per horse-power hour, thermal units per minute, thermal efficiency percentage, mechanical efficiency percentage, efficiency ratio or potential efficiency percentage, cylinder efficiency, commercial efficiency, and duty.

Q. What is the difference between actual and indicated steam consumption?

A. One is the actual steam represented by the weight of water evaporated, the other that calculated from the indicator card.

Q. How is the heat consumption expressed?

A. By the above the maximum temperature at which the condensation could be returned to the boiler (inapplicable to locomotives).

Q. What is the thermal efficiency?

A. The proportion of heat turned into useful work to that supplied (measured above the heat in the exhaust).

Q. What is the mechanical efficiency?

A. The ratio of the actual horse-power developed to the indicated.

Q. What is the efficiency ratio?

A. The ratio of the thermal efficiency to that of an ideally perfect engine.

Q. What is the effect of increased piston speed on the water rate?

A. To decrease it. On one engine the steam used ran down from 18 lbs. per i. h. p. hr. at 200 ft. per minute to 14½ lbs. at 850 ft.; in another, from 21 lbs. at 200 ft. to 17 lbs. at 850 ft.

Q. What are the fuel consumptions in the various classes of service?

A. 0.169 lb. of coal per ton mile in freight, 0.194 in express passenger, and 0.335 in express local passenger service. (N. Y., N. H. & H. R. R.)

Q. How many pounds of coal per indicated H. P. for passenger service?

A. Average 4.37 for express and 4.61 for local. (This includes all idle engine time in the 24 hours.)

CHAPTER LXXIV

FUELS*

Q. State the relationship between heating value and fixed carbon percentage of coal.

A. According to Mahler, it is as follows:

% of Fixed C. in Coal (Dry, Ash-Free)	Br. Thermal Units per Lb. of Combustible	% of Fixed C. in Coal (Dry, Ash-Free)	Br. Thermal Units per Lb. of Combustible
100	14,600	68	15,480
97	14,940	63	15,120
94	15,210	60	14,580
90	15,480	57	14,040
87	15,660	55	13,320
80	15,840	53	12,000
72	15,660	51	12,240

Q. Give an idea of the composition of the various fuels used in locomotive furnaces.

A. Kent's classification is according to the percentages of dry combustibles, as follows:

	% of Dry Combustible	
	Fixed Carbon	Volatiles
Anthracite	97 to 92.5	3 to 7.5
Semi-anthracite	92.5 to 87.5	7.5 to 12.5
Semi-bituminous	87.5 to 75	12.5 to 25
Bituminous (Eastern)	75 to 60	25 to 40
Bituminous (Western)	65 to 50	35 to 50
Lignite	Under 50	Over 50

Q. What are the advantages of fuel oil?

A. Reduction of hostler service; elimination of ash-pit

* See also "Combustion" and "Firing."

service; pressure more readily controlled; fuel waste through grate and stack diminished; smoke lessened; cinders done away with; no danger of setting fire along right of way.

Q. What is lignite?

A. An early formation of coal, containing more than 50 per cent of volatile matter in the combustible portions; coming in age of formation between peat and bituminous coal, which latter has 25 to 50 per cent of volatile matter in its combustible portions (that is, less ash and moisture).

Q. Give the average weights per cubic foot of various solid fuels.

A. Large bituminous coal, 52 lbs.; run of mine bituminous, 54; large anthracite, 54; buckwheat anthracite, 52.

Q. Give the cubic contents of a short ton of coal.

A. Bituminous, 38.4 cubic feet; anthracite, 37.

Q. Of a long ton.

A. Bituminous, 43 cubic feet; anthracite, 41.5.

Q. Give the weight and volume of fuel oil (crude petroleum).

A. As under:

Lb.	U. S. Gal.	Bbl.	Gr. Ton
1	0.13158	0.0031328	0.0004464
6.7	1	0.02381	0.003393
319.2	42.	1	0.1425
2240	294.72	7.017	1

CHAPTER LXXV

FIRING*

Q. How many pounds of coal do American engines burn per mile run?

A. There can be no such rating given, for very obvious reasons. For instance, upon the I. & N. R. R. the passenger engines, according to one report, took 52.62 pounds; freight, 83.27; mixed, 47.45; switching, 38.34; work trains, 64.37; average for all, 62.67. But this is influenced largely by grades, curves, etc. Upon the line just quoted, the greatest grades run from 46 to 105 feet per mile; the average grade, 7.6 to 22.2 feet per mile.

Q. What class of roads demand the greatest care and skill on the part of engineman and fireman?

A. Hilly ones, especially from the fireman.

Q. How is his skill best shown?

A. By having his fire well made up and kept at its best before "rushing" an up grade.

Q. Is the danger of the fire being "turned" greatest on the up grade, or in getting ready to run it?

A. In getting ready.

Q. What is the greatest disgrace that can befall an engine-runner or fireman?

A. "Burning" his engine.

Q. Should the fireman be on friendly terms with his engineman?

A. It would be unfortunate if he were not; because it is in the engine-runner's power to help him gain a knowledge of the construction and operation of the engine, so that he can some day get a better run.

Q. What should the fireman observe carefully besides his own regular work?

A. The operations of boiler-feeding, oiling, braking,

* See also "Combustion" and "Fuels."

etc.; he should learn to judge of the train-speed by night and by day, through the appearance of the landscape, the sounds of the exhaust and of the wheels, etc.; also to note by the sounds of the moving parts whether or not everything is in good order.

Q. Should the engine steam badly, what should first be examined?
A. The petticoat-pipe net and deflector plate.

Q. What are the two objects of the deflector plate?
A. (1) Draft regulation; (2) prevention of spark-throwing.

Q. Do these two harmonize?
A. No; if too much attention is paid merely to spark-throwing, the draft will be inordinately lessened.

Q. What is necessary to the efficiency of a petticoat pipe?
A. That it shall have proper diameter in proportion to that of the stack and be central, vertical, and at the proper hight.

Q. How can one judge of the proper proportions and setting of the petticoat pipe?
A. All flues should be uniformly free from soot.

Q. What is the evil effect of setting the petticoat pipe too high?
A. Choking of the upper flues.

Q. What are the bad consequences of a wrongly-set petticoat pipe?
A. Tearing of the fire, hence waste of fuel, and leaky sheets and flues.

Q. What is the only way of keeping up steam where the petticoat pipe is badly set and tends to tear the fire?
A. Excessively heavy firing, to prevent inlet of cold air through the grate.

Q. When an engine with a "long front end" does not steam properly, what should be done?

A. The diaphragm should be tried at various angles until the best and most evenly distributed draft is attained.

Q. What is the effect of closing the nozzles in such case?
A. To make things worse; the obstacle remains.

Q. What kind of nozzles do enginemen like, who want to make a good record and understand how to attain it?
A. Wide ones.

Q. How do you take care of a boiler with old and tender or leaky flues?
A. By feeding regularly, only when running; keeping an even bright fire and regular steam-pressure, and avoiding sudden chilling of the fire-box sheets and the flues.

Q. What else will help to keep the flues tight?
A. If the top of stack is covered after the fire is cleaned and engine is in the house, to keep cold air from drawing in and up through flues.

Q. Before starting the fire, what should be looked to?
A. The water supply (by the gage-cocks, not by the glass); then the grates should be cleaned, the shaking levers connected, and cinders cleaned out from the brick arch, water-table or combustion chamber.

Q. Explain how you would fire an engine to make her steam well, run light on coal, and avoid unnecessary smoke?
A. Little and often, regularly over the entire surface of the box, leaving a fire of that thickness which produces the best results with the fuel; paying especial attention to have the edges and corners covered so as to prevent the entrance of cold air and the consequent cooling of the fixe-box sheets; the coal being broken to that degree which will produce the most prompt and regular results, and as nearly regular in size as possible.

Q. How do you keep smoke from trailing over the train when running shut off?

A. By avoiding opening the fire-door, and using the blower sparingly.

Q. What effect does it have upon the fire to open the fire-box door when the engine is working?

A. It causes excess of cold air to chill the combustion-gases, and makes black smoke; besides this, tends to crack sheets and make fires leak.

Q. What effect does wetting the coal have?

A. In some cases it improves the combustion; this being the case only with soft coal, and usually only with small sizes.

Q. What is the bad effect of drenching the fire with water?

A. To hurt the fire-box sheets, especially if of steel.

Q. What will you do with a fire that is banked?

A. See that it does not get any more draft through it than can be helped; especially if banked by reason of such a failure in some vital part, or of an imperfectly-stopped leak, as would cause trouble by rise of pressure. At the same time see that it did not go out entirely.

Q. Do you use the blower on a free-steaming engine to prevent dense black smoke when shut off?

A. Sparingly.

Q. If blower is put on too strong when changing the fire, what is liable to happen?

A. Tearing of the fire, forcing cold air through the hot flues, causing leaks about the stay-bolts.

Q. What is the disadvantage of opening the fire-box door?

A. It allows cold air to strike the hot sheets and tubes, thus tending to cause leaks; also usually causing black smoke.

Q. What is the disadvantage of excessive air supply?

A. The causing of black smoke; giving no time for the combustion-gases to give their heat to the tubes on their way to the stack.

Q. What is the evil effect of firing small mounds of coal, instead of spreading the fuel evenly over the grate?

A. Between the mounds cold air comes in and causes smoke; under them clinker forms and calls for frequent shaking.

Q. What are the evil effects of shaking fuel, instead of only clinker through the grate?

A. (1) Waste of fuel, (2) risk of burning the grate.

Q. What is essential in making an engine steam well with anthracite coal?

A. That the fire be laid very evenly, not thick (say 10 inches as a maximum) and that it be burned through before starting out.

Q. How much time is required for this?

A. From one and one-half to two hours.

Q. What is the advantage of a thin fire?

A. Combustion may be more rapidly and regularly effected (especially with anthracite coal) if the draft is not too strong, so as to tear the fire.

Q. What is the danger of allowing cinders to accumulate in the ash-pan?

A. It is liable to burn the grates, especially if it contains sulfur.

Q. What about the condition of the fire in starting?

A. It should be good, clear, and uniform, so that the fireman may have time and opportunity for seeing and hearing signals.

Q. What kind of firing should be done before reaching an up grade?

A. The fire should be got so as to draw on the reserve power or momentum of the train, and at the same time be bright, clear and strong to keep the steam-pressure up to the desired point, and never let the train get down to that speed at which the traction lessens.

Q. What sort of a fire should there be when feeding after climbing a hill?

A. Bright and good, to prevent the cold water chilling the flues.

Q. Which gage-cock is it especially necessary to keep open?

A. The lower one.

Q. Should water in a gage-glass fluctuate with the water line in the boiler?

A. Yes.

Q. With how much steam should the engine be brought in at the end of the trip?

A. With just enough to bring it into the roundhouse after cleaning the fire.

Q. When an engine comes in from a trip, what is the custom on most roads?

A. The fire is cleaned and then banked.

Q. Where this is not done, what is the best way to be sure of quickly starting up a new fire?

A. Having plenty of good dry wood handy.

Q. What is the advantage of not drawing the fire?

A. The cooling and reheating strains are avoided, and time is saved.

Q. What should be done in cleaning out the ash-pan?

A. The dampers, if there are any (and there should be) should be closed so as to prevent the further passage of cold air through fire-boxes and flues.

Q. What is the effect of blowing off while hot?

A. It often cracks sheets and breaks stay-bolts; and tends to cause hard scale.

Q. What is the best way of preventing blowing off?

A. Regular firing; but when it occurs in spite of that, the ash-pan should be closed rather than the fire-door opened.

Q. What should be done with an extended smoke-box engine with a diaphragm, when the fire does not burn well and the inside of the fire-door gets black?

A. Either the flues should be cleaned or the apron raised.

Q. What is one of the signs that an engine has proper draft?

A. The inside of the fire-door getting quite hot when running.

Q. What should be done if the fire burns more at the back than at the front of the fire-box?

A. The draft-pipe should be raised.

Q. How may the draft-pipe be raised or lowered?

A. Usually by a sleeve provided for this purpose.

Q. What should be done in case the engine tears her fire?

A. First the exhaust-nozzles should be examined to see if they do not need cleaning; if they do not they are probably too small, and should be changed for larger.

Q. What will be the effect of too low a draft-pipe?

A. The fire will be burned proportionately too much at the back of the fire-box.

Q. Should the fire-door be opened during the starting strain?

A. No.

Q. Which are the hardest to start—American or European trains?

A. European, because their bumpers are brought up together and the whole train must be started at once.

Q. What can be said about grate-shaking?

A. If not properly performed, much fuel is wasted, and holes appear in the bed of coals, letting in cold air.

Q. What is the real object of shaking with good coal?

A. Merely to keep clinkers from chilling between the bars.

Q. What is the proper way to shake?

A. With short quick jerks.

Q. At a stop, should the fire be replenished?

A. No.

Q. What is the effect of firing just as the throttle is opened?

A. The cold air coming in through the fire-door causes leakage of tubes and sheets.

Q. Should firing be done while pulling out of a station?

A. No. The fireman should be watching for signals.

Q. How much difference in the coal consumption can be made by proper firing, over bad?

A. A quarter.

Q. In case of drawing the fire, what precaution should be taken?

A. Not to have the drawn fire directly under the air-reservoir; or if this was absolutely necessary by reason of the position of the engine, as in a derailment, the air-reservoir valve should be opened to release the air and prevent explosion.

Q. Under what circumstances should the fire be drawn most promptly?

A. In case the crown-sheet or flues are left uncovered by water.

Q. In case the fire cannot be dumped (as by reason of the ashpan being jammed), how may it be damped?

A. By covering it with sand, earth or sods or by drowning it out by snow or water.

Q. What is one of the difficulties encountered in using big engines?

A. The inability of the fireman to maintain steam.

Q. What is the real use of the damper?

A. To control the air supply so as to permit good combustion.

Q. Does the fire-box usually get too much or too little air?

A. Too much, especially where double dampers are used.

Q. How is this evil lessened?

A. By using the back damper only, except when the fire begins to get dirty and the grate clogged.

Q. What is the especial evil of running with only the front damper open?

A. It causes trouble with the bottom edges of the fire-box and the mud-ring.

Q. Should the damper-rods have notched sectors?

A. Yes.

Q. Would firing with both dampers closed and swinging the door between each shovelful cause leakage of flues?

A. Yes. The exhaust draws cold air exclusively through the door. When dampers are open the cold air is mixed with hot air passing through fire.

Q. Is banking of fires economical, or not?

A. It is not.

Q. Given a coal which puts a clinker upon the flue-sheet, that gradually covers up the flue openings and greatly reduces the steam-making capacity, what is the best remedy?

A. To keep broken limestone upon the tender, and throw a shovelful into the fire-box every hour or two. Two shovelfuls before starting will generally keep off the clinker for a whole division.

Q. Is smokeless firing practicable?

A. Yes; but until there are fines for producing smoke, firemen will be apt to leave the door open, overload the grate, and do other things which produce smoke.

Q. What should be done to prevent black smoke trailing when the throttle is closed?

A. The blower should be put on.

Q. What are the adjustable parts in the front end, by which the fire is regulated?

A. The ash pan and the fire door or doors.

Q. Explain what adjustments can be made, and the effect of each on the fire.

A. Closing the ash pan tight lessens the draft through the fuel and retards combustion; opening the fire door does this also, but has a bad effect on the flue sheet.

Q. How may smokeless firing of soft coal be accomplished?

A. As carried out on the C. N. O. and T. P. Ry., the engines were equipped with brick arches and four holes were made on each side, a foot above the grate, to admit air. Four tubes passed through the arch, and in these the outside air was heated to a high temperature before entering the fire-box.

The coal is fired a shovelful at a time, and at each shovelful the door left open an inch or two for two or three seconds. Before starting, the blower is put on, the box well filled, and the door left on the latch until the smoke disappears. Before tunnels the fire is coaled in ample time to enable the train to go through without smoke, with closed fire doors.

In approaching a stop station the blower is on, the door is opened as little as possible. On side tracks both dampers are closed. Grates are shaken seldom and ash pan kept empty; the coal (screened lump) is wet before firing.

Q. Now that on some roads the use of coke as fuel is compulsory, it would be well to know what is the best way to handle it. What can you say in this connection?

A. The preparation of the fire must receive careful attention. Wood and semi-bituminous, "low volatile" soft coal is first applied to the grates to assist in igniting the coke and prevent it from clinkering over the grate surface. After the coal is thoroughly ignited the coke is introduced until the fire-box is filled, and the steam blower then used until the coke is well burned through and makes a solid body of fire. The fire is left in this condition until the locomotive has commenced work and until

15 or 20 miles have been run, then at the first opportunity, usually when the steam is not being worked, the fire-box is refilled with coke.

Q. What conditions will admit of holes being torn in a coal fire?

A. Thin plates on the grate, and excessively small nozzles.

Q. Is it a waste of fuel to open the fire-box door to prevent the pops from opening?

A. Yes.

Q. How far can the average fireman throw coal in a fire-box?

A. Not over ten feet.

Q. What would be the advantages of a good stoking apparatus for a locomotive?

A. To lessen the work of the fireman; to do work that would be beyond the physical strength of the fireman; to put the coal into the box in small even charges, distributed uniformly over the entire grate; to lessen the contraction and expansion on the side sheets and flues, as the fire is brought all over the grate at all times and no air goes into the fire-box through the door; to keep the fire-box door always closed; to burn a cleaner fire, and go further without cleaning the fire.

FIRING WITH OIL

Q. How long has crude petroleum been used as fuel for locomotives?

A. Since 1883, when it was applied by Urquhart on the Grazi Tsaritzin railway in Russia.

Q. What is the most usual way of introducing the fuel into the fire-box?

A. By an atomizer or spray.

Q. Why is oil more used in Russia than in America?

A. Partly because coal is cheaper here; partly because most of the American oil is too good to be used for that purpose; it pays better to make illuminating and lubricating oil from it.

Q. Weight for weight, what are the relative values of oil and coal, properly burned?

A. One pound of oil should generate as much steam as $3\frac{1}{2}$ pounds of coal; but in practice it never does more than double as much work; usually only 50 per cent more.

Q. What are the principal factors in determining whether it will pay to use oil?

A. (1) How much it costs in comparison with coal.

(2) How much it costs to handle the oil.

(3) What the repairs and depreciation would amount to in each case.

Outside of the questions of repairs and depreciation, it may approximately be expressed by the formula:

$$\frac{(C + 10.7c)}{2{,}000\,E} = P;$$

in which C is the price of coal delivered at the engine, c the cost of firing the coal (as for instance $0.50 per ton), E the number of pounds of water that a pound of coal in question will evaporate into dry steam at the boiler pressure (as for instance 6), and P the price per U. S. gallon. (All prices in dollars or fractions thereof.)

Q. How much does a U. S. gallon of crude oil weigh?

A. About seven pounds.

Q. How many gallons in a barrel?

A. Forty-two.

Q. How many barrels in a gross ton?

A. Seven. (More exactly, 7.017.)

Q. How many U. S. liquid gallons in a gross ton?

A. Nearly 300. (More exactly, 294.72.)

Q. What is the heating power of ordinary crude oil?

A. California crude oil ranges about 19,500 British thermal units per pound.

Q. What is its evaporative power?

A. About 13.5 pounds of water from and at 212° F.

Q. At this rate, what is its efficiency in the boiler?

A. About 80 per cent.

Q. What American roads use oil burning engines?

A. The Southern Pacific, the Santa Fé, the Salt Lake, and nearly all the smaller California lines.

Q. What are the advantages of oil burners where oil is cheap?

A. (1) More perfect combustion than coal; (2) cheapness of handling; (3) absence of ashes to be handled; (4) no fuel burned at turn-outs and sidings, and little or none at stations; (5) lessened repairs, except in the matter of fireboxes and flues; (6) less expense in cleaning, because the engine remains cleaner; (7) less wear of the engine, from smoke and cinders; (8) less waste of steam by blowing off, as the combustion may be controlled; (9) no choking up of ballast by cinders thrown from the stack or dropped from the ash pan, interfering with the drainage and causing expense for cleaning; (10) less space taken up in storing, by reason of the smaller volume and the possibility of having the oil stored in tall holders, taking up less ground; (11) less dead weight of fuel to carry; that is, for a given amount of steam generated, there is needed only half as many tons of oil as of coal, and when we consider the waste by coal firing at stations, this saving is still more marked, as no oil need be carried except that actually used in running; (12) no sparks, doing away with claims for damages to passengers' eyes and clothing, to goods carried in open cars, to crops along the road, and to the paint on the cars; (13) possibility of making flues smaller and having more of them, thus increasing the flue surface that may be put into a boiler. (This is, however, of comparatively little importance, so long as in the ordinary engine there is not enough grate surface for the flues already there.)

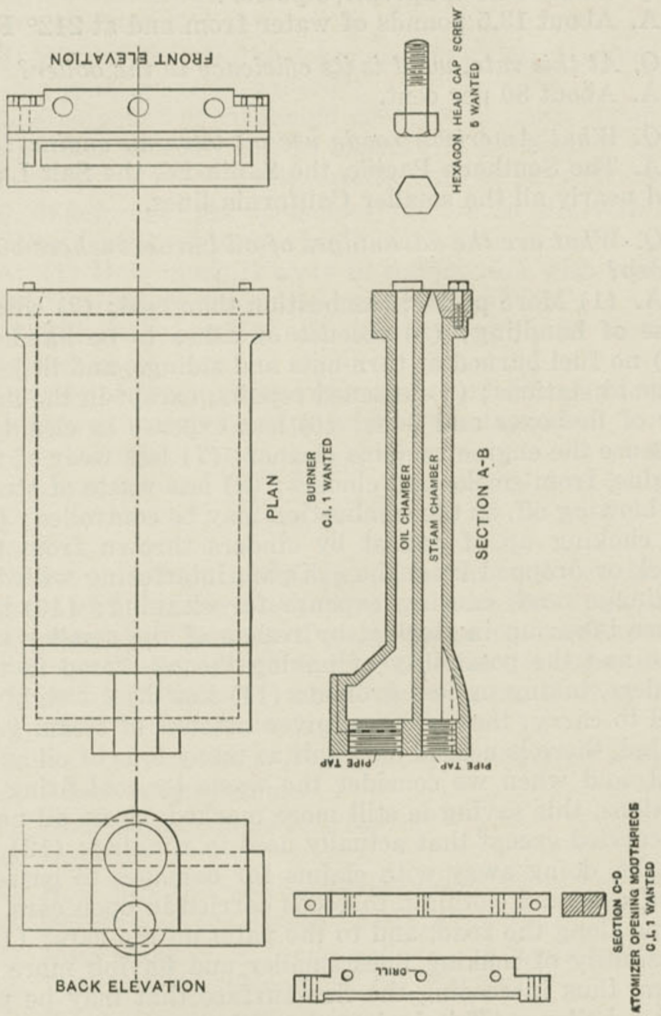


Fig. 296a. Booth Oil Burner, Santa Fé Lines.

Q. How many types of oil burners or mixers are there?

A. Two general types, outside and inside mixers.

Q. What is the distinction between these two?

A. In outside mixers the steam used to spray the oil meets it in the air; in inside mixers the oil and the steam meet each other in the jet.

Q. Name a type of outside burner.

A. The Booth-Wade, used on the Santa Fé line.

Q. Name one or more inside burners.

A. The Sheedy, used on the Southern Pacific; and the Hummel, used on the Salt Lake line.

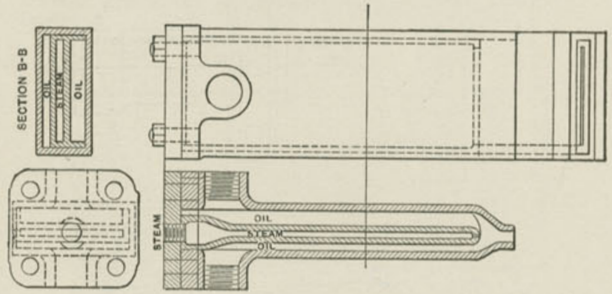


Fig. 297a. Sheedy Oil Burner.

Q. Describe the so-called Santa Fé oil burner.

A. Referring to Fig. 296a: There are two chambers, one for steam and one for oil, the latter being above and the former being supplied with a very fine slit, as shown at the left-hand end. The steam heats the upper chamber, and in time the oil as it flows from right to left in the figure. On issuing at the left it is spread by the steam into the fire, making a wide sheet of flame. The steam and oil supply valves are controlled from the cab. This burner is readily attached to the mud ring.

Q. Describe the Sheedy or Southern Pacific oil burner.

A. Referring to Fig. 297a: There are three passages, for steam, air and crude oil respectively. As seen in the figure, the oil enters above, the air below, the steam between the two, spraying the mixture of all three through one nozzle, both upwards and downwards; for which latter reason the burner is near the upper portion of the bricked-up part of the firebox.

Q. Describe the Baldwin type of oil burner.

A. Referring to Fig. 298a: This is of rectangular cross section, having a channel above for oil and one below for steam, both supply valves being operated from the cab.

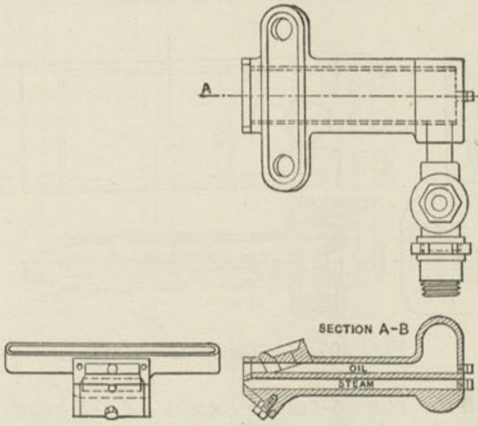


Fig. 298a. Baldwin Oil Burner.

The oil has free outlet at the nose of the burner; the steam, however, has a long narrow aperture, the width of which is controlled by an adjustable plate. The steam heats the oil above it, as in the other burner described.

Q. Where is this burner usually placed?

A. At the back end of the firebox, directing the spray against a brick arch.

Q. What other way is there?

A. To place it on the front end of the firebox, doing

away with the necessity of having a brick arch, which is a very expensive part, especially with oil burners.

Q. Describe the Lassoe-Lovekin oil burners.

A. Referring to Fig. 299a: The special feature is the absence of the brick arch. The oil is sprayed in under pressure of 120 pounds to the square inch, applied by a pump from the front end of the firebox, no steam being necessary.

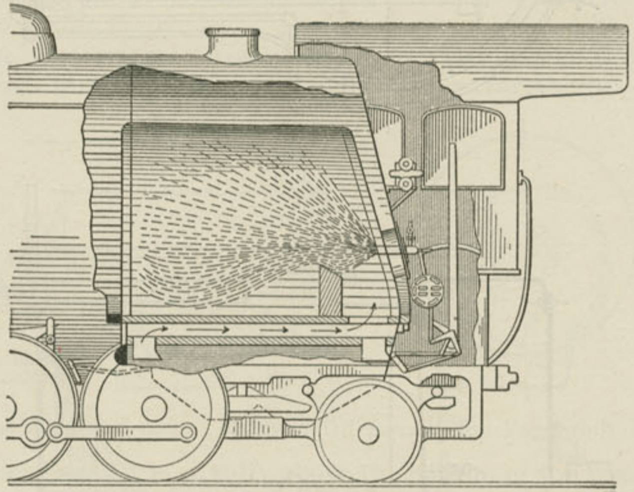
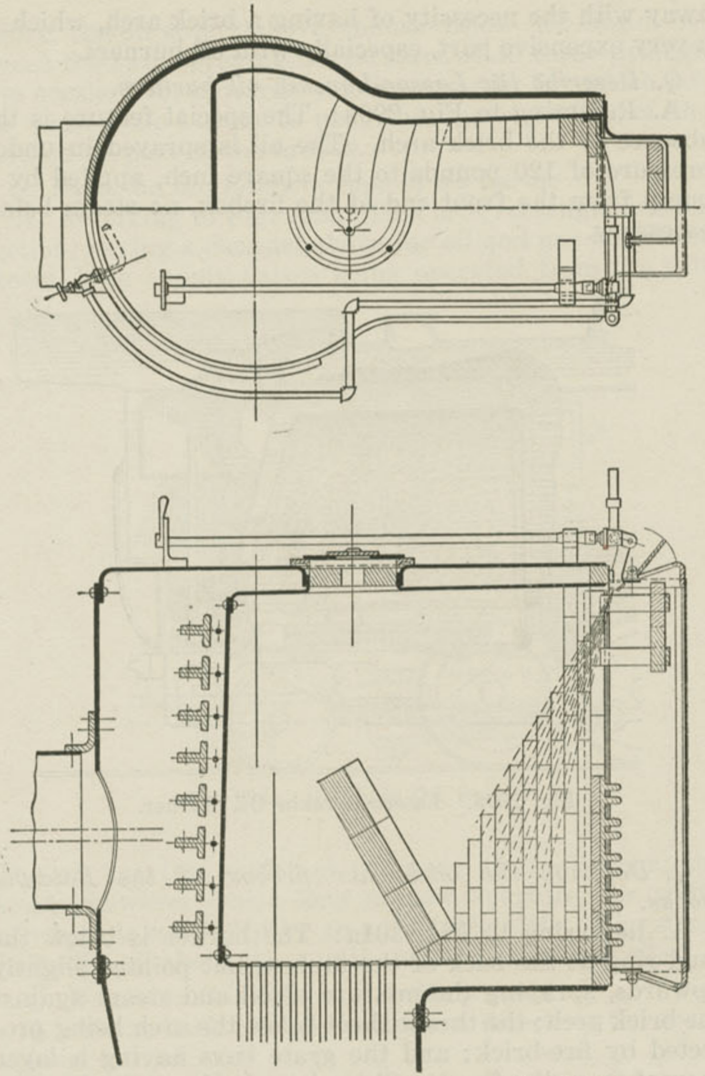


Fig. 299a. Lassoe-Lovekin Oil Burner.

Q. Describe the oil-burner firebox of the Baldwin works.

A. Referring to Fig. 301a: The burner is below the mud ring at the back of the firebox, but pointed slightly upwards, spraying the mixture of oil and steam against the brick arch; the throat sheet below the arch being protected by fire-brick; and the grate bars having a layer thereof from the front wall to about half-way back. Under the burner there is a fire-brick hearth to catch any



Figs. 300a and 301a. Baldwin Firebox with Oil Burner.

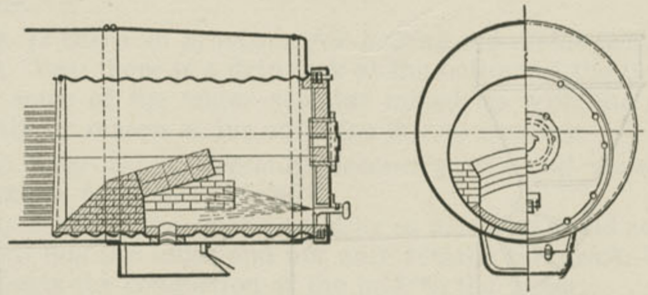
oil which may drop instead of being properly sprayed. The sides of the box are also bricked up high enough to prevent them being injured by the flame.

Q. How is the air admission controlled?

A. By a damper at the back, which can be closed perfectly airtight when the oil supply is shut off, to save cracking box and tubes. Instead of the fire-door there may be simply a peep hole. If there is a door it should be protected by fire-brick or ganister.

Q. Describe the Baldwin oil-burning firebox for the Vanderbilt boiler.

A. Referring to Figs. 302a, 303a: The burner is introduced through the line casing which forms the back



Figs. 302a and 303a. Baldwin Oil Burner for Vanderbilt Boiler

boiler head; it is slightly above the bottom of the box, and the corrugated wall of the firebox is protected at bottom and part way up by a fire-brick lining. The front wall and arch are far enough back to form a sort of combustion chamber for the gases before they reach the tubes.

Q. Should the oil be sprayed in hot or cold?

A. As hot as possible; first, because this promotes combustion; and second, because it facilitates its flow.

Q. What is the disadvantage of oil burning as regards the tubes?

A. There is apt to be a formation of gum and soot, choking up the tubes.

Q. How is this done away with?

A. It is not done away with; provision is made to remove the deposit by a sort of sand blast; there being a funnel which can be inserted in the fire-door to force sand by means of a steam jet through the tube, driving the deposit out through the stack. (See Fig. 304a.)

Q. How is the oil for oil-burning fireboxes carried?

A. In two tanks, one fitting inside of the ordinary coal bunker; the other lying over the water tank. Another way is to submerge the oil tank in the water tank.

Q. What precautions are taken with regard to the oil tanks?

A. Each of the two has an automatic check valve,

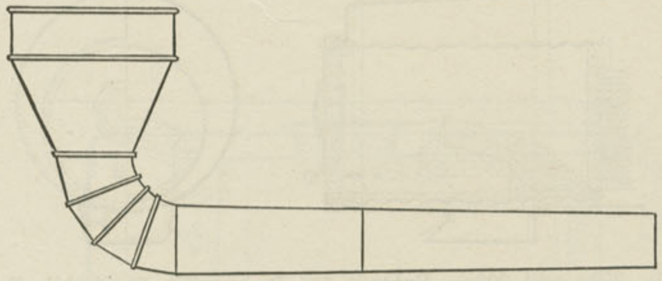


Fig. 304a. Sand Funnel for Flue Cleaning.

which closes in case connection between engine and tender is broken; there is a smaller one in the pipe between tank and burner.

Q. How is the oil heated in winter?

A. By a steam coil in the tank.

Q. Is the oil fed by gravity or under pressure?

A. Light oil can be fed in summer, or when it is warm, by simple gravity; but heavy oil, and light oil in winter, when it is not heated, must be fed in under about 5 pounds pressure per square inch.

Q. Does oil permit smokeless firing?

A. No; because it does not perfectly vaporize; the residuum causes smoke and soot; further, conditions change so often that perfect combustion cannot be maintained.

Q. Is oil firing easy?

A. From the physical point of view, yes; from that of wear and tear of the nerves, no; for the fireman has to keep his eye on the gage, and his hand on the oil throttle, all the time.

Q. What is the disadvantage of starting with oil?

A. That as the water always comes over at first, the fire is apt to spit by reason of the water putting out the flame.

Q. Is there no provision for getting rid of the water?

A. Yes; there is a drip cock at the bottom of the tank, but some of the water remains mixed up with the oil, partly by reason of the agitation due to running.

Q. Why is it specially necessary to avoid making smoke in burning crude oil?

A. Because the smoke contains so much gum and soot, which fills the tubes and not only retards the draft, but prevents the conduction of the heat to the water.

Q. What precaution must be taken in cutting down the fire?

A. With closed throttle, there is danger of putting the fire out in cutting down.

Q. What special harm would that do?

A. Sudden cooling down of the firebox, sheets, and flues, especially in view of the velocity of the moving train increasing the natural draft.

Q. How is the fire started in the oil-burning engine in the round-house?

A. Steam connection is made to the three-way cocks and the smoke arch, serving as both blower and atomizer; a piece of lighted greasy waste is put in front of the jet;

the oil is started running slowly, the steam valve is then opened enough to spray the oil, when the burning waste will light it. When steam is raised, the round-house steam should be cut off.

Q. What would be the effect of turning on too much oil?

A. Possibly to cause an explosion in the firebox, driving the flame out and injuring the fireman.

Q. What would be the effect of letting the fire go out when first started in the round-house or otherwise in a cold engine?

A. The oil would be apt to run into the pit and take fire later.

Q. How can the fireman tell if the fire has gone out?

A. By the smoke being of a milky white color; also by the smell.

Q. How can the fire be started in an oil-burning engine where no steam is available?

A. By using wood in the firebox until there is about 10 to 15 pounds pressure in the boiler; care being taken not to damage the fire-brick lining, and not to cause fires on the line.

Q. What is necessary as regards the relation of the engine-runner and fireman?

A. That they should be in perfect understanding with each other, so that before the throttle is closed the fireman can close the oil-valve to prevent smoke and popping. In starting up, the fireman should know in time to open the oil-valve just before the throttle is opened, so that the fire will be burning before cold air is drawn in by the exhaust. The fireman should reach the throttle lever and increase the oil flow in proportion to the steam consumption.

Q. What about the length of time requisite to bring steam up after it has been dropped?

A. No less time should be taken with oil firing than with steam, as the effect on the plates and flues would be bad.

Q. How should the firing be done on long down grades?

A. There should be a slight fire, and the injectors should be worked to prevent popping.

Q. What precaution should be taken as regards preventing explosion of the oil?

A. Not to go nearer to the man-holes or vent-holes of the tender than ten feet with a lighted torch or lantern.

Q. How can the fireman find out how much oil there is in the tank at night?

A. By inserting a dry clean stick, then taking this to the light, and measuring the part that has been in the oil.

Q. Is the oil tank dangerous when empty?

A. Yes; no light should be taken into it before it has been well steamed and washed out.

Q. What would be the effect of opening out the steam and oil jets before placing the lighted waste in the firebox?

A. There might be an accumulation of gas in the box, causing an explosion.

Q. What precautions should be taken before starting the fire?

A. The back damper should be raised; the fireman should see to it that there is nothing in front of the burner to obstruct the passage of the oil, and that there is no oil in the pan. The blower should be put on; the water blown out of the oil pipe; then the lighted waste put in.

Q. What about the cost of handling crude oil, as compared with that of handling coal for the same service?

A. The oil is about 75 per cent cheaper to handle.

Q. What accidents are liable to take place with the burner?

A. It may get stopped up with waste, or with scale or dirt; or it may burst from the heat.

Q. How is the fire to be put out?

A. By shutting off the oil valve from the tank, burning out all the oil that is between it and the burner and then closing the firing valve, the atomizer, and the dampers.

Q. What would probably be the effect of slipping or working the engine hard with the fire out?

A. To cause the flues to leak.

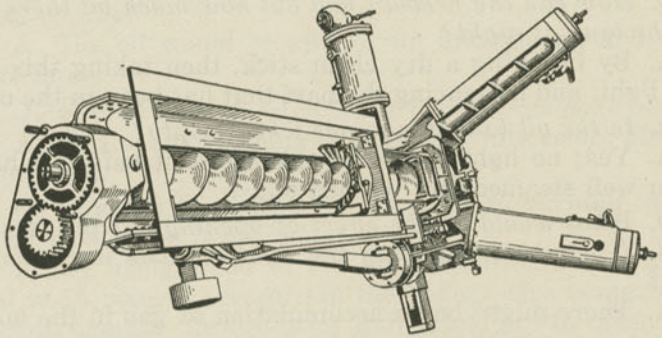


Fig. 305a. Duplex Mechanical Stoker.

Q. How are oil tanks to be cleaned?

A. By filling them with water, adding caustic soda, and turning on steam through the heater pipe until the oil boils over the manhole.

Q. Describe the Duplex stoker.

A. As seen in Fig. 305a, beneath the tender and cab decks there is a crushing and conveying system for carrying the coal from the tender to the engine, by means of a driving engine controlled by a steam valve. Beneath the cab deck is an elevating system with a hopper in which the coal is divided and delivered to two elevators that pass it to distributors set in the back head. The shovel sheet has an 18-inch opening from the coal gates to the slope of the tank; this opening being covered by 20-inch slides. After passing through this opening to the trough (1) the coal is carried by the screw 2 through the crushing zone (4) (where it is forced against the crusher casting and thus broken) and next to the transfer hopper (9). In this there are two elevator screws (11) which drop the coal into tubes fitted into elbows (16, 17) and extending through holes in the back head on each side of the fire door. Steam jets in the elbows blow the coal through the tubes, and distributors at their ends spread it. Either side of the fire box may be favored by moving the separating rib in the hopper.

Q. Of what is it a sign, if an engine is "a good smoker"?

A. That unburned or partially burned coal is going out of the stack.

Q. What is the difference between the draft in the fire-box and elsewhere?

A. It runs down in quantity from, say, 1.2 in front of the diaphragm to 1.0 back thereof; 0.4 in the fire-box and only 0.11 in the ash pan; from 18.8 in. in front of the diaphragm to 11.7 in. back, 2.9 in fire-box and 0.71 in the ash pan.

Q. What is the effect of air leaks in the front end?

A. To lessen the vacuum, hence calling for reduced exhaust nozzle opening, which in turn increases the back pressure in the cylinders and lessens the engine's tractive power.

Q. What ratios between draft and coal consumption can you quote?

A. In one fast passenger engine, with a draft of 0.4 inch of water in the fire-box, the coal fired per square foot of grate was 22.17 lbs. per hour; with 2.9 inches of draft, 173.26 lbs. per hour.

Q. What would be a good rate of hand firing?

A. 175 to 190 lbs. per hour per square foot of grate; say 12,500 to 13,300 lbs. per hour on a 70-foot grate.

Q. Does the mechanical stoker increase the evaporation and rate of firing over hand firing?

A. But little.

Q. What then are the advantages?

A. Regularity; ability to keep up steam over a longer time; more level firing.

Q. How about coal economy?

A. Hand firing is nearly 20 per cent more economical at low rates, say 2,800 lbs. per hour; but not at four or more times that.

Q. How much steam does the mechanical stoker use?

A. About 2 per cent of the total evaporation.

Q. How much coal is wasted by an unnecessary stop of a heavy train?

A. From 500 to 1,500 lbs.

Q. How much by a brake-line air leak on a heavy train?

A. About a ton every ten hours.

Q. What other fuel losses are there?

A. Using poor sand and over-sized shovels; failing to bank fires properly; overloading tenders; using heavy engines for light trains; unnecessary double-heading; not preparing for station work before the stop; unnecessary popping off; dragging brake-shoes; check-brakes; unnecessary stops at foot of steep grades.

*Q. How much coal is saved by putting in superheaters and new valve gears?**

A. Usually about 20 per cent.

Q. How much is wasted by popping five minutes?

A. About 75 pounds.

Q. How far will a pound of coal carry a ton of freight?

A. Fifteen miles on a straight level track.

Q. If only one shovelful per ton is wasted, what would that amount to in a year on the American railways?

A. About a million tons.

* See under these heads.

Q. How can firemen save coal?

A. By firing little and often; carrying a thin fire and giving plenty of air; keeping flues clean and baffles in good order; keeping soot out of stacks.

Q. Which takes the more skill, firing thick or firing thin?

A. Firing thin.

Q. How can an explosive mixture be formed in a fire-box?

A. Either with a tight box and fire-doors completely closed so that the fire-box is filled with a combustible gas that may burn so rapidly as to practically constitute an explosion, or when with the doors wide open and the box full of air, slacky coal is fired on the grate and the doors quickly closed, so that the gases from the new coal form an explosive mixture with the air already in the fire-box.

Q. What causes clinkering?

A. Melting the ash.

Q. Will all coal clinker?

A. Yes, if the ash is fused.

Q. What are the most common causes of clinkering?

A. Thick fire, excessive slicing, burning coal in the ash pan, excess of slack in the coal, closed ash pan, excessive pre-heating of the air under the grate.

Q. Why does a thick bed cause clinkering?

A. Too little air comes through the grate, so that the ash gets heated; also, the heating is partly done in a reducing atmosphere of CO.

Q. How does excessive slicing cause clinkering?

A. The fireman pries up the crust from below and thus lifts ash and clinker into the burning coal.

Q. How does burning coal in the ash pan cause sticky clinker?

A. It is shaken through, or fresh fuel drops through holes in the bed; melted ash above the grate stops the air spaces and makes it worse.

Q. How does slacky coal cause clinkering?

A. It forms a crust, which when broken causes ash to mix with the burning coal.

Q. How can smoky coal be burned without visible smoke?

A. By mechanical stoking, or if that is not practicable by (1) effecting complete combustion by admitting more air than theoretically necessary for complete combustion; (2) intimate mixing of the air with the combustion gases and floating tar particles; (3) keeping the temperature high enough to ignite the combustible while it is mixing with the air.

CHAPTER LXXVI

CAB, TENDER AND ACCESSORIES

THE CAB

Q. What sorts of cabs are used on engines having broad fire-boxes?

A. On those having broad (Wootten) fire-boxes there are two cabs: a large one saddled over the boiler waist; the other, much smaller, to shelter the fireman at the back end. With the latter type a roof on the forward end of tender is frequently used, the tender-cab roof being slightly lower than that of the engine cab.

Q. What are included under the term "cab fittings"?

A. The special devices on and near the boiler head under the direct control of the engineman. These include the steam gage, sight-feed lubricator, air-pump throttle valve, blower valve, steam-heat valve, air gage, cylinder-cock handle, sander handle, bell ringer, injector valves, gage cocks, water gage, throttle, reverse lever, air-signal whistle, cab lamp, etc.

THE TENDER

Q. Where are the fuel and water usually carried?

A. In a tender; a separate vehicle having its own trucks but always run just back of the engine, to which it is attached by a coupling and safety chains. Most commonly the water tank is of U shape with the opening toward the cab, and the coal in the space between. Sometimes the coal is on top of the tank, a flaring edge preventing its falling off in case it is piled up.

Q. What is the usual way of filling the tender tank?

A. By hose from a pipe or tank at the watering stations; the tender tank having a manhole or filling hole into which the free end of the hose is put.

Q. By what means can a tender tank be filled with water without necessitating stoppage of the train?

A. By having a trough in the center of a level reach of track for a mile or so, and a scoop tube let down from the tender after it has got over the tank, and withdrawn before the other end of the trough is reached. The velocity of the train causes the water to be forced up the scoop tube into the tender.

Q. Describe this scoop in detail.

A. It consists of a hung cast-iron or steel-plate conduit of rectangular cross section, about 8 x 12 inches, passing up through the tender tank and turned over at the top, to discharge the water downward. The lower end, underneath the tender frame, is fitted with a scoop that can be lowered into the trough by a lever worked by hand, or by compressed air in a cylinder, the piston rod of which is connected to a mechanism for raising and lowering the scoop. The water is forced up through the pipe into the tender tank when the scoop moves through the trough at 25 to 40 miles per hour.

Q. How does the water reach the engine from the tender?

A. There is between the two a flexible hose, usually attached to a sink or cistern in the bottom of the tank, which lessens the probability of air being sucked into it when the water is nearly all drawn out; the opening to this sink or cistern being controlled by a disk valve working in a strainer chamber, which prevents the passage of trash that might clog the pump valves.

Q. What is the disadvantage of having a tank on the boiler?

A. It is inconvenient and unsightly; has not room for much water; the driving wheels may have too much load on them when the tank is full, and then when there comes need for plenty of traction, the tank may be empty and the useful load not be there.

Q. How are the tender trucks made?

A. About like the engine trucks, except that the journal bearings and frames are outside the wheels instead of inside, to give greater facilities for oiling, or for renewal of the bearings.

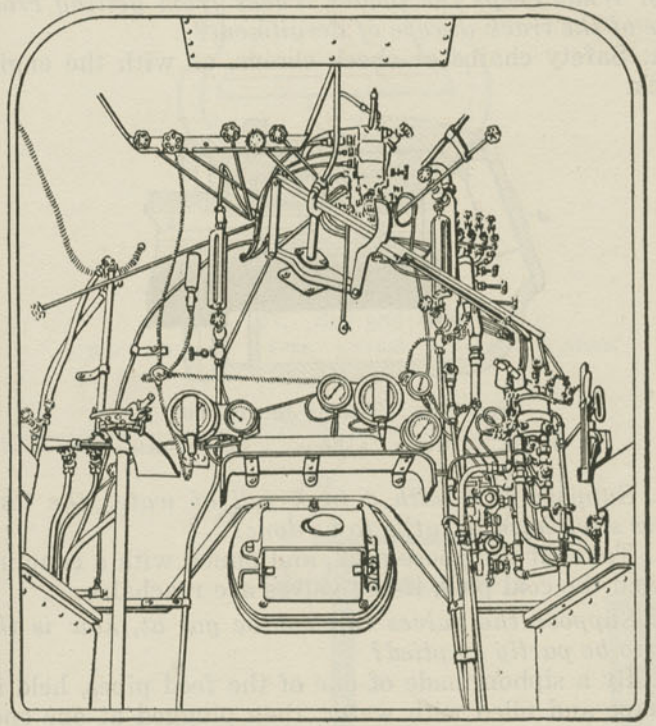


Fig. 306. Interior of Cab.

Q. How are the tender-axle boxes made?

A. About like car-axle boxes, the journals being in a cast-iron box open front and rear and having a cover. (Fig. 306.)

Q. What keeps the oil from leaking out of the box, past the journal, and dust from getting in?

A. A wooden or leather packing piece or dust guard.

Q. How is the tender usually borne by its trucks?

A. On two points at the back axle, and on a center pin at the front axle, thus giving a three-point bearing.

Q. What keeps the tender trucks from getting crosswise of the track in case of derailment?

A. Safety chains or check chains, as with the engine truck.

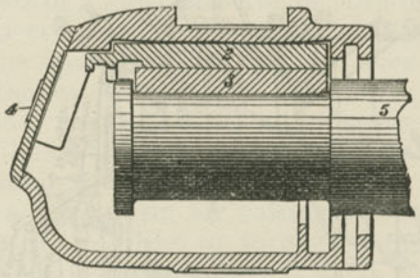


Fig. 306a. Tender Journal-box.

1. Box. 2. Wedge. 3. Brass. 4. Lid. 5. Axle.

Q. Suppose that with a tank full of water the tank valves stick hard, what is to be done?

A. Take off the goose-neck, and punch with a coupling pin and the coal pick, if the valves are reachable.

Q. Suppose the valves can not be got at, how is the tank to be partly emptied?

A. By a siphon made of one of the feed pipes, held in U shape and filled with water, then plugged at one end, inverted in the water, and opened out; care being taken to have the short leg in the tank.

Q. How are you to tell, at night, if the tender tank is full?

A. By a stick or the hand, or by spitting; as the reflection of a torch is apt to be misleading.

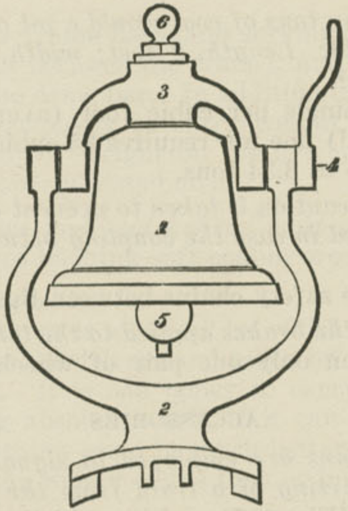


Fig. 307. Bell and Frame.

1. Bell. 2. Frame. 3. Yoke. 4. Crank. 5. Tongue. 6. Acorn.

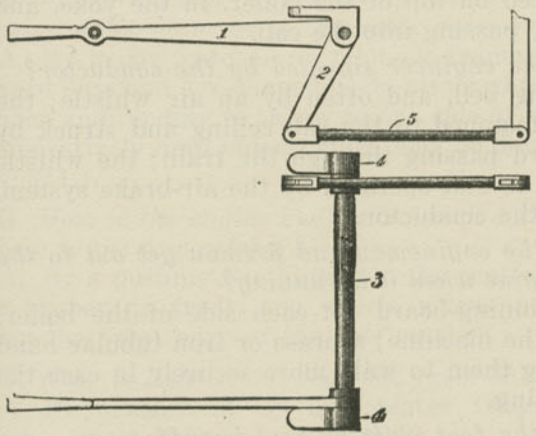


Fig. 308. Whistle Work.

1. Lever. 2. Arm or Crank. 3. Shaft. 4. Shaft-bearing. 5. Link.

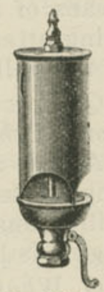


Fig. 309. Chime Whistle.

Q. How many tons of coal would a pit of the following dimensions hold: Length, 9 feet; width, 4 feet; depth, 3 feet 3 inches?

A. At 57 pounds per cubic foot (average weight of bituminous coal) one ton requires 35 cubic feet, and $9 \times 4 \times 3.25 \div 35 = 3.34$ tons.

Q. What precaution is taken to prevent engine and tender being parted in case the coupling between them gives away?

A. There are safety chains between them.

Q. How are the brakes applied to the tender?

A. Usually on only one pair of wheels; properly on both.*

ACCESSORIES

Q. What means are employed to signal the approach or intended starting of a train from the train itself?

A. The bell (Fig. 307) and the whistle (Figs. 308 and 309).

Q. Where is the bell usually placed, and how is it rung?

A. It is placed on top of the boiler, in the yoke, and rung by a rope passing into the cab.

Q. How is the engineer signaled by the conductor?

A. By a gong bell, and often by an air whistle; the former being fastened to the cab ceiling and struck by means of a cord passing through the train; the whistle being attached to and operated by the air-brake system, at the will of the conductor.

Q. How do the engineman and fireman get out to the front of the engine when it is running?

A. By a running-board on each side of the boiler, lengthwise of the machine; a brass or iron tubular hand railing enabling them to walk more securely in case the engine is lurching.

Q. What is the foot plate or foot board?

A. A heavy iron horizontal plate connecting the back ends of the upper frame bars, and serving as a floor for the cab, as a strut between the frames, and as a point of attachment for the draw bar. In addition to this, it may, by being made purposely of extra weight, serve to increase the amount of weight on the drivers, where the weight is not properly distributed.

* See under Brakes.

Q. Where do we find foot boards most common?

A. With engines burning soft coal or wood.

Q. Is this a good policy?

A. No, not if there is any way by which more weight may be thrown on the drivers and taken off the truck, by equalizing levers. It is bad policy to carry any weight that is not doing absolute work, if it can be dispensed with. The same thing could be much better done by supporting some of the weight of the tank or bunkers, by the rear frame end.

Q. How are obstructions, such as small animals or comparatively light rocks, etc., thrown from the track and thus prevented from getting under the train and causing either damage to the valve gear, or derailment?

A. By a cow catcher or pilot—a frame having a V-shaped base and a V-shaped back, attached to the bumper timber and tending to throw to one side of the track any comparatively light object which may be thereon. (Figs. 310, 311.)

Q. How is the engine enabled to push a train, without injury to the cow catcher?

A. By a pushing bar hinged to the center of the bumper timber, in front, and which, when not in use, lies along the front edge of the cow catcher.

Q. How is light snow removed from the track?

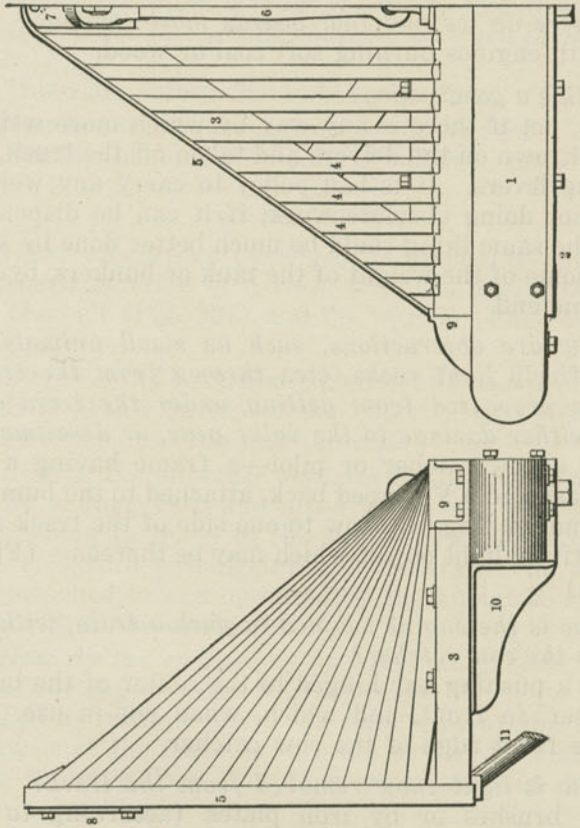
A. By brushes or by iron plates (according to its depth) attached to the cow catcher.

Q. What are the wheel guards?

A. Curved splashers of heavy sheet iron, surrounding the upper portions of the driving-wheel rims, to prevent the latter from throwing dirt on the engine.

HEADLIGHT*

Q. How is the engineer enabled to see ahead of the engine, on the track, at night?



Figs. 310 and 311. Pilot and Front Bumper.

1. Bumper. 2. Stiffening-plate. 3. Pilot-frame. 4. Pilot-bars. 5. Pilot Bottom-band. 6. Draw-bar. 7. Draw-bar Shoe. 8. Bottom Plate. 9. Pushing-shoe. 10. Pilot-bracket. 11. Middle Brace.

* See chapter on "Electric Headlight."

A. By a headlight of about 40 to 75 candle-power placed in front on a bracket and having a parabolic mirror by which its rays may be directed in a practically parallel beam striking the track in an elliptical area some distance ahead of the engine.

Q. What is the object of the headlight?

A. To cast a strong beam of light straight ahead of the

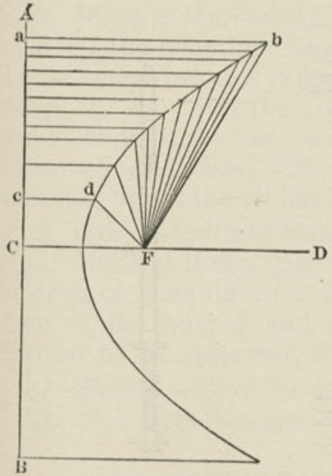


Fig. 312.

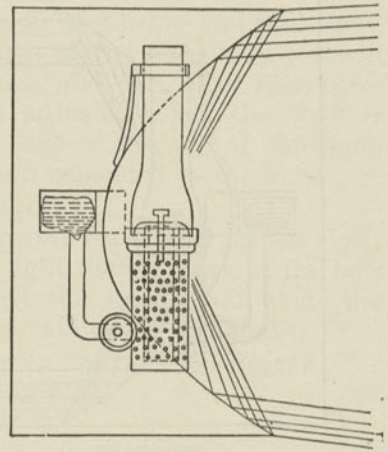


Fig. 313.

engine, so as (1) to permit the engineman to see obstructions on the track, signals, etc.; (2) to give warning of the approach of the train.

Q. What is the proper axial section of a headlight reflector?

A. A parabola; this is, referring to Fig. 312, a curve in which every point is just as far from the focus *F* as from a certain line *A B* at right angles to its axis *C D*. Thus, in the cut, $a\,b = b\,F$; $c\,e = e\,F$, and so on.

Q. Why is this curve chosen?

A. Because if the light is at the focus all the rays will be reflected out parallel to the axis, as in Fig. 313.

Q. What is the result if the flame is not in the focus?

A. The rays will either diverge as in Fig. 314, or converge.

Q. What is the object of the perforated tubing in the burner?

A. (1) To admit air around the flame, thus making the light whiter, (2) to keep the chimney cool.

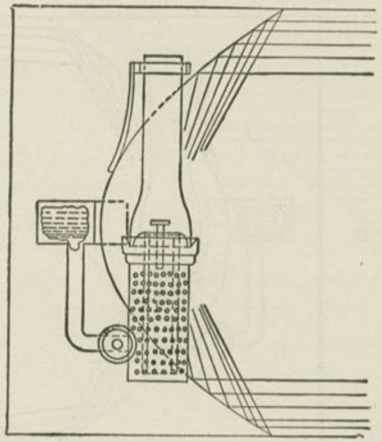


Fig. 314.

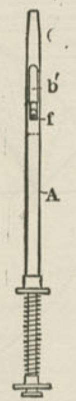


Fig. 315.

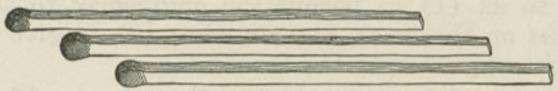


Fig. 316

Q. How may a headlight be lighted in a high wind?

A. (1) By placing three parlor matches as shown (Fig. 316) raising the wick, lifting the chimney and striking the lower match; (2) by using a tube *A*, Fig. 315, with a slot b^1, in which a match is put; putting the tube down the chimney and pressing the button; (3) by winding a small strand from a piece of cotton waste around the head of a match, removing the cap from the filling hole in the reservoir and dipping the match in, far enough to saturate the waste, then lighting the match by touching the front end. If the wind is very high, the wick may be raised a trifle.

Q. Does headlight oil expand when it is heated?

A. Yes.

Q. What is the result?

A. If the headlight reservoir is filled so full that there is no space for the expansion of the oil, the latter will force its way into the burner, and no matter how carefully the light has been adjusted when the wick is trimmed, the blaze will go out of the top of the lamp chimney when the oil has been expanded by the heat.

Q. Can a headlight blow up?

A. No; but it can burn up; the blaze may get too high; a drop of burning oil may light the drip can at the bottom of the burner and melt the solder that holds the burner to the reservoir, thus ruining the headlight.

Q. Should a torch be used to light the headlight?

A. No; it smokes and drips oil.

TURNTABLES, LOOPS, Y'S

Q. How can a locomotive be turned around on the track?

A. By a turntable, a loop, or a Y.

Q. How is a turntable usually constructed?

A. There is a circular pit of diameter rather greater than the combined engine and tender length, and having a circular track on which roll the wheels of a bridge-like table bearing the track and engine, turning about a central vertical pin. The wheels lessen the friction, and levers projecting outwards from the turntable, or gearing, enable one man to turn it with its load. Proper latch pieces lock it in position to prevent derailment of the engine in going on or off the table. The turntable of course enables an engine not only to be reversed, but to be run on any one of a number of tracks running in lines radial to the center pin of the table.

Q. On what principle is the loop constructed, by which to reverse the position of the engine?

A. There is very little to explain about it. A pear-shaped or kite-shaped siding is led out from the track and returned to it, so that the engine which starts thereon heading north returns to the main track heading south.

Q. How is the Y constructed?

A. It is simply a triangular track, usually at the end of a line; the engine starts up one branch, at an angle to the main track, and then curves off to a cross track at right angles to the main one; this gives it 90° of change in direction; then switching back to another curve it re-enters the main track in the opposite direction to that which it had on leaving.

CHAPTER LXXVII

COMPOUND LOCOMOTIVES

Q. What is a compound locomotive?

A. One in which, as ordinarily used, the exhaust from one or more cylinders is made to do work in one or more other cylinders in what is called "two-stage" expansion, instead of escaping directly into the stack after one expansion.

Q. How many cylinders may a compound locomotive have?

A. There may be (1) two, one high-pressure* and the other low; or (2) two high-pressure and one low into which they both exhaust, or (3) one high-pressure and two low into which it exhausts, or (4) two high-pressure, each exhausting into a separate low-pressure; that is, four cylinders in all.

COMPOUND VERSUS NON-COMPOUND

Q. What are the general advantages of compounding?

A. To enable the steam to be expanded more times without causing such great range of temperature in one cylinder; to distribute more evenly the pressure due to expansion, thus lessening the variation of pressure on the crank-pins during a rotation; to enable greater starting power and greater hauling power on grades, than could be obtained with cylinders of the comparatively small diameter required for non-compound engines; to call for less work on the part of the boiler; to save by the use of higher boiler pressure than would be possible with simple engines. Also, repair may be for some reasons less, by reason of the strains on the pins and axles being more even, and the boiler being less worked; and there is less cylinder condensation.

* Hereafter, the abbreviations H. P. and L. P. will be used instead of the words high-pressure and low-pressure.

Q. Considering that no engine can haul more than her adhesion to the rail will allow, and that almost any engine can slip her drivers, where does the advantage of compounding in this particular come in?

A. That by reason of the more regular pressure on the pins, due to more even distribution of the steam pressures at different piston positions, a compound will often, at slow speed and on steep grades, be able to keep the train going where the non-compound would slip and stall. The "bite" on the rails is more regular.

Q. What may be said of the maximum average or mean effective pressure of the compound engine as compared with the non-compound, at slow speeds and late cut-offs?

A. It is lower.

Q. How is it with earlier cut-offs and higher speeds?

A. The compound engine is about the same as the simple (non-compound).

Q. If the compound engine is designed for the power necessary at high speed, when will it be apt to be lacking?

A. At low speeds and late cut-offs.

Q. Suppose we made the high-pressure cylinder large enough to take care of the heaviest work, what then?

A. The engine would have too large cylinders for ordinary running.

Q. What would be the disadvantage of having too much cylinder?

A. When on straight levels, the mean pressure needed would be got with earlier cut-offs than is considered good practice with ordinary valve gear, and the final pressure in the large cylinder would be so low that it might be under that of the atmosphere.

Q. If we have the H.P. cylinder about the same size as for an ordinary locomotive, and the L. P. cylinder properly proportioned to this, what should be the increase in capacity and fuel economy in the compound over the non-compound engine, other things being equal?

A. About five to ten per cent increase of hauling power, and ten per cent fuel saving.

Q. Is re-evaporation of steam in the cylinders greater or less in compound than in simple engines?

A. Much less.

Q. Does this make dryer or wetter steam in the cylinders?

A. Wetter.

Q. How about the steam coming from the stack, in the case of the compound?

A. It is usually wetter than from a simple engine, not by reason of priming, but because it is not re-evaporated.

Q. How can this extra water be got rid of?

A. By cutting small notches in the cylinder cocks so that they will always bleed a trifle; and more particularly by having on the "low" side what are called safety valves, but are properly automatic water-valves.

Q. Is any special difference necessary in the slide valves for compound engines and those for non-compound locomotives?

A. For compound working there is needed for the H. P. cylinder larger inside clearance (negative exhaust lap) by reason of its having ordinarily such considerable back pressure, and of the necessity of keeping its exhaust open as late as possible to prevent excessive cushion in that cylinder; and as with the same back pressure as in non-compounds there should not be in the L. P. cylinder a cushion pressure higher than the receiver pressure, the same excessive inside clearance is needful for the L. P. cylinder also.

Q. On a compound should the fire be carried lighter or heavier than on a non-compound?

A. Lighter, as the exhaust is milder.

Q. How about the effect of the size of driving wheels *on compounds on the mean effective pressure at high speeds?*

A. It is even greater than with non-compound engines, as compounds lose power more rapidly with speed increase than do non-compounds.

Q. *Is balancing more or less difficult with compound than with non-compound engines?*

A. More, because of the larger and heavier pistons and all other reciprocating parts.

Q. *How about the exhaust from a compound, as compared with that from a simple engine?*

A. There being so much lower final pressure, the blast is softer; and (with two cylinders) there are but two instead of four exhausts in each turn, with a larger quantity of steam passed out.

Q. *What effect does this have on the fire?*

A. It is urged more evenly and gently, and less coal is pulled.

Q. *What is one advantage of the compound engine as regards regenerated steam?*

A. It utilizes better than the non-compound (or single-expansion) engine that steam which would be condensed against the cylinder walls of the H. P. cylinder; the walls of the L. P. cylinder not having a much lower temperature at the moment of expansion of steam than those of the H. P.

Q. *What objections are raised to compound locomotives from the point of view of the general management?*

A. That they miss trips by undergoing repairs, and fail on the road, so that the loss ensuing therefrom is greater than the gain by coal saving.

Q. *What is the reason for the drop in popularity of the compound, in spite of all the advantages?*

A. Insufficient instruction of engine-runners and overloading.

CYLINDER RATIO

Q. *Which should have the greater volume, the H. P. or the L. P. cylinder?**

A. The low.

Q. *How is this greater volume usually obtained?*

A. (1) By having the stroke the same in both the H. P. and the L. P. cylinders, and giving the latter greater diameter; or (2) by having two L. P. cylinders to one high.

Q. *What is the usual rule for the ratio (proportion) between the H. P. and the L. P. cylinder volumes?*

A. There is no general rule; a limit is placed by the maximum diameter possible to give the L. P. cylinder. In two-cylinder compounds the L. P. cylinder may have from one and three-quarters to two and three-quarters times the area of the high. Perhaps about two and one-tenth is the usual and best ratio for the present stage of knowledge in this line.

Q. *How is the division of the work between the two cylinders regulated?*

A. By proper adjustment of the valve-gear.

Q. *Could a compound be constructed, in which the proportion of expansions in the H. P. and the L. P. would be always the same, no matter in what gear? That is, where the cylinder ratios would always be the most favorable for the pins?*

A. No; if the L. P. cylinder had the proper area for cut-off at one-half in the H. P. it would have too much mean effective pressure when cut-off took place later, too little when it took place earlier in the H. P.

* Where there are two H. P. cylinders discharging into one low, or two L. P.'s getting steam from one H. P., the two are to be considered as one, as regards cylinder volume.

Q. Which type of compound permits the most efficient cylinder ratio?

A. The four-cylinder; but it usually has offsetting disadvantages in the way of valve gear.

Q. What are the usual two-cylinder (receiver) cylinder ratios?

A. From 1.75 to 2.75 to 1; 2 to 2.4 giving the best results.

Q. The usual four-cylinder ratios?

A. About three to one.

Q. Is the ratio the same for small as for large engines?

A. No; it is greater for small ones.

Q. Is it the same for freight as for passenger engines?

A. No; it is greater for passenger engines.

Q. What are the limits of cylinder ratio for four-cylinder non-receiver compounds in which both sides are alike?

A. From 2.7 to 3.2.

Q. Have European compounds greater or less cylinder volume for a given hauling power than American?

A. Greater, as a rule, despite the greater limitations there as regards clear space in bridges and tunnels.

Q. What effect has the cylinder ratio on the L. P. cut-off.

A. The smaller ratio requires later L. P. cut-off.

Q. What is an objection to two-cylinder compound locomotives having the H. P. cylinder on one side and the low on the other, as in Fig. 323?

A. It is difficult to get the power so divided between the two sides as to avoid racking the machinery and swinging the engine from side to side.

Q. How can this difficulty be avoided and yet preserve the two-cylinder receiver type?

A. By having on one side one H. P. cylinder, and on the other two L. P.'s of the same diameter as the H. P., one over the other and both taking hold of the same crosshead as in Fig. 319. (Lapage type.)

Q. How may the work be equally divided between the H. P. and the L. P. cylinder?

A. Sufficiently evenly by adjusting the cut-offs; especially where the engines always run in one motion and have Stephenson, Allan, Joy, Walschaert, or other positive motions.

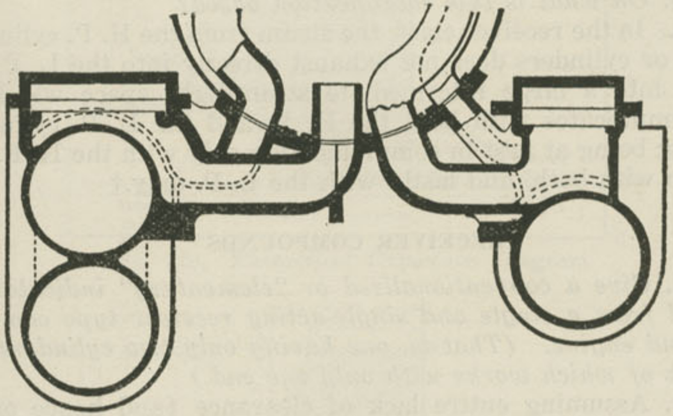


Fig. 319. Three-Cylinder Compound.

Q. What is the usual adjustment for this purpose?

A. (1) Changing the position of one link; (2) altering the link-hanger length, or (3) off-setting one reverse-shaft arm.

Q. Where engines are to run in both directions, how is the usual distribution of work effected?

A. Where the cylinder ratios are favorable, and especially if steam economy is not too important, by giving the slide-valves different outside laps.

Q. What diameter of L. P. cylinder is it practicable to get with an outside-cylinder compound engine?

A. Thirty-one inches, giving with a H. P. diameter of twenty, a piston-area ratio of nearly 2½ to 1.

GENERAL CLASSIFICATION OF COMPOUNDS

Q. What are the main classes as regards steam distribution into which locomotive compounds may be divided?

A. As in stationary and marine engines into (1) "receiver" and (2) "non-receiver," "receiverless," "continuous expansion," or "Woolf."*

Q. On what is this classification based?

A. In the receiver class, the steam from the H. P. cylinder or cylinders does not exhaust directly into the L. P., but into a large intermediate steam-tight space which communicates with both the H. P. and the L. P. cylinders; being at first in communication only with the H. P., then with both, and lastly with the L. P. only.†

RECEIVER COMPOUNDS

Q. Give a conventionalized or "elementary" indicator card from a single and single-acting receiver type compound engine. (That is, one having only two cylinders, each of which works with only one end.)

A. Assuming entire lack of clearance (and hence of compression) instantaneous admission and exhaust exactly at stroke end, no wire drawing, and no irregularity caused by the connecting rod, something like this: (Fig. 320).

The steam pressure in the H. P. cylinder rises suddenly from *A* to *B*, continues during so-called full steam, at chest pressure, falls regularly at cut-off (here at half stroke) to *D* at stroke-end; drops to receiver pressure at *E* (thereby causing loss of economy). From *E* to *F* the pressure of this exhaust rises in the receiver until half stroke, where it is released from the receiver into the L. P. cylinder. From this on up to point *A* at half stroke,

* Not to be confused with "Wolff" compounds, which have receivers. (Note two f's instead of two o's.)

† The number of H. P. or of L. P. cylinders has here no significance.

where the H. P. piston makes a new stroke, its pressure drops by reason of the H. P. cylinder's not supplying steam fast enough to the receiver. At *A* we will say that the L. P. valve cuts off receiver steam from the L. P.

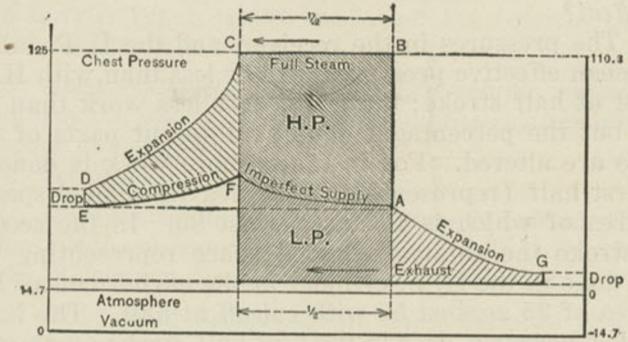


Fig. 320. Theoretical Expansion Diagram.

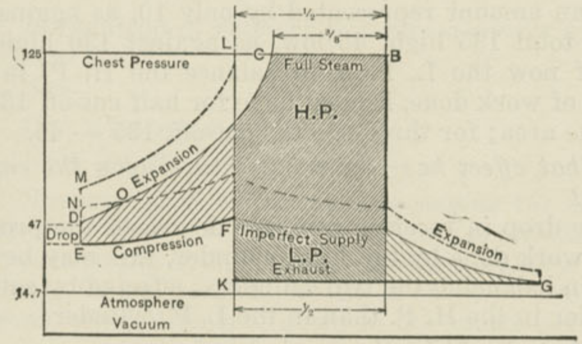


Fig. 321. Theoretical Expansion Diagram.

cylinder; hence from *A* to *G*, at stroke end, the pressure in this cylinder drops regularly by expansion.

Q. What is the effect of the engine being double-acting instead of (as here shown) single-acting?

A. A rise of pressure at *A* in both receiver and L. P. cylinder, caused by the exhaust from the opposite end.

Q. Suppose instead of cutting off at half stroke in the H. P. cylinder of the receiver engine, as in Fig. 321, reproduced here in dotted lines, steam is cut off at three-eighths stroke, as shown by full lines in Fig. 321; the low-pressure cut-off remaining unchanged; what will be the effect?

A. The pressures in the receiver, and the L. P. initial and mean effective pressures, will be less than with H. P. cut-off at half stroke; the H. P. does less work than before, but the percentages done at different parts of the stroke are altered. For instance, more work is done in the first half (represented by the heavily-shaded space) the area of which is 100 as against 80. In the second half-stroke the similarly-shaded space representing the work done in the H. P. cylinder at the earlier cut-off has an area of 35 against 50 with cut-off at half. The L. P. cylinder, however, does in the first half-stroke an amount represented by 35 as against 40 at half cut-off, and in the second an amount represented by only 10, as against 20 before; total 135 high, 45 low, as against 130 high, 60 low. If now the L. P. is to balance the H. P. in the amount of work done, it must have for half cut-off 130 — 60 = the area; for three-eighths cut-off, 135 — 45.

Q. What effect has receiver pressure upon the engine balance?

A. As drop in receiver pressure decreases the proportion of work done by the L. P. cylinder, this may be employed in balancing the two cylinders; effected by cutting off earlier in the H. P. than in the L. P. cylinder.

Q. What should be the receiver volume in comparison with that of the H. P. cylinder?

A. The greater the better, as permitting better adjustment of cut-offs and less variation of receiver pressure.

Q. What is the usual ratio?

A. From 2.5 to 4.5; 2.5 being the minimum desirable.

Q. To keep the steam as dry as possible, what should be done with the receiver?

A. It is well to inclose it in the smoke-box.

Q. How large should the receiver be?

A. It should have a volume at least as great as that of the high-pressure cylinder, especially in the Worsdell and von Borries types, where the larger the receiver the better the action in starting.

Q. Does relatively large receiver volume increase or diminish the possibility of equalizing the relative amounts of work done by the two cylinders?

A. Increase it.

Q. How closely do builders endeavor to balance the two cylinders for ordinary running?

A. Within ten per cent.

Q. How about balancing the work between the H. P. and L. P. cylinders in starting a train with a compound?

A. It is not to be expected.

Q. Is the drop in receiver pressure a source of loss in efficiency?

A. Yes.

Q. Can it be removed?

A. Only for one point of cut-off.

Q. Suppose that in a receiver engine the indicator cards show that more steam is used per stroke in the L. P. than in the H. P. cylinder; of what is that a sign?

A. (1) Of leaky valves or (2) of re-evaporation in the receiver, where this is situated in the smoke-box.

Q. Is superheating in the receiver possible, as well as re-evaporation?

A. No, there is no time therefor.

Q. Suppose that the cards from a receiver engine show that the L. P. cylinder used less steam than the H. P.; of what is that a sign?

A. Of condensation either in the receiver or in the L. P. cylinder.

Q. In what cases is re-evaporation in the receiver most likely to occur?

A. Where the receiver is in the smoke-box, especially if the tubes are short and the engine is working hard, which will give an especially high smoke-box temperature.

Q. What about steam-jacketing the cylinders, or the receiver in case this is outside the smoke-box?

A. It proves no advantage, as there is as much steam condensed in the jacket as there would have been in the receiver or cylinders. Further, steam jackets on locomotive work are troublesome to drain.

Q. What is the disadvantage of putting the receiver in the hottest part of the smoke-box?

A. Difficulty of tube cleaning.

Q. What is the advantage of a receiver cross-compound?

A. As the crank axle is connected with pistons traveling in opposite directions, good balancing in this particular; the inside cranks are also partly balanced by the outside wrist-pins; other drivers than the main ones are counterbalanced for their own weight only; the H. P. and L. P. pistons also nearly balance each other; hence in general the vertical stresses on the rails are comparatively even.

RECEIVERLESS COMPOUNDS

Q. As a general rule, do the H. P. and the L. P. pistons of receiverless engines move together or against each other?

A. Together, as in the Vauclain (Baldwin) non-balanced four-cylinder engine and the Du Bousquet (French) type.

Q. Give a "conventionalized," "elementary," or explanatory indicator card of a receiverless compound?

A. Supposing that the pistons are attached to the same crosshead and the conditions as laid down for the receiver engine in preceding paragraphs, we have a diagram somewhat like this (Fig. 322):

We have full H. P. steam from *A* to *B;* sharp cut-off at *B,* expansion from *B* to *C,* where H. P. exhaust opens; here a slight drop from *C* to *D,* as the H. P. exhaust fills the connecting passages (which constitute in effect a

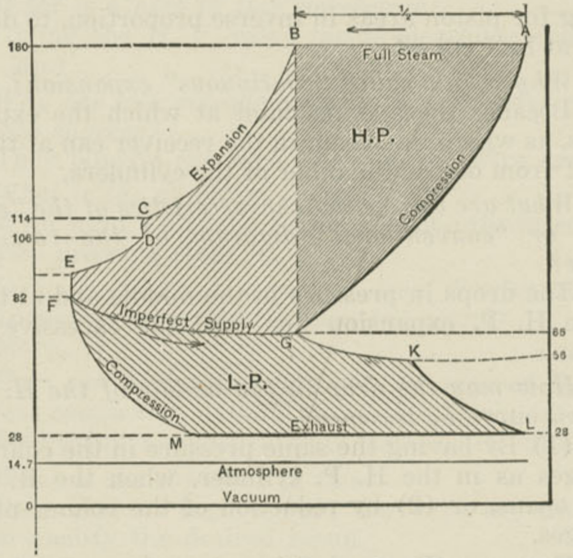


Fig. 322. Theoretical Expansion Diagram.

miniature receiver;) from *D* to *E* further expansion (this time in the H. P. cylinder plus the passage space;) at *E,* opening of the L. P. valve for admission, hence further drop in pressure owing to insufficient supply from the H. P. cylinder and connecting passages. From *F* to *G* the two cylinders are in communication, but the pressure drops, by reason of insufficient supply and of expansion, to *K,* when the L. P. valve cuts off. From *G* there are two simultaneous sets of results and pressures; compression in the H. P. cylinder and connecting passages up to *E*, where the H. P. exhaust closes; further compression in the H. P. cylinder not in connection with the passages, up to *A*, where admission again occurs; expansion in the L. P. cylinder up to *K*, where its valve opens and gives free exhaust nearly down to atmospheric pressure, at stroke end (point *L*.)

The area of the H. P. card is 275, that of the low 130, calling for piston areas in inverse proportion, to do equal work at half cut-off.

Q. Why is this called "continuous" expansion?

A. Because there is no point at which the expansion ceases, as where the steam in the receiver can at times be cut off from one or the other of the cylinders.

Q. What are the special characteristics of the "elementary" or "conventional" diagram of the receiverless engine?

A. The drops in pressure in the middle and at the end of the H. P. expansion line, and the excessive H. P. cushion.

Q. How may the drop in the middle of the H. P. expansion curve be lessened?

A. (1) By having the same pressure in the connecting passages as in the H. P. cylinder, when the H. P. exhaust opens, or (2) by reduction of the volume of those passages.

Q. How can the receiver pressure be made the same as that in the H. P. cylinder at the moment of H. P. exhaust opening?

A. By suitable adjustment of the L. P. cut-off—a complicated method, not to be recommended.

Q. How can the H. P. drop at stroke end be lessened?

A. (1) By compressing in the L. P. cylinder to the pressure in the H. P. before the drop; or (2) by reducing the L. P. clearance.

Q. In which class does the H. P. compression give the most trouble; in receiver or in receiverless engines; and why?

A. In receiverless; since to avoid excessive cushion it is necessary to have large H. P. clearance space; as the pressure at exhaust closure is already high.

Q. What does avoidance of excessive H. P. cushion, by having large H. P. clearance, entail?

A. The before-mentioned drop at the moment of opening the H. P. exhaust.

Q. What is a help in this connection?

A. Giving the H. P. valve inside clearance (negative inside lap.)

Q. Why are late cut-offs usually recommended for receiverless engines?

A. They obviate excessive cushion and wire drawing.

Q. What is the objection thereto?

A. With light loads the steam must be throttled; and here wire drawing steps in.

Q. Is wire drawing more or less disadvantageous in compound engines than in non-compound?

A. More.

Q. How can high expansion rate be secured in a receiverless compound, without excessively early cut-off?

A. By having a comparatively large L. P. cylinder.

Q. What is the objection to this?

A. Only that at high speeds the wire drawing and cushion modify the desired result.

Q. At what speeds does the actual mean effective pressure most nearly approach the calculated?

A. Low; for instance, it is sometimes, even with an excellent gear, and 175 pounds boiler pressure at 200 turns per minute, only 65 per cent that at 100; at 300, only 42 per cent; at 400, only 30 per cent.

Q. What is the effect on the draw-bar pull, of reduction of mean effective pressure with increased speed?

A. It decreases; for instance, with an extraordinarily good gear, where it was 19,000 pounds at ten miles an hour, it was only 12,000 at forty, and 5,000 at eighty.

With a poor gear it ran down from 18,500 at ten miles to 3,250 at eighty.

Q. *In the case of decrease of mean effective pressure due to increase of speed, does the power used up by engine and tender form a constant percentage of the total power developed?*

A. No; at high speeds the engine and tender use up a much greater proportion. For instance, in one case reported, with ordinary valve gear, the engine and tender used only 10 per cent of the total power at twenty miles an hour, but 80 per cent at eighty miles.

Q. *How about balancing the work between the H. P. and the L. P. cylinders of a non-receiver compound?*

A. It is not necessary in the four-cylinder tandem type, as the set of cylinders on one side balance those on the other. It is, however, quite necessary in the Vauclain "cross compound" because both H. P. and L. P. pistons take hold of the same crosshead; and here not only the mean effective pressures for the entire stroke but the effective pressures at various points of the stroke must balance at least so well that there will be no more twist on the Vauclain crosshead than with non-compounds with the Laird type.

ADVANTAGES OF THE TWO-CYLINDER TYPES

Q. *What is the special advantage of the two-cylinder type?*

A. Simplicity.

Q. *What are the objections thereto?*

A. (1) The immense size necessary for the low-pressure cylinder; (2) the difficulty of having the total crank-pin pressure on the two sides alike, especially when working non-compound (this increasing with the size of the machine, and the speed;) (3) in many cases the maximum permissible L. P. cylinder diameter is too limited; (4) the cost of the starting device.

Q. *How can the total pressure be nearly equally divided in the two-cylinder compound?*

A. By cutting off earlier in the high-pressure cylinder than in the low.

Q. *How may excessive cushion, especially in the high-pressure cylinder, be avoided in this two-cylinder type?*

A. By giving rather more than usual inside valve clearance, lead, and cylinder clearance.

Q. *In the two-cylinder or "cross-compound" as well as in the three-cylinder compound, where does the exhaust from the H. P. cylinder go?*

A. First into a receiver (either a chamber or a pipe, and usually in the smoke arch) and then (after being there somewhat reheated by the combustion gases, if the receiver is in the smoke-box) to the L. P. cylinder or cylinders.

Q. *What is the cause of the usual rise in L. P. and receiver pressure shortly after stroke commencement, in a two-cylinder receiver compound?*

A. The opposite H. P. end exhausts then, and thus raises the pressure both in receiver and in L. P. cylinder.

Q. *What is this action called?*

A. Re-admission.

Q. *Why is it usual?*

A. Because the H. P. cannot exhaust later than nine-tenths stroke, nor can the L. P. cut off earlier than three-tenths.

Q. *How many different pressures are there at once in the cylinders of a two-cylinder "cross compound" or of the two that work together in a tandem?*

A. Three; (1) the working pressure of the H. P. cylinder, (2) the exhaust pressure of the H. P. (which is practically equal to the working pressure of the L. P.,) and (3) the exhaust pressure of the L. P.

SPECIAL TWO-CYLINDER TYPES

Q. What are the principal types of two-cylinder receiver compounds?

A. (1) With automatic "intercepters" or starting gears but without independent H. P. exhaust for starting: the von Borries of 1899, the von Borries-Swiss, the Worsdell, the Schenectady (Pitkin), the Dean, the Brooks (Player), the Rogers, the Baldwin (Vauclain), and the intermediate types of von Borries.

(2) With automatic starter but no intercepter nor independent H. P. exhaust for starting: the Lindner, the Meyer-Lindner, the C. B. & Q. Lindner, the Pennsylvania Railroad Lindner, the Cooke, and the Gölsdorf.

(3) With intercepter and independent H. P. exhaust at starting; the Mallet (old and new,) the Rhode Island (Batchellor,) the Richmond (Mellin,) the Pittsburg (Colvin,) and the latest von Borries.

Q. What are the essential characteristics of the original von Borries two-cylinder receiver compound of 1899?

A. A combined intercepting and starting valve which, when the engine is working compound, permits steam to flow from the receiver pipe into which the high-pressure cylinder exhausts, to the low-pressure cylinder. There is a plate which in these circumstances stands off from the end of the receiver pipe, but on starting, is seated on that pipe-end! its movement uncovering ports which let steam from the boiler enter the low-pressure cylinder. As the engine starts, the high-pressure exhaust automatically forces this intercepting valve from its seat on the end of the receiver pipe, and closes the ports, which let boiler steam into the low-pressure cylinder, so that the engine then works compound. (See Figs. 323, 324, and 325.)

Q. How much of a rotation takes place before the high-pressure exhaust opens the intercepting valve and closes the starting valve?

A. From one-half to one rotation.

Q. Can these locomotives ever work "simple?"

A. No, because the high-pressure cylinder always exhausts into a closed receiver, never into the open air direct.

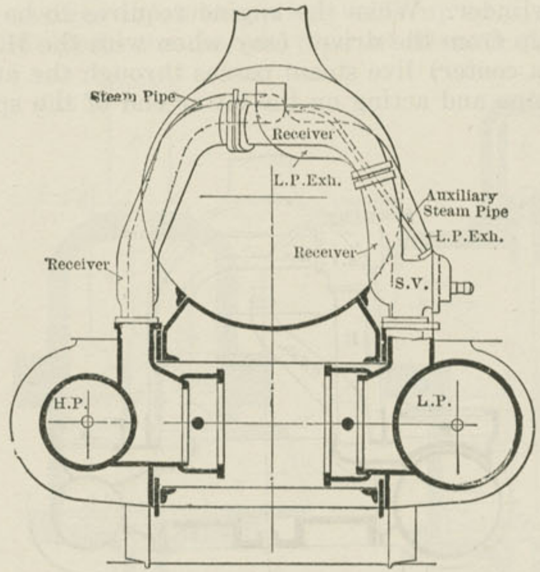


Fig. 323. Two-Cylinder Compound.

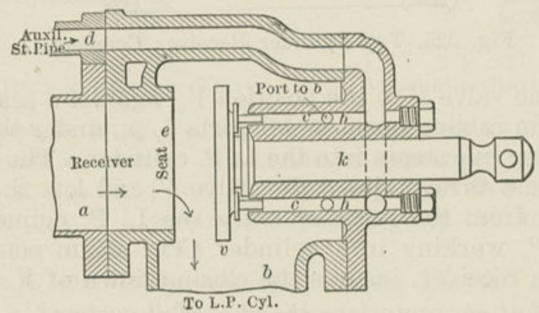


Fig. 324. Intercepting Valve.

Q. Describe the modified von Borries two-cylinder receiver engine, as used in Switzerland.

A. This has an automatic starting valve (such as is seen in Figs. 326, 327) where the receiver pipe joins the L. P. cylinder. When the engine requires to be started with help from the driver (say when with the H. P. piston on a center) live steam passes through the auxiliary steam pipe and acting on the lower end of the spindle *S*

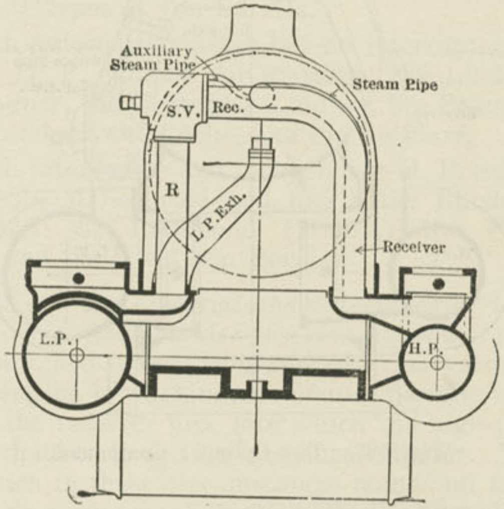


Fig. 325. Two-Cylinder Receiver Compound.

raises the valve *V* to the position V_1, against a seat. The spindle in raising opens small ports p, p_1, under the valve V_1, letting live steam into the L. P. cylinder. The first H. P. exhaust throws down the valve *V* and lets the H. P. exhaust from the receiver enter the L. P. cylinder. A piston *P*, working in a cylinder *C* in steam connection with the receiver, insures the closing down of *V*.

Q. What characterizes the Worsdell system?

A. The intercepting valve is a flap, which when the en-

gine is working compound swings down to one side of the intercepting-valve chamber and leaves the passage from the receiver to the low-pressure cylinder free. The action of steam on a small piston controlled by the starting valve swings the intercepting valve up to a position at which it closes the receiver pipe; at the same time a port

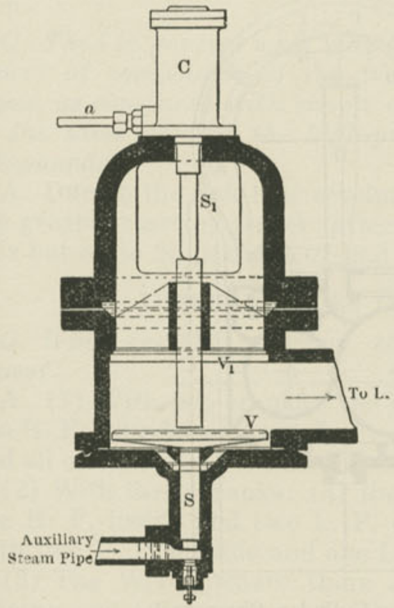


Fig. 326.
Automatic Starting Valve.

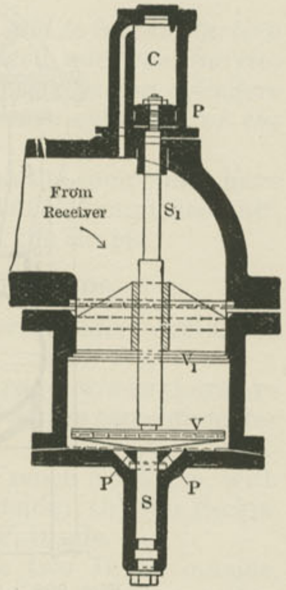


Fig. 327.
Automatic Starting Valve.

is opened, letting steam-chest steam direct to the low-pressure cylinder. When the high-pressure cylinder exhausts, it pushes back the intercepting-valve and cuts off the supply of high-pressure steam from the low-pressure cylinder (Fig. 324.)

Q. In the Worsdell and the von Borries compounds, how about the starting power?

A. When boiler-pressure steam is let into the receiver by the starting-valve, and the intercepting-valve thereby closed, the high-pressure piston starts out against a pressure in the receiver, which varies with the time that the engine has been standing, and with the condition of valves, etc.

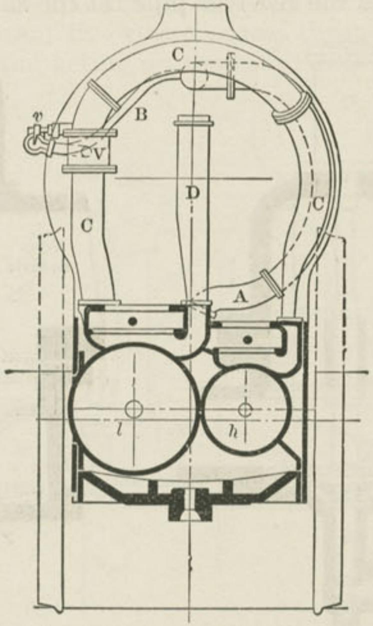


Fig. 328. Two-Cylinder Compound.

Q. In this type of engine, supposing that the crank starts at a dead point on the high-pressure side, how long will the engine move before it commences to work compound?

A. About three-quarters of a rotation.

Q. If the high-pressure piston is near the cut-off point, on starting up, where will compound working commence?

A. Usually after about seven-sixteenths of a rotation, depending on the position of the intercepting valve.

Q. Suppose the crank on the high-pressure side is in the position where the admission is cut off, how will starting be affected?

A. By the low-pressure cylinder alone, at least until the piston has reached a dead point, and then the engine will work compound for about seven-sixteenths of a rotation.

Q. Then in general what may be said to be the starting power of compounds of the Worsdell and von Borries types, as compared with simple engines having cylinders of the same area as the high-pressure cylinders of the compounds?

A. During the first half revolution the compounds have the greater starting power; after that it diminishes until it is but 80 to 85 per cent of that of the simple.

THREE-CYLINDER COMPOUNDS

Q. What are the principal three-cylinder compound types?

A. (1) With two cranks: the Lapage, where there are one H. P. cylinder and two L. P., all of the same diameter and all outside.

(2) With three cranks: (a) the French Northern, with one H. P. inside and two L. P. outside; (b) the Rickie, with two H. P. outside and one L. P. inside.

(3) The Webb, where there are two H. P. outside, driving one axle, and one L. P. inside, driving another axle, and with no parallel rods.

Q. What may be said of the steam distribution in the three-cylinder types?

A. It is essentially the same as in a two-cylinder "double-expansion" receiver engine.

Q. What is the difference between a three-cylinder locomotive and the triple-expansion stationary or marine engine?

A. In the three-cylinder locomotive there are but two stages of expansion; either the exhaust of the H. P. engine splits and goes into two separate L. P. cylinders which act alike, or the exhaust from two H. P. cylinders goes into one L. P.; in either case there are but two "steps" or "stages" to the expansion, whether there be a receiver or not. In a marine or stationary triple-expansion engine which has three cylinders, there are three successive expansion stages; the H. P. cylinder exhausting into the intermediate, this in turn into the L. P. cylinder, which may discharge either into the air or into a condenser.

Q. What is the advantage of having three cylinders for only two expansion stages?

A. Expansion may be carried further than with only one low; the work may be more evenly distributed, and weights better placed.

Q. What are the disadvantages?

A. Complication, high first cost, and subsequent maintenance.

Q. What systems have two H. P. cylinders and one L. P.?

A. The Webb, in use on the London and North-Western Railway, and the Rickie.

Q. Describe the intercepting and reducing valves of the Baldwin two-cylinder cross-compound engine?

A. Referring to Figs. 329 and 330, *A* is the intercepting valve, which consists of two pistons connected by a distance piece, *C* the reducing valve; both are in the H. P. saddle casting. *A* directs the H. P. exhaust either direct into the stack or into the L. P. cylinder, at the will of the engineman. *C* lets reduced-pressure live steam into the L. P. cylinder when working non-compound, but closes automatically when working compound. It also equalizes the pressure on the two pistons. Both valves are spring-seated and opened by steam pressure from pipes *D*, controlled from the cab. The port *E*, putting the large end of the reducer in communication with the receiver, is under the poppet valve *F*, which is open when working

compound; the poppet *G* being meanwhile automatically held closed. The reducing valve closes the steam passage *H* between the H. P. live-steam passage and the receiver, when there is too much pressure in the latter.

Fig. 329 shows the positions of the two valves for non-compound, Fig. 330 for compound running. Fig. 331 shows the receiver and the steam pipe in the front end; the live and exhaust steam courses for compound running being shown by arrows.

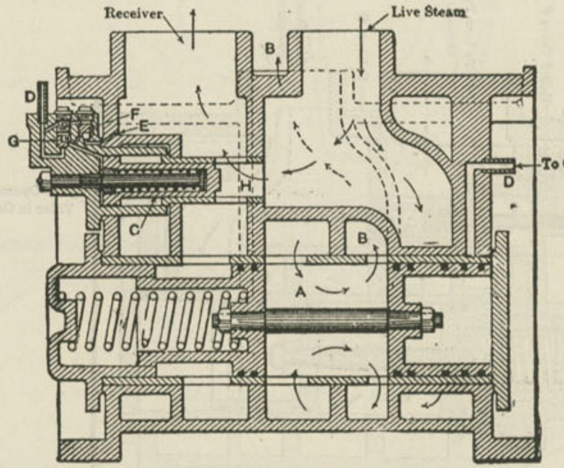


Fig. 329. Intercepting Valve in Simple Position.

Q. Describe the later or intermediate von Borries intercepter?

A. As shown in Fig. 332, it is in the side of the smoke-box and joined at *A* to the live steam pipe. Live steam passes into *C*, pressing the spindle *D* into the position shown (thus closing the main valve *V*) and enters the chamber *B*, in communication with the receiver and the L. P. chest. Live steam also acts through *F* against the piston *E;* but because of the greater area of the main valve *V*, when the H. P. cylinder exhausts into *A* the pressure balances that in the receiver, and as *E* has more area than the shoulder of *D*, the main valve *V* is moved to the right, the H. P. exhaust opened to the receiver and the openings *F* closed by the large part of *D*.

Q. What is the Hughes or Lindner starting valve?

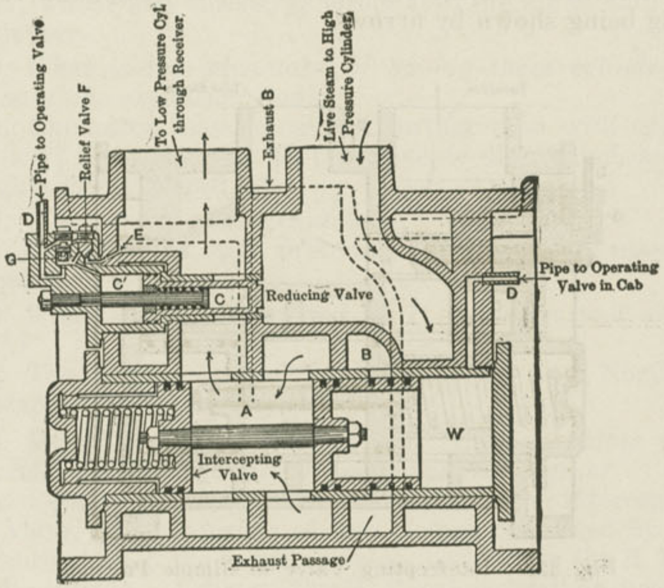


Fig. 330. Intercepting Valve in Compound Position.

A. There is a cock by which boiler-pressure steam may be admitted into the receiver from the main steam-pipe, when the valve motion is either in full forward or in full backward gear; and there are in the high-pressure slide valve two small ports, which when the valve covers the end port, after cut-off, connect that end of the slide valve with the exhaust side of the valve and hence with

the receiver; so that low-pressure steam is let into that end of the high-pressure cylinder which is covered by the slide valve, thus partially equalizing the pressures on the two sides of the low-pressure cylinders, reducing the ef-

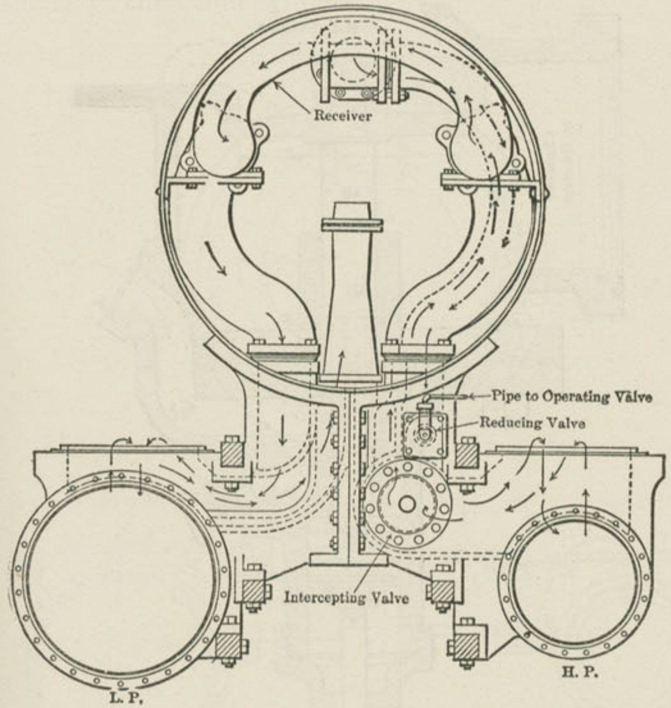


Fig. 331. Baldwin Two-cylinder Compound.

fective back pressure on the high-pressure piston, and lessening the resistance in starting in those piston positions between cut-off and stroke end, at full gear.

Q. What precaution should be taken with this arrangement?

A. To have a safety valve on the receiver, to prevent the back pressure on the high-pressure piston being increased, which would lessen the power of the high-pressure cylinder in the same proportion as that in the low-pressure was increased.

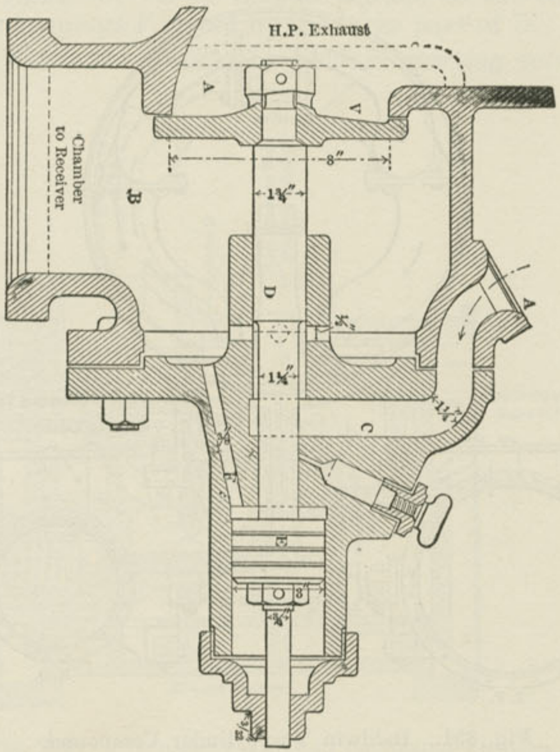


Fig. 332. Von Borries Intercepting Valve.

THE RICHMOND (MELLIN) COMPOUND

Q. Describe the course of the steam on the Richmond compound engine, working compound?

A. Referring to Fig. 333: the course from the boiler to the cylinders and then to the exhaust, is shown by arrows; from the dry pipe, down the main steam pipe at the right of the figure to the H. P. chest and cylinder; thence to the horse-shoe-shaped receiver pipe in front of the main steam pipe to the intercepting valve, thence to the L. P. chest and cylinder.

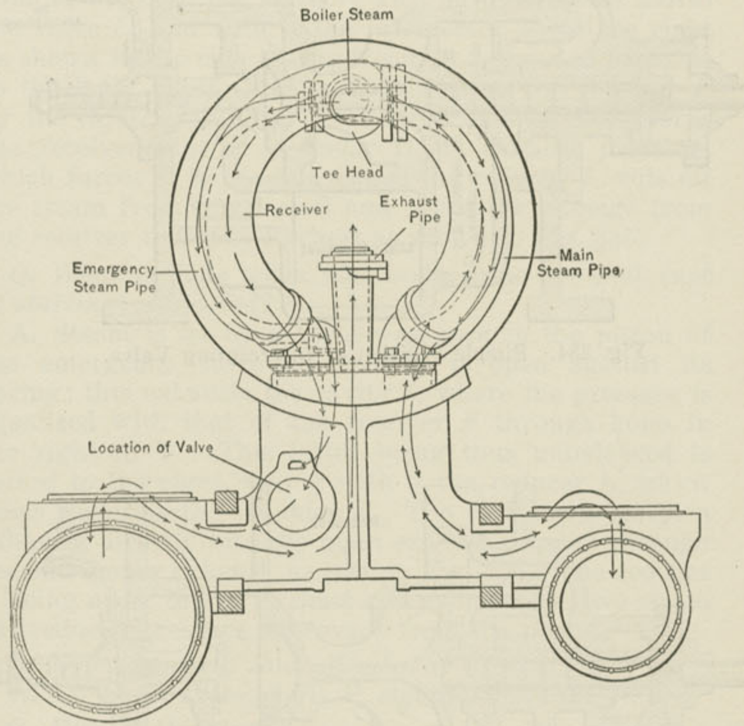


Fig. 333. Richmond Two-cylinder Compound.

Q. Describe the intercepting valve?

A. Referring to Figs. 334 and 335, where it is shown in compounding position: the passage *G* is open to the L. P. cylinder and to the receiver *F*. In starting, however, the machine starts automatically as a double H. P.

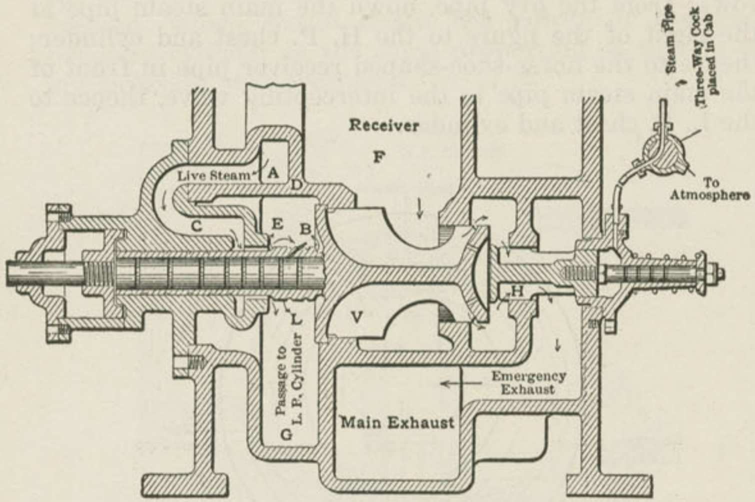


Fig. 334. Simple Position of Intercepting Valve.

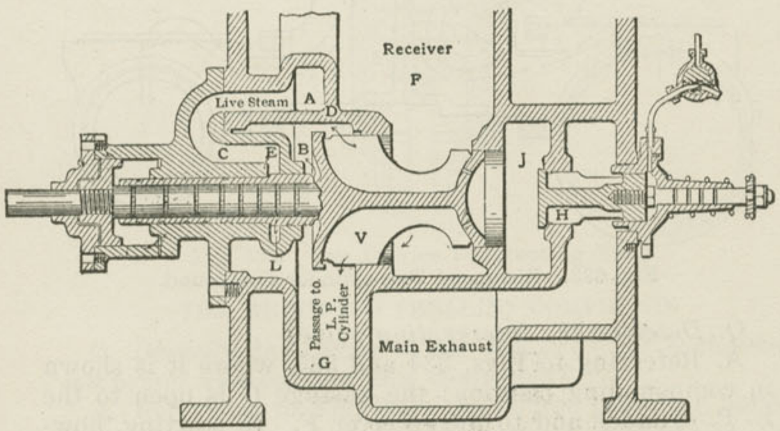


Fig. 335. Compound Position of Intercepting Valve.

engine, as live steam passes into the port *C* from the passage *A,* and enters the L. P. cylinder. There being no pressure in the receiver pipe it offers no resistance to the pressure in *C* on the shoulder *E* of the reducing valve *L* (at the left of the cut) which is a sleeve on the stem of the reducing valve *V*. This latter pressure moves the valve L_1 and with it the intercepter V_1 to the right as shown in the cut; letting steam at a reduced pressure to the L. P. chest *G* (Fig. 336) closing the receiver *F* by the intercepting valve *V*. After one or more turns the receiver pipe *F* is under H. P. exhaust pressure, which forces *V* to the left, closes the reducer *L,* cuts off the steam from the port *C* and opens the passage from the receiver to the L. P. chest as shown in Fig. 335.

Q. *What is done when maximum draw-bar pull (not at starting) is needed?*

A. Steam is let by a three-way cock to the piston of the emergency valve *H,* holding it open against its spring; this exhausts the cavity *J,* where the pressure is equalized with that of the receiver *F* through holes in the right of *V*. This latter being thus unbalanced is forced to the right, taking with it the reducer *L,* which takes steam by the shoulder *E*. The H. P. cylinder then exhausts directly into the main exhaust passage through the emergency exhaust, as seen in Fig. 336. The reducer *L* being open, the L. P. chest and cylinder get live steam (at reduced pressure, however) from the port *C*.

Q. *When running shut off what is necessary?*

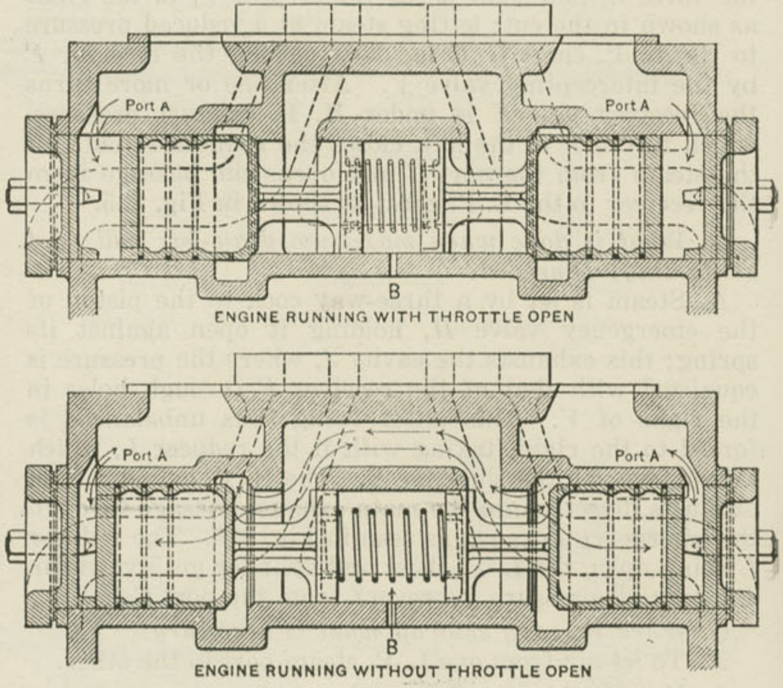
A. To let air from one L. P. steam port to the other.

Q. *How is this done?*

A. By "over-pass valves" in the cylinder casting under the steam chest (Fig. 336.) These are piston valves with conical seats, the two end ports communicating with the steam chest.

Q. *Describe the operation of these valves, in running (1) with throttle open (2) with it shut.*

A. As seen in Fig. 336, the chest pressure through ports *A A* closes the passage, with the valves, against their springs, when the throttle is open. But when the throttle is closed the vacuum in the chest, helped by the spring between the valves, forces these latter apart and away from their seats (Fig. 337).



Figs. 336 and 337.

Q. What is the peculiarity of the Mallet "articulated" or "double-bogie" four-cylinder type?

A. The H. P. cylinders are fastened to the rear part of the main frames, and drive one set of wheels, the low being on a front bogie with a separate set of wheels.

Q. What is the advantage of this type?

A. There is no dead weight; the engine may be used on very sharp curves.

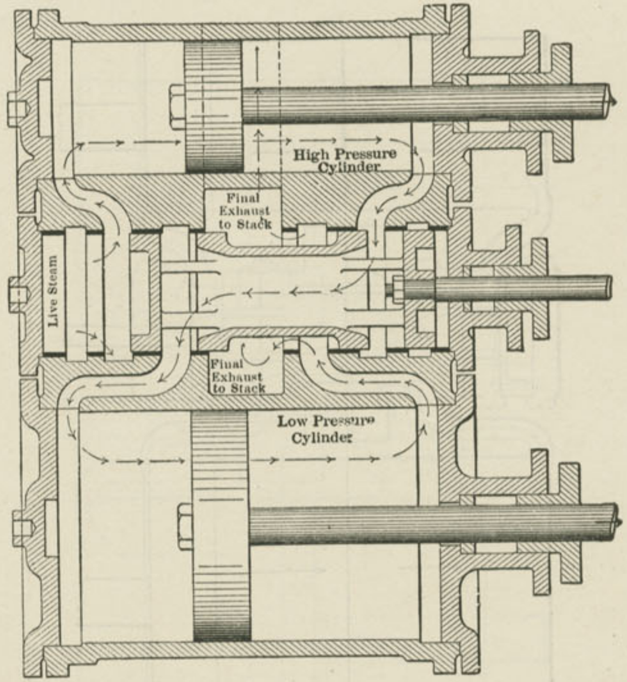


Fig. 338. Vauclain Compound Cylinders.

VAUCLAIN FOUR-CYLINDER COMPOUND

Q. Describe the Vauclain (Baldwin) four-cylinaer unbalanced two-crank cross compound type?

A. This type has four outside cylinders, the H. P. usually being above the low on each side (see Fig. 339,) and the valve chest for each side being inside and alongside of the cylinders. The valves are of the piston type, consisting of a hollow block with cylindrical rims, fitting in a hollow cylinder with apertures registering with the rims of the plugs, leading to and from the ends of the cylinders from the steam pipe and the exhaust pipe. (See Fig.

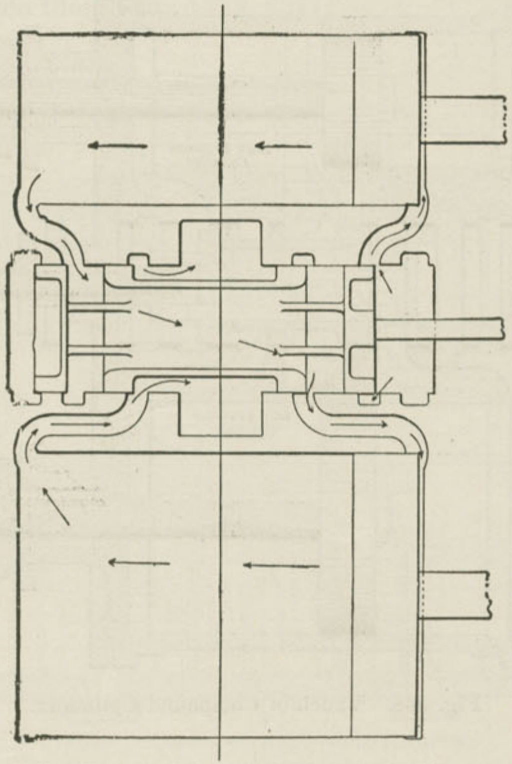


Fig. 339. Vauclain Compound.

338.) They are fitted with simple ring packings inserted by springing them into grooves in the plug. The steam enters the H. P. cylinder and drives the piston therein, on the return stroke passing through a circular groove in the center of the valve, and being discharged through the

exhaust port and the exhaust pipe. (See Figs. 338 to 341 inclusive.) The same operation takes place in both ends of the cylinder. It takes steam at once from the H. P. to the L. P. cylinder, no receiving chamber being needed.

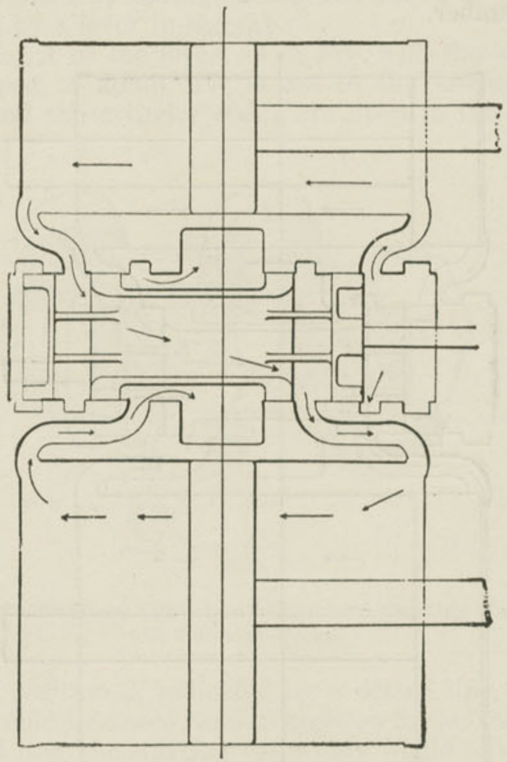


Fig. 340. Vauclain Compound.

Q. What is the piston arrangement in this Vauclain compound?

A. The pistons are connected and play together in the same direction at the same time; their position and the relative position of the valve with reference to them being shown in Figs. 339, 340, and 341. In Fig. 339, both pistons are at the crosshead end or back end of the cylinder; in Fig. 340, both are at mid-stroke; in Fig. 341, both are at front or out ends; the arrows showing the direction of the live and exhaust steam in both pistons and in the valve chamber.

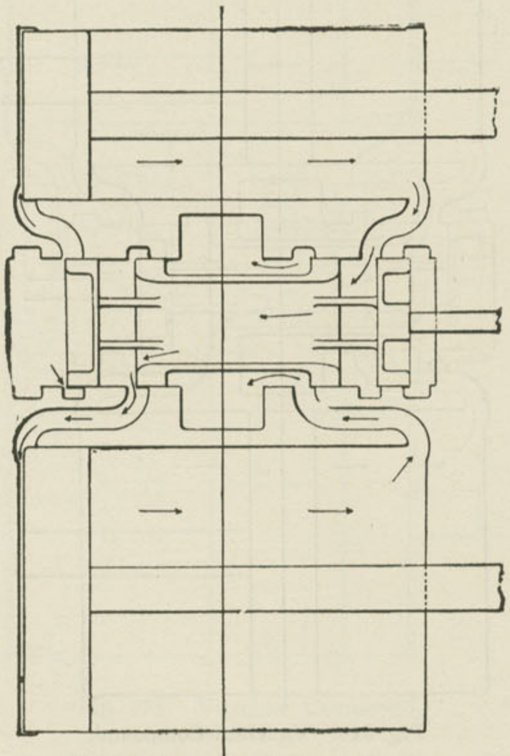


Fig. 341. Vauclain Compound.

Q. Describe the second combined starting valve and cylinder cock on the Baldwin (Vauclain) four-cylinder compound, and replacing that first used, and shown on pages 605 and 606.

A. As shown in Figs. 342 and 343, there is a casting in which are two taper plugs, *P, P*, one controlling the H. P. cylinder cock and the steam for starting, and the other controlling the L. P. cylinder cock. These plugs are held in place by springs *S* and controlled by an arm *A* operated by a lever in the cab.

In position 1 of the lever, as in Fig. 342, the starting valve is open to admit live steam to the low-pressure cylinder, and the cylinder cocks are open to the atmosphere.

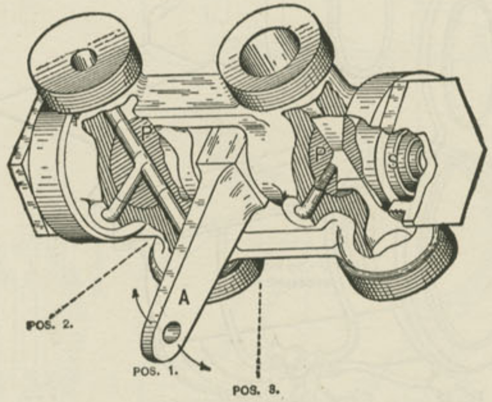


Fig. 342. Baldwin (Vauclain) Combined Starting-Valve and Cylinder-Cock.

In lever position 2, indicated by a dotted line, all the passages would be closed; and in position 3, also indicated by a dotted line, the starting valve only would be open to admit live steam to the L. P. cylinder.

Q. Describe in detail the operation of the combined cylinder cock and starting valve.

A. As shown in Fig. 342, when the valve is in starting position, live steam passes across from that end of the H. P. cylinder which is receiving steam from the boiler to the other end of the same cylinder, and thence through the main valve to the L. P. cylinder; putting the H. P. piston head very nearly in equilibrium, but giving the L. P. cylinder nearly full boiler pressure. The valve has two taper plugs, one controlling the H. P. cylinder cock, the other the low; both being held in place by springs and controlled by an arm from a lever in the cab. When the valve lets steam through to the L. P. cylinder direct, in starting, the cylinder cocks are open. In a second posi-

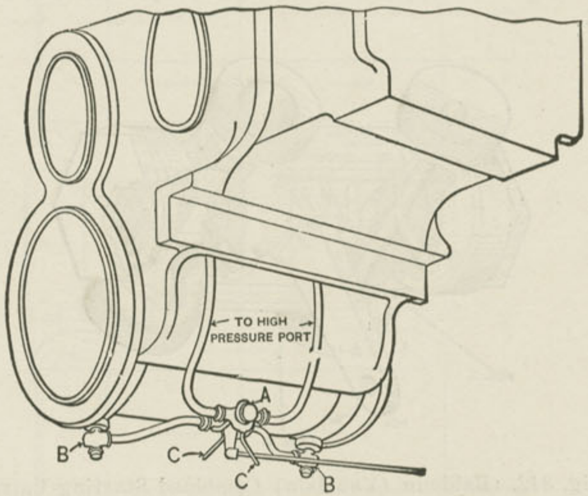


Fig. 343. Baldwin (Vauclain) Combined Starting-Valve and Cylinder-Cock.

tion all passages are closed; in a third, the only opening is to let live steam to the L. P. cylinder.

Q. In this type how is the vacuum of the L. P. cylinders relieved, when the engine is running with steam shut off?

A. By air valves in the cylinder ends.

Q. Describe the Vauclain balanced four-cylinder four-crank compound?

A. In this (see Figs. 344 and 345) there are two H. P.

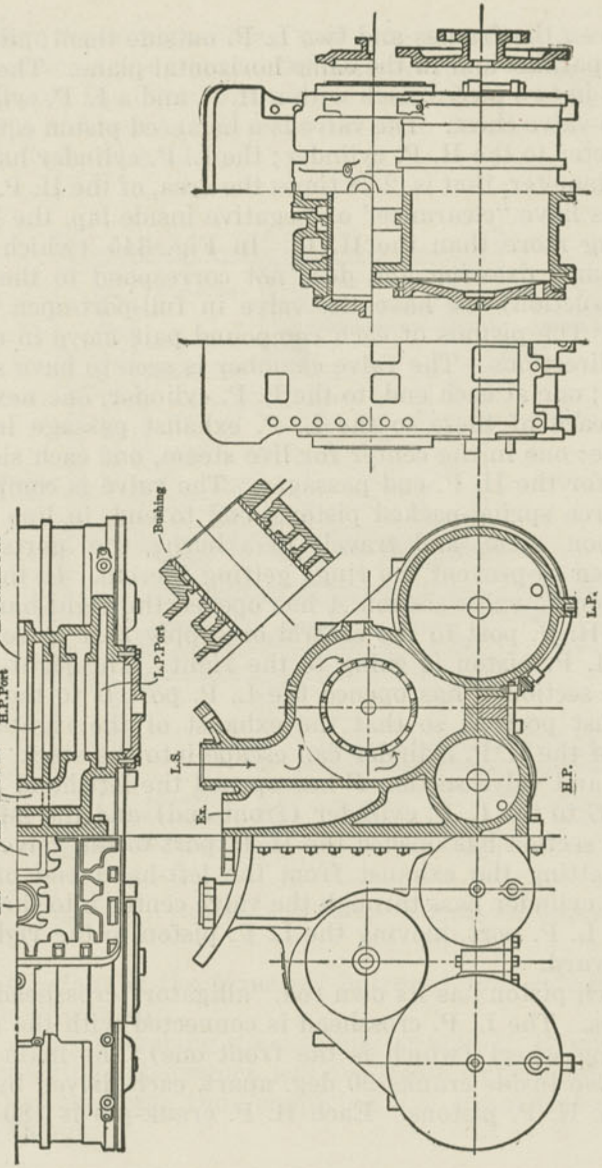


Fig. 344. Sections of Baldwin Balanced Compound.

between the frames and two L. P. outside them; all four axes parallel and in the same horizontal plane. The saddle is in two pieces, each with a H. P. and a L. P. cylinder and a valve chest. The valve is a balanced piston equal in diameter to the H. P. cylinder; the L. P. cylinder has 5-3 the diameter, that is, 2.78 times the area, of the H. P. All valves have "clearance" or negative inside lap, the L. P. having more than the H. P. In Fig. 345 (which is a "scheme" drawing and does not correspond to the real construction) we have the valve in full-port-open position. The pistons of each compound pair move in opposite directions. The valve chamber is seen to have seven ports; one at each end, to the L. P. cylinder, one next inside each of these to the L. P. exhaust passage in the saddle; one in the center for live steam, one each side of that for the H. P. end passages. The valve is composed of three spring-packed pistons, end to end, in line on a common stem, and travels in a bush; the ports are bridged to prevent the rings getting therein. In the cut the middle valve section *A* has opened the right-hand or back H. P. port to the central or supply port *B*, so that the H. P. piston is going to the right. The right-hand valve section *C* has opened the L. P. port *D* to the final exhaust port *E*, so that the exhaust of the right-hand end of the L. P. cylinder can escape into the stack. The left-hand valve section *F* has opened the left-hand L. P. port *G* to the L. P. cylinder (front end) and the middle-valve section has opened the H. P. port to the valve center, letting the exhaust from the left-hand end of the H. P. cylinder pass through the valve center into the left-hand L. P. port, moving the L. P. piston to the right or backward.

Each piston has its own rod, "alligator" crosshead and guides. The L. P. crosshead is connected with the main driving wheel (which is the front one); the main axle has two inside cranks 90 deg. apart, each driven by one of the H. P. pistons. Each H. P. crank-pin is 180 deg.

from the corresponding L. P. pin for that side. The eccentrics are never on the main driving axle; are, on a Mogul. On account of the great distance between rocker-arm and valve, the valve-rod is in two sections, and is jointed and guided.

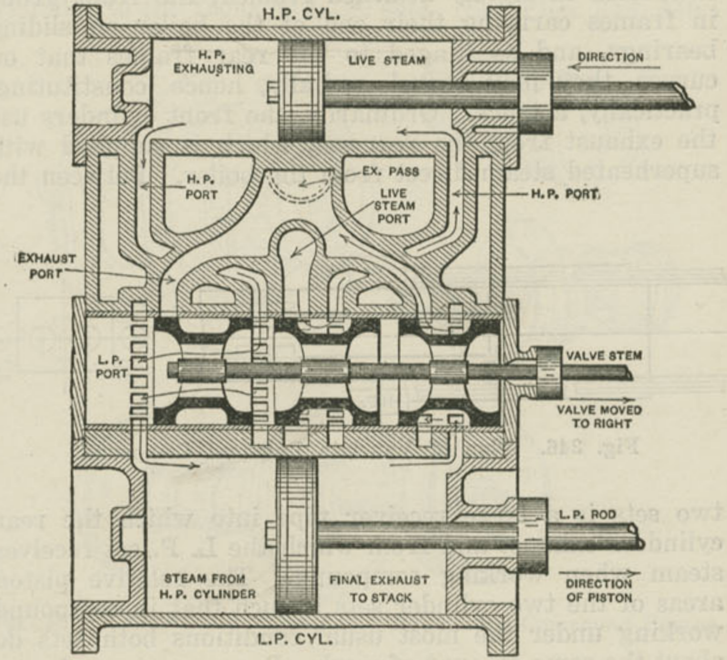


Fig. 345. Cylinders and Valves of Balanced Compound.

Q. How is the Vauclain balanced four-cylinder compound started?

A. By balancing the pressure at both H. P. pistons, by a starting valve which lets live steam to both sides thereof, at the same time supplying live steam to both L. P. cylinders.

Q. Describe the "American" articulated compound engine.

A. It has two sets of cylinders, front and rear respectively, driving separate and independent wheel groups; each set used simple or compound as desired, and all taking steam from the same boiler. The rear wheel group is carried in rigidly attached frames; the front group in frames carrying their end of the boiler on sliding bearings, and so hinged to the rear frames that on curves they may swivel radially, hence constituting, practically, a truck. Ordinarily, the front cylinders use the exhaust from the rear set, which is supplied with superheated steam direct from the boiler. Between the

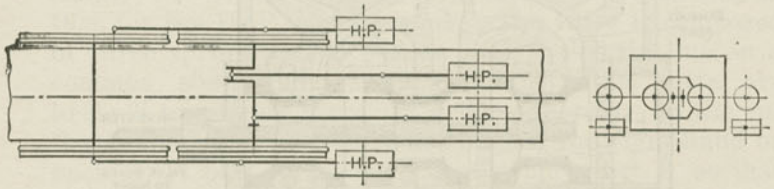


Fig. 346. Plan of Vauclain Balanced Compound.

two sets is a large receiver pipe into which the rear cylinders exhaust and from which the L. P. set receives steam when working compound. The relative piston areas of the two cylinder sets is such that in compound working under the most usual conditions both sets do about the same amount of work. In non-compound gear the H. P. cylinders exhaust directly into the atmosphere; an intercepting valve cutting off communication between the receiver pipe and the exhaust side of the H. P. pistons, relieving them of all back pressure except that due to atmospheric resistance.

Q. When working simple at slow speed, how much additional pressure is claimed for this arrangement?

A. About 20 per cent.

Q. How does the American ("Richmond") compound engine change automatically from simple to compound?

A. After one or two driver turns the H. P. exhaust pressure in the chamber F rises sufficiently to open the intercepting valve (2) which in turn closes the reducing valve (1) and admits the H. P. exhaust from the rear cylinder to the front or L. P. set. (See Figs. 348, 349.)

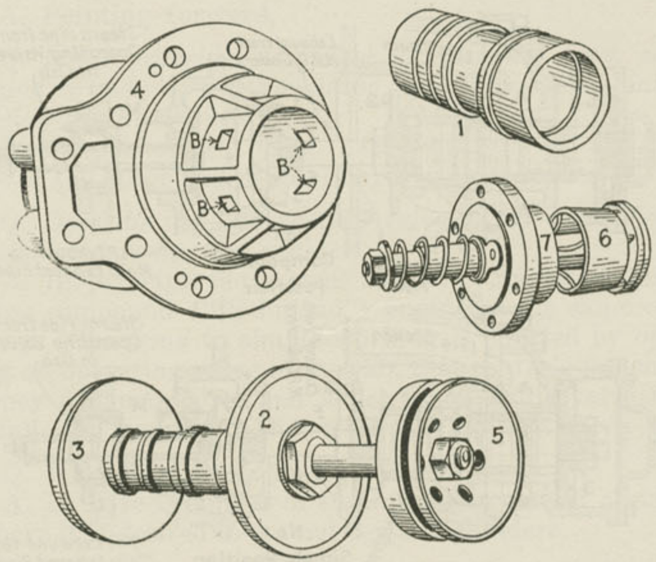


Fig. 347. Intercepting Valve Parts, Articulated Compound Engine.

Q. At what pressure will the intercepter usually open against the steam in chamber C of 40 per cent of boiler pressure?

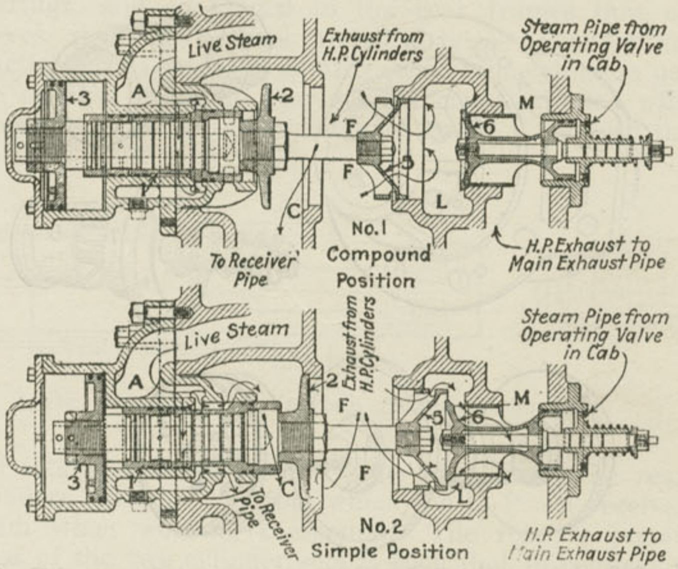
A. At about 30 per cent of boiler pressure, because the steam in C cuts against a larger area.

Q. How can automatic change to compounding be prevented?

A. By opening the emergency operating valve in the cab, by bringing the handle to point to the rear.

Q. What would then happen?

A. The emergency valve (6) would open and let the H. P. cylinders exhaust into the stack direct. The reducing valve (1) would open (there being no resisting pressure in chamber F) and close the intercepter (2). Live steam would be admitted to the receiver, which would at the same time be cut out from the exhaust side



Figs. 348 and 349. Intercepting Valve, "American" Articulated Compound Engine.

of the H. P. pistons, to permit increased back pressure on these.

Q. What is the use of the balancing piston (5)?

A. To permit exhausting chamber F simultaneously with the opening of the emergency valve (6) thus closing the intercepter (2) and opening the reducing valve (1) before, or at the same time that, the receiver is actually exhausted.

Q. What is the object of the rule not to run simple at speeds over three or four miles an hour?

A. To prevent misuse of the emergency feature, which would cause increased wear on the machinery and decreased fuel economy.

Q. What is the position of the operating-valve handle for closing?

A. Pointing forward.

Q. What prevents slamming in changing from compound to simple, while running, due to suddenly unbalancing the intercepter?

A. The piston (3), Fig. 348, works in an air dash pot at the outer end of the intercepting valve stem.

Q. Describe the intercepting valve of the "American" articulated compound engine.

A. Its principle is the same as that of the two-cylinder cross compound ("Richmond") engine of the same company. Changing to simple working is effected by opening an operating valve in the cab, that controls the emergency exhaust valve, and which is an angle valve in a small pipe running to the emergency exhaust valve.

Q. When is it to be used?

A. If there is danger of stalling, or in case of accident where it is desired to cut out certain cylinders.

Q. What are the functions of the American Locomotive Company's reducing and intercepting valve in starting and working in simple gear?

A. It closes the intercepting valve when the throttle opens, admits live steam into the L. P. cylinder; regulates the live-steam supply to the L. P. cylinder so as to give equivalent work with the boiler pressure in the L. P. side.

Q. How does it operate when working compound?

A. By shutting off the live steam supply to the L. P. cylinder.

Q. How, when working "simple"?

A. By admitting boiler pressure steam to the L. P. side.

Q. How is it held to its seat in compound gear?

A. By a receiver pressure equal to about one-eighth of the H. P. steam-chest pressure.

Q. How is leakage to the atmosphere prevented?

A. By a ground seat.

Q. What are the functions of the intercepting valve used in connection with this receiver valve in starting?

A. It shuts off the H. P. from the L. P. side of the receiver by the action of the reducing (inlet) valve.

Q. How does it work in simple gear?

A. By exhausting the pressure in the balancing chamber.

Q. How does it work for compound gear?

A. It opens the receiver by the accumulation of high-pressure exhaust in the balancing chamber.

Q. How does it operate in changing from simple to compound working?

A. It does not open the receiver at the moment that the H. P. exhaust is closed, but remains in "simple" position until this exhaust has reached normal receiver pressure, when it pushes the valve over into compound gear, and in the meantime the L. P. side of the receiver has had its live steam supply (which is shut off only at the opening of the intercepting valve) and the normal receiver pressure for that gear is restored without any intermediate drop during the change.

Q. What would be the effect if the intercepting valve were opened at the same moment that the H. P. valve was closed, with no pressure in the H. P. side of the receiver, and no further supply to the L. P. cylinders?

A. It would cause the latter to become lame for some time; as it would draw off the H. P. exhaust nearly as fast as it came, causing the engine to stall if the change was undertaken on a grade, without considerable momentum of the train to carry it over this period of reduced L. P. work.

Q. Suppose that in addition to this the L. P. cylinder was for any instant in connection with the atmosphere during the change, what would be the result?

A. Still more serious; as if once changed to "simple" on a grade, the risk of stalling would make the engineman hesitate to turn back to compound before the top of the grade was reached; whereas simpling might not be needed for more than train length at a time at critical points, if the limit of the load when working in compound gear should be exceeded.

Q. What is the object of the balancing piston at the inner end of the valve?

A. It serves several purposes—it neutralizes the impact of the H. P. exhaust, forms a balancing chamber the exhaust of which puts the intercepting valve in simple gear without any reduction in receiver pressure; and it opens up direct exhaust from the H. P. cylinder at the completion of the following motion of the intercepting valve.

Q. With this combination, is the change from compound to simple or vice versa, when running, fully subject to the engineman's will?

A. Yes; he merely opens and closes communication between the balancing chamber and the atmosphere by a so-called emergency valve, and the reducing and intercepting valves accomplish the rest, as above described.

Q. What advantages are gained by compounding?

A. Higher expansion rate, less steam consumption, cylinder condensation, clearance loss and leakage loss; equalized crank-pin pressures.

Q. What are the disadvantages?

A. Increased number of parts, cost, bulk, wear and tear, and radiation loss.

Q. Where is the intercepting valve placed?

A. In the left H. P. cylinder saddle, to the left of the vertical and above the horizontal center of the cylinders.

Q. Can you describe its construction?

A. Fig. 347 shows its various parts. They are shown assembled and in their relation to the steam passages in the cylinders in Figs. 348 to 352, inclusive. Parts 2, 3 and 5 of Fig. 347 show the intercepting valve proper. Part 1 is the reducing valve or sleeve that fits on the stem of the intercepting valve, along which it is free to slide lengthwise as seen in Figs. 348 and 349.

Q. What controls the movement of all these parts?

A. They move automatically.

Q. Describe the emergency or high-pressure exhaust valve.

A. It is seen in Part 6 of Fig. 347 and is the only not entirely automatic part of the intercepting mechanism; being under the engineman's control through an operating valve in the cab. It is at one of the outer ends of the intercepting-valve chamber. (See Figs. 348 to 352.)

Q. Show is the intercepting valve parts as they automatically have taken their places in compound working.

A. In Fig. 348 we have these positions shown.

Q. How are they for simple working?

A. As in Fig. 349.

Q. Give a detailed description of the communications of the various passages.

A. Referring to Figs. 348 to 352, inclusive: Chamber A, surrounding the reducing valve (1) is in direct communication with the live-steam passages of the H. P. cylinders. Chamber C opens directly into the receiver pipe; and is in communication with chamber A through the reducing valve (1). Chamber F connects directly with the H. P. cylinder exhaust passages. Between it and C comes the intercepting valve (2), and between it and chamber L there is connection through the perforated balancing piston 5. The emergency valve 6 establishes connection between chambers L and M, the latter opening directly into the H. P. exhaust pipe, which is a small pipe running along the left side of the engine and leads into the main exhaust pipe.

Thus: the reducing valve (1) controls steam admission from boiler to receiver pipe; the intercepter (2) opens or closes the latter to the exhaust from the H. P. cylinders; the emergency valve (6) either permits or prevents the passage of this exhaust through the main exhaust pipe to the stack.

Q. In ordinary starting, what takes place?

A. The pressure in A opens the reducer (1) which closes the intercepter 2. Live steam is admitted to the receiver but the intercepter prevents its backing up against the exhaust side of the H. P. pistons.

Q. What initial pressure do the L. P. cylinders usually get?

A. About 40 per cent of the boiler pressure.

Q. What would happen if the receiver pressure rose above the normal amount?

A. The valve would close automatically and cut the live steam from the receiver, until the movement of the L. P. pistons lowered the receiver pressure to normal. (See Fig. 351.)

Q. Can the reducing valve close without opening the intercepting valve?

A. Yes.

Q. Can both valves be open at the same time?

A. No.

Q. Describe the double-ported piston valve used in the L. P. cylinders of the American articulated compound engine?

A. There is nothing special about its design, but it has the same diameter as that of the single-ported one of the H. P. cylinders, so that packing rings, followers and casing heads are interchangeable for the two kinds.

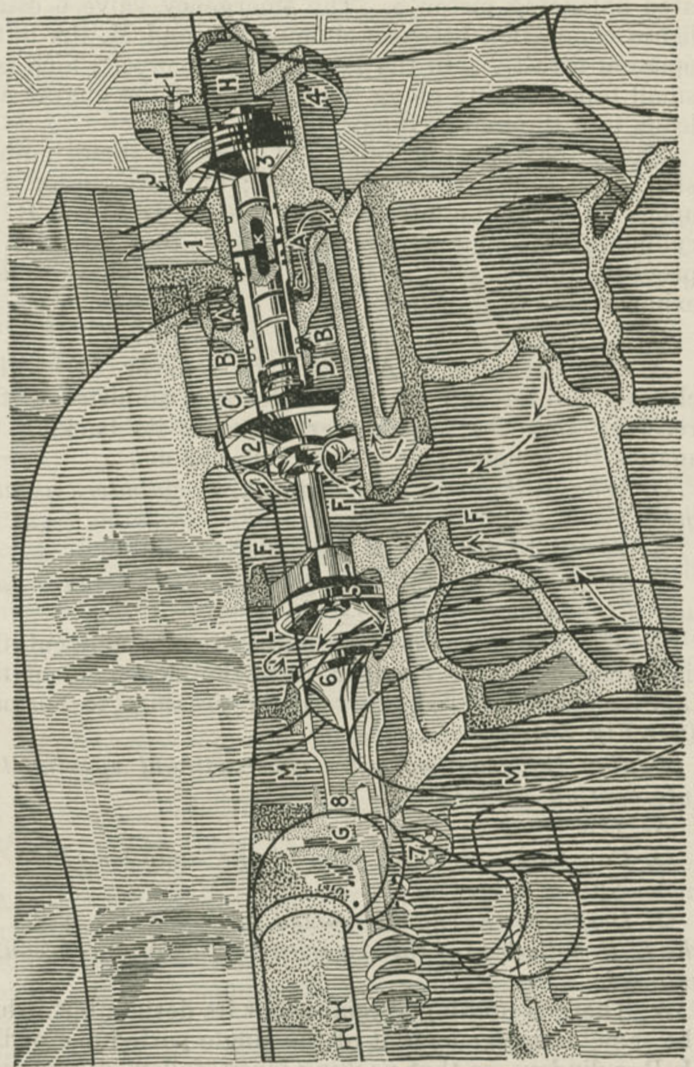


Fig. 350. Predetermined Maximum Pressure in Receiver Pipe is Exceeded.

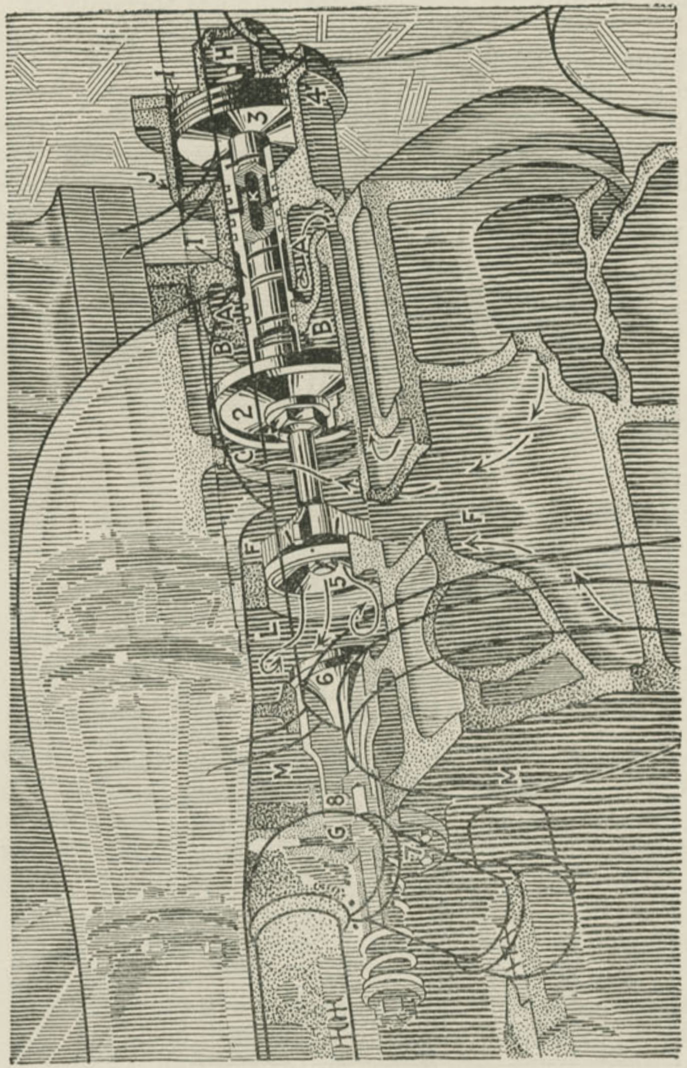


Fig. 351. Intercepting Valve in Compound Position.

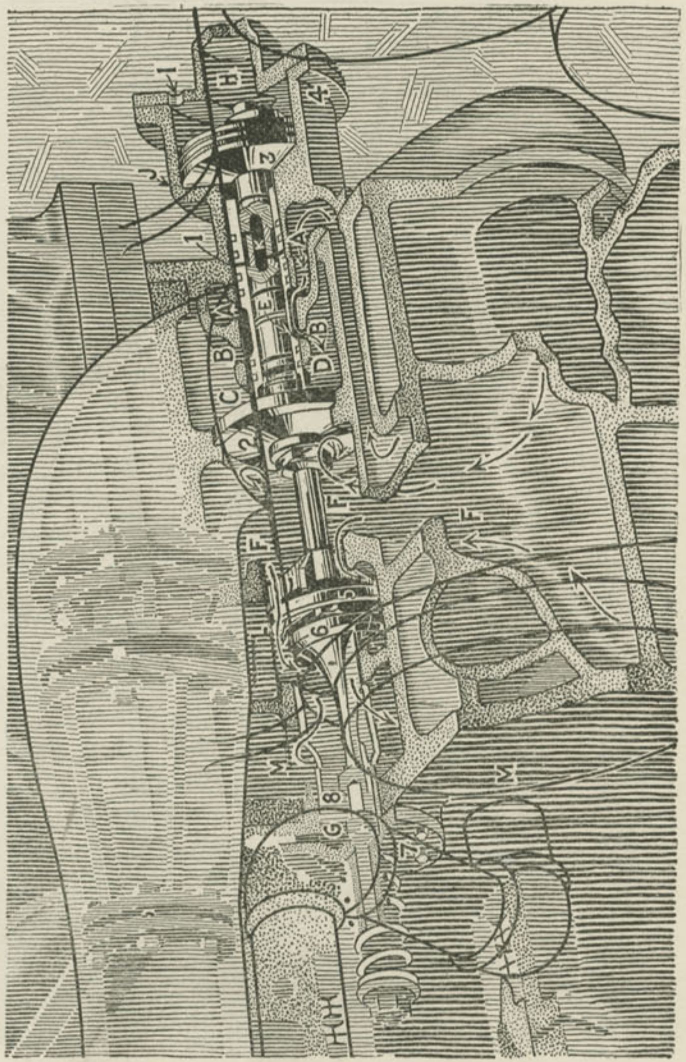


Fig. 352. Intercepting Valve in Simple Position.

Q. Describe the automatic by-pass valve of the American articulated compound engine.

A. Fig. 353 shows these valves when assembled in their chamber, and their relation to the cylinder steam ports. (Each cylinder has a pair of these valves, in chambers cast outside them.) With open throttle the steam-chest pressure acting through the small ports, S, keeps the valves closed as shown in view B, Fig. 353.

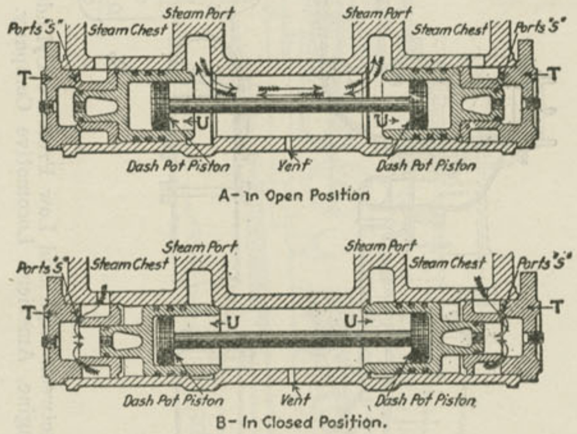


Fig. 353. By-Pass Valve, Articulated Compound Engine.

With open throttle, they are automatically opened by the atmospheric pressure admitted through the air vent (shown below in the cut) and they then connect the admission ports at either end of the cylinder, as shown in view A.

Q. What is their object?

A. To permit the engine to drift freely when running with a long cut-off.

Q. What is the advantage of the "articulated" engine?

A. No dead weight; for a given weight per axle, greater hauling power; or conversely, for a given tractive power, less weight per axle. The articulation halves

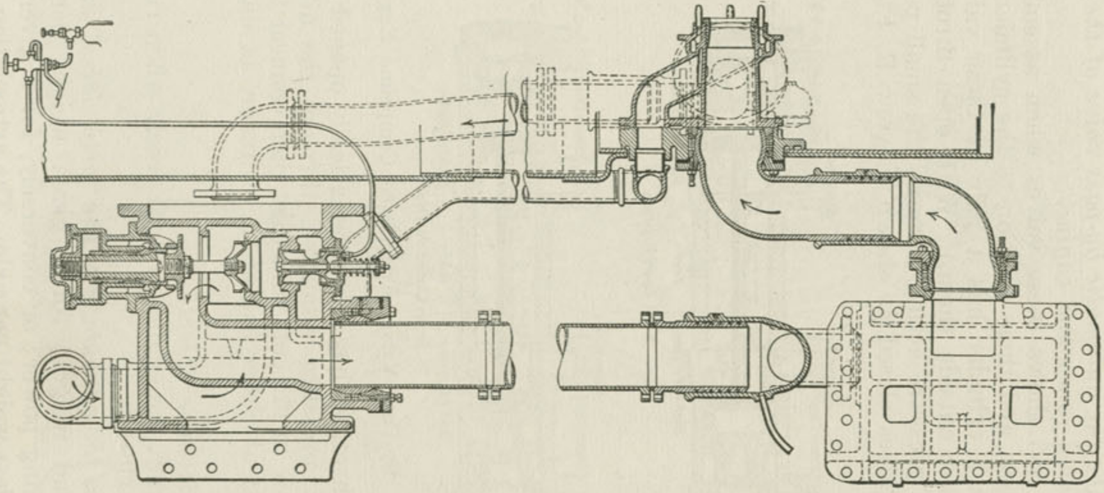


Fig. 354. Connections Between High and Low Pressure Cylinders, Mallet Compound Engine, American Locomotive Company.

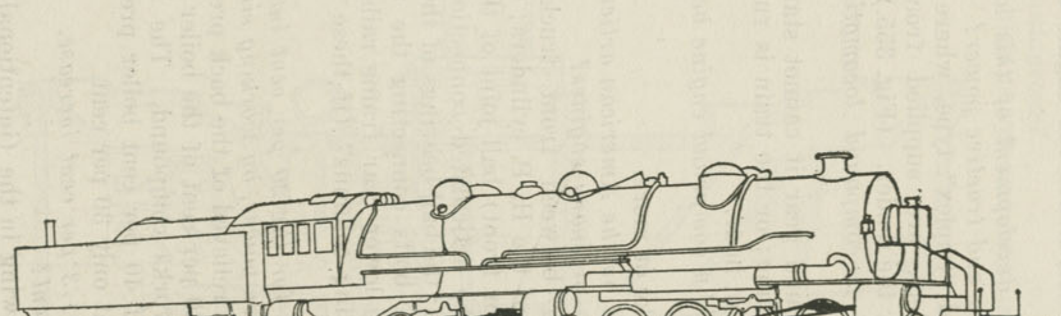


Fig. 355. Baldwin Triple Articulated Engine No. 5921, Erie R. R.

the strictly rigid wheel base, hence the engine can be used on shorter curves.

Q. Is there any further development of this idea of distributing boiler capacity and tractive power?

A. Yes; in the so-called "triplex" type, where three engine sets, placed tandem, are supplied from one boiler; one set being under the tender. (Fig. 355.)

Q. When, only, should a compound locomotive be worked simple?

A. Only when in compound gear it cannot start the train, or keep it from stalling; or the train is running under three or four miles an hour.

Q. At what cut-off should a compound engine be held, for drifting?

A. At three-fourths stroke or more.

Q. What parts are found on the American articulated compound that are not on ordinary engines?

A. The sliding bearing between front truck and boiler; ball joint in front of the H. P. cylinders; upper (or rear) and the lower (or front) ball joint of the exhaust pipe; the bolt of the articulated connection between the two main frames; the ball bearings of the vertical suspension or "trim" bolts connecting the upper front frame rails with the lower rear frame rails; the ball bearings of the "floating columns" (if these latter are applied).

Q. How do you account for the 20 per cent increase claimed over normal tractive power, by working simple?

A. The H. P. pistons are relieved of the back pressure in the receiver pipe (say 30 per cent of the boiler pressure) when the engine works compound. The L. P. cylinder gets live steam of 40 per cent boiler pressure instead of exhaust steam at only 30 per cent.

Q. That would make 33 1/3 per cent increase. What becomes of the 13 1/3 per cent?

A. It is lost by wire drawing in the (intentionally reduced) reducing valve ports.

Q. Under what conditions are compound locomotives most advantageous?

A. For high power and long unbroken runs.

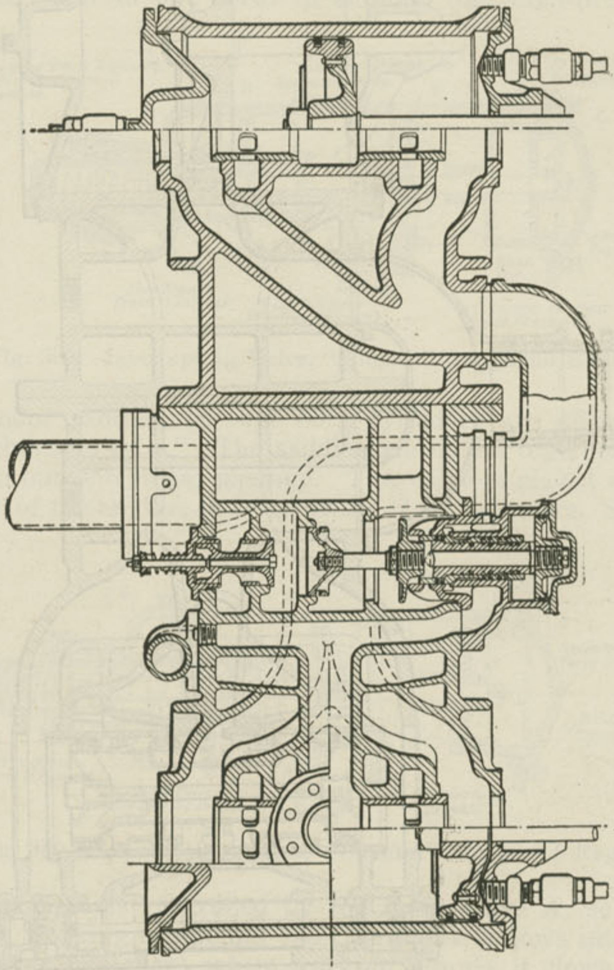


Fig. 356. High Pressure Cylinders, Mallet Compound Engine, American Locomotive Company.

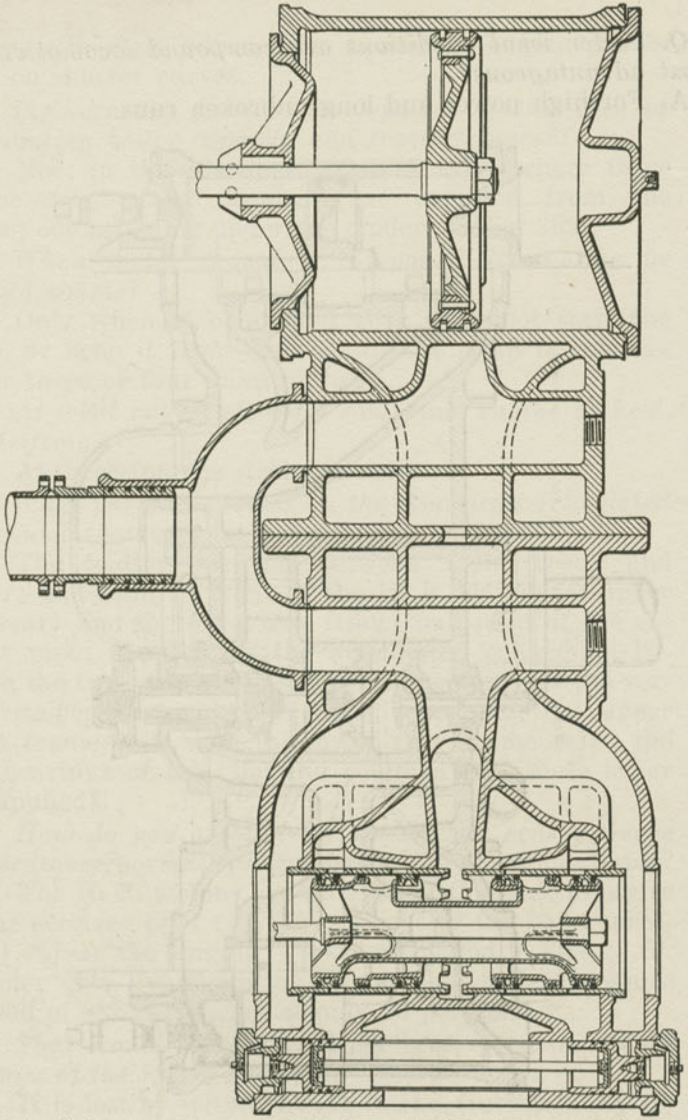


Fig. 357. Low Pressure Cylinders, Mallet Compound Engine, American Locomotive Company

Q. Describe the "Simplex" compound intercepting valve and system of steam distribution.

A. It is intended to increase the pressure in the receiver, and in one form to simplify the high-pressure

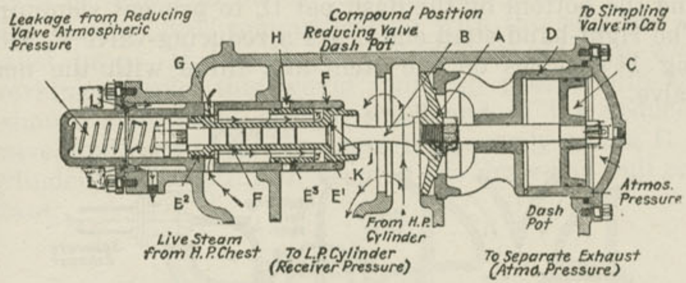


Fig. 359. Intercepting Valve, "Simplex" Compound Engine.

cylinder saddles, so that both cylinders are alike, not "rights and lefts." The saddles are bolted together and have but one steam passage. The valve is placed crosswise of the engine, in front of the H. P. cylinders. Steam

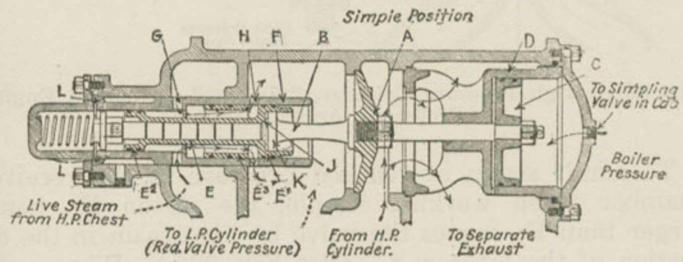


Fig. 360. Intercepting Valve, "Simplex" Compound Engine.

from these is controlled by the main valve A, so that when working compound (see Fig. 359) it flows into the receiver chamber; when working simple it flows into the separate exhaust chamber. The stem B, on which is secured the main valve A, is continued toward the left-hand side of the engine, and bears a piston C, working in a dash pot D. When the valve in the cab is put in simpling position, the main valve A is forced into that shown in Fig. 360. The inner piston face traps air between it and the bottom by the dash pot D, to prevent slamming. The right-hand stem end bears a reducing-valve E, moving $1\frac{1}{2}$ inches on the stem and three with the main valve.

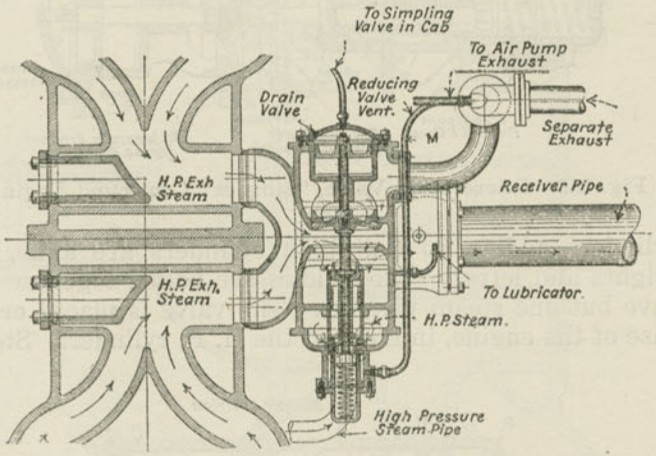


Fig. 361. High Pressure Cylinder, "Simplex" Compound Engine. (Preferred Application.)

To admit steam at reduced pressure to the receiver chamber when working simple, the piston E^1, being larger than E^2, moves the valve by live steam in the direction of the large end. (See Fig. 360.) When sufficient pressure is built up in the receiver, this pressure moves the valve in the opposite direction and cuts off the flow through the port H, thus keeping a constant pressure in the receiver.

To bring the valve into compounding position, the valve is moved in the direction of the larger piston E^1,

acting on the ground joint J on the piston K of the reducing-valve dash pot.

The intermediate piston E^3 closes the port H as soon as the stem B has moved sufficiently towards the compound position, Fig. 360. The small end of the reducing valve is vented to the air through the ports L and the pipe M, Fig. 361, communicating with the separate exhaust pipe. If the H. P. cylinder should slip when working simple, this would build up pressure in this exhaust pipe, react on the small end of the reducing valve, and admit high pressure temporarily to the L. P. cylinders, thus acting in keeping the draw-bar pull constant.

CHAPTER LXXVIII

DIMENSIONS AND PROPORTIONS*

Q. What is the rule for calculating the piston area where the engine has but two cylinders?

A. Divide the total weight on drivers (in pounds) by one-fourth the driver circumference (in inches). Multiply the maximum boiler pressure (in pounds per square inch by the gage) by 3.6 times the piston stroke (in inches). Divide the first product by the second; the quotient will be the area of each piston in square inches.

Q. How do you get the piston diameter from the area?

A. Divide the area by 0.7854 (or multiply it by 1.273) and find the square root of the result. Thus: if the area is 255 square inches, the diameter will be $\sqrt{255 \div 0.7854}$ or $\sqrt{255 \times 1.273}$ = practically $\sqrt{324}$ = 18 inches.

Q. What factors determine the cylinder dimensions?

A. Total weight on drivers, driver diameter and boiler pressure.

Q. What name is given to the cylinder capacity in cubic inches per net ton of weight in drivers and inch of driver circumference?

A. Propulsion modulus.

Q. How is this calculated?

A. By dividing four times the area of one piston (in square inches) by the driver circumference (in inches) and by total weight (in net tons) on drivers.

Q. What name is given to the cylinder capacity in cubic inches, in relation to boiler pressure?

A. The traction modulus.

* See also under "Slide Valves," etc.

Q. How is it calculated?

A. By multiplying the boiler pressure in pounds per square inch by the propulsion modulus.

Q. What factors determine boiler dimensions?

A. Adhesive weight and speed; the greater each of these, the greater the steaming power the boiler should have.

Q. Which requires the greater heating surface (other things, for instance, cylinder capacity being equal), an engine for fast service or one for slow?

A. The former.

Q. What determine the maximum dimensions of the boiler?

A. Weight on drivers and space.

Q. What factors determine the steaming capacity of a boiler?

A. Size of grate and fire-box, character of grate, area and disposition of heating surface, draft, whether or not there is a superheater and a feed heater; adaptability of grate, fire-box and tubes to the fuel and the method of firing.

Q. What is the usual ratio between heating surface and grate surface?

A. Between 50 and 70 to one.

Q. Is the steaming capacity of the boiler the same thing as its "duty" or "efficiency"?

A. No; often a boiler with great steaming capacity will have a very low "duty"; that is, will have more fuel per pound of water evaporated than one of less capacity.

Q. How is the duty reckoned?

A. In pounds of water from and at 212° F. per pound of fuel fired (sometimes per pound of combustible in the fuel).

Q. Which give the best draft; large or small drivers?

A. Small ones; there being more and more regular blast puffs.

Q. What other advantages in small drivers?

A. There is less weight of cylinders, frames and other parts; hence greater dimensions and weight may be given to the boiler. Also there is less cylinder condensation and radiation.

Q. What imposes a limit to the reduction of driver diameter?

A. Excessive piston speed.

Q. What causes rolling?

A. One cause is the upward thrust of the main rod on one side when there is none on the other. Another is the slewing action of the truck.

Q. How can this slewing be lessened?

A. By bringing the truck axles nearer together—up to a certain limit.

Q. What factors determine choice of an engine for a given service?

A. Maximum train weight, speed, grades and curves.

Q. Is horsepower the main thing in determining the choice?

A. No; almost any engine has power in excess of its adhesion.

Q. Is this desirable?

A. Not to any great degree, as it makes unnecessary weight and is apt to cause slip.

Q. What is the usual ratio of adhesion to weight on drivers?

A. About one to five; the extremes being one to three and one to six.

Q. As an example of recent practice, give some weights, dimensions, etc., of the K 4 s engines of the Penn. R. R.

A. This engine weighs in working order 309,140 lbs. (202,880 on drivers); cylinders (simple) are 27 x 28 in.; driver diameter, 80 in.; tube heating surface (water side), 3728.64 sq. ft.; heating surface of Belfaire fire-

box (including three arch tubes), 306.77 sq. ft.; of superheater (fire side), 1171.85 sq. ft.; making total heating surface, based on water side of tubes and including Schmidt superheater, 5207.26 sq. ft.; based on fire side (also including superheater), 4863.96 sq. ft. Grate surface (126 in. long, 80 in. wide), 69.26 sq. ft., making grate area 66 sq. ft. Boiler pressure permissible, 205 lbs. by gage. 237 tubes, 2.25 in. outside diameter, 227.23 in. long (length, 114 internal diameters), 40 superheater flues, 5.5 in. outside diameter, 12 in. piston valve; Walschaert valve motion with screw-reversing apparatus. Maximum tractive effort in starting, 44,460 lbs. with 174 lbs. m. e. p. in cylinders; equals 255.15 lbs. per pound m. e. p. Weight on drivers to calculated maximum tractive effort, 4.54 : 1. As seen in Fig. 78 the boiler has a wide grate and a sloping bulkhead and throat sheet; brick arch is carried on three water tubes. The boiler is 78½ in. in diameter at front sheet, 87 in. at rear barrel course. Smoke-box (Fig. 83) is self-cleaning; 7¼ in. nozzle (Figs. 92 and 93) with four internal projections (net opening, 38.19 sq. in.). The front driving axle is equalized with the front truck, the others with the pony trailer truck.

Q. Can you give the principal dimensions of the largest locomotive in the world at present (February, 1923)?

A. Without question, the largest and heaviest engine is the "Virginian,"* 2—10—10—2, with cylinders 30 and 48 inches by 32, drivers 56, boiler 103⅛ inches inside diameter, carrying 215 lbs. gage pressure; fire-box 181 1/16 inches long, 108¼ wide; 361 tubes 2¼ inches diameter, 25 feet long; 70 flues 5½ inches diameter, 25 feet long; driving -wheel base, each 19 feet 10 inches; total wheel base (engine and tender), 97 feet; weights in working order, 32,000 lbs. on leading axles, 617,000 on drivers, 35,000 on trailers; making total for engine 684,000 lbs.; tender 214,300 lbs. Heating surface: tubes

*Built by the American Locomotive Co.

3,580 sq. ft.; flues 2,510; fire-box 437.5; arch tubes 78.5; total 8,606; superheater 2,120 sq. ft. Grate, 144⅝ in. long, 108¼ in. wide; area 108.7 sq. ft. Tractive power, simple 176,600 lbs.; compound 147,200 lbs.; adhesive factor 4.19. The eight-wheeled tender carries 13,000 gallons of water and 12 tons of soft coal.

CHAPTER LXXIX

STARTING AND STOPPING*

Q. In starting up, what is the action?

A. The reverse-lever being put in either forward or backward position, either one or the other of the eccentric-rods is brought opposite the rocker-pin, so that the rod will operate the slide-valve as soon as the throttle is open. Then the throttle is opened by means of the throttle-lever, admitting steam through the dry-pipe to the stand-pipe, dry-pipe, branch-pipe and steam-chests respectively; thence it is admitted to the cylinders by the slide-valves. The fire door should be open and the fire clean and level.

Q. Should the engine be started with the throttle wide open?

A. No; with it only partly open.

Q. As the train gets under way, what is done?

A. The links are gradually hooked up towards the center, to save steam and give the fireman a chance to make up his fire. But if the coal is a kind that needs a strong draft, there should be less expansion than where it burns freely.

Q. In starting a train, why should the reverse-lever be in full gear?

A. Because at first the valves run hard by reason of there being no steam film between them and their seats, and greater power is required to move them; also there is the inertia of the train to overcome.

Q. Where should the reverse-lever be set when the engine is drifting without steam?

A. In full gear, to prevent wearing the valve round and the seat in the center.

* See also "Power Brakes," "Traction" and "Booster."

Q. If either, when does an engine start the easier—on the top quarter or on the lower quarter?

A. There is no difference.

Q. What makes one engine "smarter" than another?.

A. It develops more mean effective pressure or has less internal friction, or both, independent of lead.

Q. What may be said about the quality of "liveliness" in the locomotive?

A. The principal duty of a locomotive is not to be "lively," but to "get there." The engine which starts out lively from one station does not necessarily get to the next one any sooner than a more sluggish machine; and the latter may haul more cars with a given fuel consumption, or use less coal to haul a given train than the "lively" one.

Q. Should starting up with increasing speed be done suddenly or gradually?

A. As gradually as possible, so as not to strain the couplings unduly or risk cocking the valves.

Q. Why is it that an engine is harder to start up after being still for a while than after only a few seconds' stop?

A. Because the valve seat has become dry, except for a small portion of oil that really increases the friction of the valve on its seat.

Q. What position of the valve makes it the hardest to start the engine?

A. Where it covers both end-ports, and hence has on it no back pressure tending to counteract the downward pressure in the chest, on its back.

Q. What is the proper way to start a heavy train?

A. One car should be started at a time, so as to avoid parting the train; then when all the cars have been started the engine should be opened out; then when all is going well the reverse-lever should be hooked back to near the center in order to save steam.

Q. What are the evil effects of drips from feed-pipes or cylinder-cocks, other than waste of water from the former?

A. They wet the rails and lessen the starting or climbing power of the engine.

Q. What precautions should be taken in "breaking in" an engine?

A. To run slowly for ten miles with frequent stoppages to feel every brass; to keep wedges down until it is certain that the boxes are not warped or twisted by heating.

Q. Should the speed be regulated by the throttle or by the reverse-lever?

A. Usually by the reverse-lever alone, the throttle being kept full wide open—except in the case of very wet steam, where sometimes it may be found that it can be made drier by having the throttle partly closed.

Q. What should be done with the links every time that steam is shut off, on fast-running trains?

A. They should be dropped, so as to prevent the formation of a vacuum in the cylinder and the consequent drawing in of cinders from the smoke-box; also compression to such an extent as to cause valve-cocking.

Q. Can an engine be entirely shut off by putting the reverse-lever in the middle notch?

A Very few can, particularly if they have uncrossed rods.

Q. What should be done before shutting off, if the engine is under full steam?

A. The blower should be put on a trifle, and the fire-box door opened, to prevent flame and smoke coming out of the fire-box door when the latter is opened.

Q. How should sand be used when an engine is slipping?

A. Sparingly. The best plan is to close the throttle until engine has rolled far enough to get sand under all the drivers.

Q. Why is it that in starting up, unless the safety valves are blowing off, there seems to be (particularly if the pump or injector has been on recently) less life to the steam, with a given gage-pressure, than if the valves are blowing off?

A. The steam is wet, or only saturated, instead of being slightly superheated, as might be the case when the engine has been standing without doing any work or having a stream of cold water fed in.

Q. Under what other circumstances does the steam seem to be "dead"?

A. After the fire has been drawn; the gage may not show any less pressure for a time, but the steam seems to have less life.

CHAPTER LXXX

ACCIDENTS CONNECTED WITH BOILER AND ACCESSORIES

Q. Where should the cleaning process be begun on a boiler?

A. In the lower parts, working gradually upward.

Q. If you had an engine with a common ash pan, and you burned or broke your dump grate, how would you fix up, so as to avoid delay?

A. If the grate was burned or broken, so I could not make it stay, I would fill up from the bottom of ash pan to the level of the good grates with cobbles or scrap iron, spread the fire over, and go along.

Q. If you broke or burned the "drop" grate on an engine that had a deep or "hopper" ash pan, how would you fix up?

A. Pull the fire back off the front of the remaining grates for three feet or so, then (if near a section house) bridge the opening with splices laid lengthwise. If I could not get splices, I would take the next best thing I could get.

Q. Would it be possible to draw your train any distance with the drop grate down?

A. No; if a space of the size of the drop grate in any engine were open, all the air that the exhaust would draw could pass up through it, and the fire on the remaining grate would not burn enough to maintain steam, even with light engines.

Q. What do you mean by "all the air that the exhaust would draw"?

A. All the air needed to fill the vacuum made by the exhaust in the smoke-box.

Q. What is "honey-comb"?

A. A sulfuret of iron forming on flue-sheets.

Q. When is it most likely to form?

A. Where the flues have large end beads, or are weak and sweating, or the sheets are covered with mud on the inside (hence hotter than if clean).

Q. What classes of coal cause it to form?

A. Those containing much sulfur.

Q. Where is the shell usually most pitted?

A. Below the checks, and around rivets, studs, or tap bolts, as for instance where the guide yoke or the frame brace angles are fastened to the shell.

Q. What should be done if a gage-glass breaks?

A. If there are automatic valves to close it, it is only necessary to put in a new glass; otherwise the hand-valves will have to be depended upon; both cocks should be shut off and the gage-cocks tested as frequently as the water-glass would have been looked at.

Q. Should the glass of a water-gage break, that had no automatic valve, what should be done?

A. The hand-valve closed.

Q. How may non-automatic water-gages be cleaned?

A. By removing the valves and punching clear through with a steel wire of the same diameter as the bore of the fitting.

Q. What should be done in case of a burst flue?

A. If it does not put out the fire, the engineman should dump this latter; he should lower the steam-pressure in order to save the water in the boiler; then he should plug the flue.

Q. With what should it be closed?

A. With an iron plug held in a special pair of tongs while being driven in; or if no iron one is carried, by a wooden plug.

Q. What precaution should be taken in driving flue-plugs?

A. Not to drive too hard, lest the flue-sheet be broken.

Q. If a wooden plug is used, what precaution should be taken?

A. To drive it into the flue for some distance.

Q. Where are wooden flue-plugs apt to be unreliable?

A. In case of a burst in the flue when near the flue-sheet.

Q. How far should a wooden plug be driven in a flue in case of a burst?

A. About six inches.

Q. Why will it not burn up?

A. It cannot, inside the flue, as little or no air can get at it to supply oxygen for its combustion.

Q. How can you clear the smoke-box from smoke in case of the necessity of plugging a flue?

A. By putting on the blower slightly.

Q. How can you get at the flue to plug it?

A. By putting a plank on the coal.

Q. Under what circumstances cannot you very well calk or plug a burst flue?

A. If there is a brick-arch or similar obstruction in the fire-box.

Q. What is the proper treatment for an engine with old and tender or leaky flues?

A. Regular pumping, holding steady pressure, keeping a bright, even fire, keeping cold air from the flues, letting the fire die out when the time comes, slowly shutting dampers after going into the round-house, and covering the stack after the fire is cleaned.

Q. How may leaky tubes or stay-bolts be cured temporarily?

A. By putting in the feed some starchy substance, as bran, potatoes, or rye-flour.

Q. What is the effect of too liberal dosing this way?

A. Foaming.

Q. What is the permanent remedy?

A. Calking.

Q. If the petticoat pipe falls down and fouls the exhaust tip, how may the trouble be removed on the road?

A. The smoke-box door may be opened, the netting trap door removed and the pipe taken out.

Q. Is not this difficult, by reason of the smoke and hot gases in the smoke-box?

A. It is not necessary to get into the smoke-box to remove the split keys from the netting trap door bolts. In most cases one can stand on the pilot sheet, and with cold chisel and hammer draw the keys from the bolts by inserting the chisel in the loop of the key and striking it gently until it comes out. When all keys are removed, the trap door may be taken out and the rake used to haul the petticoat from over the exhaust; it may then be taken out and placed on the tank. The netting trap may then be replaced and the smoke-box door closed.

Q. Suppose an engine suddenly begins to steam badly and the pressure falls from say 200 to 80 pounds, and that when it is shut off the smoke and blaze come out around the fire-box door; what is probably the matter?

A. The petticoat pipe is down; perhaps only one of the hangers is broken and the pipe is lying so that the exhaust is turned to one side of the stack base.

Q. Suppose that the diaphragm, or its slide or plate, falls down and "smothers" the engine?

A. The engineman should open the smoke-box door, get a pinch bar or something else that will serve as a pry, insert it under the diaphragm or plate, pry it up and shove the bar into one of the flues. When the diaphragm is as high as wanted, the other end of the bar should be rested on the flange of the smoke-box door, or it should be blocked up on a steam pipe, and the door closed.

Q. In order to change the boiler, what must be done?

A. The engine must be stripped, the wheels, truck and back frames removed; if there is no crane to lift the boiler, it must be run off and trucks placed under the mud-ring and just back of the cylinder saddle. The distance between the front of the water leg and the back of the cylinder saddle must be measured on a wooden strip before the boiler is loosened. The cylinders should be blocked up level both ways, the back ends of the front frames supported by screw jacks, all scale and dirt removed from the saddle top, and the new boiler run ahead on trucks until the distance between the saddle back and the front of the water legs is the same as with the old boiler. The front end of the boiler should be lowered by a jack nearly to the saddle and the front end set central to the cylinders by running over the barrel a line weighted on both ends, and measuring between the hanging ends of this line and the inner sides of the cylinder. The back end is then to be plumbed in the same way; it first being made sure that the boiler-leg sides are parallel with each other and with the boiler axis. The boiler must be level lengthwise. Lines should be run through the cylinder axis to the back end of the boiler, and the latter set equidistant therefrom. The smoke arch is then to be fitted to the saddle by a line on the back and one on the front of the saddle. A wooden templet being made of the curve of the smoke arch at the front, the saddle must be chipped to fit this. The frames are then to be put up and lined.

Q. What are the usual causes of incontrollable throttle?

A. (1) Breaking or coming out of bell-crank bolts or other connecting bolts within the dome, (2) breaking of a throttle-valve rod, (3) working off of nuts in the connecting pieces, as on the top of the throttle-valve stem; (4) sudden reversal causing the steam-pipe release-valve (where there is one to keep undue pressure from the pipe) to jump out and leave a passage for steam between boiler and valve-chest.

Q. How would you handle an engine if the throttle became disconnected while open?

A. Reduce pressure and handle with reverse lever and brakes.

Q. If you had just left a terminal, would you go on?

A. If I had an important train, and could not give it up without long delay, yes; if relief were handy, no.

Q. Suppose the throttle should fail when open, at a time when the engine was working on damp rails, causing bad slipping; what should be done?

A. The reverse lever should be put in mid-gear.

Q. Should you use sand in case of the throttle being stuck open?

A. No, at least as little as possible, as it would injure the machinery if used too liberally; the engine could be controlled by the reverse-bar.

Q. What should be done in case of the throttle getting disconnected inside the body while open and the engine running?

A. The fire-door should be opened and the engine cooled to let the steam-pressure down to a point at which the engine could be controlled by working it with the reverse-lever. The train-men should be notified and the train worked to a siding by the reverse-lever and controlled by the power-brake.

Q. In case of the throttle-valve being stuck shut, can the engine be run?

A. Yes, if there are tallow-pipes from the cab to the steam-chest, the engine may be run by them without train.

Q. What should be done in case of the throttle being disconnected while closed?

A. The train should be guarded against approaching trains, and help sent for to the nearest telegraph station; the boiler should be well filled, the fire dumped, and (unless there was danger of freezing up) steam blown off. The engine should be disconnected ready for towing in; if it was a line on which there was not much traffic, or if I could make a siding, I should take off the dome-cap and try to fix the valve.

Q. What accident is much like an unshipped throttle?

A. Blowing out or unseating the relief-valve between the throttle and the boiler, provided on some engines to prevent bursting of the pipe in case of sudden reversal.

Q. What should be done in case of the bursting or unseating of the throttle relief-valve?

A. Just as in the case of an unshipped throttle.

Q. Suppose it is found that the nuts on top of the throttle-valve stem have worked off, leaving the valve closed, what is to be done?

A. The valve should be opened, to let steam to the chests, and after the dome-cover is replaced and steam got up, the engine should be run as in the case of an unshipped throttle, as the valve in this case cannot be closed, unless there should happen to be spare nuts about, or the old ones can be found.

Q. How can you tell whether it is the throttle or the dry pipe that is leaking?

A. If it is the throttle the steam that comes out will be dry; if the dry pipe, it will be accompanied with a constant drip of water.

Q. How can the cylinders be oiled in case of a broken throttle-valve?

A. If there are automatic lubricators that work with steam on, there will be no difficulty; but if there are no such feeders, the best way is to oil from the cab when running down grade at high speed; or on a level track, with a low fire, getting up a burst of speed and putting feed full on; then as the steam drops the reverse-lever should be put in full motion, when oiling can usually be done.

Q. How can the valves be oiled when the throttle is disconnected and there are no automatic feeders?

A. At the top of a grade, by letting the steam down and running at high speed; or on a level, by letting the fire down low, running fast, putting on full speed, and putting the reverse lever in full motion.

Q. In case the safety-valve should stick shut at a time when there is over-pressure, should it be jerked open?

A. No; as sudden release of steam pressure is apt to cause an explosion; and the same may be said about sudden opening of the throttle. A great many explosions have occurred just at the moment of starting, and from this cause.

Q. In case of over-pressure and non-working safety valve, what should be done?

A. The pressure may be relieved by putting on the feed, opening the heaters, and damping the fire; and the whistle may then be muffled and tied open.

Q. How may leaky steam-pipe joints be located?

A. By opening the smoke-box door and giving the engine steam.

Q. What is the effect of a burst dry-pipe?

A. The engineman cannot shut off steam, but control by the reverse lever is even harder than with stuck-open throttle.

Q. What is to be done in this case, if the reverse-lever gets beyond control?

A. Brakes on, fire-door open, dampers closed, feed on, whistle muffled and open, fire damped.

Q. What are the bad effects of leaky steam-pipe joints?

A. They waste steam and lessen the draft.

Q. In case of a broken whistle-valve, what should be done?

A. The whistle-bell should be muffled with waste or other material.

Q. Can you locate the trouble if the steam-pipe is leaking?

A. There will be a hard blow all the time in the fire-

box even when shut off, particularly with open fire-door. It may be more distinctly noticed when the reverse-lever is on the center and the throttle wide open.

Q. What should be done in case of breakage of a steam-pipe in the smoke-box?

A. A wrought-iron plate should be fastened to the top joint of the steam-pipe, or a stout hardwood plug driven into the opening and braced, if the run is short.

Q. Is a hardwood plug stopper for a burst steam-pipe very reliable?

A. Not for a long run, as it shrinks by reason of the heat in the smoke-box.

Q. What should be done in case the steam-pipe breaks inside the boiler?

A. The pressure should be run down and the valve placed in the center of its travel by the reverse-lever. If necessary to take water, the engine must be kept still by chocking the wheels.

Q. If front end is broken, but flues and steam pipes in good order, how could you make sufficient repairs to run in with?

A. Board up front end of smoke arch or close it up some way, as with grain doors, so the exhaust would draw air through the flues, instead of the break. If the studs in front end are good, it is easily done; the curtain will help close the cracks. If the studs are not good, bracing must be resorted to.

Q. Of what is the bursting of the branch-pipe, forcing of gaskets, and so on, a sign?

A. Usually that there is clogging between the check-valve and the boiler; as from accumulation of lime.

Q. On an engine with the Master Mechanics' front end, where would you first look for trouble, if she failed in steaming?

A. At the petticoat pipe. I would examine the hanger bolts, and if loose, would tighten them, but if gone entirely, I would open up the front end, and get the bolts back in and the pipe in proper position:—if possible, without knocking out the fire. But if necessary I would knock it out, trying hard to get on the side track before doing so.

Q. What should be done in case of a broken off or stuck open blow-off cock?

A. The fire should be dumped and the engine disconnected ready to be towed in, unless the hole could be plugged.

Q. How can you plug a hole in the boiler, or a broken blow-off cock?

A. By a wooden plug split at one end, driven in, and tightened by driving a wedge in the split.

Q. In case of the boiler check being broken out, what is to be done?

A. The fire hauled or deadened with earth, sand, sods or such like.

Q. What should be done in case of blowing out a safety plug from the crown-sheet while on the road?

A. The train should be disconnected and both sides disconnected ready for towing.

Q. Should not the fire be drawn or dumped?

A. No; the water and steam from the plug-hole would put it out.

Q. What is the course in case of a blown-out plug?

A. Fire killed, hole filled with a soft-wood plug, boiler refilled; then ahead under low steam.

Q. What should be done in case of a broken blow-off, or of a hole being opened in the boiler, or of other bad leak?

A. The fire should be drawn, and the engine disconnected in order to be towed back to the shop, after the conductor is notified to send to the nearest telegraph office. A man should be sent back to prevent accident from or to a following train.

Q. In case of having to disconnect the engine in order to be towed to the shop by reason of a leak or other accident to the boiler, what parts should be fixed or taken down?

A. The steam-ports should be closed, the valve-rods and main rods disconnected, and the crossheads blocked at one end of their stroke.

Q. How would you be able to know that the steam-ports were closed?

A. By opening the cylinder-cocks and giving the engine a little steam, which would show if the ports were not blocked. There should also be scribe-marks or prick-punch marks that would show the mid-position of the valve.

Q. What should be done in case of blown-out hand-hole plate?

A. Fire killed; hand-hole plate repacked and put back with an old bolt or one from somewhere else (taking care that the eccentric strap clears it) ; boiler refilled if possible, so as to proceed.

Q. What should be done in case of blown-out pop or whistle?

A. Both injectors started, to hold the water; fire killed or smothered; the hole plugged with soft wood; then ahead under low pressure.

Q. In case of broken whistle-valve, how can the noise be deadened?

A. By stuffing the bell or cup with waste.

Q. What must be borne in mind in case of this accident?

A. That extra feed is necessary.

Q. Suppose it were a broken-off whistle-stem?

A. The feed must be put on and the fire killed.

Q. What is to be done for a cracked or broken off blow-off cock?

A. The fire hauled at once; if the injector can feed faster than the break can leak, it should be put on.

Q. In case of foaming, what should be done?

A. First it should be seen whether the foaming was by reason of soap, oil or alkali in the boiler, or on account of too much water; then if it was caused by foreign material in the boiler, as would be shown by the try-cocks, with the throttle shut off, the surface-cock should be opened to let the foul water blow off, and the injectors or pumps put on to keep up the level. If by doing this the engine would not get to working right, and the water should still discharge from the stack, the fire should be drawn or damped to save the boiler.

Q. What should be done in case of a broken blow-off, or of a hole being opened in the boiler, or of other bad leak?

A. The fire drawn, and the engine disconnected to be towed back to the shop, after the conductor was notified to send to the nearest telegraph office. A man should be sent back of the train to prevent accident from or to a following train.

Q. In case of having to disconnect the engine to be towed to the shop in case of leak or other accident to the boiler, what parts should be taken down?

A. The steam-ports should be closed, the valve-rods and main rods disconnected, and the crossheads blocked at one end of their stroke.

ACCIDENTS TO PUMPS AND INJECTORS.

Q. What should be done in case the pumps will not work well?

A. The tank should be looked at to see that it has plenty of water in it; then the tank-valve inspected to see that it is connected; next, the heater-valve opened a few seconds, and the pet-cock opened; then the heater may be closed and the pump tried. If then the pump will not work, the next point along the line should be tried—the lower pump-joint may be slacked to see if the water reaches that far. If it does, the engine may be run slowly

a few turns and the joint tightened. But if the water does not flow freely from the lower joints, there must be a choke somewhere in the feed-pipe, strainer, or hose, calling for attention in those quarters. If the pump does not work, although the water flows freely from the joints, the lower valves should be taken out and examined. If they are all right and the pump still does not work, it had better be taken down at the shop and overhauled.

Q. Suppose you had an engine with a pump on only one side, and broke the slide-valve on that side, what would you do?

A. Block the ports on the crippled side, disconnect the valve-stem, take the piston-rod out of the crosshead, and run with the good side, the main rod on the crippled side working the pump.

Q. How then could the train be held still in order to take water with the pump?

A. By chocking the wheels.

Q. What should be done in case of the injectors or pumps giving out entirely while on the road?

A. The engine should be stopped, and the fire damped, to prevent further generation of steam. Then the tank hose should be disconnected, the tank valves raised to see if they were connected and all right and the tank-hose strainers examined to see that they were not stopped up. If it is the pump that has given out, it should be taken down to see whether the valves are all right; and then tried again.

Q. What should be done when the feed cannot be maintained up to the point required to keep the water-level constant?

A. After looking for the obstacles which prevent the water reaching the boiler or staying therein, then the safety of fire-box and flues should be insured by dropping the fire, or better yet, by damping it with wet earth or wet coal.

Q. Should the fire be drenched with water?

A. Not except as a last resort, as this ruins the sheets, especially if of steel.

Q. Suppose the tender is empty, from leakage or other cause; what should be done?

A. The fire should be banked or smothered, enough water being kept in the boiler, if possible, to enable steam to be raised after the engine has been towed to the water-tank.

Q. How may the boiler be filled, other than from the tender?

A. Through the safety-valves.

Q. How can trouble with the pump usually best be placed?

A. By opening the pet-cock and watching what sort of a stream it throws; whether it gives the same stream on both strokes of the pump, or not, etc.

Q. What would be the effect of the check-valve being stuck open so that the hot water would blow back and heat the pump and valves?

A. The pump might not work, by reason of expansion of the valves.

Q. What may cause pounding of the pump-valves?

A. Too much lift.

Q. Which usually have the greater pump-valve lift, fast or slow engines?

A. Slow.

Q. How can an engine be pumped by towing her with another engine?

A. By closing all openings into the boiler except those from the tender, opening lazy-cocks, throttle, and injectors, and putting the reverse-lever in the motion corresponding to the direction in which she is being towed. The main pistons will exhaust the air from the boiler, and water will flow in from the tender to supply its place.

Q. Will an injector work unless all the steam is condensed by the supply of water?

A. No.

Q. Will it sometimes work better if steam-throttle on boiler is shut off so as to supply only steam enough to work the injector?

A. Yes.

Q. Will an engine steam any better if this is done?

A. Yes.

Q. Will an injector take water from the tank if the air cannot get into the tank as fast as the water goes out?

A. No.

Q. If sand or dirt gets in the passages, will the injector work?

A. No.

Q. In case an injector will not work when it has always been reliable before, where would you look for the trouble in the first place?

A. In the tank, strainers and all supply-pipe connections.

Q. If it will not prime at all?

A. Then I should suspect an overflow-valve stuck down, or a combining-tube broken, or the inside tubes out of line.

Q. If it primes well, and breaks when opened wide, where would you expect to find the trouble?

A. In insufficient water-supply for steam of the temperature of that supplied by the boiler.

Q. When the boiler-check sticks up or leaks back as water comes from the boiler, how do you remedy it?

A. By jarring on the check-box with a piece of wood.

Q. Is there more than one check-valve between the injector and boiler?

A. Sometimes; not usually.

Q. Where a stuck-open check-valve can not be jarred down, what should be done?

A. The lazy cock in the feed-pipe closed; if there was none, the feed pipe plugged at the next water tank.

Q. Why do this?

A. To keep the water in the tender cool enough for the other injector to lift it, even if this latter could keep the boiler full against the leak back.

Q. How would you keep your water-level right while seeing what was the matter with the injector, check, or attachments?

A. The pressure should be kept down by opening the fire door; if it took long to make the examination the fire should be banked.

Q. On which side of the engine are the injectors or pumps usually in the worst condition?

A. On the left, because generally used too seldom and not kept properly packed or attended to.

Q. What is the most natural cause of non-working injector or pump?

A. Lack of water in the tender.

Q. When the tender tank is empty and no water station is near enough to be reached, how may the boiler be filled, in case there is an unfrozen ditch or other water supply near the track?

A. Through the safety-valves, by means of pails.

Q. Suppose the tank is empty, the fire-box full and fire fierce, there is not enough water in the boiler to quench the fire, and all near-by sources of water are frozen over, how can the fire (too heavy to dump) be smothered?

A. If there is snow on the ground, with snow; if no snow is obtainable, the fire-box can be filled nearly to the crown-sheet with fine coal and the smoke-box door opened; then with wide-open throttle and reverse-lever well hooked up the engine may perhaps be run to a water-station.

Q. Why "with throttle wide and reverse lever well hooked up"?

A. To economize steam.

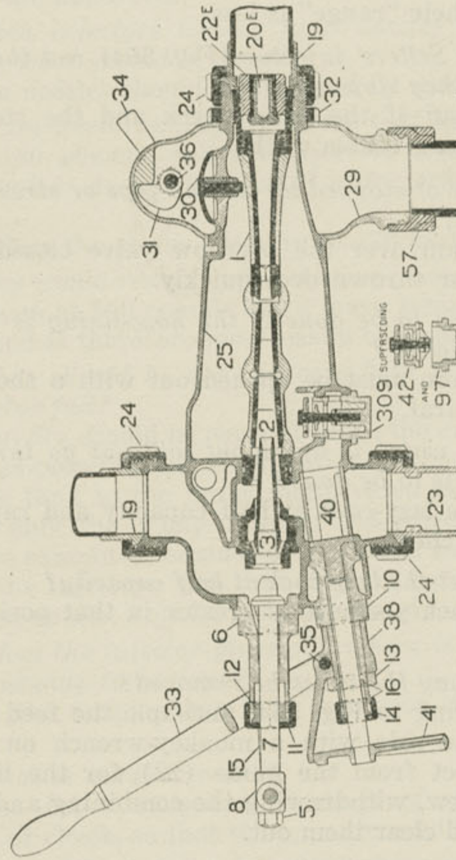


Fig. 364. Injector—William Sellers & Co.

Q. Why will an "open overflow" injector sometimes work well at 160 pounds but not at 180?

A. The steam is too hot to be entirely condensed by the feed.

Q. Is it any better with closed-overflow injectors?
A. In this particular, yes.

Q. Is there any counterbalancing disadvantage?
A. Yes, their "range" is less.

Q. In the Sellers' injector (*Fig.* 364) *can the tubes be removed if they stop up?*
A. Yes, but if the main check and the steam-valve leak, it is disagreeable work.

Q. In case of stopped-up suction-pipe or strainer, what is to be done?
A. The cam over the overflow valve closed and the starting-lever thrown over quickly.

Q. What is to be done if the hose-lining is loose and stops the injector?
A. The hose must be opened out with a short nipple or a wire spiral.

Q. If the water is lifted but will not go through the check, what is to be done?
A. Set the lazy-cock at half capacity and rap the cap of the main check.

Q. Why set the lazy-cock at half capacity?
A. The back pressure is greater in that position than if full open.

Q. How may the tubes be removed?
A. Referring to Fig. 364, uncouple the feed pipe and swing it one side with a monkey-wrench on the lugs which project from the guide (22) for the line check (20); unscrew, withdrawing the combining and delivery tube (2) and clear them out.

Q. What would cause a double-tube Metropolitan injector to lose water at the overflow while working?
A. Probably a leaky overflow valve. In this injector this valve is subject to boiler pressure when working; this causes leakage while working, if the valve is worn.

Q. Can a Monitor injector be worked with the priming nozzle broken out?
A. Not unless the water in the tank is high enough to run into the apparatus.

Q. When injectors having fixed nozzles get worn in this part, what should be done?
A. The nozzles should be replaced by new ones.

Q. If you were running an engine that carried a pressure of 180 pounds, and the injectors would not work well enough to keep boiler full of water, what would you do?
A. Reduce the steam pressure to 170 or 160 pounds.

Q. Why would reducing the steam pressure help?
A. Steam at 160 pounds has a lower temperature than at 180, and is therefore more easily condensed.

Q. What should be done in case both the pumps and the injector fail?
A. The fire should be covered dead; the engine stopped as soon as possible, and examination of the line of water from the tank to the lower pump valve made as in the case of only the pump failing; the injector feed-pipe should be examined, because a very small leak here is apt to stop the injector. See that there is no obstruction in the steam-nozzle; and that the branch-pipe is clear.

Q. When the injector gives out, where is the source of trouble usually to be found?
A. In the tank; either it is empty or the strainer is choked.

Q. What is another cause?
A. Hot tubes caused by leakage of steam through throttle or check, so that the apparatus will not prime.

Q. For gritty water, what check-valve setting is inadvisable?
A. Horizontal.

Q. What is the most simple way of putting to rights a check-valve that remains open?

A. Jarring the casing, but with a piece of wood so as to avoid deforming the casting.

Q. *What is the great enemy of good working of an injector?*

A. Leaky joints in the supply side of the pipe line.

Q. *What is the action of the air which leaks in?*

A. To decrease the speed of the water, hence its power to open the boiler-check.

Q. *Name another source of failure of an injector to work.*

A. Loose tubes, which get out of axial line and break the stream.

Q. *Where injectors are coated internally with scale or other deposit, how may they best be worked?*

A. With low steam.

Q. *How can an injector be kept from freezing?*

A. It should have frost-cocks so that all pipes from and to it can be bled. The pipes should be free from pockets or sinks, but if these are unavoidable they should have bleeders.

Q. *In case the injector does not work and the trouble is not in the tank-valve, what should be done?*

A. The entire pipe line looked to for leaks.

Q. *What should be done in case the injector works all right except when the engine is running fast?*

A. The experiment may be tried of putting at the end of the feed-pipe a washer with only a small hole.

Q. *Should an injector get over-hot, what should be done?*

A. Cooled from without; or the hot water let escape at the screen; or the tank-valve removed and the water blown back into the tender.

Q. *What should be done in case of the injectors or pumps entirely giving out while on the road?*

A. The engine should be stopped, and the fire damped, to prevent further steaming. Then the tank-hose should be disconnected, the tank-valves raised to see if they were connected and all right, and the tank-hose strainers examined to see that they were not stopped up. If it is the pump that has given out, it should be taken down to see that the valves are all right, and then tried again.

Q. *Suppose that the water in the boiler should get dangerously low, what should be done?*

A. The fire should be drawn, or damped with sand, earth, or with coal dirt.

Q. *In case you got out of water in the tender, on the road, what would you do?*

A. Bail into the tank with a pail from nearest supply; or shovel snow in and melt it with steam on one side only.

Q. *In case there was no water supply, what would you do?*

A. Either bank the fire or dump it, as the case might be—depending on the distance I would have to be towed to the next water-station, and the time which would elapse before I got there.

Q. *If the boiler and tender were empty?*

A. Draw the fire and send for help.

Q. *How could she be filled up with hot water from a live engine, if you had a hose and suitable connections?*

A. By connecting the hose from the injector of the live engine to the check-valve of the dead one.

Q. *When an engine dies on the road in freezing weather, what should you do?*

A. Empty the tender and boiler and break all joints at places likely to have "pockets" of water, which have no pet-cocks or other appliances for draining them; blow steam through the pipes. Empty the lubricators of water; blow off the boiler clear and dry (by taking out the wash-out plugs (if necessary), disconnect for being towed in dead.

Q. *How would you fill the boiler with water and get* *the engine alive, when fire is drawn on account of low water?*

A. Remove the whistle or the safety-valve, and fill through the opening where it was; using pails unless there are small hose facilities.

Q. *Why should the water be let out of the tank and boiler in excessively cold weather?*

A. To prevent the sudden expansion of the water in freezing deforming or straining them.

Q. *Why should all pumps and injectors and their pipes be drained in freezing weather, when put out of service?*

A. To prevent freezing and bursting.

Q. *What is the best way to get the steam out of pumps and injectors and their pipes in putting them out of service?*

A. To blow steam through them.

Q. *What is to prevent them filling again, in case there are leaky tank-valves or check-valves?*

A. The frost-plugs should be taken out, if there are any; if there are none the joints should be slacked, to permit leakage.

Q. *What can be said of putting water on the fire?*

A. It should never be done without first damping it with sods, sand, or similar deadening material, else scalding would be apt to result from the steam coming from the fire-door.

Q. *In case of its being necessary to dump a fire while standing on a bridge or trestle, what precaution must be taken?*

A. First to close the ash-pan dampers.

Q. *Name some of the common causes for injectors not working?*

A. Leaky suction pipe; obstructed strainer or one of insufficient size; liming up of nozzles; loose hose lining; obstructions, as pieces of coal, or other foreign matter washed in from the tank, in the nozzles; obstructions in

the delivery pipe, as a sticking boiler check; leaky steam valve and boiler check, heating the suction pipe and feed water.

Q. *What should be done with check-valve stuck open?*

A. If it has no stop valve, close the heater cock and water-valve of the injector, to prevent water from the boiler from running out through the latter. In this case, reliance for feeding the boiler must be had on the injector, the check of which must be in good condition. If the boiler check has a stop valve, this can be closed to shut off the boiler pressure therefrom, in which case the check can be taken out for cleaning or for the removal of the causes which made it stick open.

Q. *How may one know whether the check valve or the steam valve is leaking?*

A. By opening the frost-cock, with which all delivery pipes and most check valves are provided. If water issues therefrom, the check-valve leaks. To determine whether the steam valve leaks, the cock cap and check should be removed. If the steam valve leaks, steam will issue through the opening.

Q. *What may be done in this case?*

A. The check-valve and the injector must be reported for repair, and the leaky valves ground in at the shop.

Q. *What must be done if a combining tube is obstructed?*

A. It must be taken out, the nozzles cleaned, and obstructions removed.

Q. *How may it be determined if the trouble is on account of a leaky suction pipe?*

A. When the suction-pipe leaks, the injector works with a hoarse, rumbling sound, caused by the air drawn in through the leaks. A leaky suction-pipe may also be determined by closing the tank valve, and opening the steam valve of the injector slightly, with the heater cock closed. If there is a leak anywhere in the suction line, the steam under such circumstances will issue through it.

Q. What should be done in case of obstructed hose or strainer?

A. The connection between hose and strainer should be broken, and, with the heater cock closed, steam blown back through the strainer. The water allowed to flow through the open hose will usually wash out the obstruction. In most cases it will be sufficient to remove the strainer waste cap and allow water from the tank to flow through.

Q. What should be done in case the feed water in the tank is too hot?

A. To get fresh water as soon as possible, to reduce the temperature.

Q. Will an injector work if all the steam is not condensed by water?

A. No.

Q. If necessary to take down the tank hose, how can the water be prevented from flowing out of a tank that has the siphon connection instead of the old style tank valve?

A. By opening the air vent at the top of the pipe. Siphon pipes are usually large enough to admit air when the hose is disconnected, so that there is little danger of the water being siphoned out.

Q. How can the water in the delivery pipe be protected from freezing in cold weather?

A. If the injector is not in use for a long period, the frost cock in the delivery pipe should be opened.

Q. How would you prevent the waste pipe freezing either while the injector is working or when shut off?

A. As the waste pipe contains water only during the short period in starting, and as even then it flows out rapidly, the danger of freezing is remote. When the injector is not working, the waste pipe is empty. Gradual

freezing as a result of a leaky lifting valve or steam valve may be prevented by occasionally opening the lifting valve slightly, and allowing steam to blow through the waste pipe.

Q. How can the suction pipe and injector hose be protected from freezing?

A. By using the injector as a heater.

Q. How is the heater used on a lever type Monitor injector?

A. By closing down the heater cock, and opening the lever very slightly, and fastening it by the thumbscrew on its side.

Q. How is the heater used with a screw type Monitor injector?

A. By closing down the heater cock and opening the steam valve about a turn.

Q. How should an injector be stopped?

A. The steam valve should be pressed firmly and gradually on its seat, avoiding (particularly in the case of a lever injector) closing of the valve with a shock, which injures it and its seat, and tends to loosen these seats, where they are inserted in the valve body.

Q. Should the blow-off cock or the wash-out plug refuse to close?

A. Kill the fire; get off the main line if you can. In freezing weather, drain boiler, tanks and connections and prepare to be towed in.

Q. If the blow-off cock or the wash-out plug blows out?

A. Kill the fire; plug the hole with a long soft wood plug, refill the boiler if you can; then fire up and run under low pressure. Otherwise prepare for towing.

Q. What is to be done if the gage glass breaks?

A. Close both cocks and rely on the gage cocks, testing them more frequently than usual.

Q. What is the procedure in case a safety-valve blows out?

A. Start heavy feed at once; smother or kill the fire; plug the valve opening with soft wood, holding down the plug with a plank bound to the hand rail. Inspect the other valve.

Q. For a broken safety-valve spring?

A. Put the valve out of action.

Q. Suppose the whistle blows out?

A. Plug the hole as for a blow-out safety-valve.

Q. What should be done if the injector suction is clogged?

A. Close the overflow; blow steam back through the pipe.

Q. In case there is hot water in the suction pipe?

A. As just cited; then reopen the overflow.

Q. If the tank water gets too hot for the injector to work, what is to be done?

A. The tank cooled by opening the cover; if possible, adding cold water.

Q. If the water is only warm?

A. Throttle down the injector.

Q. If the injector nozzle is clogged?

A. Remove and clean in a pickle of one part of muriatic (hydrochloric) acid to ten of water.

Q. If the injector lifts but does not force?

A. Seek the cause: either obstruction on the suction side, tank valve partly closed, water supply too great or too limited, delivery nozzle in bad condition, suction leaky, check valve stuck; frost cock too wide open; overflow leaking; tank cover closed air tight. Then remedy the defect, as pointed out elsewhere in this book, where common sense does not indicate what to do without reference.

ACCIDENTS TO CYLINDERS

Q. What may cause breakage of a cylinder-head?

A. A broken main crank-pin or crosshead-pin, a loose piston-rod key working out, a follower-bolt nut working off or head breaking, part of a piston-packing ring catching in the steam-passage, or a broken crosshead or piston-rod.

Q. What should be done in case of breakage, or of blowing out of a cylinder-head?

A. If not near the end of a run, the disabled side should have its valve-rod disconnected and the ports closed, the latter to be proved by opening both cylinder-cocks and giving a little steam. Then the valve-rod on that side should be jammed fast by the stuffing-box gland, which should have the nut screwed up on only one side so as to cock it. The main rod should be disconnected and, sometimes, the crosshead blocked at one end of the guides.

Q. If you blew out a cylinder head near the end of a run, how would you manage?

A. Take out the back cylinder cock, cover the ports and run in with main rod up.

Q. Why would you take out the cylinder-cock?

A. So that when the piston was coming to back end of cylinder there would not be so much compression.

Q. Why should not the crosshead always be blocked, in case of a broken cylinder-head?

A. As a usual thing the break lets the steam out and the piston cannot be sent to either end of the cylinder.

Q. What should be done in case both front cylinder-heads are broken?

A. If the piston and valve-gear are all right the front steam-ports may be blocked with wood and the engine run with all the train that it can take, with the back cylinder ends. If they are not all right, the engine should be disconnected on both sides and made ready for towing in.

Q. What should be done in case of blowing out the stuffing-box gland and breaking off one lug and one stud?

A. Most of the packing should be taken out, the gland run clear back into the box, and the lug bolted solid to the head by the remaining stud.

Q. What might be done in case of both stuffing-box lugs being broken off?

A. The outside of the gland-body might be wrapped with cloth and forced into the box by a jack.

Q. What would you do in case of breakage of the body of a gland?

A. Disconnect the engine on that side.

Q. If you broke both gland studs what would you do?

A. Put a small amount of packing in the box and wedge in the gland.

Q. How would you wedge it?

A. On an engine with the ordinary four-bar guides, wedge between the guides and the remnant of the gland, using the long taper wedges that hold the brake shoes to the head on tenders or cars.

Q. If it were any other style of guide bar?

A. Put a little packing in the box, wrap some cloth or canvas around the gland, and force it into the box.

Q. How would you force it in?

A. Place the engine on that side within an inch of the end of travel ahead, to cover the back steam port, put a block between crosshead end and gland, and move engine ahead a little, thus forcing the gland in.

Q. What is to be done in case the metallic packing gives out on the road?

A. The stuffing-box removed, any of the old packing left, that can be; temporary packing made of wicking or old cloth to fill the cone; then the stuffing-box replaced.

Q. Would you take out the cylinder-cock at the end the piston is in?

A. No; I should block the cylinder-cocks open; disconnecting the cylinder-cock rod if necessary.

Q. What other way is there of shutting off the cylinders, than blocking the valve or boarding over the ports?

A. Where there is a neck joint between the chest and the smoke-arch, this may be uncoupled and the rings replaced by a piece of board and an old shovel blade, the latter towards the smoke-arch.

Q. What should be done in case the relief-valve is blown out from the steam-chest?

A. The hole may be plugged from the inside.

Q. Can an engine be run with both front heads or both back heads broken or disabled?

A. Yes, by blocking the ports at that end and running with the other end only.

Q. What should be done in case cylinder-lubricators do not work right?

A. All the cocks should be taken off and the lubricator-cup taken off, while the engine is drifting without steam.

Q. What will be the effect of this?

A. Probably to draw air through them and clean them out.

Q. What precaution should be taken in taking down a cylinder-head, as regards the nuts?

A. To lay them in such order that each can be put back in the place from which it was taken.

Q. What is a good way to hold a crosshead at one end of the guides?

A. To have a one-and-a-half inch iron hook to pass around the crosshead-pin, the end of this hook being threaded; hook this around the pin, with the crosshead at the back end of the stroke, pass the threaded end of the hook through a hole in a straight piece of iron about four by one and a half inches, which is placed across the straight piece which bears against the yoke supporting the back end of the guides; run a nut up on the threaded end of the hook, and the crosshead will be held at stroke-end.

Q. It frequently happens that a piece will be broken out of a locomotive cylinder or other casting that can be patched, and the expense of replacing the whole obviated. Give a good method of doing this?

A. The main casting is cut off inside the crack to a fairly uniform line. A model is then made by means of the portion cut off, to fit over the end of the break and make the necessary junctions with the adjoining parts of the machine. The lower half of the mold flask is fitted around the broken end of the casting and well secured thereto, and the joint sealed with clay. The model is then set into the flask over the broken end, on which it, of course, should lap a certain amount, and the molding is proceeded with. The upper half of the flask has, of course, a core fitting into the hollow of the broken end, if such there be. Before casting, the broken end should be well warmed by a charcoal fire placed within.

ACCIDENTS TO PISTON AND ROD

Q. What would you do in case the piston head broke?

A. Disconnect that side unless the whole piston was gone, in which case I would leave the main rod up and block the valve in the middle.

Q. Is there any means of detecting a cracked follower-plate or head without removing the cylinder head?

A. No.

Q. What is the effect of a follower bolt working out?

A. It will cause a "pound," by its head striking the front cylinder head.

Q. Will shutting the engine off stop such a "pound"?

A. No; in that case it would strike harder, because there would be no steam in the cylinder to "cushion" the piston.

Q. When you have reason to believe that a follower bolt is loose, what should you do?

A. Stop the engine at once, take off the cylinder head, and tighten or remove the bolt.

Q. If the follower-head bolt broke and smashed the piston entirely off the rod, how would you disconnect?

A. If the piston rod were not badly bent, remove the broken stuff, disconnect the valve stem, cover the ports and go along.

Q. Do you know of anything being done to prevent such failures?

A. Some roads are making the pistons solid, cutting grooves therein for the packing and springing the rings into place; the diameter of the rings being about one-fourth of an inch greater than that of the cylinder bore.

Q. If the piston is fastened to one end of its stroke, what should be done with the cylinder-cocks?

A. They should be tied open or taken off.

Q. What is the reason for this?

A. To prevent the knocking out of the cylinder-head or smashing the piston in case the blocking gives out.

Q. What is a hasty way to keep a piston at one end of the cylinder?

A. Push it to the end, and push the valve in the same direction so as to keep the steam-port open at the end furthest from the piston; thus keeping the cylinder full of steam pressing against the piston.

Q. What is the objection to this?

A. If the valve should get away from its position, to the opposite end of the seat, the steam would move the piston back and smash out the head.

Q. What is the objection to putting the valve in mid-position and leaving the piston unfastened?

A. If the valve should slip there might be a smashed piston or cylinder-head.

Q. What precaution should be taken with the follower bolts in dismounting the piston?

A. To lay them in such position that each one can be put back in the exact place from which it came.

Q. How can a piston be got in the center of the cylinder?

A. By a pair of inside calipers or by a stick cut to length; or better yet by a wire pointed at each end, and of the proper length.

Q. In packing a piston, what precaution should be taken as regards the equality of the spring pressure?

A. To see, by tapping them with a hammer, that each is just snug and that no one bears harder than another.

Q. After the packing is set out, what should be done with the follower?

A. It should be cleaned before putting on.

Q. Before putting back the cylinder-heads, what should be done thereto?

A. Their joints should be cleaned.

Q. What is the danger of screwing up cylinder-head nuts?

A. That they will be screwed too hard and the studs broken.

Q. In what order should cylinder-head nuts be put on?

A. The top one first, then the bottom one, then those at the quarters, and so on; dividing the space equally, and being sure that no one is run up hard before all are run up slightly.

Q. Suppose that after taking off the follower the packing will be found not to be tight, although it seemed so before the follower was taken off; what does this show?

A. That is was too long and was held clamped by the follower.

Q. How can a follower-bound packing be remedied?

A. By putting a piece of stout paper between the follower and the spider.

Q. What may be done in case the piston-packing is too short?

A. A piece of wrapping-paper may be put between the packing-rings.

Q. How often should a piston-packing be examined?

A. About every eight to ten weeks, according to the service in which the engine is engaged.

Q. What would you do in case a piston rod broke and went clear out of the cylinder, taking the front head with it?

A. Disconnect the valve rod, cover the ports and go along, using one side.

Q. If the piston head broke off the rod, but did not knock out all of the front head?

A. If I could get it out of the cylinder, and the rod was not bent, I would not take down the main rod; otherwise I would.

Q. What is liable to spring and break piston-rods?

A. (1) Loose guides; (2) badly-lined pistons; (3) loose piston-key.

Q. Suppose a piston-rod breaks without smashing anything else, what should be done?

A. The cylinder-head should be taken off and the piston taken out; the ports covered, and if the crosshead is injured the main rod should be taken down.

Q. What is liable to result from a loose piston-rod key?

A. Knocking out a cylinder-head, or cracking a piston-rod.

Q. What is a frequent cause of the keyway in the piston-rod cracking?

A. The guides being worked up and down by reason of insufficient stiffness in the frames to which they are keyed.

Q. Which is the best end at which to block the crosshead; and why?

A. Usually the back, because in case the blocking comes out and lets the crosshead move, the front head would be cheaper to repair, than the back.

Q. How can this be done if the guides are opposite the front drivers?

A. It can not; else the front crank pins would strike either it or the wrist pin.

Q. What precaution must be taken in blocking an underhung crosshead?

A. To block it at the travel mark, to keep the packing rings out of the cylinder counterbore.

Q. What precaution is necessary after blocking the crosshead?

A. If the steam cap of the valve, or the valve seat, is broken, to remove the cylinder cocks or fasten them open, to let out condensed steam.

Q. Where both sides are to be disconnected for towing, what must be done?

A. The reverse lever put half way down the quadrant (in the desired direction); main rods and valve rods removed; valves left untouched if the crank-pins clear the crossheads; if fire is down, drain injectors, pumps, and pipes (boiler too, if danger of freezing is great). Fill all oil cups.

ACCIDENTS TO VALVE, YOKE AND STEM

Q. In what way is a slide-valve apt to wear?

A. With convex face.

Q. In what way is the valve-seat apt to wear?

A. Concave.

Q. What causes a cut valve?

A. Tight fitting of a yoke, or its lack of alignment with the valve-stem.

Q. What causes valve-cocking?

A. Valve-yokes tight fitting or out of line with the stem.

Q. When does the cocking usually occur?

A. On slowing down and stopping.

Q. What will usually bring a cocked valve in place again?

A. (1) Giving the reverse-lever quick jerks to shake the valve; or (2) taking out the steam-chest tallow-cup and with a metal rod driving the valve down out of the yoke.

Q. In case this fails, what should be done?

A. The valve-stem should be disconnected and the valve shaken that way.

Q. Suppose that fails?

A. The chest-cover should be taken up.

Q. What is the sign of a cocked valve?

A. A roar through the stack, caused by the steam rushing through.

Q. In case of a cocked valve, should the chest-cover be removed before exhausting other means?

A. No.

Q. How can the tightness of the valve be tested?

A. By getting the rocker-arm vertical, blocking the engine, opening the smoke-box door, giving steam, and watching the nozzles. A leaky valve will show by the steam coming from the nozzle on its side.

Q. Having ascertained on which side the valve is broken, what is the next course?

A. It should be removed, and if unbalanced, a flat piece of inch board laid on the seat to cover the ports; on this the valve should be laid, at mid-travel; both the board and the valve blocked, the chest-lid put on, the stuffing-box plugged with waste or packing (held in by the gland), the main rod taken down and the crosshead blocked; then the engine may go on with as much train as possible. In the case of a balanced valve the board on the seat is omitted. (Fig. 366.)

Q. How may the valve be blocked without taking off the chest-cover?

A. Where there is a relief-valve in the front side of the chest, by removing this, and pushing the valve against the stem or the yoke, clamping this latter, and putting in a wooden plug long enough to reach from the D-valve to the relief valve when the latter is secured in place.

Q. After disconnecting, is there any way to clamp a valve stem having United States packing, or would you have to remove the steam-chest cover and block the valve?

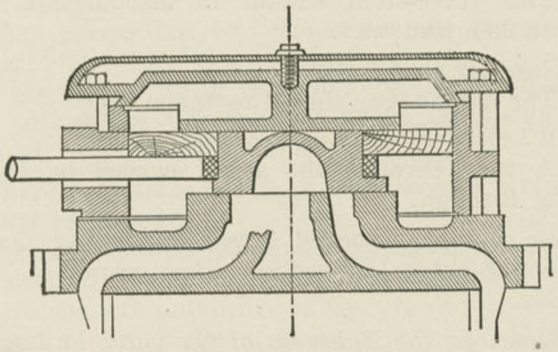


Fig. 366. Balanced Valve Blocked in Steam Chest.

A. All up-to-date engineers carry a cramp for holding a valve stem that has metallic packing, for keeping it in position.

Q. What is the best method of blocking a piston valve, broken within the chamber, or with valve-stem broken within this latter?

A. To take off both valve chamber covers, center the valve, put a block of wood of proper size in each end to hold it central, and put on the covers. If in a desperate hurry and you know positively whether the valve is an outside or inside admission, direct or indirect connected valve, to push it to the front end and secure the stem. This fills the cylinder with steam. Move the engine so that this will hold the piston against the cylinder cover at one end; disconnect and block. If not absolutely sure of what you are doing, adopt the first mentioned plan.

Q. What should one avoid, in locating a broken valve yoke or other such cause of a heavy blow?

A. Placing the engine on the good side on the dead center and thus being unable to move either way.

Q. Which side should one look at first?

A. That side which is on the quarter.

Q. Why?

A. Because if this side were not disabled it would move the engine off the center on the other side.

Q. When is it not necessary to take off the chest cover?

A. When there is a relief valve; as in this case the valve-stem may be disconnected and the relief valve taken out, which will permit shifting the valve to cover the ports and help the good side off the dead center.

Q. What is a cause of balanced slide-valves running hard?

A. The valve and lower seat having been re-faced, the balance-strips come out too high and cant, letting steam in on back of valve, hence increasing pressure and friction.

Q. What is a frequent cause of broken balance-strips?

A. Re-facing valve and seat, which brings the strips out too far and is apt to cause cocking and breakage.

Q. What is the remedy or prevention?

A. Lowering the upper valve-seat.

Q. What is a common cause of breakage of balanced valves?

A. Broken springs getting out from under the valve-strips.

Q. How may this evil be lessened?

A. (1) By dowels; (2) by small lugs under the strips, (3) and much better, by sheet iron cases such as are shown in Fig. 367.

The case which is fitted at each end of the valve is made of 1-16 inch sheet iron, the corners welded. *B* lies flat in a groove at the end of the valve, with spring resting on it, and the strip moves vertically on top of the spring, inclosed at the corners by walls *D* and *C*. *A* protrudes into

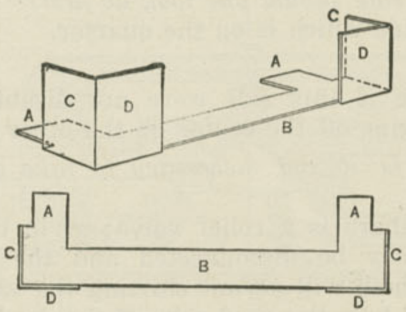


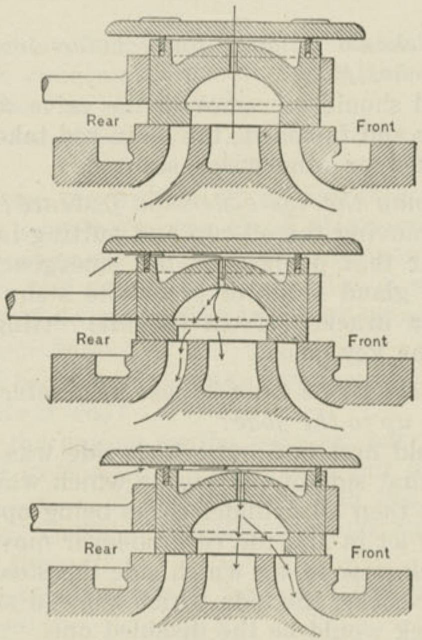
Fig. 367. Casing for Balanced Valve.

the long groove extending from one end of valve to the other. The end *A* is bent down and filed to a razor edge, so that the edge always bears tight on the bottom of the groove. *B* is bent slightly, so that the ends are always down solid.

Q. Should you suspect a broken pressure-strip or spring on a balanced valve, how would you detect it?

A. Say for instance that the right side is suspected. Put the right crank-pin on the forward center and the reverse-lever in the center notch, and open the cylinder-cocks. The valve position will be central as shown in Fig. 368. Put the reverse-lever over until the valve-stem has moved about 3/8 inch; this will bring it into the position of Fig. 369, and any leak such as is shown by the

arrows, past the strip and into the exhaust-arch, will pass to the rear end of the cylinder and show at the cock as well as the exhaust-nozzle. Put the valve in the position shown in Fig. 370, then a leaking strip will cause a blow at the front cock and at the exhaust nozzle.



Figs. 368, 369 and 370. Balanced Valve Positions.

Q. Why try both valve positions?

A. To be sure that the blow is not caused by a leak under the valve.

Q. How would you disconnect the valve-stem from the valve-rod socket?

A. Remove the rocker-arm pin, wind a piece of waste around the small end of the pinch-bar, stick it in the eye in the back end of the valve-rod, and then by pushing down on the pinch-bar free the stem (having blocked up the back end of the rod to prevent springing it by prying down).

Q. Should a valve-stem break, need the corresponding eccentric-strap or link be "doctored"?

A. No.

Q. What should be done for a valve-stem broken off outside the chest?

A. Its rod should be removed, the valve set on the exhaust center and fastened; the main-rod taken down, the piston blocked or otherwisee secured.

Q. How may the valve-stem be fastened?

A. By removing the oil-cup and putting in a set-screw provided for that purpose in the emergency kit, or by cocking the gland so as to pinch the stem hard; or by the use of a bracket (from the kit) fitting the gland-studs and the key-hole.

Q. What should be done in case of a valve-stem breaking off close up to the yoke?

A. I should first find out which side was disabled, by examining that side of the engine which was nearest the half stroke; then all cylinder-cocks being opened, a little steam being let in and the reverse-lever moved from forward to back gear to see which side the steam showed at the cylinder-cocks, the side which showed steam at only the back cock would be the disabled one.

Q. Why is this?

A. Because if the stem was broken off inside the chest it could only push the valve ahead and not draw it back, and steam would show on only the back cock on that side the stem of which was broken inside the chest.

Q. Why would you choose the side that stood nearest half stroke?

A. Because that being the side which would have fullest port-opening, the test would be plainer.

Q. Can a valve-stem be mended on the road?

A. Yes, if you have with you a clamp with good sharp set-screws; the ring being small enough to clear the packing gland studs.

Q. How would you fasten a valve-stem, where U. S. packing is used, in case there are no clamps for such purpose?

A. Place the valve over the ports, and tie the stem, one rope or wire running back to the yoke, the other around the steam chest or relief valve.

Q. What would you do in case of a broken valve-stem gland?

A. With one lug broken off or one stud gone, do the same as for a broken piston-gland (take out all the rod-packing except one turn, push in the broken gland as far as it will go, and screw up the gland-stud nuts), or, the gland can be held in stuffing-box with wire or bell-cord around steam-chest.

Q. If you broke a valve-yoke how would you determine on which side it was?

A. Place the engine on the quarter, put the lever "in ahead," and give a little steam, then put her "in back" and do the same. If the steam would not come out of both cylinder cocks alternately I would know that was the broken side.

Q. When a valve-yoke is broken, what disconnections should be made?

A. The chest-cover should be removed, and the valve placed centrally over the ports, and blocked in position; then the chest-lid replaced. After that the valve-rod and main rod should be disconnected, and the crosshead blocked, on that side. Instructions should be asked for as to whether the train should be brought in as a whole, or only part brought in and the rest left.

Q. How would you disconnect in such a case?

A. Take up the steam-chest cover, block the valve over the ports, take down the main rod and go along.

Q. How can a broken valve-yoke be discovered without removing the chest-cover?

A. By putting the crank on the quarter, opening the cocks full and the throttle slightly, and working the reverse-lever both ways. In case of a broken yoke, steam will show at the rear cock.

Q. Why put the crank on the quarter?

A. To give the valve full travel.

Q. How can a broken valve-yoke be held in place?

A. By a plug or stick placed in the relief-valve opening, and long enough to jam the loose front part against the back part (which remains on the stem) when the valve is on the center.

Q. What is the object of taking down the main rod in case of a broken valve-rod?

A. To prevent the piston from cutting the cylinder by running dry.

Q. Should this accident occur near a siding, in what case should the main rod not be taken down?

A. In case the line is pretty well traveled, then the main line should be cleared as soon as possible and the rod taken down later on the siding.

ACCIDENTS TO THE VALVE CHEST

Q. What should be done in case of a burst or broken steam-chest?

A. If it interfered with the running of the engine, the steam-pipe joint on the disabled side should be broken by taking out the bolts, the flanges pried apart, and a "blind gasket" or thin disk of sheet metal inserted between the flanges, after which the latter should be bolted together again, the valve-rod and main rod disconnected on the disabled side, and the crosshead blocked.

Q. Suppose that in case of a broken steam-chest or chest-cover it is found that the steam-pipe cannot be slacked up to put on a blind gasket, what should be done?

A. Wood should be fitted into the steam passages and braced in place by the steam-chest bolts; or, a piece of strong plank faced with rubber gasket should be bolted to the T-head (sometimes called "nigger-head") after the branch-pipe was removed: and the main rod and valve-stem rod on the disabled side should be disconnected.

Q. If the steam-chest was broken all to pieces how would you get in with one side?

A. If the steam connection was outside, I would plug up, or bolt a piece of plank lined with sheet iron over the end of steam way in saddle. If I used a plug I would fasten it so it could not be blown out. If the steam-passage joint was in the smoke-box, 1 would cool off the engine and insert a blind joint of wood and sheet iron in place of the joint ring.

Q. Suppose the steam-chest is broken and gone entirely, and also the studs, and the front end netting and crowded nuts and bolts at steam-pipe joints prevent using a board or a piece of sheet iron, how can the steam be cut out?

A. By filling the end ports with waste or old overclothes, covering the seat with two-inch planks and putting another plank across the first layer; putting a chain around planks and cylinder and wedging or jacking the chain tight.

Q. How may the cylinder be oiled in case of a broken steam-chest?

A. By slackening the front cylinder-head nuts and squirting in oil with an oiling syringe if there should be one at hand, otherwise by removing the front head and slushing in well with oil, and preferably with flake graphite.

Q. In case of damage to steam-chest or vaive calling for blocking of the steam-pipe or of all the steam-ports, what disconnections should be made?

A. The main rod and the valve-stem rod.

Q. *How do you keep steam from coming out of the dry-pipe into a broken steam-chest?*

A. Remove the chest-cover, block the steam-inlet by wood-filling; put a board on that; set the valve on the board; plug the inlet with wood; disconnect that side.

Q. *Can valve and valve-seat be smooth and yet out of true?*

A. Yes; both can be worn rounding so that there is an appreciable leak.

Q. *How is this revealed?*

A. By the straight-edge.

Q. *What part of a valve-seat ordinarily breaks?*

A. A bridge between an end port and the exhaust port.

Q. *What is to be done to test for a broken bridge?*

A. Put the engine on the quarter, and the lever in the front notch, and give steam. If there is no blow, try the lever in the back notch.

Q. *For a broken bridge, what is to be done?*

A. Block both ports, disconnect the valve-stem; if there is time take down the main rod.

Q. *What is the remedy for a broken valve-seat bridge?*

A. The damaged ports covered, that side stripped as for a broken valve-yoke, the engine run with the other side.

Q. *What is the sign of a considerable break in a bridge?*

A. A strong blow through the exhaust.

Q. *Of what else is this the sign?*

A. Of a cocked valve.

Q. *What would be the effect of a crack in the valve-seat bridge?*

A. To make the engine blow when taking steam at that end; leaking through to the exhaust passage.

Q. *When a valve-seat breaks, does it ever do any damage to other parts of the engine?*

A. It may break the valve, or bend either the valve-rod or the rocker-arm, or may cause breakage of the piston or the cylinder-head in case a broken piece falls into the cylinder.

Q. *What is the apparent sign of a broken outside port wall?*

A. When steam cannot be kept out of some particular one of the ports.

Q. *What is then to be done?*

A. Push the valve to that end which will leave that port half open and the other end port and the exhaust port covered; take down the main rod, if there is time; push the piston to the opposite end from the broken port wall; block the crosshead and let the cylinder fill with steam; remove the cylinder-cock nearest the piston, secure the valve-stem and go ahead.

Q. *How should one put on a new false valve-seat, where it has wings inside the chest?*

A. Clamp the seat square and central with the cylinder ports; put up the chest with a stud at each of two diagonally opposite corners; scribe the wing outlines inside; then chip and file to lines.

Q. *Where there are no seat-wings?*

A. Drill and countersink holes for flush-screws; clamp the seat square and central with the cylinder-ports; drill and tap through the seat-holes; run the screws in below the countersinks, after graphiting them well to enable subsequent removal.

Q. *What is the procedure where the false valve-seat is broken?*

A. To remove the chest cover and the valve, make a tight joint over the ports by means of a board held down by blocking, and disconnect that side.

Q. *For a broken piston valve what is to be done?*

A. Take off the chest head; if the break does not keep steam from the exhaust fasten the valve in mid-position, disconnect the rod, open the cylinder cocks, provide for lubrication and proceed on one side. If the steam edge is broken so as to admit steam, remove the cock at the end where the piston stands and fasten the other one open; prepare for towing.

Q. What is to be done for broken piston-valve body or heads?

A. Put a blind gasket in the live steam port joint; remove valve and broken parts; enclose a wooden cylinder large enough to fill the valve chamber in sheet iron and insert it; disconnect the valve rod; provide for lubrication and air circulation; run on.

ACCIDENTS TO CROSSHEADS AND GUIDES

Q. What is a common cause of broken crossheads?

A. Pounding main-rod connections; pump-plungers working out of line, or badly fastened in the lug.

Q. What should be done in case of a broken crosshead?

A. The piston should be taken out, the valve blocked at mid-travel, and the main rod taken down.

Q. Why should crossheads usually be blocked at the back end of the guides?

A. Because if there should be a smash by reason of the crosshead getting away it is better that it be the front head, by reason of its greater cheapness; besides which, if the back head were smashed there would be likelihood of the piston, guides and guide-yoke being broken also.

Q. In case it is absolutely necessary to block the crosshead at the front end, what extra precaution should be taken?

A. To clamp the valve-stem so as to lessen the probability of the valve moving back.

Q. What should be done in case the crosshead is broken so that it cannot be blocked?

A. The piston should be taken out, if possible.

Q. In case the piston cannot be taken out in this instance?

A. It should be pushed against the front cylinder-head, the valve pushed to the front end of its stroke, and the valve-stem clamped.

Q. Can the crosshead be blocked at the back end of the guides in all engines?

A. No, there are some engines, with four pairs of wheels connected, in which the front crank-pin will not clear the crosshead.

Q. What should be done in case the crosshead cannot be fastened at the back end of the guides?

A. The piston should be blocked at the front end of the cylinder with the valve at mid-travel; or, in case there is no damage to the front end of the valve or to the front steam-port, the valve may be put at the front end of the cylinder so as to let steam at the back end of the cylinder. The valve-stem should be well clamped.

Q. Under what circumstances need not the crosshead be blocked?

A. If there is no pressure in the boiler.

Q. How may the crosshead best be held in place?

A. By a special hook of 1½ round iron having threaded shank, to fit the wrist-pin, with a straight piece about 15 inches x 4 inches x 1½ inches, having a hole for the hook-shank to pass through. This is hooked on the wrist-pin when the piston is at back stroke end, the straight piece, passed across the back guide-yoke and the nut run up on the shank until all is tight.

Q. When the piston is secured, what else should be done?

A. The cylinder-cocks removed or at least tied open, as security against the accidental influx of at least a little steam.

Q. Will a broken crosshead shoe always disable the engine on that side?

A. Not if it is the under one; and not always if it is the upper one and more than half remains.

Q. Why this distinction?

A. Because in running forwards the upper guide gets most of the wear.

Q. In case the upper one was entirely gone?

A. The engine could be run forwards with the other side, or backwards with both.

Q. What should be done in the case of a broken cross-head shoe?

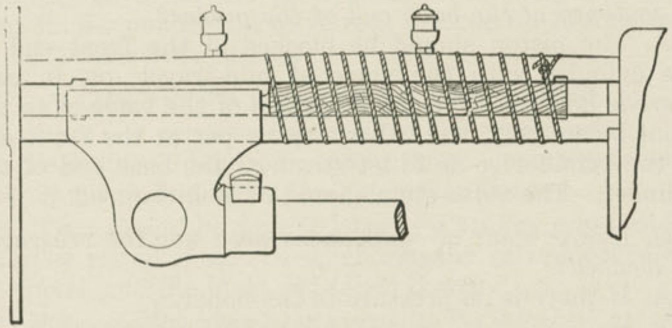


Fig. 371. Blocked Laird Crosshead.

A. If it is the lower one, a smooth slip of hard wood may be placed on the guide-bar to hold the crosshead up to the upper one. If it is the upper one it would not be safe to run in the forward motion if more than half the shoe was gone.

Q. When the piston is secured by being run to stroke end, and the valve run to the same end, what holds the piston?

A. Only steam-pressure.

Q. Is this way advisable?

A. No, it is too risky; the valve might move and cause smashing of the cylinder-head.

Q. What may be said of the method of putting the valve on the center and leaving the piston unfastened?

A. It is risky and not to be recommended.

Q. Why does the middle of Laird crosshead guides wear faster than the ends?

A. Because the main rod transmits the greatest pressure upon the guides when the crosshead is at mid-stroke.

Q. Would you disconnect an engine for a broken guide?

A. Yes.

Q. In what shape does the crosshead-pin wear?

A. Oblong in section; getting much wear on front and back and but little on top and bottom.

Q. Which of the brasses sometimes has only one key?

A. That at the back end of the main rod.

Q. In what position can a forked or spade-handle rod be taken down?

A. With the pin on the forward center.

Q. With a new engine, and crosshead and guides running hot and cutting, what would you do?

A. Slack up the bolts at the end of the guides and open them up by putting in a very thin tin or paper liner.

Q. Why not cool them with water?

A. That would warp and, perhaps, ruin the guides and necessitate disconnecting.

Q. How can an emergency crosshead gib for a four-bar guide be made?

A. Out of oak, soaked in oil.

Q. How can the crosshead wear best be determined?

A. By having two circles of the same size made from prick punch marks which correspond in hight to the cylinder axis, and measuring from their circumference to the top and bottom crosshead faces.

Q. With broken main rod, on an engine with inside admission valve, how would you disconnect and block the valve?

A. Free the radius rod from the lap-and-lead lever; hang it clear therefrom; cover the ports with the valve (by set-screw or valve stem clamp), clamp or block the crosshead at back stroke end. Come in with one cylinder.

Q. *With bent piston rod, what is to be done?*
A. As above.

Q. *With broken crosshead arm?*
A. The same.

Q. *With broken lap-and-lead lever connector?*
A. The same.

Q. *With broken lap-and-lead lever?*
A. The same.

Q. *With outside admission valve engines, what course should be pursued with broken parts as just described?*
A. The same, except that the lap-and-lead lever must be removed, clear of the radius rod.

Q. *What would you do, if the valve were to be blocked, and main rod left up with inside admission valves?*
A. Disconnect the radius rod from the lap-and-lead lever, hang it clear therefrom (using chain or wire, as rope would cut through); tie the lower end of the lever ahead to clear the crosshead on the forward stroke; come in with one side.

Q. *Same, with outside admission valve?*
A. Take down the lap-and-lead lever; otherwise as under the last question.

ACCIDENTS TO MAIN AND SIDE RODS

Q. *What should be done in case a main rod broke without smashing the cylinder-head?*
A. It, as well as the valve-rod, should be taken down, the valve blocked at mid-travel, and the crosshead and piston blocked at the back end of the stroke.

Q. *How far back should the piston be secured?*
A. Not back of its usual stroke, else the rings might drop into the counterbore.

Q. *How may this be guarded against?*
A. By watching the travel-marks on the guides and putting a block on the latter to keep the crosshead going beyond those marks.

Q. *What should be done in every case, when a main rod is disconnected?*
A. The piston should be blocked and the valve-stem disconnected.

Q. *What should be done when a set-screw in the back end of the main rod is broken and cannot be backed with the chisel?*
A. The strap-bolts should be taken out at that end and the crosshead blocked; then the engine should be pinched along until the key was loose.

Q. *What may be said about taking down main rods?*
A. This should be done as seldom as possible.

Q. *What is the advantage of leaving the main rod up?*
A. It will often do away with the necessity of using a pinch-bar.

Q. *Why should a valve-rod be disconnected when its connecting-rod is down?*
A. To prevent the valves being worked on their seat when there was no steam, which would cause cutting.

Q. *Why should liners be put back of the brasses where they belong, when rods are taken down?*
A. That they may be found at once when the engine is made ready for service, and that each one may be just where it belongs.

Q. *In case of breakage of a side-rod or of its pin, what should be done?*
A. Both side-rods should be taken down.

Q. *Why both rods?*
A. Because if the main wheel should slip and the back wheel be caught on either center, the back axle could not be turned, or would turn the wrong way, and there would be liability of either a broken pin or a bent side-rod.

Q. *What should be done in case of a broken side-rod on a four-wheel engine having the main rods connected to the back wheels and the eccentrics on the front axle?*
A. All rods should be taken down, the ports closed, the

crossheads blocked, and help asked to tow the engine to a siding or to the shops.

Q. *What should be done in case of breakage of the middle section of a six-wheel-connected engine?*

A. All side-rods should be taken down and the engine run without train to the shops, siding or destination.

Q. *What should be done in case of breakage of a pin or rod on the back section of a six-wheel-connected engine?*

A. The back section should be disconnected on both sides, and as much of the train as possible run with the forward four wheels.

Q. *What should be done in case of breakage of either the front or the back section of a side-rod on a consolidation engine?*

A. If it was a back section broken I should take off both back sections; if a front section, both front sections, and should come in with about two-thirds of the train, unless I could haul more.

Q. *What would you do in case of breakage of the middle section of a consolidation engine side-rod?*

A. Take down all side-rods and run in without any train.

Q. *Under what circumstances would an engine not get along very well with the side-rods down?*

A. With wet rails.

Q. *What should be done in case of breakage of the set-screw in a side-rod?*

A. The bolts should be taken out of the straps by it, the other drivers blocked, and the wheels pinched over until the screw is loosened.

Q. *On a "tandem connected" piston valve engine, should the side-rod break between the intermediate and main driving wheels, could you bring in the engine if the eccentrics were on the intermediate wheels?*

A. When one side-rod breaks, it is safe to take down its mate on the other side. There being nothing to make the axle carrying the eccentrics revolve in unison with the main driving axle, the engine should be towed in. Engines thus disabled have been run by leaving the side-rod up on the good side, but it is not safe, because there is no guarantee that one side-rod will always turn the wheel in the same direction as the main driver. If the main drivers slipped at or very near the forward or back quarter, the one side-rod might turn the intermediate wheel backwards, with disastrous results.

Q. *Can an engine be run with only one side-rod on a pair of drivers?*

A. Not well, as when on either center there is just as much tendency for the rear wheels to turn in the opposite direction to the forward ones, as to turn with them. This would probably break a rod or pin.

Q. *This being the case, suppose a forward section or coupling-rod breaks where there are three or more pairs of drivers coupled?*

A. Then all the coupling-rods must be taken down or dispensed with.

Q. *What is the effect of taking down coupling-rods?*

A. To lessen the tractive force, as there is less weight on the drivers that are left in service.

Q. *In running with coupling-rods disconnected, what would be the effect of opening the throttle full wide?*

A. It would be apt to cause slipping, by reason of the cylinder-power then being too much for the tractive power—a condition of affairs that sometimes exists even before an accident.

Q. *What might be the result of running with one side-rod of an eight-wheel engine down and its mate on the other side in place?*

A. The main pin might run one way and the back one the other.

Q. *How is it on consolidation engines?*

A. If a back or a front section is down, only its mate on the opposite side must come down too. If, however, the middle section on one side breaks, all parallel rods must come down.

Q. How is it on six-wheel-connected engines?

A. Here the back end of the forward side-rod has the knuckle; in case the back section breaks only its opposite mate must come down. If, however, the front section goes, all parallel rods must come down.

Q. If you broke a side-rod or a back-pin on an eight-wheeler, or mogul, where the knuckle joint is located back of the main pin, what would you take down?

A. All side-rods.

Q. In disconnecting an engine that has a broken side-rod, why would you take off the other side-rod?

A. If one rod were off, the other might not pass the center; at least, it would be as liable to go under as over, and thus make trouble.

Q. If on a ten-wheel engine the eccentrics are on the front driving axle and the intermediate drivers are the main ones, the front and main drivers connected with a solid rod, and the knuckle joint behind the main pin, and the front rod sections should get broken, can the engine be made to bring herself in? If so, how?

A. Unless the back section of the rods were of the same length and other dimensions as the front ones and could be changed from back to front, one would have to be towed in.

Q. If you broke a side-rod or a back pin on an eight-wheeler, what would you take off?

A. Both side-rods.

Q. Why?

A. If one side-rod were taken off, there would be nothing to carry the pins on the opposite side past the centers.

Q. In disconnecting by reason of a broken main rod, where the crosshead is blocked and it is desired to disconnect the valve-stem, how may the latter be held in one position?

A. It may be tied to the hand-rail if it has a joint.

Q. Can all four-wheel switch engines be run with the side-bars down?

A. Not those which have the eccentrics on the front axle and the main pin on the back wheel.

Q. Why do you take down rods on the opposite side to that broken?

A. To prevent straining.

Q. If you broke a strap on the back end of the main rod and knocked out the front head, what would you do?

A. Take off the broken strap parts, cover the ports, disconnect the valve rod, and, if there was a yoke for the main rod to lie in, block the crosshead and leave it there.

Q. What can be used in an emergency to fix a rod brass, when no babbitt is at hand?

A. Wood or sole leather, a trifle below the brass level, so that when it swells with oil it will not bind the pin.

Q. How can a sheared rod-bolt be removed, if it sticks?

A. (1) By putting a jack under it, tightening up the jack, putting a nut over the bolt head and striking hard; (2) if still stubborn, expanding the rod about the bolt by means of live coals.

Q. How can the main rod be left up if in condition to run?

A. By removing relief or vacuum valves from cylinder heads, thus preventing cushion and permitting lubrication.

Q. How can the Walschaert gear be disconnected when the valve need not be blocked?

A. By dismounting the main rod, disconnecting the radius rod from the lift shaft, and securing the link block to the link centrally.

Q. What then moves the valve on the lame side; and how much?

A. The lap-and-lead lever, opening the port to the amount of the lead (thus giving short cut off).

Q. Can the engine then be reversed?
A. Yes.

Q. How is the link block secured centrally?
A. By two wedge blocks.

Q. In the above condition what precaution must be taken in stopping; and why?
A. Not to have the main pin on the lame side on either quarter, else the valve on that side would be in mid-position and on the other side the crank pin would be on the dead center, thus prohibiting starting.

Q. On taking down a main rod what details should be observed?
A. To replace the links and brasses properly in the straps, see that the side rod is held in position; clamp the crosshead full back; take out the valve rod; fasten the valve stem; cover the ports.

Q. How is the valve stem to be fastened?
A. If there is no set screw therefor, either clamp it, or pinch it by tightening one side of the gland.

Q. How is the valve covered centrally?
A. By moving it by direct steam until steam shows at either cylinder cock.

ACCIDENTS TO CRANK-PINS

Q. What should be done in case of breakage of a main crank-pin close up to the wheel?
A. The main rod and valve-rod should be taken down, the valve blocked at mid-travel, the crosshead and piston blocked or fastened at the back end of the stroke, and both side-rods taken down; and as a usual thing, the engine run in without any train.

Q. What should be done in case of breakage of the back crank-pin on a four-wheel-connected engine having the front wheel the main one?
A. Both side-rods should be disconnected and the engine run with the main rods only.

Q. Why is it that the breakage of one back crank-pin on a four-wheel engine is liable to be followed at once by the breakage of the opposite one to it?
A. Because the breakage of the first pin throws extra pressure upon the main wheel and causes slip, and the unbroken side is apt to be caught on one of the centers and broken, unless the rod bends.

Q. What are the principal causes of broken crank-pins?
A. (1) Improper lining of the engine, throwing too much strain on the pin on passing a dead center; (2) thumping by reason of loose rods, causing crystallizing of the pin; or (3) running on sharp curves with heavy solid rods having non-adjustable bushings for bearings.

Q. Which style of rods breaks the most pins: those with solid brasses or bushings, or those with adjustable brasses?
A. The solid rods, by reason of their having no give.

Q. What is the reason that in case one crank-pin breaks, both side-rods must be taken down?
A. If the engine slipped when going over the center the side-rod on the good side could not slip its wheel, and either the rod or the crank-pin would be likely to suffer.

Q. If a crank-pin brass got hot so the babbitt melted, would you cool it off with water before all the babbitt came out?
A. No.

Q. What fault is sometimes mistaken for a bent crank-pin?
A. A distorted crank-pin hub.

Q. What is the cause of such distortion?
A. Shrinking on very heavy tires.

Q. Can a crank-pin be circular in cross-section and yet wrong?
A. Yes, it may be eccentric with the original center of the pin.

Q. What is often a result of this?
A. Shearing rod bolts, and losing keys.

Q. If the main pin has been in service any length of time, what is the best position in which to key up?
A. On the forward upper eighth or the back lower eighth; else the brasses would be liable to be keyed on a pin diameter which is not the greatest one, and in other positions the brasses would pinch the pin.

ACCIDENTS TO THE ECCENTRICS

Q. If the eccentrics are badly cut on one side, will there be any more strain on the eccentric and rocker arms on the lame side than on the other?
A. Yes.

Q. If you broke a forward motion eccentric, how would you disconnect?
A. Cover ports on that side, take off the good eccentric, together with the remnant of the broken one, and take down the main rod.

Q. What should be done in case of breakage of a backing eccentric?
A. If not near destination, both eccentric-rods should be taken down on that side, the main rod and valve-stem disconnected on that side, and the link disconnected from the tumbling-shaft by taking down the hanger. (The engine could be run in full gear on that side, if there was no danger of the link swinging against anything.) If near destination, take off the remnant of the broken eccentric and run in at full stroke.

Q. You say, "if near destination." Why not run in any distance?
A. Because it is not advisable to do so, on account of the slow speed necessary.

Q. Why not run towards mid-gear in the first case; or in other words, hook up?
A. Because that would swing the link.

Q. Suppose the back-up eccentric broken, should the forward eccentric be disconnected?
A. Not if there was nothing to do but go ahead. The bottom link end can be fastened down and the engine worked with the lever well forward to prevent the fastenings at the lower link end being pulled loose.

Q. If you broke both back motion and one forward motion eccentrics, how would you manage?
A. Take off the remnants of all broken eccentrics and run in at full stroke, using one side.

Q. If an engine on the road, fifty miles from terminal, should break both back-motion eccentrics, and one of the forward ones, how would you get her "home"?
A. Disconnect the side of the engine upon which both eccentrics were broken, take off all the damaged parts, and run in at full stroke, using one side. If the back-motion eccentric rod on that side was good, leave it attached to the link and clamp its back end to the forward motion rod to hold the link in position, and "hook up."

Q. If you were on a busy piece of road and fifty miles from destination when your eccentric broke, would you stop on main line to disconnect?
A. If it were a forward motion that broke I would have to; but if a back motion I would pull on to the first side-track, and disconnect there.

Q. What would probably take place if, having one link blocked up, the lever were dropped when the engine was shut off or in starting the train?
A. An eccentric strap would go.

Q. What sort of damage may a broken eccentric-strap cause?

A. The rod may strike the ground, double up, tear away the whole of the motion on that side and punch a hole in the fire-box.

Q. What should be done in case of a broken forward eccentric-strap?

A. Both eccentric-rods and straps should be taken down on that side, the main rod and valve-stem disconnected, the ports covered with the valve, and the link disconnected from the tumbling-shaft by taking down the hanger.

Q. What is the objection to leaving the back-up eccentric-strap and rod on in case the forward strap or rod has broken?

A. It might prove dangerous.

Q. Supposing the backing eccentric strap is broken and the rod remains good, can the back end of the rod be bolted to the go-ahead strap and the engine run ahead at short cut-off?

A. No; if the link is fastened in a vertical position, the valves will have full travel.

Q. Is it always necessary to take down both eccentrics when one is broken?

A. No; if the eccentric rods are very long and the forward one is broken, the weight of the long eccentric rod will hold the link even when the engine backs up.

Q. Why will the same rule not always apply, in case of a broken back-motion eccentric strap?

A. In most ten-wheelers the link would strike the truck frame.

Q. In case an eccentric gets hot on the road, how should it be treated so as not to break the straps?

A. The strap bolts should be loosened up and a piece of tin put in the joints between the halves of the strap.

Q. Would this be necessary in case the strap was worn, say an eighth inch?

A. No. All I would do then would be to loosen the packing in the oil pocket and use a little valve oil.

Q. Why use valve oil?

A. It will stand a higher temperature before igniting, and hang on better to a hot surface.

Q. What do you think of bolting the back end of the back-motion eccentric rod to the forward-motion strap when a back-motion strap is broken?

A. Unless I had suitable bolts and clamps I would not attempt it.

Q. What should be done in case of breakage of a go-ahead eccentric rod?

A. The broken rod and its straps should be taken down, as also the main rod and the valve-stem on that side, the main rod and valve-stem disconnected, and the link disconnected from the tumbling-shaft by taking down the hanger.

Q. How should eccentric (and other) set screws be made?

A. With cupped, not pointed, ends.

Q. How could you run in a big engine without taking down the main rod in case the eccentrics or the valve motion were disabled on one side?

A. Block the valve so as to leave the back port open for lubrication; leave both cylinder cocks open on the disabled side.

Q. Should she stick on the center, what then?

A. Close the back cylinder cock.

Q. Suppose that with the engine moving slowly ahead, and the cylinder cocks open, there is too early admission on both strokes, or too late admission on both strokes, of what is that the sign?

A. Of a slipped eccentric.

Q. Suppose that in this case the admission is too soon on both strokes, which eccentric will that show to have slipped?

A. The forward one; and *vice versa.*

Q. What is the most common cause of slipping eccentrics?

A. Dry slide valves, especially on new engines.

Q. Why "especially on new engines"?

A. Because the engine runner has no lost motion to look after, hence does not catch the evil in time.

Q. What is the test for a dry valve?

A. To lift the dog out of the quadrant; if one valve is dry there will be two jerks per wheel turn; if both are dry, four.

Q. What is another of the causes of slipping eccentrics?

A. Clogging up of the oil passages in the eccentric straps, putting extra twisting strain on the sheaves.

Q. What is the best way to insure that slipping eccentrics can be put right in place without much or any "cutting and trying"?

A. Their proper places should be marked, so that if they slip they can be put right back where they belong.

Q. Suppose a go-ahead eccentric slips and its place is not marked, what should be done?

A. The engine on the disabled side should be put on either center, the reverse lever put in the back notch of the sector (quadrant), and a fine line scratched on the valve stem right at the gland; then the lever being put in the forward notch, if the slipped eccentric is moved until the line comes to the gland again, and the set screws on the toothed keys are then fastened, the engine will be adjusted well enough until more correct setting can be done (of course, care being taken that the two eccentric bellies are not on the same side of the shaft).

Q. How do you test for a slipped eccentric when the exhaust is so uneven as to show something very wrong?

A. Shut off steam and drift. Put the reverse lever full forward. If no usual jerk is manifest, there is probably only a slipped eccentric sheave or rod or a bent rocker. If it jerks and slams into the forward corner there is probably a broken eccentric sheave or strap, link block, or valve seat.

If the indications are for a slipped eccentric, watch the crosshead and opened cylinder cocks when drifting under part steam, with lever in the center. See on which side the cocks show steam exactly at stroke end. If all seems square in forward motion the trouble is probably with a back-up eccentric. Put the lever in the usual notch, and watch again; if you can now place the faulty side, it will be a back-up eccentric.

Q. If you have reason to believe that one of your eccentrics has slipped a little, how can you prove this, and locate the right one?

A. Place my engine on the center, on one side, as near as possible, have the fireman put the lever "in ahead." Make a knife mark on the stem, after which have the lever put "in back."

Q. What accidents are often caused by slipping eccentrics?

A. Broken cylinder heads; sheared crosshead or spider keys, caused by over-compression.

Q. Under which circumstances will the front-head go?

A. When the front end is full of steam that is shut in by the valve remaining over the front port.

Q. When will the keys shear?

A. When the back end is thus choked off.

Q. Where both eccentrics and blades are slipped at the same time, can you give a way of setting them?

A. It is simply a case of "valve setting," since the eccentric rods, by changing their length, have destroyed the equality of valve travel, and the shifted eccentrics have produced a like result for the angular advance. The eccentric rods should be brought to such length as will cause the valve to travel equally over the ports, and the eccentrics turned to get the required angular advance or lead.

One way would be to put the engine on the forward center, and set the go-ahead eccentric above the axle, and the back-up below; to put the reverse lever in the forward notch and advance the top eccentric until the front cylinder cock showed steam (the wheels being blocked and the throttle very slightly opened). Then the go-ahead eccentric might be fastened.

To set the back-up eccentric the reverse lever may be put into back gear, and the eccentric turned toward the crank pin until steam shows at the front cylinder cock; or else the back-up eccentric be set by the forward one which has just been set, as though the latter had not slipped.

Q. *How may an eccentric be set on the road?*

A. (1) By putting the engine near the center, and turning the eccentric until steam comes out of the cylinder cock nearest the piston; or (2) setting the slipped one by the one that has stayed in place; or (3) putting the crosshead about half an inch from stroke end at front end for a slipped forward eccentric (at back end for a back-up eccentric) dropping the lever into the forward (or backward) notch, opening the cylinder cocks, turning on the oil blower, putting the slipped eccentric opposite the fixed one, and turning it ahead (or backward for a back-up sheave) until steam shows at the proper cylinder cock; then make fast and go ahead.

Q. *Why put the crosshead half an inch from stroke end?*

A. To give a little lead.

Q. *How should a slipped forward eccentric be set on direct-motion engine?*

A. Place the engine with the crosshead within $\frac{3}{4}$ of an inch from the extreme travel ahead (pin above center line); put the reverse lever in the forward notch, give a little steam, and turn back the eccentric until steam comes out of the front cylinder cock, and set up the set screws there.

Q. *If a sectional eccentric is slipped and you cannot move it on the axle to get it back in position, what should be done?*

A. The section bolts slacked up so it can be moved, and, after getting it in proper position, and before the set screws are set up, the section bolts drawn up tight again.

Q. *In resetting an eccentric on the road, what attention should be given to set screws and feathers?*

A. Feathers should be taken out and the metal cleaned out of the teeth. If set screws alone are used, the end "up" should be clean.

Q. *In case of shifted eccentrics, where the key and set screws are lost, what is to be done?*

A. Borrow a set screw from each of two other eccentrics.

Q. *How can a slipped backing eccentric be put into good enough position to run with, if there are no marks by which to set it exactly?*

A. Get the engines on their dead center, hook the reverse lever clear forward, clamp the valve stem so that it cannot move, remove the bolt connecting the backing-eccentric rod to the link, throw the reverse lever all the way back, then move the slipped eccentric until you can put in the jaw bolt—being careful that the bellies of the two eccentrics on that side are on opposite sides of the axle.

Q. *How would you find the center in case of a slipped eccentric?*

A. I would not try to find it. I would, if I had slipped the right forward-motion eccentric, move engine ahead until cross head reached a point within one-half inch of end of its travel at forward end of the guides, then set the eccentric. At the end of the trip I would report what I had done.

Q. *What usually causes eccentrics to slip?*

A. Among other reasons, the set screws not being kept tight, or the eccentric getting hot and tightening up in the strap.

Q. *If an eccentric is slipped, on which center should the engine be placed to get at the eccentrics?*

A. The forward, because it is much more convenient to work in front of than behind the main axle.

Q. *How can you set a slipped eccentric "by feel"?*

A. If the set-screw head is not twisted off and the screw can be backed out, usually the little finger can be put in the screw hole clean down to the axle and the sheave moved around until the "bite" or scar is felt, where the set-screw tip was forced into the surface of the axle.

Q. *In what cases will this not work?*

A. Where the eccentric is very thick; in this case sometimes the scar can be fished for with a stout wire.

Q. *What should be the course in setting a slipped go-ahead eccentric, where the engine has piston valves with inside admission, and both rocker arms turned down?*

A. Run the piston ahead within half an inch of stroke end; put the lever in back motion, scratch the valve stem, put the lever full forward and move the eccentric ahead (following the pin) until the valve-stem mark comes back to the same place.

Q. *For a back-up eccentric?*

A. Put the lever full front, scratch the valve stem; set the lever full back, turn the sheave toward the cylinder until the valve-stem mark comes to the same place again.

Q. *What is the sign of excessive eccentric-rod length?*

A. In slow running ahead with open cylinder cocks the front cock shows steam much before stroke end, or

the back cock does not show steam until after the back stroke end.

Q. *What is the sign of too short an eccentric rod?*

A. In slow running ahead with open cylinder cocks, the steam showing too late on the back stroke, too early on the front.

Q. *How does this compare with the effect of a slipping eccentric?*

A. In the latter case steam is too late or too early on both strokes.

Q. *What is the effect of a nut working off an eccentric-strap bolt?*

A. The bolt drops out and the strap, if it does not break, opens out, thus giving the valve too much travel.

Q. *What kind of eccentric rods are liable to slip?*

A. Slotted ones.

Q. *How can this trouble be distinguished?*

A. By running slowly with open cylinder cocks first in one direction, then in the other. This will show too free admission on one end and too slow on the other of one cylinder, in one gear, because the valve-travel is unequally divided each way from the exhaust center.

Q. *What is the difference between the irregularity here caused and that due to lengthening or shortening the valve stem?*

A. In the latter case the engine will be out of square in both gears; in the former only in the one affected by the slipped blade.

Q. *How is it when the engine is closely hooked up?*

A. The back motion, if very badly out, will affect the forward motion also.

Q. *What should be done when an eccentric strap is removed?*

A. The link top should be wired to the short tumbling shaft arm.

Q. What should be done if one side rod must be taken down?

A. The other one should come down, if possible; if not, all rods should come down.

Q. What effect has removing the rods on the wheel counter balance?

A. It destroys it.

Q. In removing eccentric sheaves what else must be done?

A. Remove the straps.

Q. What is to be done in case of a broken link?

A. Disconnect the crippled side, take off both eccentric straps, and either remove the link or tie it to the tumbling-shaft arm with wire of bell cord.

Q. Where both links are broken?

A. Prepare to be towed in dead.

Q. Suppose a link hanger is broken, is it possible to keep the engine on that side in steam?

A. Yes; by slipping a block in the link on the broken side so that the weight of link and eccentric rods will hold it in, and being careful not to cut off below a point corresponding to the limit set by the block.

Q. Why not?

A. The lifting-shaft arm would not clear the eccentric rods and link.

Q. In letting the link carry on the block, what precaution should be taken?

A. To tie some waste between link and block, to prevent damage to the block.

Q. What do you do in case of a broken link-block pin?

A. Take out broken pin and disconnect that side of engine, taking down both eccentric straps, as when link-block is not held by rocker-arm by its pin the link can tip against rocker-arm and catch, so as to spring eccentric-rods or move rocker-arm and valve. Although some disconnect valve from eccentric by taking out link-block pin and leaving eccentric straps and link still coupled up and moving, or disconnect the valve-stem, it is not safe.

Q. Why disconnect the valve-stem?

A. To avoid the possibility of the link uncovering the ports by striking the rocker-arm.

Q. If a solid link is sprung, what must be done?

A. The valve gear must be disconnected.

Q. What may be done with a sprung sectional link?

A. Unless too much damaged, the nuts on the top and bottom of the link bolts may be slacked, the latter partly withdrawn and a washer inserted, thick enough to let the link block move freely in the link when the lever is thrown over. After tightening the bolts, the engine may run.

ACCIDENTS TO ROCKER AND ROCKER SHAFT.

Q. What is the course in case of a broken rocker-shaft?

A. Both eccentrics, the link and the main-rod must be taken down, and valve and piston secured.

Q. What should be done in case the upper rocker-arm was broken?

A. The valve-stem rod should be taken down and the valve set on the middle of the seat, the main rod taken down and the piston fastened at one end of the cylinder.

Q. What should be done in case of a broken bottom rocker-arm?

A. The valve-rod should be taken off and the valve jammed in the central position; the main rod disconnected and the crosshead blocked at one end of the guides; perhaps eccentrics and link taken down.

Q. Should not the eccentric-straps and rods be taken off?

A. Not unless the engine was in bad shape and the link-hangers loose.

Q. Does a broken tumbling-shaft necessarily disable the engine?

A. No, although the train will not be so well under control.

Q. How may the accident be temporarily healed?

A. By putting the links in the most usual position to pull the train, and choking both link-blocks with wood, so they cannot travel either up or down. (If the engine need travel in only one motion, only one end of the link need be blocked.)

In the "emergency kit" there can be kept two hard-wood segments, each as long as the link-slot less the block; and these can be quickly sawed across, when wanted, at the necessary point.

Q. What should be done in case it is desired to reverse the engine?

A. The piece of wood that is fitted in the link should be reversed so as to give the back motion.

Q. If you lost, or broke, a rocker-arm pin, what would you do?

A. Get a bolt that would fill the holes in rocker-arm and valve-stem, and go along.

Q. Would you not be afraid of damaging the bushings by an ill-fitting pin?

A. No; those bushings are usually case-hardened, and even though rendered unfit for use again, the cost of replacing them would not be of so much importance as that of taking the train through.

ACCIDENTS TO THE LIFTER

Q. If you broke a lifter, how would you manage?

A. Place the lever at a point where the engine would start the train; put a block on top of link-block on the broken side, long enough to carry that link at about the same hight as the good one, and go along.

Q. After you had blocked up, would you for any cause drop the lever to a longer "cut-off" while engine is running?

A. It would not be safe.

Q. Why not?

A. Because the lifting arms of nearly all modern engines are fairly in line with the links.

Q. What precaution must be taken about reversal in case of a broken lifter?

A. The engine must not be reversed, as the lame side would be in forward gear and the good side in back-ward.

Q. What disconnections should be made in case of a broken link-hanger?

A. For a short run to the end of the trip, or to a shop, if the engine were running ahead and no reversals required, there need be no disconnecting; but for a long run the valve-rod should be taken off on the disabled side, the ports closed on that side, the valve-rod jammed, the main rod disconnected and the crosshead blocked at one end of the guides. Or, the link-slot chocked with wood, as for a broken tumbling-shaft.

Q. Why do you say in your answer to this last question, "if the engine were running ahead and no reversals required"?

A. Because if the link-hanger let the link drop I should have the engine in full forward gear and could run in that gear; but I could not reverse, as there would be no way of raising the link on the disabled side.

Q. What should be done in case of a broken saddle-pin?

A. The link-lifter should be disconnected, and a piece of wood fitted in the link-slot between the top and the link-block, to hold up the link, in the desired position.

ACCIDENTS TO THE REACH-ROD.

Q. What is the course with a broken reach-rod?

A. Block under one link-block and put a very short block in top of link on that side. When engine is moving, one link tends to slip up on its link-block while the other one is slipping down. If both links are blocked solid, top and bottom, the tumbling-shaft has to bend or spring. Some men block on top of link-block only. To reverse, put block in top end of one link to hold them up in back gear.

Q. In this case, where should the link be blocked?

A. So as to cut off at about half stroke.

Q. How can the engine be controlled?

A. By the brake, where there is one.

Q. Suppose the reach-rod breaks on an engine without a driver brake, on a long down grade, what is to be done?

A. (1) Fish for the links with a clinker hook, if the speed is not too great; (2) pump her full of water if you can't catch the links.

Q. Why should not both links be chocked above and below the link-block when the reach-rod is broken?

A. The tumbling-shaft or reversing arms would get bent.

Q. Suppose the equalizer is broken, the reach-rod bound, the engine hooked up near the center and refusing to move; what is to be done?

A. Remove the pin from front reach-rod end; put the links down in go-ahead motion; run the front wheel on a wedge, chock with iron between back driver-box and frame; run the back wheel up on the wedge and chock between the front driver-box and the frame.

BLOWS AND LEAKS

Q. Where may a blow take place?

A. In the steam pipes or "nigger head," from a split or hole in the steam ports, in the piston packing, valve-seat or balanced valve packing.

Q. What is the usual nature of a blow in the cylinders?

A. Either intermittent with each double stroke, or a roar.

Q. How can you tell in which cylinder it occurs?

A. By running slowly and watching the position of the crank-pin when it is the loudest.

Q. What is the usual nature of a valve-seat blow?

A. A sharp shrill whistle-like sound.

Q. When the valve cocks at one end, how is the sound?

A. Intermittent.

Q. With a balanced valve, of what is a steady strong blow usually the sign?

A. Of a broken valve-strip, rider or packing.

Q. How is a cocked valve cured?

A. By sharp reversing two or three times.

Q. Do balanced valves cock?

A. No.

Q. Of what is it a sign when a valve blows under light throttle, but does not blow with throttle full open?

A. Of a slightly bent valve-stem.

Q. Can a blowing valve always be told by the cylinder cocks?

A. No, not unless the engine is running; as a blow from a valve when the engine is standing will pass up the stack.

Q. How can you tell a chest blow from a steam-pipe blow?

A. The former blows up the stack with a clear ring. The latter is more muffled; if strong, increases the draft; sounds, when the fire door is open, like a stay-bolt leak; shows water in the front end.

Q. What is the cause of losing one exhaust?

A. Probably a slipped eccentric, a cracked or broken valve-yoke, or a break, crack, or sand-hole in the bridge.

Q. What is the blow caused by a broken valve-stem?

A. A strong blow as long as the throttle is open.

Q. What is a good way to test for a broken bridge?

A. Steam showing at one cylinder-cock with the piston at one end of the cylinder, at two when it is at the other.

Q. What is the blow peculiar to over-travel?

A. Blowing in full gear and not when hooked up.

Q. What causes this over-travel?

A. Sometimes a loose top arm of the tumbling-shaft; some times a lost key.

Q. What sound is due to a stopped-up nozzle?

A. A wheeze or whistle which may be taken for a blow.

Q. What sound is due to a lost nozzle-tip?

A. Two very heavy and two very light exhausts.

Q. What is the effect of a loose exhaust-pipe?

A. The creation of a back draft, thus causing bad steaming.

Q. What else produces the same effect as a leaky exhaust pipe joint?

A. Leaky steam-pipe joints; also loose diaphragm, loose exhaust-pipe thimble, or cinder-cap off the hopper or side of the extension.

Q. What is the result of a leaky dry-pipe?

A. Water working through the cylinders.

Q. What is the sign when in the round house?

A. Dribbling at cylinder-cocks.

Q. What is the result of a leak at bottom of exhaust-pipe?

A. Increased exhaust, without blowing.

Q. How can a steam-chest blow be located?

A. By blocking the wheel, putting first one rocker-arm, then the other, in a vertical position, and slightly opening the throttle. If no steam shows at the cock, the valve seats are tight. If there are exhaust-port drain-cocks, open them and see which side blows. If there is a double nozzle, open the front end and see which tip shows steam. If the tip is single, note the difference in the draft by means of a broom or a lighted torch; the blow will be on the side which shows the weakest draft. Or make a little extra smoke with fresh coal, and watch which side has the most draft.

Q. What effect has a chest blow on the valve friction?

A. To increase it and cause the valve to jerk; it also will make the leaky side handle harder when the pin is on the quarter.

Q. What is usually the sign of a leaky valve-seat?

A. Steam showing at both cocks with covered admission ports (but only in case the opposite side is tight).

Q. Of what else may this be the sign?

A. Of a leak beneath the false seat, if there is one; or in case of a valve with inside clearance (negative inside lap) a blow-hole in the valve itself.

Q. If steam shows at only one cock, with covered ports, what does it show?

A. Usually a loose false seat; although it might be a sand-hole between the supply-port and the steam-port.

Q. How can you tell which end of a false seat is loose?

A. The cylinder-cock of that end will show steam.

Q. How is the piston-packing tested for tightness?

A. By putting each main pin first on one quarter (not center), then on the other, and giving a little steam with the lever in full forward movement. Steam showing at only one cock proves the packing on that side. Putting the lever in full back-up position, steam at both cocks with one port open (but at only one) when the other is open shows a broken bridge, a broken valve-strip or ring, or a sand-hole in the bridge below the seat.

Q. How can the broken bridge be placed?

A. When steam shows at both cocks, it is bridge at the end which is open.

Q. What difference in the blow from a broken bridge and that from a crack or a sand-hole?

A. The former is usually much stronger.

Q. If much steam shows at both cocks with the lever in both motions, what is indicated?

A. A broken seat, or broken piston-rings.

Q. How may this be decided?

A. By taking off the cylinder-head.

Q. How is a broken piston-ring to be told from a leaky one by the blow?

A. The blow in the first case is stronger.

Q. If the blow cannot be located by the steam test, what is to be done?

A. First one supply port, then the other to be filled with water, and the corresponding open cock watched for a leak; if none shows, the cylinder and steam-ports are to be filled and the exhaust-cocks watched for a leak.

Q. Can an engine cough unequally although the gear is correct?

A. Yes; by reason of incorrect driver quartering, bent main-axle, ports of unequal size (either originally or by reason of a patch or a clog of some sort), unequal bores of cylinders that should be of equal diameters; unequal eccentric-throws or eccentric-link radius; a hole in petticoat pipe or in stack, leaky exhaust-pipe joint, cracked valve-yoke, cylinders loosely bolted on frames.

Q. If there is a blow, how is it to be known whether it is a valve-blow or a packing-blow?

A. By the sound—valve-blowing usually having a whistling sound at first.

Q. If there is still a doubt as to whether it is valve or packing that is blowing, what should be done?

A. The engine should be put at half stroke, the front cylinder-head taken off, and the valve placed so as to admit steam back of the piston; then it can be seen whether the escaping steam comes from the port or from the packing.

Q. To be sure which side of an engine is blowing, how would you test the matter?

A. By opening the smoke-box door and giving a little steam so as to see which exhaust-pipe gave out the steam.

Q. Of what is it a sign when an engine blows only when passing both centers?

A. That the cylinder-packing is wrong.

Q. Of what is it a sign when an engine blows when passing over only one center?

A. That there is a hole in the follower or spider on the side on which the blow occurs.

Q. Of what is it a sign when on passing only one of the centers, there is a blow from both cylinder-cocks at once?

A. If there is steam packing, that one of the rings is broken on the side of the blowing center.

Q. Suppose that a blow occurs at the time when an engine is running, of what is it a sign?

A. That there is trouble in the valves or in the steam-pipes.

Q. Suppose that when an engine is running, steam comes from both cylinder-cocks at once at the time when the upper rock-shaft arm is vertical, of what is that a sign?

A. That the valve on that side of the engine is blowing.

Q. How can you tell whether or not the valve is at mid-travel?

A. By opening the cylinder-cocks and admitting steam. If there is no blow, then the valve is certainly covering the ports. If there is a good blow at one end, it is by reason of the valve being in such position as to leave one of the ports uncovered. If there is a slight blow at both ends, it may arise from leakage of the piston, or from the valve being cocked, or from a broken valve-seat.

Q. With the reverse-lever in forward gear, when should the forward cylinder-cocks show steam?

A. When the crank-pins are below the exhaust; and *vice versa*.

*Q. Suppose that there is an uneven sound of the exhaust, and on inspection the eccentrics are found in the proper position, the rocker-box all right, and all visible *bolts, keys and pins in good order and proper position, where should the fault be looked for?*

A. In the steam-chest.

Q. *What sort of sound is made by a blowing valve?*

A. A wheezy sound with a suggestion of a whistle.

Q. *Is a whistling exhaust always a sound of a blowing valve?*

A. No; it may mean that the nozzles are clogged with gum from bad oils.

Q. *What would be the effect upon the sound of the exhaust if a nut should work off an eccentric-strap bolt and let the strap open?*

A. It would make an uneven exhaust.

Q. *What should be done in case of the sudden starting of an uneven sound in the exhaust?*

A. The engine-runner should stop and look about the valve-motion to see if there is not some lost motion which may be remedied at once; otherwise there might be an accident.

Q. *What will show whether or not the piston-packing has been getting loose?*

A. An asthmatic sound of the exhaust instead of the proper sharp ring.

Q. *How many sounds of the exhaust are there for each driver-revolution?*

A. Four.

Q. *How can the engineer tell which piston is blowing?*

A. From the sound of the exhaust; thus in looking at the crank-pin of the right-hand drive, the exhaust that takes place just before it reaches the forward and the back centers will be from the right-hand piston, and those which occur just before it reaches the bottom and top quarters will be from the left-hand piston, so that an intermediate blow coming between the forward center and the bottom quarter or between the back center and the top quarter, will be likely to be from trouble at the right-hand piston.

Q. *Do piston blows start suddenly, or come on gradually?*

A. Usually suddenly, by reason of a broken ring.

Q. *What is the sign made by a leaky steam-pipe?*

A. Much like the blower sound.

Q. *What is the sign of a leaky dry-pipe, as distinguished from a leaky throttle?*

A. A leaky dry-pipe will usually leak water if the boiler be well filled up with water.

Q. *How can a blow from a valve balancing-strip be identified?*

A. By putting the valve at mid-travel and slightly opening the throttle; the hole in the valve being then over the exhaust-port the leak will blow through into the stack.

Q. *With balanced valves, of what is a uniform blow with a jerk on the reverse lever characteristic?*

A. Of a broken balance-strip spring.

Q. *Why does the cylinder-packing blow most at the beginning of the stroke?*

A. (1) There is more steam pressure; (2) this has already caused more wear in the box, where there is steam piston-packing.

Q. *What is the only sure way for a beginner to locate a blow?*

A. To see it.

Q. *How can this be done?*

A. By putting the engine on the suspected side so that the back steam-port is open, taking off the head, and giving a little steam. If the blow is in the packing, the steam will follow the cylinder-wall; if in the valve it will show at the front port.

Q. *Why not put the valve central?*

A. Because the seat might be cut but yet the valve make a good joint when central.

Q. Will a cylinder-packing blow cause water to foam in a boiler?

A. No. It is harmless as far as its action on the boiler is concerned, except in waste of steam.

Q. If your engine suddenly commenced to blow badly when taking steam in one end of either cylinder, what would it denote?

A. That the valve seat was broken.

Q. How would you make sure?

A. By placing the engine on the quarter and letting steam into both cylinder ends alternately.

Q. How would you disconnect in such a case?

A. Cover ports, disconnect the valve-stem and take down the main rod.

Q. What is the character of the blow due to leaky balance-valve strips?

A. Intermittent and stronger at mid-valve travel than at the ends.

Q. If the hole in the back of the valve is not large enough to take care of the leakage, what will be the result?

A. Jerking of the reverse lever when the crank is on the centers.

Q. What is essential in testing any engine for leaks and blows?

A. That the cylinders be hot and well lubricated.

Q. How can you tell on which side a balanced valve is blowing?

A. (1) By putting the valve at mid-travel so as to bring the relief hole over the cylinder exhaust port. (2) Where the engine has two holes tapped into the base of the exhausts under the saddle for condense water, block the driving-wheels and give steam; this will show which side blows. Where there are no holes under the saddle, open the front end and see out of which exhaust steam

comes. (3) On pulling out, or on a heavy up grade, put your foot on the valve-stem; the side that blows will jar the foot on account of the extra friction if the lubricator is working well. (4) Put the engine on the quarter, first one side, then the other; open the throttle a little; move the reverse lever back and forth; as only one valve is moved at each operation the slowing one can be detected. (5) Put on the driver-brake; make a little smoke in the fire-box; shut off the air-pump; open the throttle. The smoke will ascend straight up that side of the stack corresponding to the "good" side. (6) Where the valve-rods are long, the blowing side will have the most rod vibration. (7) If at night, stand on the boiler behind the stack, hold a lighted torch in front and see from which side the most steam comes. (8) By day, put both hands over the stack and feel from which side the most steam comes. (9) Move the engine with a light throttle; watch the cylinder-cocks; the side with the broken strip or weak spring will blow continuously at the corresponding cocks. (10) Put the engine on either center; the side on which the valve blows if the lever moves hard will be the opposite side. (11) Running at 10 to 15 miles an hour, open the throttle just so that the lever can be held with latch free; hook it down to half stroke or so; if either valve blows, there will be two jerks of the lever per wheel turn, one at each reversal of the valve movement; and by watching the valve-rod or the rocker-arm the faulty side may be detected. (12) In backing out under cover, use light throttle and watch the crosshead; the leaky valve will muffle the exhaust on its side just as the exhaust fills the valve-arch.

Q. In case there should be four jerks of the lever per wheel turn, in the eleventh test mentioned, of what is that a sign?

A. That both valves were blowing.

Q. If the cylinder packing is blowing through, how do you tell which side?

A. By placing the engine on the top quarter, then putting the lever ahead, to open the back steam-port, and opening the throttle. If the front cylinder end fills with steam, that side blows.

Q. *If steam comes out of both cylinder-cocks on one side, and at the same time, what does it denote?*

A. That the cylinder-packing is blowing, or the valve or seat badly cut.

Q. *Can you distinguish the difference between the blow of a cut valve and that of cylinder-packing?*

A. Yes. If the cylinder-packing is blowing, it will make a uniform sound to nearly stroke end, and then let up a little; if it is the valve, the blow will start in heavy, let up about the middle of stroke, and be heavy again at stroke end.

Q. *At what point in the stroke does cylinder-packing blow the hardest?*

A. At the beginning, because (1) the pressure is the greatest; (2) the wear of the cylinder is also greatest at the ends.

Q. *At what point of the stroke does the piston-packing blow the most in a simple engine?*

A. At the beginning.

Q. *How can it be detected from the right side only?*

A. Watch the right crosshead; if the blow is when this is at stroke end, the blow is on that side; if when the crosshead is at mid-stroke, it is on the left side.

Q. *If you had disconnected and found that the valve leaked a little steam into the cylinder, what would you do?*

A. Take out the cylinder-cock at that end where the piston is blocked.

Q. *Why not take out both cocks?*

A. The steam that would leak in at that end would help keep the disconnected piston in place.

ACCIDENTS TO THE WHEELS

Q. *In swinging the back drivers, how would you place weight on the tender truck without throwing it on the springs?*

A. I would not put it on tender at all, but would block between boxes and frame of the forward wheels, transferring the load from the back drivers to these. The same thing applies to a ten-wheeler as to a Mogul, excepting the truck. Except on small roads, the first thing is to get off the main line, to prevent traffic delay.

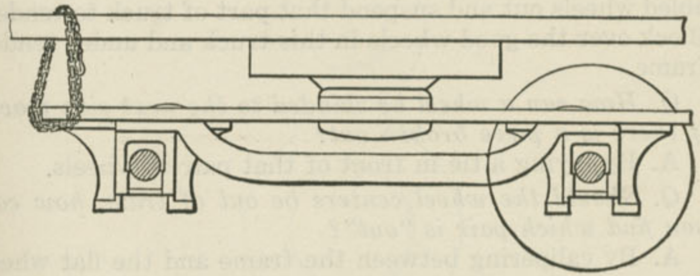


Fig. 372. Broken Truck Wheels.

Q. *What precaution should be taken about backing, with an engine that had broken or lost a back driving wheel?*

A. Backing would not be safe, particularly on curves, by reason of there being nothing to guide the engine, so it should not be attempted.

Q. *What would you do in case of a broken rear wheel on a four-wheel truck?*

A. Chain it to a piece of timber or a piece of rail laid across so that it could not turn; then go ahead, skidding the wheels of that axle.

Q. *What would you do in case of the breakage of the front wheel of a four-wheel engine truck?*

A. As for a rear wheel, but only in order to get to a side track, if there be one near, as the best place to turn the truck around. Then, having made the front wheel the rear one, it may be run skidding.

Q. With a broken mogul engine truck wheel or axle, what would you do?

A. Take it out if necessary; chain engine truck to engine frame; block up on top of forward driving boxes.

Q. With broken tender truck wheel or axle, what would you do?

A. If with broken wheel, try and skid it to the next station, to clear main line. With broken axle, take disabled wheels out and suspend that part of truck to tender. Block over the good wheels in this truck and under tender frame.

Q. How can a wheel be skidded to the next side track, if there is a piece broken out?

A. By laying a tie in front of that pair of wheels.

Q. Should the wheel centers be out of tram, how can you find which pair is "out"?

A. By calipering between the frame and the flat wheel faces at the largest wheel diameter. The clearances should be the same, measured at the same distance from the wheel centers.

Q. How may a wheel hub be mended, when there is a split or crack from the axle toward the pin?

A. By a dovetail or dumbbell piece, fitting in an opening made by slotting out between two drill holes. The piece should be driven in hot and let draw the parts together. The recess should be undercut (Fig. 373).

ACCIDENTS TO THE AXLES

Q. What should be done in case a driving axle breaks?

A. If the wheels are in position, it is often the case that the engine may be run without its train to a side track, pending the arrival of the wheels and axle.

Q. What is to be done when an axle breaks on a consolidation engine?

A. Drive out bolts at the knuckles and front end of main rod, remove rods and wheel; run the fourth wheel high up on a wedge, clearing the frame of the first and second boxes; block well up on top of these; run the fourth wheel off the wedge and raise the second; then block up on the fourth set of boxes; run the second wheel off the wedge to see if the pilot clears the rail well; with a lever raise up the axle against the resistance of the spring; block under the cellar. Disconnect valve stem

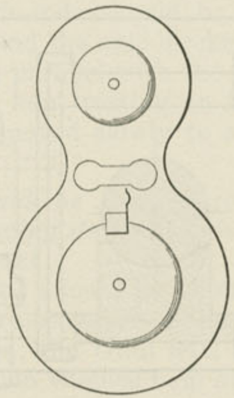


Fig. 373. Broken Wheel Hub.

and block crosshead, etc. Screw up the side rods; start easily without slipping; run to side track.

Q. Suppose you can not start easily?

A. Get pulled or pushed out.

Q. What damage is likely to be done in this run?

A. Shearing strap bolts.

Q. Where do the driving axles of outside-connected engines usually break?

A. In the box, or between it and the wheel.

Q. Can an engine be run with a broken fore axle?

A. Depends on where it is broken; sometimes, where the break is outside the frame, the truck may be raised on the side in question and chained so that the wheel will hug the rail.

Q. Can this be done with a Bissell (two-wheel) truck?

A. No.

Q. What should be done with a broken main axle on a ten-wheeler, where the break is close to the wheel?

A. Take down all side rods, jack up the broken axle, replace the oil cellar on the short side by a block, and

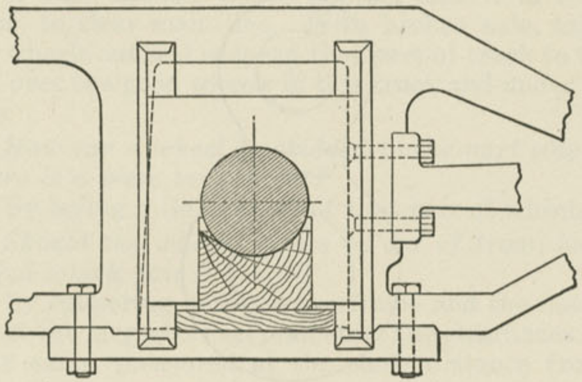


Fig. 374. Blocked Driving Axle.

chock in between that block and the pedestal brace. Remove main rod, disconnect valve rod, cover the ports on the lame side, run in light.

Q. Suppose the break is inside the journal bearings?

A. Jack up the wheels on the broken axle until the boxes touch the frames; hang the wheels to the frame by running a tie between their spokes and over the frame, and wedge under the tie so as to chock the boxes against the frame; chain the wheels together at the bottom. Jack up one side so that the pedestal braces touch the boxes; block up (or down) the ends of the spring and equalizer; repeat this on the other side. The lame wheels being

clear of the rail, the engine may be towed in, after all rods and eccentric straps are taken down.

Q. Suppose the springs will not carry the engine high enough?

A. Jack up again and block between driving boxes and frames.

Q. What should be done in case of the breakage of the front driving axle on a six-wheel-connected engine, outside the driving box?

A. All the side-rods should be taken off, the broken wheel removed, and the axle blocked up from the pedestal cap to a position parallel with the other axles. The good wheel should be kept resting on the rail, the train left, and the engine moved slowly to a position whence help may be asked.

Q. What should be done in case of a six-wheel-connected engine having its front driving axle broken inside of the driving box?

A. All side rods should be taken down, the wheels on the broken axle raised clear of the rails and blocked from the pedestal caps; the train left, and the engine moved slowly to a position whence help may be asked.

Q. What should be done in case of the breakage of the back driving axle of a four-wheel-connected engine?

A. The same as in the case of breakage of a front driving wheel on a six-wheel-connected engine.

Q. What should be done in case of breakage outside of the box, of the back driving axle of a six-wheel-connected engine?

A. Take off the wheel and both back side rods; block up the axle from the pedestal cap so as to bring it as nearly as possible parallel with the other axles, letting the guide wheel rest on the rail; leave the train and run the engine slowly to the nearest place from which to get help or at which to get instructions.

Q. What should be done in case of breakage, inside of *the box, of the back driving axle of a six-wheel-connected engine?*

A. Both side rods should be taken off, both wheels raised to clear the rails and blocked from the pedestal caps, and the engine run without train.

Q. *What should be done in case of breakage, outside of the driving box, of the main driving axle of a six-wheel-connected engine?*

A. All side rods and the broken wheel should be taken off, the main rod taken down, the crosshead blocked at the front end of the guides, the valve rod disconnected, the ports covered with the valve, and the latter clamped in place; the broken end of the axle blocked up from the pedestal cap, the train left, and the engine run slowly to the nearest place from which help may be asked.

Q. *What should be done in case of breakage of the main driving axle of a six-wheel-connected engine, inside of the driving box?*

A. Help should be sent for to the nearest telegraph station. Pending its arrival the engine should be got ready for towing in.

Q. *In what cases cannot driving axles be supported from the pedestal caps?*

A. In the rear drivers of a Mogul engine.

Q. *What would you do in the case of a broken tire, or bent or broken driving axle, of a Mogul engine?*

A. I should disconnect the back parallel rods, get a piece of timber or of railway iron as long as the axle and thrust it between the spokes of the wheels on the crippled axle, in order to keep them from turning, then run to a siding with the forward wheels, letting the rear ones skid.

Q. *What is the effect of excessive end play between driving wheels and boxes?*

A. It is hard on the rods and makes a rough-riding engine; besides being hard on the road bed.

Q. *How much end play should there be between driving wheels and their boxes?*

A. One-sixteenth inch, at most.

Q. *What should be done in case of a broken tender axle?*

A. The truck should be chained up as in the case of a broken wheel.

Q. *What other breakages generally accompany breakage of a driving axle?*

A. Breakage of side axles and main rod, on pins.

Q. *What is to be done for a broken front axle or journal in the truck?*

A. The front end jacked up free of the truck; pilot removed, front jaws taken out, wheels rolled out, a tie run across the main frames and another under the truck frame where the brass had been, the truck frame jacked up close to the main frame and the ties chained together at each end.

Q. *Suppose there is no front or pilot sheet and the main frames are inconveniently placed?*

A. Chain each side of the truck frame up to the main frame, independent of the other side.

Q. *In case of a broken back truck or journal?*

A. The same as for the front.

Q. *What precaution should be taken in running with a chained-up truck axle?*

A. To run very slowly for fear of displacement, particularly over frogs.

EQUALIZERS

Q. *If you broke an over-hung equalizer, what would you do?*

A. Jack up the back end of the engine on the damaged side, take out the broken equalizer and springs, run the front wheel on a wedge, or jack it up, block up between top of back driving box and frame, run the back wheel on the wedge and block between front box and frame, remove spring saddles, if possible, and nuts, and put in washers (or better yet, rubber springs) on top of the driving boxes where the broken equalizer had been.

Q. Is it always necessary to block over the axle box?

A. No; if the break is very near the end, a beam or a piece of rail may be thrust under between the stump and the frame.

Q. What is the proper material to use in blocking up over driving boxes with under equalizers?

A. Iron is about the only thing that will carry a heavy engine.

Q. What is to be done in case of a broken intermediate equalizer on a Mogul?

A. Block between the cross equalizer and the boiler; remove the broken parts.

Q. For raising an engine for broken equalizer, which is better—wedges or jacks?

A. Wedges are usually easier to handle, but are only recommended for straight tracks; otherwise the rear end should be jacked up.

Q. What is the objection to the use of wedges?

A. Liability of the wheels becoming derailed.

Q. Suppose you have no jacks, what should be done in case of a broken equalizer?

A. Nuts should be used to block up, on top of all driving boxes; one of the driver pairs that has no spring on it should be moved on to the hard wedges or blocks, and one that has wheels on the rail should be blocked with hard wood on top; next, the wedges should be taken out and placed under the other driving wheels, the engine moved on to them, and blocked up on top of the other driving boxes, then the wedges and all nuts used for blocking on the other boxes should be taken away, and the engine will be ready to start.

Q. In case of a broken center pin in the forward end of a long equalizer on a Mogul, what should be done?

A. (1) The front end jacked or wedged up, the dropped end of the equalizer jacked up to place and pinned there if there is a pin handy; if not, chained to a tie placed across the front end. Or (2) the free end of the equalizer jacked off the axle, and let down on a truck brass.

Q. What would you do if the equalizer were under the frame and broken off very near the end?

A. Chain the stump down to the frame.

Q. What is the remedy in case of a broken equalizer stand?

A. As for a broken equalizer.

Q. What should be done in case the equalizer stand bolts are broken?

A. Jack up the engine and put in other bolts.

Q. If the "Aleck pin" is broken on a Mogul engine and you block over the truck axle and under the truck equalizer, is it necessary to block over the cross equalizer and under the boiler?

A. No; only to see that something is put between the axle and equalizer, which will not cause too much friction.

Q. In case an equalizer breaks, in an underhung engine, how must the engine be blocked up?

A. By running first the front wheel and then the back up on a wedge and each time blocking between the frame and the driving box; then prying down the equalizer ends and blocking between them and the frame; next taking out the block from the boxes and you have both springs in use—but no equalization.

Q. How may the equalizer ends be kept in place in case of accident?

A. By safety-strap or check pieces as shown in *CD*, Fig. 274a, instead of being left unprotected as in Fig. 374b.

Q. What is to be done for broken equalizer post or bracket bolts, letting the engine down on the boxes?

A. The cotters removed from the upper ends of the end front and back spring hangers, the back driver run up on a wedge, an iron block put between the front driver

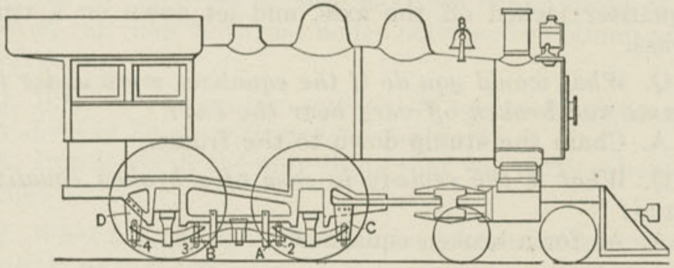


Fig. 374a. Broken Equalizer and Safety Straps.

box and the frame, then the front wheel run up on the wedge, and an iron block put between back-driver box and frame.

Q. What would you do for a broken cross equalizer on a Mogul?

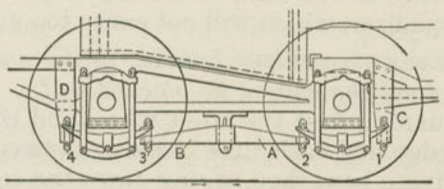


Fig. 374b. Broken Equalizer and Safety Straps.

A. One way would be to jack up the front end of the engine and carry the frame on blocking over the front driving-axle boxes; take out the springs and the broken parts of the equalizer, and block down the intermediate equalizer by pieces between its end and the upper bar of the frame.

Q. Any other way?

A. Jack up the front end of the engine, and chain the front end of the driving spring down to the frame, in case there is room for a chain.

Q. Should the intermediate equalizer of a Mogul be broken, what would be the remedy?

A. Jack up the front end of the engine, and either (1)

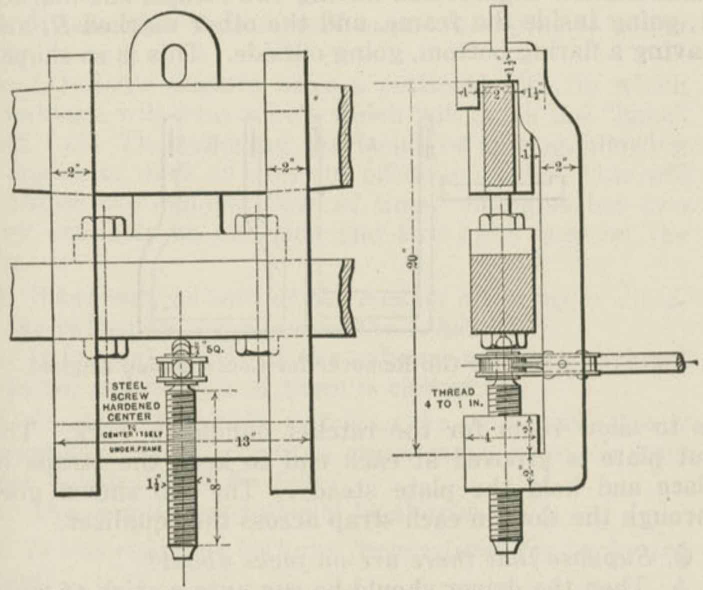


Fig. 375. Clamp for Removing Gib in Spring Equalizer.

block over the front axle box, as for a broken cross equalizer, or (2) block between the cross equalizer and the boiler; of course taking out the broken part; then run slowly.

Q. What should be done in case of an equalizer that is broken or cracked at the center?

A. Take it out, or chain the ends of the springs to the frames as if it was broken.

Q. In case it is cracked near the end?

A. Take out the spring hanger at the injured end and chain the spring to the frame, blocking between the equalizer and the latter, between the crack and the post.

Q. What is the best device for removing gibs from spring equalizers, without jacking up the engine?

A. As shown in Figs. 375 and 376, the latter being for consolidation engines and having two straps, one marked *A*, going inside the frame, and the other marked *B*, and having a flaring bottom, going outside. This is so shaped

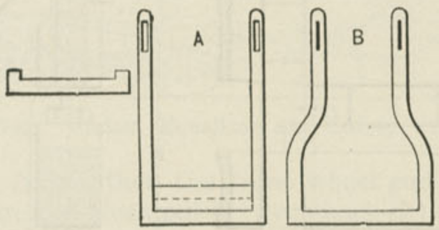


Fig. 376. Equalizer Gib Remover for Consolidation Engines.

as to allow room for the ratchet handle to work. The nut plate is grooved at each end to keep the straps in place and hold the plate steady. The gib shown goes through the slots in each strap across the equalizer.

Q. Suppose that there are no jacks about?

A. Then the driver should be run onto a stick of wood or a block of iron four to six inches thick, under the front wheel, to ease the back one, or under the back wheel if it is the forward one that is crippled.

LAME EXHAUST

Q. What are the principal causes of lame exhaust?

A. (1) The valves may need to be squared; (2) there may be a loose eccentric or strap or other part of the valve-gear; (3) one exhaust-nozzle may be closed more

than the other, or be choked; or (4) a main rod may have been lined too long or too short.

Q. If you stopped and found none of the latter three the cause, and when you started up she was "square," how would you account for it?

A. That one of the valves was dry and that after I shut off, the oil had run down out of the pipe and lubricated it.

Q. What other defects will cause an engine to sound "lame"?

A. (1) Some engines have a petticoat pipe, in which the exhaust will wear a hole which will make the "lame" sound. (2) The tumbling shaft may be sprung, allowing the engine to work at later cut off on one side. This will not throw the exhaust "out of time," but give her two heavy exhausts on one side and two light ones on the other.

Q. What may be said of the custom of lining or dividing the valves by the sound of the exhaust?

A. It is good enough if the exhaust-nozzles are closed the same, and neither of them is choked.

Q. Suppose that while watching the crosshead a heavy exhaust-beat comes when the crosshead is near the back center, what should be done?

A. The eccentric-rod should be shortened.

Q. Is this rule true both for forward and for backward motion?

A. Yes.

Q. About how much should be let out or taken up, at a time, in changing the length of the eccentric-rod to square the valve?

A. Not more than one-sixteenth of an inch at a time.

Q. How can you square the valves by the use of the cylinder-cocks?

A. Mark the guides at the end of the crosshead stroke; open the cylinder-cocks and move the engine slowly until steam shows at one of the cocks; measure the distance from the mark on the guide to where the crosshead is when steam first shows; then do the same thing at the other end, and see if the two distances are the same. If steam comes later at the front end than at the back (and there is a rock-shaft), the eccentric-rod should be shortened; if it comes too soon at the front end, the eccentric-rod should be lengthened.

Q. In which direction should the engine be moved in squaring the valves by means of the cylinder-cocks?

A. Ahead in squaring for forward motion, and backward in squaring for backward motion.

Q. Is this the case both for engines having rock-shafts and for those not having them?

A. Yes, as far as regards the direction of running the engine; but in case there is no rock-shaft the eccentric-rod should be lengthened in case steam is too late at the front end, and shortened in case it is too early at the front end.

Q. How may the valves be squared or divided with the chest-covers off?

A. The valve should be made line to line with the outside edge of the end port at one end, and the position of the crosshead marked on the guide; the position of the crosshead when the engine is on each center should be marked; the engine should be turned over until the valve is line-and-line with the outside edge of the other end port, and the position of the crosshead on the guides marked. If the distances of the crosshead marke from the stroke-end marks are the same, the valve is set square as regards admission; if not, the eccentric-rod should be lengthened or the valve-rod shortened, or *vice-versa*, until the two distances are the same at both ends. The engine should be worked in the backward motion for squaring it for the forward motion, until it is as square as possible for both motions.

Q. In marking the crosshead positions, what precautions should be taken to insure squareness?

A. That the same mark on the crosshead is made to come line-and-line with the marks on the guides, at all positions. This being the case it makes no difference at what part of the crosshead the mark is made.

ACCIDENTS TO THE FRAME

Q. Should an engine frame break, what should be done?

A. As a rule, run slowly with a light train.

Q. In case of a frame being broken between the cylinder and forward driving box, what should be done?

A. Main rod taken down, if the crack opens up when the engine is working steam, as it usually does.

Q. In this case, how about getting towed in?

A. Another engine pulling would be dangerous.

Q. Is it necessary to take down the main rod if the frame is broken between the cylinder and forward driving box?

A. If the opening of the frame at each stroke caused or permitted the piston to strike the cylinder head, that side should be disconnected.

Q. What is to be done where one frame breaks between the main axle and the cylinder?

A. Watch out for the same break on the other side; get in light, unless you can get towed in.

Q. What should be done if the frame were broken between the forward and back driving boxes?

A. Take down the side rods.

Q. Would you take down either main rod if the frame is broken between forward and back driving boxes?

A. No.

Q. What is to be done for a broken truck frame?

A. Try splicing it together, using a piece of rail or a wooden beam as a "fish," and a chain.

Q. For a broken pony truck center pin, what is to be done?

A. "Mend it with a new one" if possible.

Q. How would you fasten up to pull a full train to terminal in case you broke the drawbar between engine and tender?

A. (1) Use a steel tail rope or switch rope; couple one end to the engine-deck pin, run rope under the engine and fasten the other end to the first car, solid and without slack. There would be no strain on any coupling between engine and tender, and if the train coupling broke it would not pull the tender loose. Or (2) use a chain in the same manner; but it would be more trouble to get it back under the tender among the brake rigging. Some iron-framed tenders can have the chain from the engine-deck run around the forward center casting but it is no safer than to chain to the first car.

Q. Suppose the pin hole in the deck is broken out?

A. A short piece of T-rail can be put across in the frame and the chain put around it.

ACCIDENTS TO TIRES

Q. What are the indications that a driving-wheel tire is loose?

A. Oil is generally seen oozing out between center and tire.

Q. If an eight-wheel engine breaks off a front tire, and wheel center is swung clear of rail by blocking up over pedestal brace, and block put under forward end of equalizer instead of taking spring out over broken wheel, is it safe to run in with main rod connected up to broken wheel?

A. It is done often and successfully.

Q. With a broken tire on an eight-wheeler, should the side rod be taken down?

A. Not necessarily, especially for a front tire, unless perhaps to lessen the weight behind.

Q. What would you do in case of broken front tire on Mogul or ten-wheel engine?

A. Same as for any tire on an eight-wheeler.

Q. Main tire on Mogul?

A. Same as for preceding question.

Q. With the back tire on a Mogul?

A. Block up both back wheels as far as possible (after taking down back rods) ; block on top of both main driving boxes and below the cellars, in boxes that are up on blocks; and between the engine deck and the tender draw bar.

Q. With both back tires on Mogul?

A. Same answer as for preceding question.

Q. What should you do when a main tire breaks and comes off the wheel on a standard engine?

A. If a main tire, raise that wheel center a little higher than the tire thickness, to allow for settling when blocked up; take out oil cellar so journal would not get cut on its edges; put a block between pedestal brace and journal, to hold wheel center clear of rail, and block up over back driving box, so engine could not settle or get down to allow cast-iron wheel center to strike the rail. Take considerable strain off the pedestal brace by putting a block under spring saddle and on top of frame. Taking out this driving spring makes a sure job. Take off all other broken or disabled parts; if rods are in good order, leave them up.

Q. If it is a back tire?

A. Block up in the same manner as for main tire, except what blocking comes next other journals and boxes. If engine is very heavy, it may be necessary to carry part of the weight of back end of the engine on tender. This can sometimes be done by wedging up under chafing block on engine deck and over coupling bar; at other times it may be necessary to lay a solid tie or short rail on the deck, the end against the fire box, extending back into tender. Chain around this tie or rail and to the frame at back driving-box pedestal, and block up under the end that is on the tender, so engine weight will be carried on the rail or tie back on tender. This leaves three good tires on the rails, and the disabled wheel is away from the rail. Run wheel on blocks to raise it clear of rail when possible.

Q. With front tire on Mogul or ten-wheel engine?

A. Block up under journal of the disabled wheel, same as described in previous answer; in addition, block up to put more weight on engine trucks.

Q. With main tire on Mogul?

A. Block up under main journal and over back driving box. If, with either tire broken on Mogul or ten-wheel engine, side rods have to be taken off, it may be necessary to be towed in if crank pin of forward wheel does not clear crosshead when side rods are uncoupled. Some Mogul and ten-wheel engines have the main tires without flanges, others have the forward pair "blind," which makes a little difference in keeping them on the track when blocked up.

Q. With back tire on Mogul?

A. Same as for back tire on any other engine, taking off all broken parts. To hold flanges of the good tire against the rail when running, chain from end of engine frame and deck (the step casting is handy) across to corner of tender behind the good tire; this will hold flanges over and tender will be used to hold back end of engine on rail.

Q. With both back tires on Mogul?

A. Raise both wheel centers up to clear the rail and block under journals to hold them up. Arrange to carry part of weight of back part of engine on tender, chain back end of engine each way to tender frame, so the main wheels will have no chance to get off track. Or a shoe or "slipper" having a flange on one side can be fastened to the wheel center—a piece of old tire will make a good one—and the center blocked so it will slide and bring engine in that way. Another way is to take out the back wheels, as in the case of a broken axle, and put in a car truck, blocking up under engine deck; this is a job for the wrecking car.

Q. With back tire of back driver broken off, how do you fix engine so you can back around curves when necessary?

A. Chain across from step on engine deck on disabled side to tender frame on other side or put a block from cab casting or chafing iron on deck across where the block can brace against tender frame. This will hold flange against the rail. Look out when going through frogs, as there is nothing to keep the flange from leading into the frog point.

Q. What is the proper way to block up a consolidation engine for a broken front tire or driving wheel; the second and third drivers having plain tires?

A. Raise the front wheels clear of the rail by blocking between the pedestal braces and driving boxes, after removing the front side rods.

Q. Could engine be run ahead in this condition on a curvy road?

A. Not with safety; the plain tires would be quite likely to drop off the rails on a sharp curve.

Q. In case of a broken front tire on a ten-wheeler, what is to be done?

A. If the rods are damaged on that side, remove them, and take down the side rods on the good side. Run the wheel up on a five-inch wedge, replace the oil cellar with hard block *B*, fit a block *A* between this and the binder; chock up the front end of the equalizer nearest the tireless wheel with a block *C*, and go ahead, being sure from time to time that the lame wheel still keeps off the rail.

Q. What should be done in case of a broken main-driver tire on a ten-wheeler or a Mogul?

A. Run the wheel up on a wedge; with a hard block, *C*, chock the back end of the short equalizer and the front end of the back spring; remove the pedestal brace and

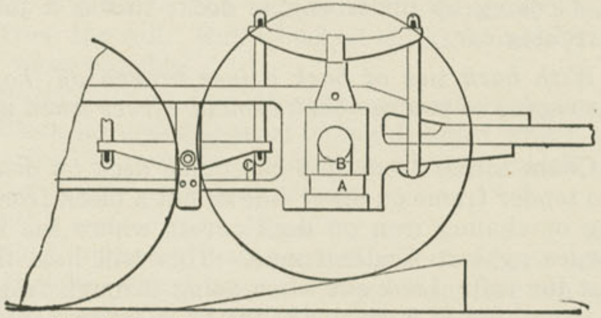


Fig. 378. Front Driver with Tire Removed.

replace the oil cellar with a block *A*, the grain lengthwise of the journal; chock under the box with a block *B*, and replace the pedestal brace. The journals require especial care in running in, as they are doing extra work.

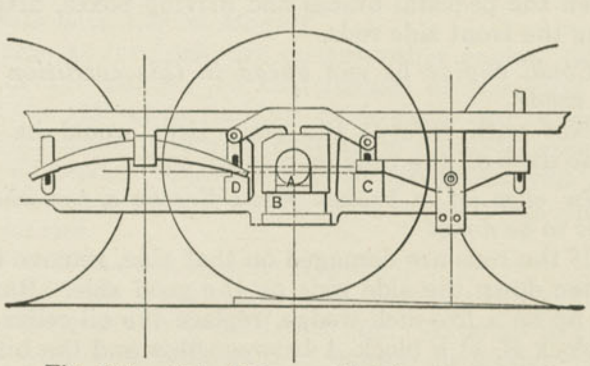


Fig. 379. Main Driver with Tire Removed.

Q. What is to be done for a broken back tire on a ten-wheeler, where the main wheel is blind?

A. Run the damaged wheel up on a wedge, replace the

oil cellar by an oak block *A* with the grain lengthwise of the journal, chock in with another wooden block, B, between box and pedestal binder; chock the back end of the long spring well up with an iron block *C*. Pass a chain from the opposite front tender-frame corner, over the drawbar to the cab support or jacking beam on the engine, wedging tight.

Q. What is the programme in case of a broken front driving tire on an over-hung eight-wheeler?

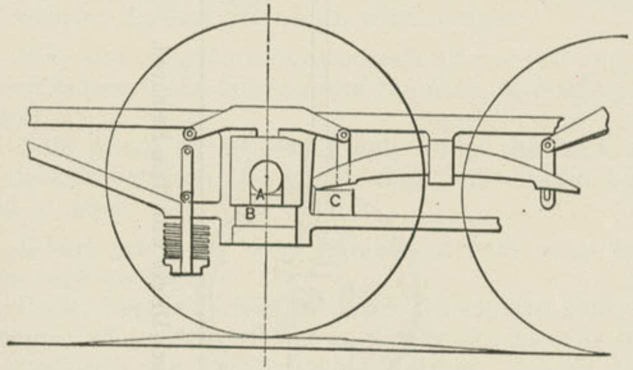


Fig. 380. Back Driver with Tire Removed.

A. Run the tireless wheel up on a six-inch wedge. Chock up the high end of the equalizer, replace the cellars by a wooden block, and chock all the space between this block and the binder with wood. If the back driver spring will hold her up, you can go ahead.

Q. Suppose this spring is too weak?

A. Run the tireless wheel again on the wedge and chock over the back driver box as for a broken spring.

Q. What is the procedure in case of an under-hung engine?

A. The same except that the equalizer end is to be chocked down.

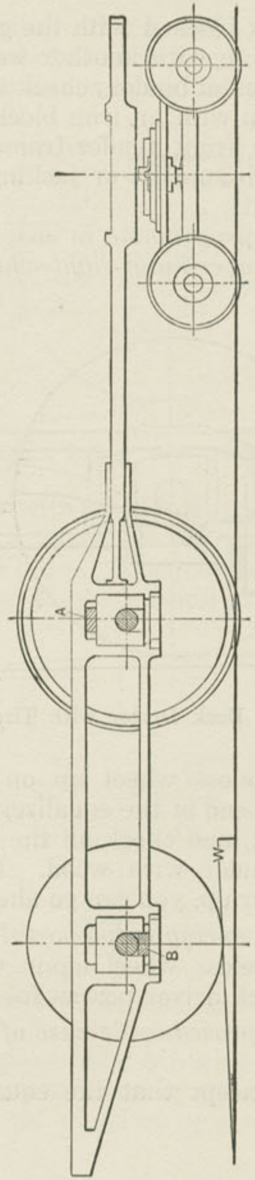


Fig. 381. Back Driver with Tire Removed.

Q. What should be done for a broken back tire on an eight-wheeler?

A. Take off rods (only to lighten weight on the front driving axle; keep down water in boiler for the same reason), run up the tireless wheel (see Fig. 381) on a wedge *W;* chock (with an iron block) between front driving box and frame, replace the oil cellar with wood blocking *B;* if necessary disconnect and take out the springs. Pass a chain from the tail beam at the same corner with the tireless wheel through over the drawbar to the opposite tank corner; tighten this chain with wedges.

Q. Why not sling both back wheels off the rail and put a T-rail between the fire-box and the tank, to hold up the wheels?

A. This would be necessary only when the back axle was broken between the boxes, and necessitated being towed in dead.

Q. Which gives the most trouble—a back or a front tire on such an engine?

A. Back; because when the back wheels are slung up the center of gravity of the engine comes too far back and overloads the front driving springs, risking their breakage.

Q. Suppose the front tire is broken?

A. The pair of wheels on one of which the tire is broken should be run on hard wedges or blocks to clear the rail; the oil cellars taken out, wooden blocks placed between the axle and pedestal caps, and the front side-rod keys slacked; then the engine should be run slowly.

Q. What should be done in case of a broken back tire?

A. Both back side rods should be taken off, the wheels run on to hard wedges or blocks to clear the rails, the oil cellars taken out, and wood blocking put between the axle and pedestal caps; the engine run without train to the nearest telegraph station where help may be asked from headquarters.

Q. *How fast is it safe to run an engine with the back tire broken or lost off?*

A. Five or six miles an hour on straight reaches, two and a half to three on curves.

Q. *What should be done in case of breakage of a forward tire on a ten-wheel engine?*

A. The wheel should be jammed up until the axle was level, a block put between the pedestal brass and the oil cellar on the disabled side, and the train run in without disconnecting anything.

Q. *Could a regular train be taken in this way?*

A. Yes.

Q. *How would you get away with a Mogul with front flanged tires swung up?*

A. As the truck wheels and the back driver flanges would guide the engine on a 15-deg. curve, nothing special need be done.

Q. *If a back flanged tire were swung up?*

A. Raise the tireless wheel and hold the opposite one on the rail by a chain from the tail beam on the side without the tire to the opposite front corner of the tender.

Q. *Does breakage of a tire always necessitate the engine being towed in?*

A. No; the loss of any one tire or of all except one main tire will permit the engine being run slowly.

Q. *What is to be done for a broken engine-truck tire?*

A. Jack up the front end, replace the cellar of the box nearest the broken tire with a block, raise the truck corner so as to clear the rail about five inches with the tireless wheel, and chain it to the main frame above and also across; then run slowly on three truck wheels.

Q. *What will be the effect if one side of the engine is lower than the other?*

A. The wheel flanges will cut on the low side.

Q. *Suppose that the driving axles are not square with the cylinders, or not parallel with each other, what will be the effect?*

A. The wheel that is too far back will cut its flanges.

Q. *Of what are cut truck flanges a sign?*

A. That the engine is not centered with the truck.

Q. *If the engine is not in the center of the truck, as shown by cut truck flanges, which way should it be moved?*

A. Toward that side of the truck which is cutting.

Q. *What will be the effect if the engine is not in the center of the truck?*

A. The truck-wheel flanges will cut, and the front driving-wheel flanges may cut also, on the opposite side to the truck-wheel flanges.

Q. *What should be done in case of a broken truck-wheel flange?*

A. The engine should be run very slowly if necessary to run at all.

Q. *If an engine cuts her truck flanges on one side, what could be the cause?*

A. (1) Driving-wheel axles nearer on the cutting side than on the other, tending to drive the engine in a circle, even on a straight track; (2) truck axles in same condition; (3) so-called center casting under the saddle not actually central, but a little toward the cutting side; (4) frames in front of the forward jaws a little bent toward the cutting side.

Q. *In case of a broken chilled truck flange, where the tread is uninjured, what is to be done?*

A. Chain the corner of the truck next the broken wheel to the opposite engine frame, thus crowding the good flanges of the opposite wheels against the rail and keeping the broken one away.

Q. *Suppose you have no chain?*

A. That would be my fault; but if I had none, I would chock the truck over with a wooden block so as to crowd the broken flange away from the rail.

Q. What should be done in case of a broken tender-truck wheel flange?

A. The same as for a broken engine-truck wheel flange.

Q. Suppose part of the tread is broken out with the flange of an engine or tender-truck wheel, what is to be done?

A. Bring the good part of the tread on the rail, stick a bar through the wheels so that it cannot turn, and skid in to a siding.

Q. Suppose it is a plate wheel?

A. Bring the break uppermost and block in between that and the frame.

Q. Suppose the wheels are steel tired and you wish to save the good one from the skidding action?

A. Raise the truck corner until the crippled wheel clears the rail; block up under its journal, against the pedestal brace; chain the truck corner up to the frame so as to keep the good wheel on the rail, as for a broken driver tire.

Q. In what cases could this not be carried out?

A. With some makes of ten-wheelers, where the valve rod and rocker arm would come in the way.

Q. Suppose the truck wheel were broken off the axle outside the box?

A. That corner of the truck could be chained up and the weight taken by the other three wheels.

Q. What can be done in the way of skidding on a tie?

A. Notch a hardwood tie for the wheels and let them run up thereon and lock fast; run to a siding.

Q. Which wheels are the more easily handled this way, and why?

A. The front, as the binders interfere with the rear wheels.

Q. Suppose the rear tender-truck wheels are ruined?

A. Jack up the tender, get out the wreckage, roll the good wheels under the rear truck end, put two ties across the axle lengthwise of the tender, next the wheels, and two others crosswise of these under the frame to keep the latter clear of the wheels.

Q. Suppose one truck axle or journal breaks without ripping up the trucks?

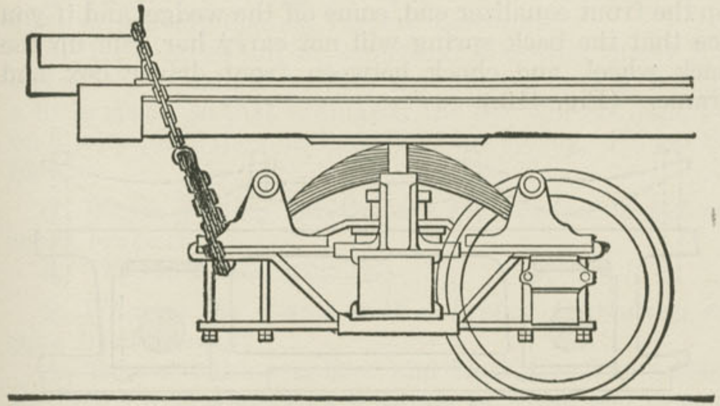


Fig. 382. Broken Tender Wheel.

A. (1) Remove the wreckage, raise the tender, block up over the oil-box tops on the good axle; sling the crippled truck corner to a tie across the tender top. Or (2) if a standard freight-car truck will fit, use it and leave the car there.

Q. What should be done in case of breakage of a tender wheel?

A. A tie or a piece of rail should be placed across the tender apron to keep the wheel from turning, with blocking between it and the tender body; the broken truck should be chained to the tie at both ends of the latter, and the train should be run in to the nearest telegraph station with that pair of wheels sliding—the broken part of the wheel being of course away from the rail. (Fig. 382.)

ACCIDENTS TO SPRINGS AND SPRING HANGERS

Q. What is the proper procedure with a broken front driver spring on an eight-wheeler with springs above the boxes?

A. Run the front wheel up on a four-inch wedge, chock up the front equalizer end, come off the wedge, and if you see that the back spring will not carry her, run up the back wheel, and chock between front driver box and frame. (Fig. 413.)

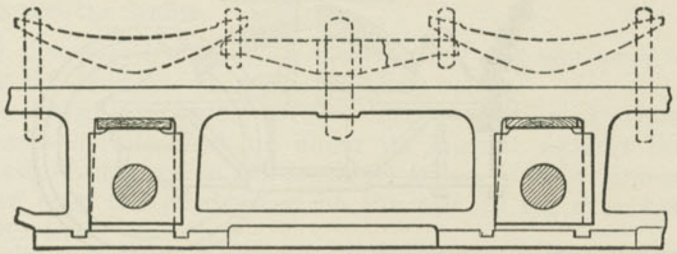


Fig. 383. Broken Springs.

Q. What is to be done with a broken back-driver spring or spring hanger on an eight-wheeler with springs above the boxes?

A. Run the back driver up on a four-inch wedge, pry up the back end of the equalizer, and block it high up; run the front driver up on the wedge and chock between rear driver box and frame; slack up a bit on the back wedges and run in with regard to hot boxes.

Q. Can a broken back spring or hanger always be handled so?

A. Usually, although there are times when the reverse lever cannot be moved. In such a case I would have to raise the engine with jacks.

Q. Which driver springs usually give the most trouble when broken?

A. The back ones are more difficult to get at, but less likely to cause mischief; therefore they may often be left in place.

Q. When blocking up for a broken driver spring, should both ends of the axle be raised?

A. Not on a standard engine.

Q. Suppose a spring partly gives out, what is to be done to provide against further damage?

A. Tie a large nut or something like that under that end of the equalizer nearest the cracked spring, leaving a little space, so that ordinarily the nut will not jam, but on a jolty place the nut, instead of the spring, will get the blow.

Q. Which driving springs are the hardest to get out when broken?

A. The back ones, usually.

Q. What is the course with a broken four-wheel engine truck spring?

A. Take out the equalizer and block the frame above the boxes with something yielding, as wood, and in some cases it may be necessary to put in a cross tie to take the weight which the spring had held. Blocks can be placed between the equalizers and the center plate.

If the break is bad, take out the spring and run in with the frames on the boxes, unless the pilot is too low. If, however, this latter is the case, jack up the end of the truck frame and chock between box and frame, front and back.

Q. Why put the blocking on the equalizers? Why not over the axle blocks?

A. To avoid springing the frame by the increased leverage.

Q. What should be done in the case of the breakage of a pony-truck spring?

A. The engine jacked up, and blocking put between the frame and oil box.

Q. Suppose you have no small jack?

A. Lift the front end off the truck by a long jack under the buffer beam; pry the truck frame up from the boxes and chock.

Q. What makes a good chock in this case?

A. A piece of car-spring rubber between two wooden boards.

Q. Name a cause of broken spring hangers?

A. The hanger being rusted to the upper pin, so that

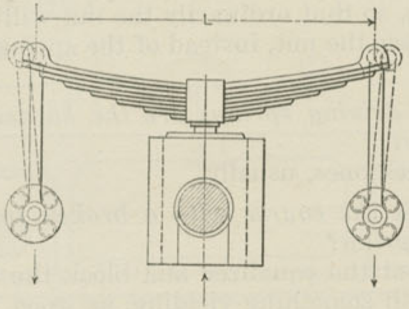


Fig. 384. Broken Spring Hanger.

it cannot vibrate laterally as the distance *L* between centers lengthens and shortens. (See Fig. 384.)

Q. What should be done in case of a broken spring hanger?

A. It should be removed, and if there is a spare one the latter should be replaced in its stead; the end of the spring being held by the new hanger.

Q. How can this operation be performed?

A. By jacking the engine up at the back under the foot board to take off the weight until the new hanger is inserted.

Q. Suppose that there is no spare hanger, what should be used?

A. A chain, if there is one handy. (Fig. 385.)

Q. Suppose neither hanger nor chain is available, what should be done?

A. The equalizer should be raised about level by a

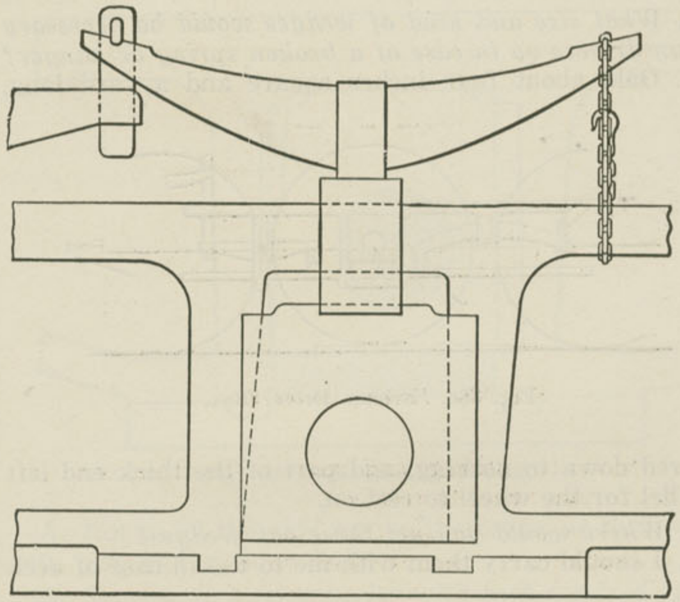


Fig. 385. Broken Spring Hanger.

block of wood or copper, jacks being used under the foot board.

Q. Suppose that in this case the engine has far to go, what special precaution should be taken?

A. To ease the other spring by putting a block of wood between the driving boxes and the frame, and over the wheel where the hanger is broken.

Q. Where the spring rigging is underneath the frame, how may it be handled in case of breakage of a spring hanger?

A. As where the spring rigging is above the frame, except that it may be better to put a wedge or its equivalent under the lower end of the equalizing bar, and move the engine back, thus raising the bar; then it may be chained fast to the frame.

Q. What size and kind of wedges would be necessary to run drivers on in case of a broken spring or hanger?

A. Oak, about four inches square and a yard long,

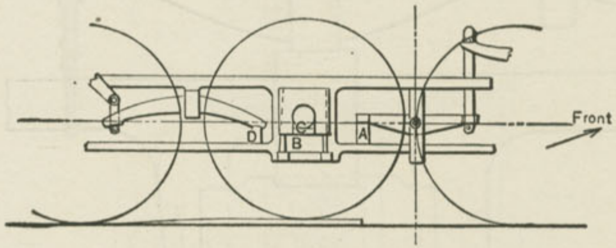


Fig. 386. Broken Driver Box.

tapered down to nothing, and part of the thick end left parallel for the wheel to rest on.

Q. Where would you get these oak wedges?

A. I should carry them with me to use in case of accident.

Q. Should any special precaution be taken in fitting in the block of wood between the oil cellar and the pedestal brass in raising the wheel center clear of the track?

A. Yes, if the engine has far to go, the block should be shaped out underneath to prevent the axle from resting on the thin edges of the oil box.

Q. Why should an engine be raised at the back end in case a spring, a hanger, or an equalizer is broken?

A. To take weight off the driving-axle springs, and to

keep the engine level so as not to uncover one part of the boiler or leave the other with too much water.

Q. What makes the best blocking for raising an engine in case of a broken spring, hanger, or equalizer?

A. Wood, by reason of its elasticity, and because it will stay in place better than iron.

Q. What precaution should be taken in blocking up?

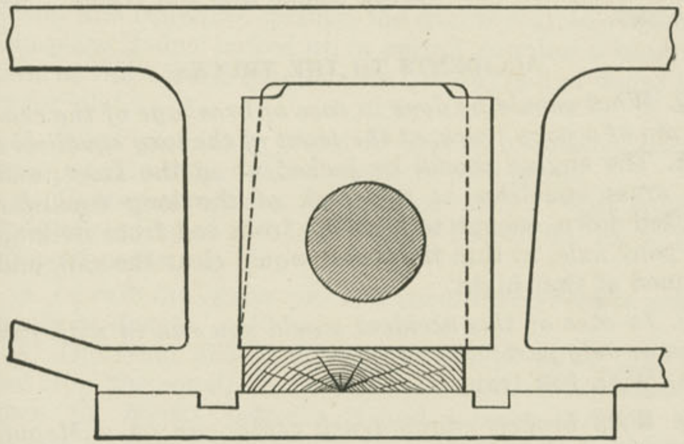


Fig. 387. Blocked-up Wheel.

A. Not to let the axle run on the cellar, as that would ruin one, and perhaps both.

Q. Suppose in a ten-wheeler with such a mixed spring arrangement as is shown in Fig. 386 the main driver box breaks on both sides and the brass comes down into the cellar, what is to be done?

A. Wedge up the lame wheel as high as possible, put a liner behind the box wedge at the top, and wedge up hard to pinch the box top and keep it off the journal; take out the pedestal binder and remove the cellar and box fragments; from a tie saw a block *B* large enough to fill the space between the binder and the journal; after this is notched for the latter put in the notch a bar of hard soap as a lubricant. Chock up the front end of the back spring and the back end of the front equalizer by blocks D and A, and run the wheel off the wedge.

Q. If driving box or brass breaks so it is cutting the axle badly, what can you do to relieve it?

A. Relieve it of some of its weight by a wedge, and blocking between the spring saddle and the frame. See Fig. 387.

ACCIDENTS TO THE TRUCKS

Q. What should be done in case of breakage of the center pin of a pony truck, at the front of the long equalizer?

A. The engine should be jacked up at the front, and the cross equalizer at the back of the long equalizer blocked down, enough to keep the front end from striking the pony axle, so that the wheel would clear the rail, and chained at that hight.

Q. In case of this accident would you run in with full train or only part?

A. With full train.

Q. With broken engine-truck center-pin on a Mogul, what is to be done?

A. Jack up the front end of the engine and that of the long equalizer; put a car brass between the equalizer end and the truck-wheel axle, and run home slowly.

Q. How would you remove the truck of a Mogul engine on the road?

A. By first taking off the radius bar, blocking up the front high enough to get out the center pin, then removing the truck.

Q. How would you block the equalizer?

A. That depends on the build of the engine. In some cases it would need no blocking; as, for instance, where the rear end would strike the boiler before the front end came down. Otherwise it should be blocked at the back.

or else a chain passed up from its front end over the frame and round the center pin.

Q. How would you remove the truck of a consolidation engine?

A. In the same way as for a Mogul.

Q. What should be done in case of a broken four-wheel engine-truck frame?

A. That depends on the kind of break. If between bolster and equalizer springs, the engine may be run with it in place; being jacked up to permit running a beam or piece of rail across, lying on the equalizers and under the center plate.

Q. What should be done to repair a broken truck-frame on the road, where repair is necessary?

A. It may sometimes be mended with a "fish splice" made of a piece of rail or a wooden beam, chained to the adjacent parts.

Q. In case the center pin of a pony truck breaks, what should be done?

A. The front end of the engine jacked up to take all load from the equalizer, the back end of the latter blocked down by blocks between it and a beam through the frames, to keep its front end from striking the axle; the engine then run slowly (naturally after taking out the jacks) to prevent its leaving the rails.

Q. Why would there be special danger of leaving the rails?

A. Because the front truck would have no load on it.

Q. In case of the breakage of a center casting of a four-wheel engine truck, what is advisable?

A. To block it with timber or rail over the equalizers.

Q. In the case of a pony truck?

A. To block it between the truck-frame top and the engine frame.

Q. Is the engine in these last two cases safe to run at high speed?

A. No; because the truck will not swing.

Q. What should be done in case the transom of a four-wheel engine truck breaks?

A. Generally the bolster can be chained; if the truck is rigid, a piece of timber or rail may be laid across the equalizers to take the load.

Q. What can be done with a broken back truck wheel?

A. Usually it may be chained to a rail or a cross tie across the engine frame.

Q. In case of broken front truck wheels, what should be done on the first opportunity, after temporarily attending to them?

A. Turn the truck around so as to give a good pair of leading wheels.

Q. How may a broken tender wheel or tender axle be attended to?

A. By chaining up to a rail or a cross tie placed across the tender top.

Q. In case of a ten-wheeler with totally disabled truck, what is to be done?

A. If the front and back drivers are flanged, block between the top of the front driving-boxes and the frame.

Q. In case of a consolidation or Mogul?

A. Block down the end equalizer.

Q. Suppose the front tire is "blind," how can the engine be guided?

A. Usually by chaining the front end short to the rear of the tender or to a car having its truck near the end, so as to prevent the "muley" wheels from swinging clear of the rails.

ACCIDENTS TO BRASSES, WEDGES, AND BOLTS

Q. Will an engine pound if the pedestal bolts are loose?

A. Yes. With an engine that has the brace bolted to a hook over the bottom of jaws, if bolts work loose, it will let down the brace and wedge. If there is a large bolt from one jaw to the other, the wedge cannot drop, as it is held up by the thimble on the pedestal bolt between the jaws; but the jaws will spread apart if the bolt gets loose, and let the box pound.

Q. Where wedge bolts are broken, how do you keep the wedge in position?

A. If there is a jam nut or wedge bolt on top of pedestal brace, and bolt breaks on top of this nut, it can be spliced by running the nut up over the break and putting between it and the brace a washer equal to half the thickness of nut, thus having half the nut each side of break; this will not prevent the wedge going either up or down. Or a nut of the right size between the wedge and brace and tied with wire will hold the wedge from coming down.

Q. What is to be done for a broken main pedestal bolt or binder?

A. (1) Replace the broken piece with the corresponding one from the back jaw. Or (2) if it is a broken bolt and the piece is long enough, batter a head on it and use it in the back jaw with one nut instead of two.

Q. Suppose the binder comes off and both wedges come out, what is to be done?

A. Make wooden wedges, put the engine on center and drive in the wedges; make a timber binder.

Q. If you broke a driving box and the brass turned down into the cellar, what would you do?

A. Run that wheel on a thick wedge and block, up or down, as the case would demand, the ends of spring and equalizer nearest that box; put a liner between wedge and box, set up the wedge, to hold the box off the journal, uncouple the spring hangers near that box, and run her off the wedge.

Q. Is that the only way for holding the box up off the journal?

A. No. I could fit iron blocks between box and pedestal brace.

Q. Would you take down the main rod in this case?

A. Not if the engine was to go on light.

Q. What is the simplest way to handle heavy driving boxes?

A. By a plank (blocked up to the right hight and a two-inch pipe as a roller, as shown in Figs. 388 and 389).

Q. If an engine-truck brass became burned out and no other brass was available, what should be done?

A. Raise the box off the journal, cut a piece of hard wood to put in place of the brass, run this as far as it

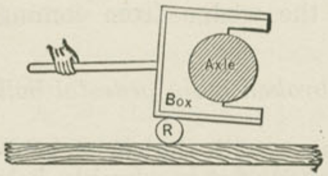


Fig. 388. Handling Driving Boxes.

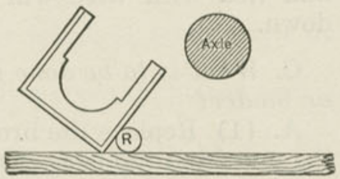


Fig. 389. Handling Driving Boxes.

will go and renew it as often as necessary; stop often to insure absolute safety. Pack the cellar the same as though a proper brass were on the journal; pour a bucket of water over the whole thing at every stop.

Q. How would you replace an engine-truck brass?

A. Take out cellar, jack up the truck box with a pony jack until brass will slide out along axle. Put in a new one, let down the box, pack the cellar and replace it. With a heavy engine, lift front end with big jacks, to take part of the strain off the pony jack.

Q. How can you take out a tender-truck brass and replace it with a new one?

A. By taking off the oil-box cover, and all the packing, jacking up the box, removing the wedge or step and the brass, putting in the new brass, then the wedge or step on top thereof; next taking out the jack and re-packing the box.

Q. When a brass does not wear an even thickness at both ends, what is apt to happen?

A. It is apt to run hot, by reason of one end getting more weight than the other.

Q. Should driving and truck boxes be cooled with water when they run hot?

A. Yes; it is advisable to pipe, for that purpose, from the injector discharge to all axle bearings, each having an independent valve.

Q. What is the best place to apply the water?

A. In the cellar.

Q. What are the principal causes of hot journals and broken boxes?

A. (1) Boxes working at bottom or top, (2) poor bearings between box and wedge or shoe.

Q. How can rocking be detected?

A. By putting the engine on the quarter on the suspected side, blocking the wheels on the opposite side, and reversing a few times.

Q. How can you tell whether a box bears fully and evenly on the shoe or wedge?

A. Tighten the wedge, put the engine on the quarter, get the fireman to reverse a few times with open throttle, and watch the box from inside and outside.

Q. What is the result of broken wedge bolts?

A. The wedge being caught by the box and pulled up too high, and held there, causing sticking and heating of the box.

Q. Suppose the wedge bolt is broken in the thread, what is to be tried?

A. Splicing it with a nut, blocking up under the wedge, and pulling down on the nut under the pedestal brace.

Q. *When wedge bolts are broken irretrievably, how do you keep the wedge in position?*

A. With a suitable chock or block between the pedestal and the wedge bottom, and one above the wedge.

Q. *In what does the importance of correct laying off of shoes and wedges consist?*

A. In the fact that it lessens liability of breaking crank pins and cutting tires, and saves trouble with rod and driving brasses.

Q. *What guiding methods are used in getting a square line on the frames in laying off shoes and wedges?*

A. (1) The use of the fish-tail tram; (2) the use of the three-point tram; (3) lining one cylinder; (4) lining both cylinders.

Q. *Of these which is preferable?*

A. The last, which keeps the main axle square with both cylinders.

Q. *How may wedges be adjusted?*

A. The engine may be placed at half stroke on one side, the wheels on the other side blocked, steam put on, and the box driven from the wedges; then the latter may be put up tight, their hight scribed on the pedestal, and they may then be slacked back about $\frac{1}{8}$ inch.

Q. *What is the tendency of driving boxes with worn half-round brasses?*

A. To close at the bottom.

Q. *How may this be prevented?*

A. To some extent by closing the jaws at the bottom.

Q. *What new trouble does this bring?*

A. It increases wear, and may cause the box to catch in rough riding.

BRAKE ACCIDENTS

Q. *What should be done in case the air pump gives out?*

A. The pipe leading from it to the reservoir should be taken out and the pump tried without it.

Q. *Suppose that after the pipe has been taken out between the air pump and the reservoir the pump will not work; of what is that the sign?*

A. That something is wrong with the steam valve, or with the ports and passage connected therewith.

Q. *Suppose that the air pump works with the air pipe taken down, but does not with it in place, of what is that apt to be a sign?*

A. That the pipe or its check valve is choked, as with ice or gum.

Q. *In case the air pump will not work in cold weather, what should be the first thing to be done?*

A. To run a lighted torch along the air pipe and on the check chamber, and to examine the receiving screen to see that it is free from snow or ice.

Q. *Suppose that air escapes from a brake cylinder in freezing weather, by what may that be caused?*

A. By frozen packing.

Q. *Suppose that in freezing weather air escapes from a brake cylinder and the brakes fail to act, of what may that be a sign?*

A. That there is ice in the triple valve.

Q. *Suppose that the air pump works well in only one direction, of what is that a sign?*

A. That one of the air valves is choked, cocked, or otherwise crippled.

Q. *Suppose that the air pump works well both ways, but fails to produce the proper effect upon the gage, what does that show?*

A. That there is an air leak.

Q. *Suppose that you cannot readily locate the air leak, what should be done?*

A. The air should be locked in the pipe, and if it does not come from the governor exhaust pipe, there may be a crack in the diaphragm.

Q. What is the trouble with an air pump when it "short-strokes" or flutters?

A. The reversing rod is loose where it passes through the reversing-valve bush, and also in the top cap, and there is not friction enough to hold the valve and rod from dropping; the reversing rod may be sprung so that it strikes the side of the hollow piston hard enough to push the rod and valve up or down; or the little port leading top of reversing rod may be stopped, and the steam cannot get there to balance it while piston is on the down stroke.

Q. When the brake releases (through the exhaust port) with light reduction of from 5 to 10 pounds, but stays on with a 20-pound reduction, what is the matter?

A. The graduating valve leaks.

Q. When driver brake releases on emergency application with light engine, what is wrong?

A. Engineman's valve handle is not in full emergency position.

Q. Should the Westinghouse rule of 20 pounds reduction for full brake application always be followed?

A. No. If packing leathers in brake cylinders leak, further reduction will supply the loss as long as there is any air left in auxiliary reservoir. But it is a question whether there is enough benefit from further reduction to pay the tax on the pump in restoring train pipe pressure for release. Of course, in case of emergency you leave the engineer's valve in full emergency position and the port is open between auxiliary reservoir and brake cylinder until released.

Q. Why is rapid working of the air-pump injurious?

A. Because the pump is apt to pound and get hot, then stand still and get water in it. If it will supply the system at all, it will do it at slow regular speed.

Q. What is generally the cause of the air-pump getting hot and burning out the packing?

A. Compression valves not working right.

Q. How can a badly-gummed air-pump be cleaned?

A. With lye and hot water, used with a swab outside, let run in or sucked in at both ends, for the inside; the main-reservoir drain cock opened, hot water poured through to wash out the lye, then dynamo oil in liberal quantity used.

GENERAL

Q. What is your first duty after a breakdown, and what should be done next in order?

A. After getting stopped, to see that I am protected in both directions from approaching trains, both for my own safety and for theirs; with some breakdowns, kill the fire. Next locate the damage, to see if any outside help will be needed, and the kind needed, so that it can be sent for at once, or a report made of the parts disabled and the probable time before the engine can proceed with the train. Next get the engine ready to move as soon as possible.

Q. Can all four-wheel switch engines be run with all side rods down?

A. Yes; but that necessitates cutting off or "lining-out" the inside end of the key that holds the piston-rod in the crosshead.

Q. Why?

A. Otherwise the forward crank-pin would strike the crosshead key.

Q. Under what circumstances in taking down a main rod would it be allowable to leave a steam-port open?

A. Where only the back main-rod end was taken down, so that the weight of the rod would help the steam in the back port to hold the crosshead and piston on the forward center.

Q. How far may an engine be run disconnected on one side, without cutting the cylinder so as to require reboring?

A. Fifty to a hundred miles if the lubrication is good and all properly done.

COLLISIONS

Q. What class of collisions occur most frequently?

A. Rear-end.

Q. Where a head-to-head collision is imminent, what is to be done with a fast-running train if it has continuous brakes?

A. Throttle to, all brakes on, sand-valves open; then look out for "number one."

Q. Why not reverse?

A. Because the wheels would only slide.

Q. What measures are to be adopted with a freight train to avoid a head-to-head collision?

A. Whistle for train brakes and reverse. Where there is a driver-brake the wheels must be watched, and as soon as they slip the brakes let off and the cylinder-cocks opened.

Q. What is the object of this precaution?

A. To prevent tire-flatting.

Q. At thirty miles an hour, how far will a train go during the time of closing throttle, putting on brake and opening the sand valves?

A. If the retardation did not commence until all these operations had been performed, nearly five hundred feet, as that speed corresponds to forty-four feet a second, and ten seconds is none too much time.

DERAILMENT

Q. What are the principal causes of engine derailment?

A. Passing switch-ends, taking a curve too suddenly, jumping a bad track, broken flange, striking an obstruction.

Q. How is a derailed engine to be put on the track again?

A. By hauling or pushing from another engine, sometimes; again, by jacking up and working back over planks or regular wrecking-frogs.

Q. In jacking up, what precautions should be taken?

A. The front end should come first. The axle-boxes should be blocked down in the jaws, to save unnecessary jacking; every inch made in jacking should be saved by plank wedged under the wheels, as safeguard against slipping off the jacks.

Q. In jacking up, how about the truck?

A. The engine front being jacked up high enough, the truck should be pried up with rails as levers and chocked in place by planks and wedges under the wheels.

Q. When the truck stands askew of the track, how is it to be brought in line?

A. By chains or ropes, and tackle-blocks, and rails as levers.

Q. How may running the engine back on the track sometimes be facilitated?

A. By loosening two rails; swerving them aside so as to make a sort of switch, spiking them in the new position, and hauling, shoving or running the engine on. This is usually more feasible where the rails do not "stagger" or "break joint."

Q. In the use of wrecking-frogs, what precautions should be taken?

A. To use wooden filling-pieces between the ties to keep the wheels from sinking between them should they slip off the frogs.

Q. In case it is necessary to jack up an engine to get it on the track again, what precautions should be taken?

A. To take down the rods to prevent their being sprung.

Q. What is usually the best direction in which to get a derailed engine back on the track?

A. Retracing the line along which it came.

Q. If your engine was off the track and listed badly to one side, what would you look out for?

A. Be very careful that there was water enough in the boiler, so that no portion thereof would be damaged by the fire.

Q. If you had any doubts, what would you do?

A. Get the fire out as soon as possible.

JACKING UP, ETC.

Q. What is the disadvantage of wooden wedges as compared with jacks?

A. When the engine cannot move they are useless.

Q. How can the engine be moved if the lever is cramped, as by a broken driver-spring hanger?

A. By taking out the front reach-rod pin, thus dropping the links.

Q. How can a tender truck be lifted on one corner without a jack?

A. By cutting the engine loose, running ahead, putting a six-foot wedge, made from a tie, under the tank corner, so that backing the engine against the timber will cant the tank.

Q. What hardwood blocks should there be on the engine to use in case of breakdown?

A. A set of crosshead block for each side of the engine, two blocks of straight-grained hardwood that can be split to proper size for blocking under driving-axles or over engine truck equalizers with broken truck-springs (or two iron blocks for this purpose), suitable wedges or blocks 4 inches x 4 inches at the large end for running driving-wheels upon in case of broken springs, tire, etc.

Q. Where is the weight carried when blocked up over the forward driving-box?

A. The same answer as in the preceding case, on a good track.

Q. When blocked up over the back driving-box?

A. Over that box.

GETTING TOWED IN

Q. What should be done in case the engine is to be towed backwards, having no other accident but a plug blow out of the fire-box?

A. The lever should be put in the back motion and about every five or six miles the valves and cylinders should be oiled up liberally.

Q. Why not disconnect the engine?

A. Absolutely a waste of time and money, although on some roads a cast-iron rule for all accidents requires towing. If however there is plenty of oil, and especially engine oil, and it is not freezing, valves and cylinders can be lubricated through the steam-chest oil-plugs; hence disconnecting would be necessary.

Q. Why "engine oil"?

A. Because for cold surfaces it is a better lubricant than cylinder oil.

Q. Why "if it is not freezing"?

A. Because water in the passages might freeze and prevent the flow of the oil.

Q. What precaution is, however, to be taken when one locomotive is to be towed by another?

A. To take down the main rods, disconnect the valve-rods and tie them to clear the rocker-arms, and put all liners in their respective straps; besides the special precautions which should be taken in case of any accident in freezing weather when the fire is drawn.

Q. Which are the more easy to get home with in case of accidents that do not entail picking the engine out of the ditch: eight-wheelers, or moguls and consolidations?

A. The latter, because they have more wheels, and there is also proportionately less weight on the trucks.

Q. What is your idea about the disgrace of being towed in?

A. It is an old one, which seldom holds good on important lines. The main thing is to get the road open.

It might be cheaper even to ditch the engine than to block the line.

ADJUSTMENT*

Q. How would you adjust the link motion of your engine?

A. I would not do it, because that is not my duty. I would report at the round house anything wrong about it.

Q. What then are your duties about the engine?

A. To run it, adjust the wedges, keep the rods keyed up, if they had not solid bushings; and attend to the stuffing-box packings, and to the headlight.

Q. In what position should an engine be put in order to key side-rods?

A. On its parallel center, because then the crank-pins will be held at the proper distance apart by the driving-axles being held by their boxes. Otherwise their length might be made greater or less than the distance between wheel-centers.

Q. What exception to this rule?

A. In adjusting the front end of the main-rod, the pin should be on a quarter, as the crosshead pin is often worn thinner front and back.

Q. What might take place if side rods were keyed with the pins on the top quarter?

A. The wheels might be slipped by the keying.

Q. Can rods be keyed too long or too short on the parallel centers?

A. Yes, if the pins or the axles are bent, or the pin much worn out all around, or not properly "quartered" as regards the pins on the other side of the engine.

Q. Why commence to line or key parallel rods at the main pin?

A. The liners can be better divided each side of the pin.

* See also Valve Setting.

Q. When keying the main-pin brasses, what should be done with the others?

A. All of them should be loose.

Q. Which pins on the engine get the most strain?

A. The crosshead pins, because they carry the strain to, or receive it from, all the others; strain that is properly divided among all the other pins on the side, is borne by the crosshead pin alone.

Q. With which brass should keying up commence?

A. That depends on the number of keys to a brass, and on the number and arrangement of the rods.

Q. If one pair of parallel rod brasses is filed, what should be done with the other?

A. It should be filed also.

Q. How may you be certain that both pairs of brasses are filed alike?

A. By calipering them between the edges that are to be filed and the back of the brass; testing the filed edges from time to time on a flat surface to see that they are dead flat.

Q. Do brasses always need filing when they are knocking?

A. No; sometimes they do not fit the strap, and require only a thin liner between them and the strap.

Q. Should a brass be filed enough to make it possible to pinch the pin when keyed up?

A. No.

Q. What should be done in case this is done through accident or carelessness?

A. Liners should be put between their formerly abutting edges.

Q. Which is better to use between edges of brasses; one thick liner, or two or more thin ones?

A. One thick one.

Q. If it require a thick and a thin liner between a brass and a key, which one should be next the key?

A. The thick one.

Q. Is it always necessary to file rod-bearings that have been running well and suddenly commence heating?

A. No; it is usually better to clean and oil them well.

Q. What precaution is necessary in lining connecting-rod brasses?

A. To be sure, from marks on the guides, that there is proper clearance between the piston and the cylinder heads, at each end of the cylinder.

Q. What should be done in lining side-rod brasses of a four-wheel-connected engine?

A. The engine should be put on a straight level track, with all the centers of the axles and those of the crank-pins in the same straight line; beginning at the main pin, driving the liners so as to give the same thickness of brass and liners each side of the pin; put up that end of the rod, draw the bolts solid and adjust the key; block up the back end of the rod level with the back upon entering the front brass, and put liners in the space between the rod end and the brass; put on the back strap with the brass, put in the bolts and draw them solid, and key up the back brasses.

Q. What is the order of procedure in lining parallel-rod brasses on a six-wheel-connected engine?

A. Put the engine at its parallel center on a straight and level track; beginning at the main pin, as for a four-wheel-connected engine, then do the front end, and last of all the back brasses.

Q. Is there any occasion to tram pin-centers?

A. No; if the axle centers are in tram and the engine is placed on the parallel centers, the pins will come right, unless either they or the axles are bent.

Q. What is the "parallel center"?

A. That position of an engine in which all the axle centers and all the pin centers are in the same straight line.

Q. How can you find the exact engine center?

A. Get the crosshead about ⅛ inch from stroke end; make a mark on it and one on the guides to correspond; make a mark on the inside of the main driving-wheel tire, and one about 13 to 15 inches from it on the main wheel-case; set a pair of dividers to the distance between the wheel-mark and the wheel-case mark; move the engine ahead until the crosshead has gone to the nearest stroke-end, and come back until the scribe marks on crosshead and guide are in line again; then with one point of the dividers on the wheel-case mark step off the same distance as before to the tire; make a mark at this second point; with another pair of dividers find on the tire a point just mid-way between the two other marks; move the engine until this middle tire mark is the same distance from the wheel-case mark as the other two were. When the engine is in this position it will be on one of the centers, and special marks should be made on the crosshead and guides to enable these points to be found again.

Q. What is a good way to make a distinction between trial marks made in finding centers, etc., and permanent marks?

A. It will be well to make the temporary marks just plain scratches or chisel marks, thus: | (representing a line-and-line mark before the edges have been moved) and the permanent ones thus: * As regards prick-punch marks: a permanent one may have a ring made around it or two light cross marks made through it, to distinguish it from a temporary one.

Q. Should the wedges be set up when the engine is hot or when cold?

A. When hot.

Q. How tightly should wedges be adjusted?

A. So tightly as to prevent thumping but freely enough to let the box move up and down in the pedestals.

Q. How can the desired tightness of wedges be obtained?

A. By moving them up tight and then bringing them down just enough to take off the side pressure; say ⅛ inch.

Q. What will be the effect of keying a crosshead pin too tight?

A. There is danger of loosening the pin or breaking the crosshead.

Q. At what points on a crosshead pin and brasses does the greatest wear come?

A. When the engine is on the front and back centers.

Q. Why is not this the case with the crank-pins also?

A. Because their brasses revolve and the wear is thus equalized.

Q. In what position of the engine should a crosshead pin be keyed?

A. Usually when the crank-pin is down, because it might be keyed too tight, as it might be if keyed with the engine on its centers.

Q. Why not key it when the crank-pin was up?

A. Because it is generally easier to get at it with the crank-pin down.

Q. In adjusting wedges, where should the cranks be?

A. The pins should be up on the side that is being adjusted, because if they were down, and the side rods were not of the right length, the driving-boxes might not properly press against the shoes. The work of adjusting is much easier with the pins up than with them down.

INSPECTION, REPAIRS, ETC.

Q. What can be said of inspection of the engine on the part of the engine-runner?

A. It is advisable and necessary. It gives him more confidence at high speeds, prolongs the life of the engine, and is a great safeguard to runner, crew and passenger.

Q. When and where should inspection be made?

A. After each trip, as the machine is over the pit.

Q. What is the first part to be inspected?

A. The truck and connections, to be sure that no bolts, nuts, or screws are missing and the oil-box packing is all right; then pilot-braces, center-castings, and all their connections.

Q. What next?

A. Passing rearwards, in the pit, the motion, to see that the eccentric set-screws, keys, and straps are right; no bolts missing, no oil-ways clogged. Then the links.

Q. And then?

A. Wedges and pedestal braces; looking for loose or missing wedge-bolts.

Q. After having thoroughly inspected the under side, what comes next?

A. Guides and rods, with their bolts, keys and set-screws, demand special attention; using a copper hammer to test the rod-keys.

Q. After these come what?

A. Say, the oil-cups and oil-holes over all; the latter must be free from dirt and gum; and it is especially desirable to see that no cups are working loose.

Q. How are the wheels tested?

A. If of cast iron, with a sharp hammer-tap on the tread. They should ring clear like an uncracked bell. All wheels should be closely inspected at the joint between rim and tire, and hub and axle; oozing moisture and dirt in the first case, oil in the second, show looseness.

Q. What tends to loosen tires?

A. Their being worn down so that they are opened somewhat large by the constant hammering against the rail.

Q. Of what are cut flanges a sign?

A. (1) The axles may be skew with the frames or not parallel with each other; (2) the frame may be sprung and hence the axle-box jaws twisted; (3) the wedges may be badly adjusted; (4) the center-pin may be shifted. In a case of flange-cutting the shop men should be called in.

Q. Should the engineman inspect the boiler?

A. Yes and no. He should not be required to do it, as a boiler-maker can usually do it better; but he can detect leaking seams or stay-bolts. The former may be accompanied by dangerous broken braces or gussets. He should of course look at the crown-sheet and flues and be sure that the water-level is all right; and see that the fire is good.

Q. How about examination of the smoke-box and stack?

A. The smoke-box door should be opened and the petticoat-pipe and cone inspected; the nettings and deflectors too, if there are any.

Q. What is the advantage of keeping the water in the boiler hot by a separate heater while the machine is in the roundhouse?

A. It lessens the liability to leaky tubes and cracked fire-box sheets.

Q. How can stuck-up check-valves be detected?

A. If steam is on, steam and water will blow back into the tank; otherwise, not. This should be looked after before going out of the roundhouse.

Q. Before firing, what should be looked to about the grates?

A. They should be freed from clinkers, and all connections with shaker levers, etc., tested; the ash-pan, brick-arch, water-table, and combustion-chamber should be cleaned.

Q. What inspection should be made at stopping-places?

A. Where there is time, all boxes and bearings should be felt and oil squirted in where needed; all parts observed, to see that no bolt, nut, or pin is missing. At coaling stations the inspection should be more extended and thorough.

Q. What about inspection of the tank?

A. It should have a sharp look if just from the shop, as it may have a bit of bagging or greasy waste therein.

Q. How often should the safety-valve and steam-gages be tested?

A. Every month.

Q. What other points should be seen to, besides those already mentioned?

A. That the frames are not sprung, nor the axle-box joints twisted out of square; that the center-pin is central; that there are no seams or stay-bolts leaking, and no leaks under the jacket; that the brakes go on and come off easily; that there is sufficient fuel and water in the tender; that all tools for repairs and for firing are at hand; that the headlight is all right and all lamps are at hand, filled, and ready for service, all signals at hand and ready for use; that there is a supply of oil and tallow, and that the sand-box is full of good dry sharp uniform sand.

Q. What special tools and appliances should be at hand in case of accidents?

A. A pinch-bar, an ax and a hand-saw; blocking for crossheads, a piece of pine board by which to cover the valve-seat; a thick board to lay in the fire-box in case it is necessary to plug a flue; flue-calking tools; some wooden flue plugs; a couple of sheets of copper or other thin metal to put between the steam-pipe flanges in case it is necessary to shut out one of the steam chests; and a pair of good jacks, or four to six oak wedges four feet long and tapering from four inches square at one end to a four-inch edge at the other.

Q. How often should you examine the ash-pan, grates and dampers?

A. At the end of each trip.

Q. What are the fireman's duties on arriving at engine before starting out on the trip?

A. To inspect the engine all over, and report in the regular requisition-book all repairs or adjustments needed, that he cannot or should not make himself.

Q. What are his duties in case of wreck when the engine is off the track?

A. First, to have the train protected front and rear; then to inspect the damage, and if it cannot be remedied by the force at his command, to report in detail to the proper official.

Q. What are the fireman's duties on arriving at engine before starting out on the trip?

A. He should be on hand from one-quarter to one-half hour before the engine is to leave the roundhouse; have the cab and its contents made clean and free from dust, windows bright, deck swept, coal watered, oil cans filled and in place, water-supply looked to, gages inspected to see that they are in working order, lamps filled and in order. He should look at the number of cars and the load to be hauled and see what character of coal he has to do it with; see that the ash-pan is free from cinders; that all the supplies, flags, lanterns, torpedoes, etc., are in place and of the right character; that all tools are in place, fire-irons on the tender in their proper places, water-supply correct, and the sand-box full of clean dry sand.

Q. What should be done before leaving the engine-house?

A. The cylinder-cocks should be opened to bleed the cylinders, the bell rung, the throttle opened slightly, and the engine brought out slowly. On the way over the brakes may be tested, and the injector or pumps tried.

Q. Should the engineman depend on the conductor and brakemen for keeping safe control of the train?

A. No; he is jointly responsible with them and should know meeting, passing, and stopping points. He should also show his train orders to the fireman: (1) because "two heads are better than one" as regards memory; (2) in case of accident to the engineman, the fireman can better protect his train.

Q. To what should the engine-runner look when an engine is taken out of the shop for the first time?

A. He should see that there are no wrenches, pieces of bagging or waste, etc., left where they may do damage. In starting up, also, if there is any apparent impediment, he should go slowly, lest he knock out a head or cause some other accident by reason of tools being left in the cylinders or steam-chests, of eccentric rods wrongly connected, and so on.

Q. What are the duties of the engine-runner after cutting off his train at a terminal?

A. To inspect his engine thoroughly and report, on the book or blanks therefor provided, any defect found.

Q. What should be one of the first duties of an engine-runner before starting out?

A. To go to the notice board to see if there is any special item that will be of interest to him; as for instance notice of a bridge being gone, or dangerous.

Q. What are the requirements of a traveling engineer?

A. He should be thoroughly familiar with the peculiarities of the various kinds of fuel; know approximately the amount of fixed carbon in each, and make a study of each class of engine, so that he may instruct intelligently just how front ends should be adjusted for each coal, and understand the different methods of treatment and handling thereof in regard to air admission, grate movement, amount of fuel supplied, etc., so that the most economical results may be obtained; should be constantly on the alert to instruct and advise any engineer or fireman, and spend a great deal of time on the road, where he can practically exemplify many of his teachings. His own knowledge, together with closer observation of the methods of the best men under him, will enable him to instruct and assist those who have failed to reach the expected standard, and to do so in a manner sure to bring about good results.

Q. What part, especially, of the engine-runner's business, cannot be learned from books or from companions?

A. The judging of distances, time, and places. These must be acquired by experience, and the latter must be gained on each road for itself and for none other; it is a question of landmarks indicating what to do in preparation for something else to come.

Q. What are other duties of the engine-runner before starting out?

A. To report "on duty" long enough before train-time to enable him to attend to all that will be required of him; look on the bulletin-board for matter that refers to his work; compare his time with that of the conductor: ask for orders.

Q. What is the best way to cool down a boiler?

A. To let out the hot water and let it stand.

Q. What is a good precaution about the rods used in cleaning out a boiler?

A. They may be of copper, or of iron with a copper or brass tube around them, to keep them from injuring the threads of the plug-holes and thus rendering the boiler likely to leak dry.

Q. In washing out, where should the hose first be introduced?

A. At the fire-box end.

Q. How may you know when the boiler is perfectly clean?

A. By the color of the water running therefrom.

Q. What should be done in putting the plugs in?

A. To grease them, or better yet to black-lead them, so that they may be taken out with ease the next time.

Q. Is the frequent testing of boilers by hydraulic pressure desirable?

A. Not by any means, as ordinarily conducted. If, however, there is just enough pressure applied to enable the finding of leaks, there may be an advantage; but the same effect might be better produced by filling the boiler full of hot water and then raising the pressure by a low fire; inspection to follow such test.

Q. How much hot-water pressure would be desirable for this?

A. Say 25 pounds per square inch, above working pressure, as a maximum.

Q. Before washing out the boiler, what should be done?

A. Before the engine is put in the shed, the smoke-box should be cleaned with shovel and hand brush.

Q. How can a gage glass be cut?

A. By scratching it inside with a file-point in a ring, just where it is to be divided, then holding it firmly in each hand and breaking it square across where the scratch line comes; or it may be broken while the file is still in; care being taken to have the end of the latter right at the scratch.

Q. What class of pieces requires special inspection and attention?

A. Split pins and cotters.

Q. Where should tools be kept?

A. In a box with compartments or trays, so that everything can be got at quickly.

Q. What is the best thing with which to grind out a cock?

A. A leaden plug cast from the same pattern as the regular brass plug, only rapped considerably in the mold so as to make it larger than the brass one.

Q. How are nozzles reamed?

A. In place, by a long-handled tool thrust down the stack.

REVERSING

Q. What is the danger of reversing the engine when running fast?

A. Breaking steam-chests or covers, by excessive pressure.

Q. What precaution should be taken in reversing suddenly?

A. Not to close the throttle-valve, else there is danger of the air that the piston compresses in the steam-chest and steam-passages, bursting the chest or some of the pipes, unless it could lift the throttle.

Q. How may such an accident be avoided?

A. By having a relief-valve in the dry-pipe, to give the compressed air passage.

Q. What may be said about reversing any engine that has a piston valve?

A. It should only be done when moving slowly, as it ruins piston-rod packing and packing-rings.

Q. How may the cylinder-cocks act in the case of a suddenly-reversed engine?

A. If opened when the motion is reversed, they will let the air out at the end in which it is compressed and at the same time let clean air in at the sucking end, thus lessening at one end the danger of bursting the pipes or chest, and at the other the amount of cinders drawn in by suction.

Q. How does opening the cylinder-cocks in case of sudden reversal improve lubrication?

A. By preventing hot air from the smoke-box lapping the oil from the valve-seat.

Q. What is the advantage of having two enginemen to run on alternate trips?

A. It enables the work of one to be compared with that of the other and thus maximum service to be got out of both man and engine; besides enabling incompetent men to be sifted out.

HOOKING UP

Q. What is the effect of excessive hooking up?

A. Where there is no superheater, there is too great loss from cylinder condensation.

Q. What is the usual limit of cut-off?

A. The earliest economical point is generally quarter stroke.

Q. In what cases is it not advisable to work with wide throttle and short cut-off instead of partly-closed throttle and longer cut-off?

A. In the case of an engine that does not lubricate well at short cut-off; that is, "goes lame when hooked up short," and has considerable lost motion between main axle and slide-valve.

Q. For a light load, what are the most economical points of cut-off and throttling?

A. One-third cut-off and partly-closed throttle.

Q. What is to be done at the top of a down grade?

A. The links hooked up and the throttle partly closed and kept so until near the bottom.

Q. What care is needed in increasing valve-travel?

A. Not to let it go so far as to endanger the fire.

Q. What are the bad results of excessive piston-speed?

A. It is hard on the track, and also on rods, pins, and boxes, besides reducing the mean effective pressure.

ACCIDENTS TO THE VAUCLAIN FOUR-CYLINDER CROSS COMPOUND

Q. When a Vauclain four-cylinder cross compound "exhausts lame," what is to be examined?

A. The starting valve and connecting levers, if the former is central at the same time as the latter. If not, the connecting levers should be adjusted until they are "in time" with each other.

Q. Should the unequal exhaust still continue, what then?

A. The motion work should be examined for bent or loose eccentric rod, bent transmission rod, loose boxes, etc.

Q. Should all the motion work prove right and the lame exhaust still continue, what then?

A. The valve packing rings and cylinder packing rings should be tested.

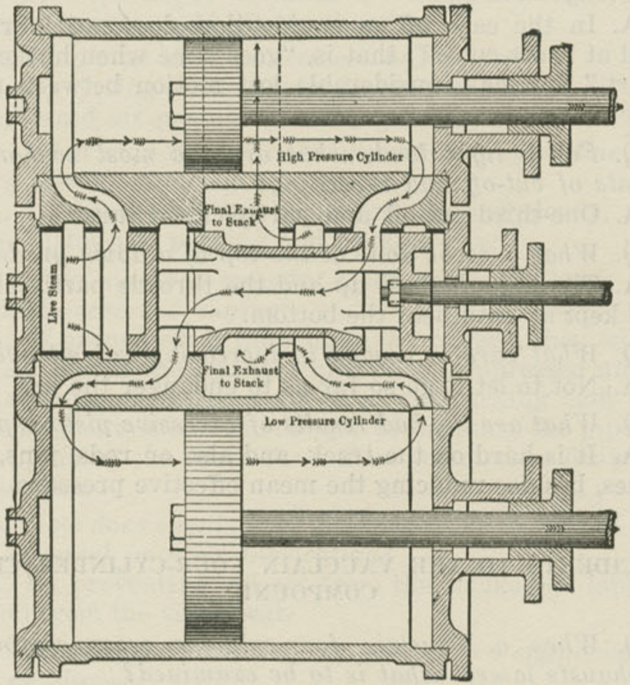


Fig. 390. Vauclain Cylinders.

Q. Referring to Fig. 391: which rings govern steam admission to the H. P. cylinder?

A. Nos. 1, 2, 7, 8; the others being for the L. P. cylinder.

Q. How can rings 1, 2, 7, 8 be tested?

A. By putting the reverse lever central (thus covering all ports), opening the throttle, and thus letting steam to the ends of the valve. If rings 1 and 8 leak, the steam

will blow through and fill the valve arch and both ends of the H. P. cylinder; and blow steadily at the H. P. cylinder cocks or indicator-plug holes; or where there is a relief valve on the end of the extended valve stem, through this valve.

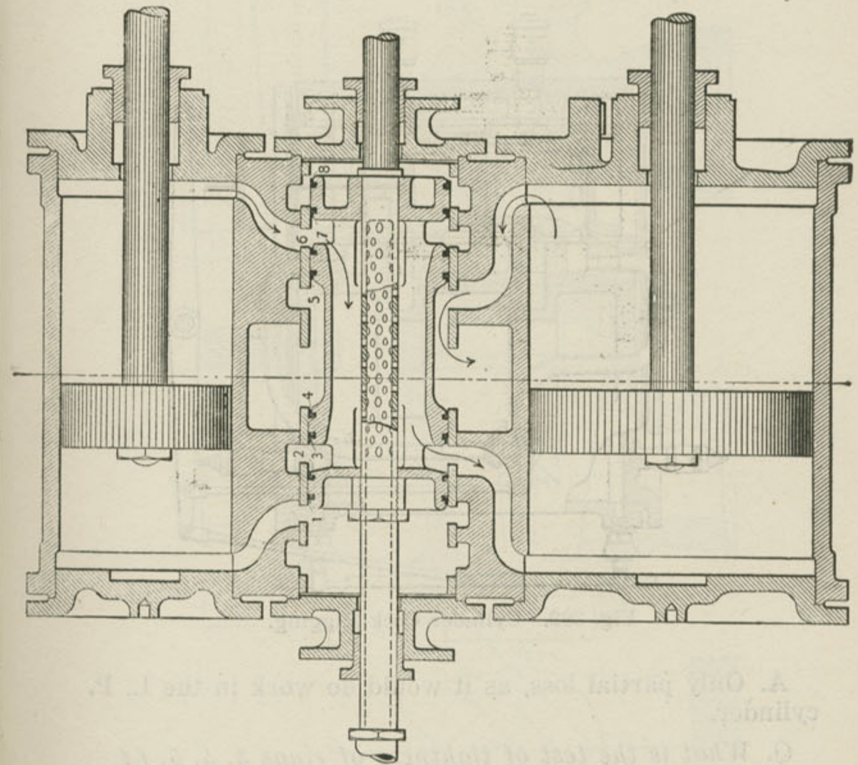


Fig. 391. Showing Valve Packing Rings.

Q. Where would leaky rings 1 and 8 show steam with the reverse lever off the center?

L. P. ports.

A. Through the air valves *C*, *C*¹, of Fig. 392, or the

Q. What is the proof of leaky rings 5 and 6?

A. With the reverse lever on the center, a steady blow through the exhaust.

Q. What would be the effect of a small leak at rings 1 and 8?

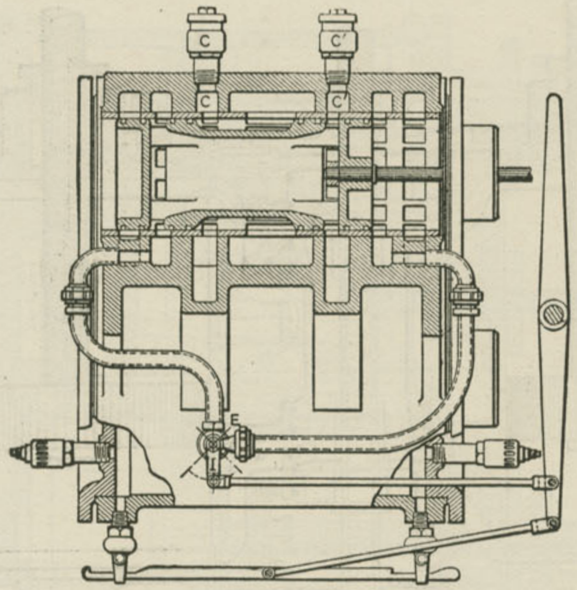


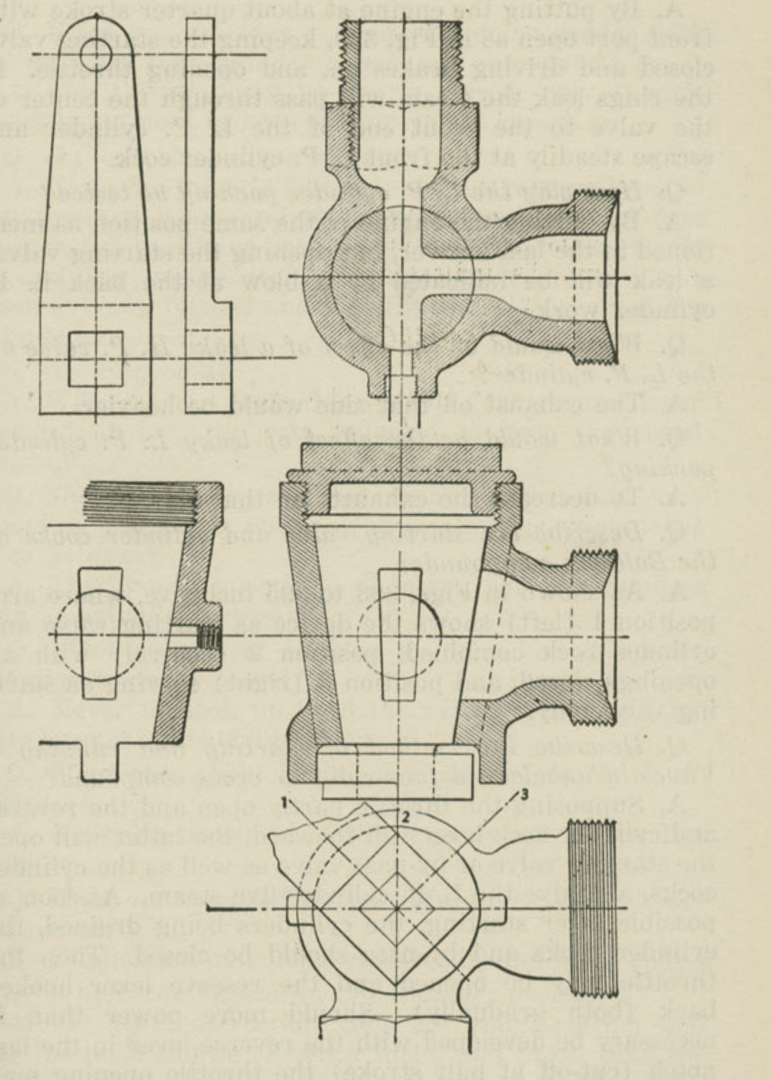
Fig. 392. Cylinder Cock Rigging.

A. Only partial loss, as it would do work in the L. P. cylinder.

Q. What is the test of tightness of rings 3, 4, 5, 6?

A. With reverse lever in full gear, starting valve open, driving brakes on, and open throttle, there would be a steady blow through the exhaust nozzle if these rings leaked.

Q. How can you test the H. P. cylinder packing of a Vauclain four-cylinder cross compound?



Figs. 393, 394 and 395. Starting Valve and Cylinder Cocks.

A. By putting the engine at about quarter stroke with front port open as in Fig. 339, keeping the starting valve closed and driving brakes on, and opening throttle. If the rings leak the steam will pass through the center of the valve to the front end of the L. P. cylinder and escape steadily at the front L. P. cylinder cock.

Q. How may the L. P. cylinder packing be tested?

A. By putting the engine in the same position as mentioned in the last answer, but opening the starting valve; a leak will be indicated by a blow at the back L. P. cylinder work.

Q. What would be the effect of a leaky H. P. valve on the L. P. cylinder?

A. The exhaust on that side would be heavier.

Q. What would be the effect of leaky L. P. cylinder packing?

A. To decrease the exhausts on that side.

Q. Describe the starting valve and cylinder cocks of the Baldwin compounds?

A. As shown in Figs. 393 to 395 inclusive, where arm position 1 (left) shows the device as starting valve and cylinder cock combined, position 2 (central) with all openings closed, and position 3 (right) serving as starting valve only.

Q. Describe the method of starting and running a Vauclain unbalanced four-cylinder cross compound?

A. Supposing the throttle partly open and the reverse and cylinder-cock lever full forward, the latter will open the starting valve or by-pass valve as well as the cylinder cocks, and give the L. P. cylinder live steam. As soon as possible after starting, the cylinders being drained, the cylinder cocks and by-pass should be closed. Then the throttle may be opened and the reserve lever hooked back (both gradually). Should more power than is necessary be developed with the reverse lever in the last notch (cut-off at half stroke) the throttle opening may be lessened.

Q. What is to be done on moderate down grades with the Vauclain four-cylinder unbalanced compound?

A. The throttle may be nearly closed, only enough steam being used to keep the air valves closed.

Q. On very steep down grades?

A. Close the throttle entirely, put the reverse lever in full forward notch and the cylinder cock and by-pass lever in full backward position, letting the air pass freely to and fro in the starting valve, thus preventing a vacuum being formed and the oil being blown out of the cylinders.

Q. On up grades?

A. With a heavy train, keep moving the reverse lever forward at just the rate required to keep the speed constant.

Q. Should there be signs of stalling in running compound up grade with lever in full go-ahead position, what is to be done?

A. The by-pass opened so as to run non-compound as long as actually necessary.

Q. What rule about hooking up on a Vauclain four-cylinder cross compound?

A. Never to hook up until the cylinder cock and by-pass lever is in central position.

Q. What rule about letting live steam into the L. P. cylinder?

A. Never to do so when the lever is not in the last notch.

Q. What are the disadvantages of a four-cylinder cross compound?

A. Duplication of guides, crossheads, and main rods.

Q. Why is the Vauclain valve chamber bushed?

A. (1) Its construction calls for rough-coring, and (2) the bush can be of better metal and finish than the main casting.

Q. What is the character of the Vauclain valve?

A. Two balanced D valves (or two piston valves) end to end.

Q. How is the Vauclain valve stem carried?

A. On a small crosshead, sliding between guides.

FOUR-CYLINDER COMPOUNDS

Q. What is the disadvantage of all four-cylinder engines?

A. For a given power they have (1) too much cylinder condensation, (2) too much complication of slide valves and stuffing boxes, and (3) too great maintenance and repair costs.

Q. Into how many classes may four-cylinder locomotives be divided as regards cylinder arrangement?

A. Four (2) Those having a H. P. and a L. P. cylinder side by side; (2) those with H. P. lying over the L. P.; (3) those having the H. P. and the L. P. arranged "tandem," that is, one before the other; (4) those having the H. P. cylinder within the L. P.

Q. What are the crank arrangements in the first type?

A. There are four cranks (that is, two cranks in the axle itself, and two crank pins outside of the main drivers.)

Q. In the second?

A. The H. P. and the L. P. rods on each side take hold of the same crosshead.

Q. In the third?

A. The rods being in line there is naturally but one crosshead and one crank (or crank pin) for each pair.

TANDEM COMPOUNDS

Q. What is a tandem compound locomotive?

A. A four-cylinder compound in which the H. P. cylinder is in direct axial line with the L. P., and there is no receiver; the H. P. and L. P. piston rods being attached to the same crosshead and both cylinders having their steam distribution managed by one link; sometimes by but one slide valve.

Q. What is the special advantage of the tandem compound?

A. Simplicity, being in this next to the two-cylinder compound; no complications in the matter of starting.

Q. What parts are omitted?

A. Distribution valves, connecting rods, eccentrics, etc.

Q. Where is the extra complication?

A. In valves, ports, and cylinders.

Q. What is the course of distributions and expansions in this type?

A. There will be cut-off in the H. P. cylinder up to a certain point, then there will be expansion in that up to the point of exhaust opening or release, when there will be a drop in pressure as the H. P. exhaust mixes with that in the passages between it and the L. P. cylinder; then there will be further expansion in the H. P. cylinder in the passages between the two cylinders; then (the L. P. valve opening) there will be another drop in pressure, up to that point at which the cylinders are in communication; next there will be expansion until the L. P. admission valve closes; from this on there will be compression in the connecting passages and in the H. P. cylinder; and when the H. P. exhaust closes there will be more compression in the L. P. cylinder.

Q. What is one of the principal troubles in the steam distribution in this type?

A. The compression in the H. P. cylinder, requiring for its reduction either (1) large volume of clearance space therein (which will make a drop in pressure at one point in the stroke) or (2) giving the H. P. valve "negative exhaust lap" and affording large clearance space; extra weight of reciprocating parts, and loss of heat by radiation, with no chance to dry the steam between the cylinders.

Q. Where the shifting link is used, what points of cut-off are to be avoided with the tandem compound type?

A. Early cut-offs, to get away with the evils of over-compression and wire drawing.

Q. Describe the Baldwin (Vauclain) tandem compound?

A. Referring to Fig. 396, there are two H. P. and two L. P. cylinders, but the H. P. are in front of and in line with the L. P. instead of alongside. Each cylinder on each side has its own valve chest and is cast separately from the saddle. A pipe from the saddle admits steam to the H. P. chest; the L. P. exhaust is through a stuffing box to the saddle, so that the cylinders and valve chests and the saddle can be "metal to metal." The steam chests on each side are similarly joined; the same bolts holding the chests together and fastening the stuffing-box gland. The valves are balanced pistons connected in line, each exhausting through the center. The driving pistons are on a continuous rod, and those on each side make their strokes in common. The H. P. and L. P. cylinders are fastened together by outside bolts securing the intermediate head and the stuffing-box gland without any bolts being able to get into the cylinder, while the intermediate head may be removed without disturbing the intermediate rod-packing.

STARTING POWER

Q. What is the starting power of the Mallet and other compounds with independent H. P. exhaust?

A. About the same as for non-compounds. With cylinder ratio of 1:2, steam at half boiler pressure in the L. P. cylinder will give the same starting power as a non-compound—except, of course, when the L. P. crank is on a center.

Q. Suppose that we have a Mallet compound with the H. P. cylinder the same area as one of the H. P. in an ordinary engine, and the L. P. twice as large; with a

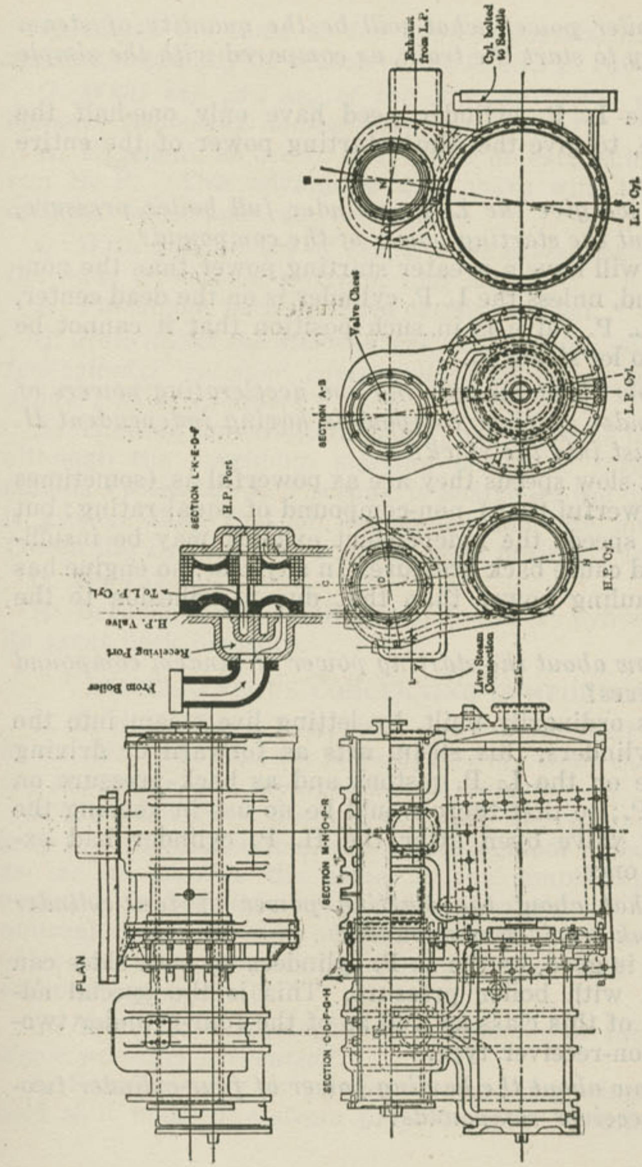


Fig. 396. Cylinders of Baldwin Tandem Compound.

given boiler power what will be the quantity of steam necessary to start the train, as compared with the simple engine?

A. The L. P. cylinder need have only one-half the pressure, to give the same starting power of the entire machine.

Q. *If we give the L. P. cylinder full boiler pressure, how about the starting power of the compound?*

A. It will have a greater starting power than the non-compound, unless the L. P. cylinder is on the dead center, or the L. P. valve is in such position that it cannot be moved to let steam in.

Q. *How about the starting and accelerating powers of two-cylinder receiver compounds having independent H. P. exhaust into the stack?*

A. At slow speeds they are as powerful as (sometimes more powerful than) non-compound of equal rating; but at high speeds the independent exhaust may be insufficient and cause back pressure. In any case, no engine has more hauling power than that due to adhesion to the rails.

Q. *How about the starting power of tandem compound locomotives?*

A. As ordinarily built, by letting live steam into the L. P. cylinders, this steam acts as forward or driving pressure on the L. P. pistons and as back pressure on the H. P.; so that there would be no use in keeping the starting valve open after the H. P. cylinder had exhausted once.

Q. *What about the starting power of four-cylinder two-crank receiver compounds?*

A. It is good, as the L. P. cylinders on both sides can be used with boiler pressure. This is the special advantage of this class as well as of the four-cylinder two-crank non-receiver type.

Q. *How about the hauling power of four-cylinder two-crank receiver compounds?*

A. About the same as for non-compounds, but more regular, especially by reason of the late L. P. cut-off.

Q. *What can you say of the starting power of four-cylinder two-crank non-receiver compounds?*

A. Excellent, as the L. P. cylinder on each side can be run H. P. (This advantage they share with the four-cylinder two-crank receiver type.)

Q. *With which class of trains have compound engines the most trouble in starting; and why?*

A. Passenger, because more closely coupled.

Q. *How about the starting and accelerating powers of two-cylinder receiver compounds that have no independent H. P. exhaust?*

A. There is sometimes difficulty, owing to the fact that although the maximum starting power of these compounds (when the L. P. crank is nearly on the quarter) is greater than that of non-compounds, the minimum (when the H. P. crank is in the same position) is less.

Q. *Why is this?*

A. Because of the small size of the H. P. cylinder and its great back pressure.

MISCELLANEOUS CONCERNING COMPOUNDS

Q. *In designing a compound locomotive, what should be considered besides the mere matter of evenly distributing the power, and saving coal and water?*

A. To keep down the first cost and the repair bill, to keep the machine simple, and make the mode of handling as far as possible the same as the simple-expansion engines; to permit a train to be brought in without unusual delay, in case of a breakdown, with one side only; and in most cases to be available for both freight and passenger service.

Q. *How is the formation of a vacuum in the L. P. steam passages prevented?*

A. Sometimes by air valves therein; being wing valves held shut under the steam pressure when running, but free to open inwards when drifting. Fig. 397 shows a cross section through main valve and ports, together with the starting valve (or by-pass valve) piping and controlling levers, and the L. P. water relief valves. In this

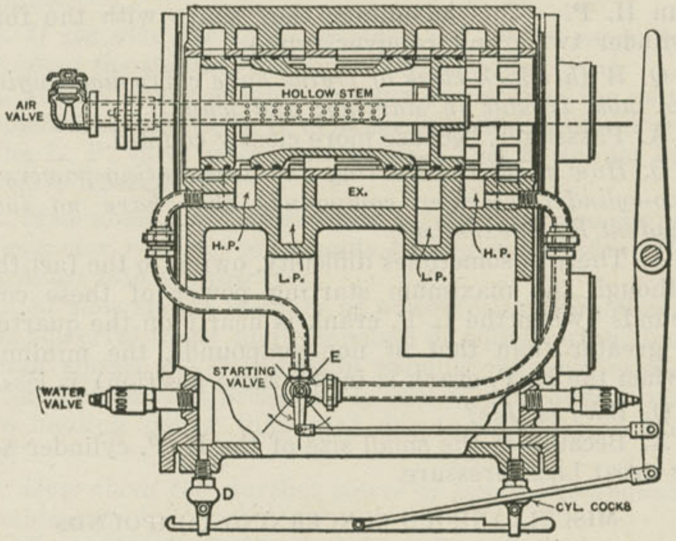


Fig. 397. Showing Main Valves and Ports.

arrangement the piston-valve rod is hollow and the bore communicates with the valve interior by a number of holes; the outer end passes through a stuffing-box and bears an air check valve. When drifting, the air passes into the L. P. passages through this valve and the hollow stem.

Q. Where does the reverse lever of a compound usually cut off in the H. P. cylinder?

A. At about half at latest.

Q. Why?

A. Because with shorter cut-off there would be too much compression in that cylinder.

Q. In running down a grade where should the reverse lever be?

A. In full gear, to give the valve full port opening; the starting valve should also be opened.

Q. Under what conditions have compounds most power at high speed?

A. With throttle partly closed and late cut-off.

Q. Why?

A. The compression is kept down.

ACCIDENTS WITH THE BALDWIN FOUR-CYLINDER UNBALANCED COMPOUND

Q. In case of a broken or disconnected main valve rod on a Baldwin four-cylinder unbalanced compound, what must be done?

A. Put the valve on the center of the seat so as to cover all the ports on that side; disconnect the main rod and block the crosshead as in directions for non-compound engines.

Q. In case a low-pressure cylinder-head on a Baldwin compound is broken out, can the engine be run on both sides without disconnecting?

A. Yes.

Q. What would be the course of the exhaust in such case?

A. On the damaged side it would pass through the open end of the low-pressure cylinder into the air, without going into the stack.

Q. If the engine were run without disconecting in this case, what difficulty might be met?

A. The exhaust escaping in front of the cab might obstruct the engineer's view, if it was the right-hand cylinder that was disabled.

Q. In case of the low-pressure piston-head on a Baldwin compound breaking away from the crosshead and going out of the cylinder, what would be the course of the steam?

A. It would go into the air from both ends of the high-pressure cylinder through the open ends of the low.

Q. How many exhausts are there to a Baldwin compound per wheel revolution?

A. Normally, four.

Q. How many would there be when both low-pressure cylinder-heads were broken out?

A. Only two.

Q. Could a Baldwin compound be run with both high-pressure piston-heads removed?

A. Yes, if the stuffing box was made steam tight; in this case the steam valves would supply live steam direct to the low-pressure cylinders.

Q. In this case what would be the course of the steam?

A. From the chest into the high-pressure cylinder, then through the main steam valve into the low-pressure cylinder at nearly boiler pressure.

Q. When a main rod of the Baldwin compound is broken or disconnected, what should be done?

A. The valve should be blocked in the center of the seat so as to cover all ports; and the crosshead blocked.

Q. How may the valve best be blocked?

A. By pieces of wood, between the guides, each side of the small (valve) crosshead.

Q. How should the cylinder cocks stand when the engine is running not under steam?

A. Open, to prevent the low-pressure piston from making a vacuum in the high-pressure cylinder and causing the latter's packing to be picked up by the piston rod.

ACCIDENTS TO THE BALDWIN FOUR-CYLINDER BALANCED COMPOUND

Q. In case of breakage of any connecting rod of a Baldwin (Vauclain) four-cylinder balanced compound, what is to be done with the other rods?

A. They may be left in place, but the engine must be run only slowly, as it would then be out of balance.

Q. If it were a high-pressure main rod, what would be the steam distribution necessary?

A. The low-pressure cylinder would be run non-compound, the undamaged high-pressure side being steam balanced.

Q. If it were a L.P. main rod?

A. The L.P. head could be removed and the engine run (unbalanced) compound on the good side and H.P. on the bad; or the good H.P. cylinder could be steam balanced and both L.P. run (again unbalanced) high-pressure.

Q. What should be done in case of a broken valve stem or valve rod?

A. The valve blocked in central position and all its ports closed; both main rods on that side taken down, the piston blocked at back stroke, and the engine taken home with one side.

Q. Can a Baldwin four-cylinder balanced compound be run with both end sections of one valve removed?

A. Yes; the middle section distributing to the H.P. cylinder, which would exhaust direct in stack, so the low-pressure pistons would be running empty and dry unless specially lubricated.

Q. In case of two broken forward side-rod sections, what must be done?

A. Get towed in dead; as the eccentrics are on the second axle, which is driven by the side rods.

Q. In case of one broken forward side-rod section failing, could the engine be run?

A. No; because the second driver pair (the third also if there were one) would have to be driven by the remaining side-rod section only, and would be likely to run the wrong way.

Q. With one defective end section of the valve, what would happen?

A. The engine would work half compound on that side; i.e., one end of the L.P. cylinder would get H.P. exhaust, the other, nothing.

Q. *How would the exhaust cough in this case?*

A. With three mild coughs followed by one sharp one, each turn.

Q. *If the engineman notices that the engine pounds badly when drifting, and that the engine lays back against the train and is inclined to stop as soon as the steam is shut off, what should he report?*

A. It is almost invariably found, with these engines, that the pounding noticed while drifting is due to gummed and stuck over-pass valves. These should receive prompt attention.

Q. *What should be done in case of a breakdown?*

A. Convert the engine into simple and proceed the same as with a disabled simple engine.

Q. *The engine suddenly fails on account of lack of steam and the engineman is unable to handle the train. There is a bad blow from the stack when the throttle valve is opened. What should be done?*

A. Examine the over-pass valves at once.

Q. *How could the over-pass valves cause this trouble?*

A. They must close when the engine is running under steam, to prevent live steam from blowing through from the cylinder to the exhaust passage. If they should stick open it would not only rob the cylinder of its pressure, but would also rob the boiler of its steam.

ACCIDENTS TO THE BAKER GEAR

Q. *What should be done if a Baker eccentric crank breaks?*

A. Take down the eccentric rod; block the bell crank vertically if two-arm; with lower bearing $1\frac{1}{2}$ inches ahead of upper, if single-arm.

Q. *What will be the valve travel then, and how given?*

A. Lead plus twice the lap; given by the combination lever.

Q. *What should be done if the eccentric rod breaks?*

A. The same as for broken eccentric crank.

Q. *For broken radius bar?*

A. The same.

Q. *For broken horizontal bell crank arm?*

A. The same.

Q. *For reverse yoke broken below the reach rod connection?*

A. The same.

Q. *Any precaution necessary about stopping, in the last four cases?*

A. Not to stop with main pin on disabled side on either quarter; else engine would not start.

Q. *What should be done if the Baker reach rod breaks?*

A. Remove the broken parts, block the lame side so as to run in the desired direction. (To run in the opposite direction, change the blocking correspondingly.)

Q. *For broken reverse arm?*

A. The same.

Q. *For reverse yoke broken at reach-rod connection?*

A. The same.

Q. *If main reach rod breaks?*

A. Block reverse yokes on each side of the engine, for the desired cut off; control speed with throttle.

Q. *For accident to reverse-shaft?*

A. The same.

Q. *For break in reverse rod connected to main reach rod?*

A. The same.

Q. *For broken main rod?*

A. Take down both it and the valve rod, unless main rod has a solid rear end, in which case leave the valve rod up and remove the eccentric crank and its rod. Fasten valve over ports (by set screw or clamp). Fasten crosshead at stroke end; come in with the good side, at long cut off.

Q. For broken main crosshead?

A. The same.

Q. For broken guides?

A. The same.

Q. For damaged piston?

A. The same.

Q. What is the procedure if the crosshead wrist pin should break, when the Baker combination lever is driven thereby?

A. The same as for broken main rod; but it will be necessary to remove the union link and fasten the lower end of the combination lever.

Q. What should be done if the vertical bell-crank arm, from which the combination lever is swung, is broken?

A. Remove the combination lever, union link and valve rod; block the valve.

Q. If the combination lever is hung from the valve-stem crosshead?

A. Take down the valve rod.

Q. If the cylinder head be damaged?

A. The same.

Q. In case the union link fails?

A. Remove the valve rod and any interfering broken parts; fasten the lower combination lever end to clear the main crosshead at forward stroke end.

Q. If the crosshead arm should be damaged?

A. The same.

Q. If the combination lever should be broken?

A. The same.

ACCIDENTS TO THE SOUTHERN GEAR

Q. What is to be done if the eccentric crank or eccentric rod of a Southern gear fails?

A. Disconnect that rod from the crank, radius hanger and transmission yoke, chain or wire up the hanger and yoke, fasten the valve centrally and proceed.

Q. If the radius hanger fails?

A. Disconnect it from the rod, take down the latter, fasten the valve in mid-position.

Q. If the transmission yoke fails?

A. Disconnect it from the eccentric rod, fasten the valve centrally.

Q. If the horizontal bell-crank arm fails?

A. Disconnect the yoke from the eccentric rod, chain up to clear, fasten valve centrally.

Q. If the vertical bell-crank arm fails?

A. Fasten the valve in mid-position. If necessary, remove the arm.

Q. If an auxiliary reach rod or reverse-shaft arm fails?

A. Block both link blocks at the same point, giving enough port opening to start train one way or the other.

Q. If the main reach rod, or the middle reverse-shaft arm fails; or if both auxiliary reach rods fail?

A. The same as for the just mentioned case.

ACCIDENTS TO THE WALSCHAERT GEAR

Q. What is to be done if the Walschaert eccentric crank is broken?

A. Take down the eccentric rod, disconnect radius rod from lift shaft, wedge the block centrally.

Q. What will then be the valve travel?

A. The lead, plus twice the lap.

Q. The port opening?

A. The amount of the lead.

Q. The cut-off?

A. Short.

Q. Can the engine be reversed?

A. Yes.

Q. What is to be done in case of a broken eccentric rod?

A. The same as for broken eccentric crank.

Q. For a broken link foot?

A. The same.

Q. What precaution must you take about stopping, in these last three cases?

A. Not to stop with the main pin on the disabled side on either quarter, as then the engine could not be started.

Q. In what accidents must the main rod be taken down?

A. Broken main rod, crosshead arm or lap-and-lead lever connector; bent piston rod.

Q. What is the procedure for broken main rod with inside admission valves?

A. Hang the radius rod clear of the lap-and-lead lever; fasten the valve to cover the ports (by set screw or clamp); fasten the crosshead at back stroke end; come in on one side.

Q. Suppose the valve had outside admission?

A. The same, but the lap-and-lead lever must be taken down.

Q. What should be done in case of broken crosshead arm?

A. The same as above.

Q. With broken lap-and-lead lever connector?

A. The same.

Q. For bent piston rod?

A. The same.

MISCELLANEOUS ACCIDENTS

Q. When the valve-gear is out of order, what is the first thing to do?

A. To see if both sides are affected, or only one; if the latter, which one.

Q. How is this done?

A. By testing the cylinder-cocks under steam. With the gear in forward motion the front cocks should show steam when the pins are in the lower half of their course.

Q. In what order should the trouble be sought?

A. Eccentrics, eccentric-shafts and blades, rocker and box, bolts, pins and keys; and finally, if not found outside the valve-chest, therein.

Q. An 18 × 28 eight-wheel engine had a light three-car train; eccentrics and straps badly worn, and ratchet on reverse-lever also somewhat worn. Engine was making about 20 miles an hour working at 6-inch cut-off and suddenly lever went into back motion. What was the cause?

A. The forward pull on the reach-rod when running ahead was caused by something caught in the steam-chest; or something hit part of the valve-gear.

Q. What might be the case if a stuffing box was not screwed up fair?

A. The rod might be heated and bent.

Q. How may an engine be got off the center when one side is disconnected?

A. (1) By the pinch-bar. (2) Where there is a push-out driver-brake on the frame back of the rear driving wheel, by letting out the adjustment on the driver-brakes, cutting out the tender-brake, cutting out the train-line with the angle-cock at the head end of the head car (or rear end of tender); taking coal-boards or other strong sticks to reach from the brake-cylinder piston to a rear driver-spoke (high up); bringing train-line pressure up to 90; this will boost the wheel off the center before the shoes are hard on the tires.

Q. What is then to be done?

A. Release the brake, open the angle-cock, pick up the push sticks and go ahead.

Q. What is the greatest difficulty in fixing up a broken spring or hanger where the spring is underhung?

A. Jacking the engine up high enough to get enough blocking in between the driving box top and the frame, between the latter and the end of the driving spring, or between the frame and the equalizer end.

Q. What care should be taken in disconnecting one side?

A. Not to set the good side on the quarter, but about on the eighth, so as to give time to take up the draft-rigging slack.

Q. Should steam be used when pinching off?

A. No; it loads the valve and actually opposes the pinching.

Q. Where should disconnecting be done in case of an accident?

A. If there is a siding near, as much of the disconnecting should be done there as possible, to free the main track.

Q. In case of a wreck on a double-track road, in what order should the tracks be cleared?

A. All of one track should be cleared first, so that trains may go around the remainder of the wreck; then the other may be cleared.

Q. In case of breaking down, what is the first duty after seeing to the immediate safety of the engine from explosion or burning?

A. To guard the train by sending a man back on the road.

Q. What precaution should be taken in freezing weather when the fire is drawn?

A. To drain all water from pumps and injectors, feed and branch pipes; and if there seemed danger of the water in the boiler itself freezing, it should be run out of both boiler and tank.

Q. What should be done in case there are no frost-plugs in the feed and branch pipes?

A. The joints should be slacked to let the water leak out through them.

Q. When running on one side, what care should be taken in stopping?

A. To stop with the working crank off the center.

Q. How may this be done?

A. Just before stopping, let off the brakes, reverse, give a little steam, and work the reverse lever to and fro until the crank is just where desired.

Q. In case of a long stall in the snow, what should be done as regards the boiler and tender?

A. They should be emptied to prevent freezing; the cylinder-cocks and wash-out plugs being removed and joints in pocketed parts, as of pipes, broken.

Q. What may be the effect of an accumulation of cinders in the "long front end"?

A. Burning or warping it, or cracking the frame door.

Q. What should be done in case of a disconnected tank-valve?

A. Arrange the injector as a heater as elsewhere explained, put on steam suddenly and try to blow out the valve.

Q. What classes of shop repairs will it pay engine runners and firemen to observe?

A. Piston packing, valve-facing, rod-brass filing or scraping, wedge-lining, truck-wheel changing, brass-replacing, spring-replacing, etc.

Q. What is one of the principal causes of hot driver, journal, crank-pin and broken rod brasses?

A. Improper setting of the driver-box wedges and keying both side-rod and butt-end main-rod brasses; as for instance setting the driver-box wedges when the engine is on the top quarter, and setting rod brasses with the engine in the same position.

Q. What is the proper way to set the wedges?

A. The engine should be placed on the center, and the driver brake (if it be applied to the wheel on the wedge side of the box) be set and allowed to remain while the wedges are being adjusted. The brake will hold the box and journal against the shoe, and thus there will be a maximum amount of slack. The adjustment can then be made to a nicety.

Q. Should rod brasses be keyed in the above-named position of the engine?

A. Yes, as the keying is done on the large part of the bearings, and if there is sufficient lubrication the engine should give no trouble by heating.

Q. In what order should this work be done?

A. First the binder braces tightened, then the wedges, and lastly the rod brasses.

Q. Suppose the driver brake is on the opposite side from the wedges, or there is none?

A. The engine should be placed on the center, the wedges set up as far as they can be set with a ten-inch wrench, next pulled down until fairly loose, then finally set up to where the slack is enough removed.

Q. What would be the probable cause of the wheel flanges of an engine just out of the repair shops, cutting on one side?

A. There may be two causes. The front truck casting, if there be a truck, may not be exactly in the center. More likely, the engine truck spring is defective or broken; and when such is the case, the leading driver on that side usually cuts its flange.

Q. What is the remedy?

A. Leveling up the truck.

Q. What would be the easiest way to block an engine in the event of a broken deck pin or casting on the engine used in coupling the engine and tender?

A. The broken pin can be replaced by another pin, using the king pin of a car (this could be taken from some "empty," on a side-track), but in the event of a fracture of the casting at the pin hole, or the breaking of the shackle bar through the pin hole, no blocking would serve. Heavy chains could be fastened to the tail brace of the engine and to the iron tender frame, or around its center casting, and the chains tightened by putting a bar between them and twisting them up, then securing the bar in place when the lost motion was taken up.

Q. Are derailments more likely to occur on curves, or on straight reaches?

A. On curves, by reason of the tangential force which tends to make the train keep on in the straight line on which it was last traveling; that it, fly off the curve at a tangent.

Q. What other name is given to this force?

A. Centrifugal force.

Q. Do all derailments on curves occur by reason of faulty track?

A. No; often they are caused by faulty rolling stock.

Q. What is the most important insurance for safety, as far as the track is concerned?

A. Smooth surface, and line.

Q. Why is a rough surface dangerous?

A. Because it sets up in the rolling stock rocking motions which relieve the outside wheels of load and permit the flanges to climb the rails more readily than when the full share of the load is being carried by the outer rail.

Q. What means are used to counteract the tendency of the train to run off at a tangent?

A. The outer rail is raised.

Q. What is often as dangerous as too little curve elevation?

A. A low joint in the outer rail.

Q. What may be said of car bearings, as regards running curves?

A. The adjustment of a car body on its bearings is an important matter; a car with weak bolsters, or one too heavily loaded on one side, may rest so heavily on its side bearings that the trucks will not swivel off the curve until very heavy flange pressure on the wheels against the rails is developed, which may cause derailment.

Q. What is a more frequent cause of derailment?

A. Sharp wheel flanges; that is, those which have lost their curvature, so that the flange climbs the rail, especially at high speed.

Q. *In case of derailment what is the first step?*

A. To draw the fire if the crown sheet or flues are not covered.

Q. *Suppose you can not draw it?*

A. Smother it with earth, ashes, sods, snow, or even coal.

Q. *What is the procedure for a burst flue?*

A. Plug it at both ends, if necessary, and there is no brick arch, cover the fire, start the blower a bit, lay a board on the coal and go into the fire box to plug it.

CHAPTER LXXXI

KNOCKS AND POUNDS

Q. *What are the most usual causes of pounding?*

A. (1) Lost motion in the connecting-rod brasses, between the driving boxes and the jaws, or (2) in the driving-box brasses; (3) side rods out of tram or with badly-worn brasses; (4) worn guides; (5) piston head touching the cylinder head; (6) spider getting loose on a piston rod; (7) a piston rod loose in the crosshead.

Q. *Where will the pounding be in case of worn guides?*

A. At the crosshead.

Q. *What is this liable to cause?*

A. A bent piston rod.

Q. *What is the best way to find out where a pound is?*

A. To put one of the cranks on the quarter, block the wheels and have the throttle opened a little, and the engine reversed with steam on; then each connection may be watched in turn as it comes and goes.

Q. *Under what conditions will a crosshead pound?*

A. When the guides are worn very open.

Q. *Under what circumstances will side rods pound on the centers?*

A. When they are out of tram or their brasses are badly worn.

Q. *Where is the most difficult knock to place on an engine?*

A. That caused by a spider that has come loose on the piston rod; or that when the piston packing is too short.

Q. *How can the knock caused by a loose spider be detected?*

A. By the slight blow and the sharp click that is made when the engine is passing over both centers.

Q. *How may a loose spider be detected?*
A. By the sharp knock made when passing the front center.

Q. *What is a very rare cause of piston pounding?*
A. Where a thick cylinder has been rebored until there is no counterbore left and the piston head has worn a shoulder; the slightest alteration in its adjustment will cause the piston to strike this shoulder.

Q. *Suppose that an engine pounds in full gear and the pounding cannot be stopped by either tightening or slackening the brasses, what should be done?*
A. More lead, or more cushion, should be given.

Q. *Why is it that engines will sometimes pound only in full gear?*
A. Because there the lead is least, with the ordinary shifting-link motion.

Q. *When pounding lessens when the engine is hooped up, of what is that the sign?*
A. Of insufficient cushion.

Q. *But why is the pounding less when the lever is in the center notch?*
A. Because there cushion and preadmission are greater than with full valve opening.

Q. *Of what may a neglected pound be the forerunner?*
A. Of a broken crank pin, cylinder head, etc.

Q. *What should the engine runner do on discovering a serious pound?*
A. First locate it, then report it, thus relieving himself of further responsibility in the matter and enabling prevention of an accident.

Q. *What are the most usual causes of pounding?*
A. Lost motion in connecting-rod brasses or between the driving boxes and the jaws, or in the driving-box brasses; insufficient oiling of piston, main shaft, main crank pin or wrist pin; side rods out of tram or with badly worn brasses; worn guides; piston touching the cylinder head; piston rod loose in either the crosshead or the piston head; too close wedges, loose knuckle pin or bushing, loose middle connecting brasses, wedge down or stuck; broken frame, loose cylinders or deck; loose pedestal braces where the frame is light; faulty fitting of shoes and wedges; loose oil cellars or driving brasses (either circle or gibbed), square-bottom spring bands, poorly-fitted spring saddles or anything that hinders free movement of the equalizers; springs rubbing the boiler, saddle striking the frame; wet steam or foaming; excessive back pressure; imperfectly balanced drivers; too much or too little steam cushion; loose cylinders; loose follower bolt.

Q. *What may be effect of lost motion in the valve gear?*
A. Rattling reverse lever.

Q. *What, of valves out of square?*
A. Jerks when hooked up near the middle.

Q. *Do parallel rods pound?*
A. No; they rattle.

Q. *Do packing springs pound?*
A. No; they click.

Q. *When an engine pounds on the back center, for what should you look?*
A. A loose spider.

Q. *On the front center?*
A. Loose driving boxes or wedges.

Q. *On the quarter?*
A. Flat spots on the tire.

Q. *What is the sign of a loose spider?*
A. A hard knock when the engine is on back center, so that the tendency is to push the spider off the fit.

Q. *What could cause pounding in a shut-off engine?*
A. (1) New piston packing striking against an old shoulder in the cylinder; (2) faulty adjustment bringing the piston too far front or back and thus striking a shoulder.

Q. What would cause a piston-valve engine to pound when running shut off with the lever hooked up, although she does not pound when the lever is in the corner?

A. Over-compression in the cylinders, with valves having no relief.

Q. What style of valve is specially addicted to pounding?

A. The piston valve, by reason of the exhaust steam passing over its ends and exerting a force which will take up the lost motion in the gear suddenly; continuing the motion of the valve in the direction in which it was going.

Q. What is often the result of this pounding?

A. Crystallizing and breaking valve stems and other parts, and causing irregularity in the steam distribution, as the valve jumps and then stops.

Q. What causes a piston valve to pound when the engine is drifting with the lever hooked up?

A. Lack of compression, by reason of the valve being open for admission, and thus permitting the air which is being compressed to escape into the steam ways.

Q. How may this pounding be stopped?

A. By placing the lever in the corner or on the center; or better yet, by keeping the main-rod brasses filed.

Q. Explain the difference in the pound of a loose piston and that of a loose driving box?

A. The two are different, but sometimes confusing. The loose piston pound may be detected by watching the fit of the rod in the crosshead, and the sound is more to the forward end than that of a driving box.

Q. How would you locate a driving-box pound?

A. Spot the engine with the crank on the upper quarter on the test side; block the wheels, have the fireman "thump" the engine. Watch the boxes to see if (1) they rock in the jaws between shoes and wedge, or if (2) the journal shakes in the box. Then test everything along the line of rods and of boxes.

Q. At what part of the stroke does the main rod pound?

A. Only at the end.

Q. What is the cause of side rods pounding?

A. (1) Wedges slack, wrongly set up, or having the wrong taper; (2) engine out of tram.

Q. Will the side rod on a three-wheel connected engine pound any more than that on a two-wheel engine?

A. Not necessarily.

Q. Why will an engine in good condition pound harder when passing the forward than the back center, when running ahead?

A. When the pin passes the front center it pushes the main axle back against the box and jaw, which are moving forward with relation to the track; on the back center the push is in the same direction as the box movement.

Q. What is the best position to place a crank pin in order to find a knock?

A. The upward, because there it is freest to move.

Q. What is the objection to bringing the crank pin downwards to find a knock?

A. It would be necessary to move the weight of the engine in order to find a knock or a thump in a driving box or a frame.

Q. What is the objection to having the crank pin on either the front or the back center, in finding a knock or a thump?

A. In that position, moving the reverse lever lets steam in at only one end of the cylinder.

Q. What are special causes of pounding on the back centers of a worn road engine?

A. (1) Forward wear of shoes and boxes; (2) displacement of the valve stem, due to lost motion in the yoke, etc.

Q. What is the effect of this wear on distances between centers of parts?

A. It lengthens the distance between the eccentrics and rocker pin.

Q. What characterizes the pound caused by a loose pedestal brace or bolt?

A. It takes place on only one center,

Q. What is the usual wear of a main journal, that causes pounding?

A. Flatted on one side, or oval.

Q. If pound is in the wedges, how can you set them up and get them right the first trial?

A. By pinching the wheels away from the wedges, screwing up the loose wedge, then trying if the box slides freely without shake; then slacking off a trifle to keep the wedge from sticking when warm.

Q. Will an engine pound if pedestal bolts are loose? If so, why?

A. Yes, because the pedestal works loose and draws down the wedge.

CHAPTER LXXXII

REPAIRS

Q. Into what classes may repairs be divided?

A. Running or "light," and complete or "heavy."

Q. How often should boilers be overhauled and retubed?

A. Every four or five years.

Q. How often should the fire-box, tubes, etc., be examined?

A. About once a month.

Q. And the injectors?

A. About monthly, according to the water used.

Q. Wheels and axles?

A. After a certain mileage, according to speed and weight; say 3,000 to 4,500 miles.

Q. In stripping an engine what precaution should be observed?

A. As far as possible to note or remember the exact order in which parts are removed so as to replace them in the same order; also where possible to remove groups of parts, separating them afterwards; if the parts are not stamped "R" and "L" to stamp them so, and, what is more important, with the engine number.

Q. What care should be adopted in stamping?

A. To avoid vital parts.

Q. What kind of a hammer should be used?

A. Copper, lead or raw hide.

Q. What precaution is desirable in chipping off rivet heads?

A. To chip them into bagging or something similar to prevent their rebounding.

Q. How can the piston rod and valve spindle be removed?

A. By removing the cotters and using a wedge and plug to force out the rod from its seat.

Q. What is the best way to remove a riveted-over crank pin?

A. By drilling an axial hole in it for the spindle of a ring cutter that faces off the riveted-over portion and a small portion of the end of the pin proper; then using a hydraulic press.

Q. How are ferrules removed?

A. By a rod with flared end pushed in from the smoke box; thin end; this flare being of the same outside diameter as the inside diameter of the flue.

Q. Suppose the tube is flattened?

A. Then it may be necessary to take out some neighboring tubes and cut out the flattened portion.

Q. How are copper and brass tubes cleaned from deposit?

A. By pickling in muriatic acid.

Q. How is incrustation removed?

A. By careful chipping.

Q. How can you tell if a side stay in the fire-box is defective?

A. By holding a hammer against the inside end and hitting the outer end a smart blow; if it is sound the first hammer will rebound.

Q. How can scale be removed from the outer surface of tubes?

A. By tumbling in a barrel for that purpose; their mutual friction removing the incrustation.

Q. How is soft-patching done?

A. The surface should be well cleaned, the fittings filled with iron cement, smoothed off; the area covered with red lead or graphite paste and the patch bedded down hot and riveted—not bolted.

Q. Why not bolted?

A. Bolt heads obstruct the waterway and facilitate lodging of incrustation about them.

Q. Should cracks be patched?

A. No, as they may extend beyond the patch.

Q. Should bulges be hammered or pressed into place?

A. Pressed.

Q. What is a dumbbell patch for tube plates?

A. A patch of dumbbell shape, at right angles to the line joining the tube centers, fitting snugly against the ferrules, and fastened by screws to the tube sheet.

Q. What is a spectacle patch for tube sheets?

A. One fitting snugly around adjacent tubes and having two holes coming fair with the ends of the tubes between which there is a crack; it is fastened to the sheet by 10 tapped-in screws.

CHAPTER LXXXIII

MILEAGE AND RUNS

Q. How long should an engine run before the valves need facing?

A. That depends on the road, on the engines, on the service, and on the engine runner. On the N. J. C. and the P. & R., John Cline made with engine No. 172, 82,000 miles before the valves needed facing; this engine having the Allen valve, balanced. Before balancing the valves, it was hard to get engines of the same lot to run 20,000 without facing. Engine No. 165, on the same road, John Rhodes on the foot plate, made 13,411 miles on express train running before the engine was jacked up, the fire-box needing no work and the principal boiler work done being taking out and resetting the flues.

Q. Give an instance of locomotive mileages in regular service?

A. On the N. Y. C. & H. R. R. R., engine 84 after coming out of the shop, was put on the Chicago Express, running from New York to Albany and back, seven days per week, 284 miles a day, with two crews; D. Caffin one day and E. Stamford the next. Before any work was done to fire-boxes or flues she had run 26 months, making 165,000 miles; and then got only light repairs to machinery, and nothing to heating surface; the water used not being good. She had Buchanan fire-box.

Q. Given a road with 1.25 per cent. grades 2 to 2.5 miles long; what engine weight would be needed?

A. Referring to Fig. 398: the maximum trailing load would be 7.7 times the engine weight, or 220 tons, with natural ventilation.

Q. Suppose the ends of the electric line have considerably different elevations?

A. Then either forced ventilation or reduced load would be necessary.

Q. Given the speed and locomotive weight, how is the minimum equipment determined?

A. Suppose 14 miles an hour is desired, with a 47-ton engine. Fig 399 gives the minimum rated H. P. at 14

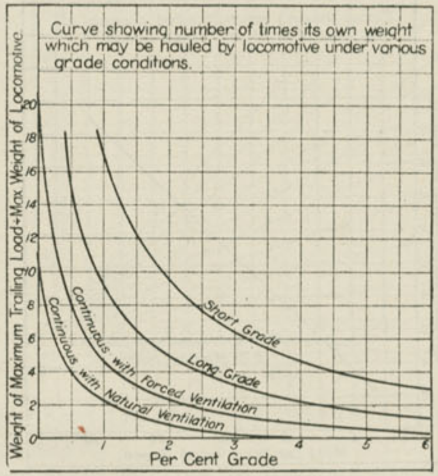


Fig. 398.

m. p. h., as 10.6 per ton, which would make at least 470 H. P. necessary (say four 125 H. P. motors).

Q. Given the long and short grades assumed a few questions back, how is the required electric locomotive weight known?

A. Suppose 500 tons trailing load were needed, and the road such as to be equivalent to continuous pulling on a 0.3 per cent. grade; the free running speed on the level being 12 m. p. h. and using forced ventilation the short grade curve (Fig. 398) shows that a locomotive can handle 9.6 times its own weight on the maximum short grade; with continuous forced ventilation, 10.7 times. The short 2 per cent. grade fixes the weight: not less than

50÷9.6=5.2 tons. Fig. 399 shows at 12 m. p. h. with forced ventilation, minimum equipment necessary, 7.6 H. P. per ton. Hence the locomotive should exert 7.6× 52=395 H. P. (*i.e.* for electric traction four 100 H. P. motors geared for 12 m.p.h. rated speed and with forced ventilation).

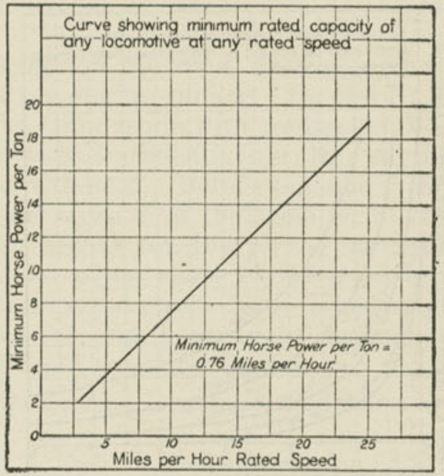


Fig. 399.

Q. On what does the current demand for an electric-drawn freight train depend?

A. Primarily upon speed, train weight, and grades; secondarily on alignment, average car weight, and frequency and length of stops. Fig. 400 assists in fixing the maximum train weight.

Q. Give an example?

A. With maximum grade 3 per cent. for 1.5 miles, and current drawn from a 500-ampere station, 8 m. p. h. desired. The sub-station may work at 50 per cent. overload: 750 amperes. Fig. 400 shows 2.5 amperes per ton needed at 8 m. p. h. on a 3 per cent. grade. Hence the maximum train weight at that speed is 750÷2.5=300 tons, including locomotive weight.

Q. What would it be at 12 m. p. h.?

A. 8-12 of 300=200 tons.

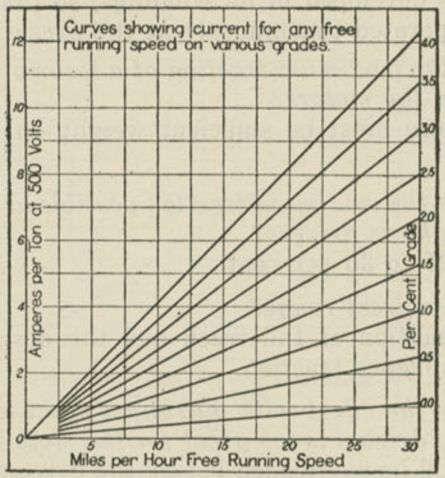


Fig. 400.

Q. How about the train weights that can be started on a given grade?

A. Given train friction 10 lbs. per ton, acceleration 20 lbs. per ton, adhesion coefficient 25 per cent. The table gives the desired data:—

TONS WEIGHT OF TRAILING TRAINS

Locom. Wt. Tons	Grade				
	1%	2%	3%	4%	5%
25	225	155	115	90	70
30	270	185	135	105	85
40	360	245	180	140	115
50	450	310	230	180	140
60	540	370	270	210	170
70	630	430	320	250	200
80	720	490	365	280	230
90	810	550	410	320	255
100	900	615	455	355	285

Q. Why is it that a relatively small motor can exert a comparatively enormous power for only a short time?

A. Heat is developed in its windings, so that it would burn up if operated continuously at the excessive power.

Q. Is not the maximum traction of a locomotive wholly dependent on the motors?

A. No; there must be sufficient weight on drivers to grip the rail.

Q. What is the maximum traction possible as compared with the weight on drivers?

A. From 25 to 35 per cent.

Q. Why this great range?

A. The condition of the track and the design of the locomotive influence traction.

Q. What is the effect with maximum train load, when the weight on drivers is too great for the motors?

A. They will be overloaded before the drivers will slip.

Q. With practically level road, horse power and speed given, how is the proper engine weight found?

A. Suppose 240 H. P.; speed 11 miles an hour. 240÷11 =21.8. The scale here given (Fig. 401*) shows the maximum locomotive weight to be 28.5 tons.

Q. How can the possible trailing load be found?

A. It depends on the profile of the road. Say there are 2 per cent. grades for 1,500 to 2,000 feet. Fig. 398 is a diagram showing the comparative trailing loads with various grades. On 2 per cent. the engines can haul 9.6 times its own weight; i. e., 9.6×28.5=273 tons, say seven or eight average cars of 35 to 40 tons gross weight.

Q. How about the influence of ventilation on electric locomotive traction?

A. Fig 398 shows the influence of both natural and

*These cuts are given by courtesy of the Westinghouse Electric & Manufacturing Co.

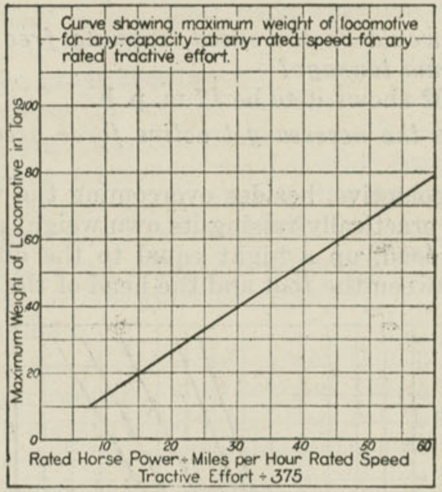


Fig. 401.

forced ventilation. On a level (0 per cent. grade) the engine named would pull 11 times its own weight: 11× 28.5=313 tons.

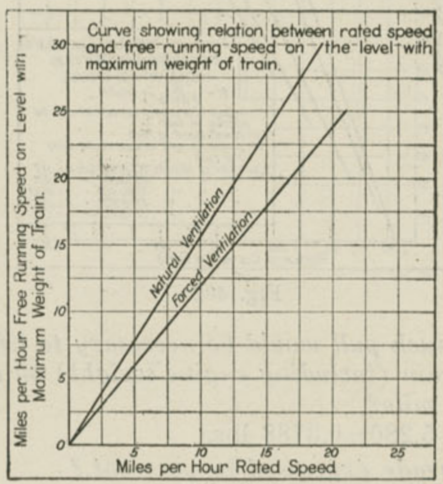


Fig. 402.

Q. What would be the speed, running free on a level with maximum tonnage?

A. Fig. 402 shows it to be 17 m. p. h.

Q. Why is the necessary tractive force greater on up grades?

A. The locomotive, besides overcoming the various resistances, is practically raising its own weight and that of the trailing load, up a hight equal to the difference of elevation between the foot and the head of the grade.

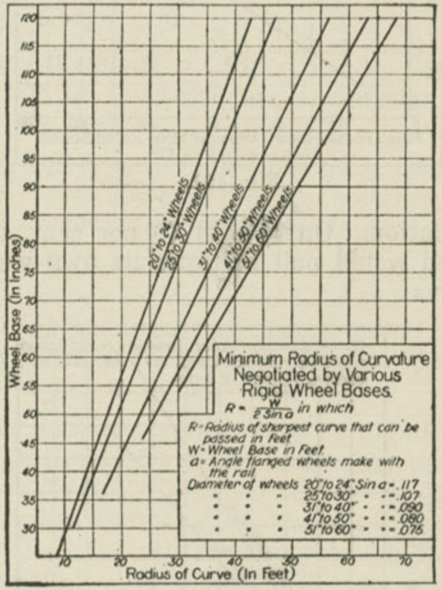


Fig. 402a.

Q. How much pull would be necessary to lift each net ton of the train (including engine weight) on a grade of one foot per mile?

A. 2,000÷5,280=0.3788 lbs.

Q. On a grade expressed in per cent.?

A. 20 lbs. for each per cent.

Q. To what is the total train resistance on a grade equal?

A. To the grade resistance (or weight lifting) plus the train resistance (or friction resistance) on a level.

Q. How are American track curves expressed?

A. In degrees, noted by the deflection from the tangent at points 100 feet apart; that is, the number of degrees corresponding to a 100-foot chord.

Q. In American railway practice, to what radius does each degree of curvature correspond?

A. 5,730 feet.

*Q. How can the shortest curve (that is the one with the shortest radius) be determined, that a locomotive or a car with a given rigid wheel base can round?**

A. This calls for considerable mathematical knowledge, and engineers use for that purpose either tables or diagrams such as Fig. 402a.

*The expression "negotiate" is a vulgarism, and not warranted.

CHAPTER LXXXIV

ELECTRIC LOCOMOTIVES

Q. Describe the electric locomotives on some well-known American system?

A. On the N. & W. road each unit consists of two like parts; the main trucks hinged on the Mallet system, each having two driving and one guiding axle, and being placed back to back, making the wheel system 2-4-4-2. Drivers are 62 inches, guide wheels 30; total weight 270,000; on drivers, 220,000 lbs. Length over all, both units, 105 ft. 8 in. Rigid wheel base, 11 ft.; total wheel base, 83 ft. 10 in. In each unit, four three-phase, adjustable-speed motors. Maximum accelerative tractive effort of the two units together, 125,000 lbs.; one-hour tractive effort 87,-000 lbs.; continuous, 68,000 lbs.

Q. What gives especially smooth handling of long electric trains with pushers?

A. They can stand at full tractive effort for a minute or more before the road engine has pulled out enough slack to let the pusher move; conversely, when a train is coming to a stop on a heavy up grade, and the road engine shuts off and brakes, the pusher can keep moving until the cars are bunched.

Q. What is a special advantage of the liquid rheostats?

A. They permit adjusting the load to the individual motors, so that the driver, by watching his ammeters, can develop maximum tractive effort without burn-out.

Q. Where is this of especial worth?

A. On a heavy grade with bad rail, as each motor can be loaded up to the slipping point, regardless of differences of driving-wheel diameters or of the local track conditions.

Q. How is the regenerative control handled?

A. As the engine goes over a summit, the driver watches his ammeter; when the current drops he shuts off the controller, opens the regenerating switch, then reopens the controller to "running."

Q. What happens then?

A. In a few seconds the current is 300 or 400 amperes; the train is at synchronous speed plus slip. It works up hill at synchronous speed minus slip, down grade at that speed plus slip.

Q. How is braking done on down grades?

A. By air alone, all through; because time is needed to change the phase-converter connections after synchronous speed has been reached, and in that time train control might be lost by the speed causing the wheels to slide back to "synchronous," when regenerative braking would be impossible.

Q. What can be said of the electric locomotive's capacity for sustaining overloads?

A. It can do so over much longer periods than the steam locomotive without difficulty.

Q. What is the effect of increased load on electric engines with series characteristics?

A. It slows them down.

Q. Of what types is this true?

A. The single-phase and the direct-current.

Q. What is the greatest advantage of the electric engine over the steam locomotive?

A. It utilizes its weight much better.

Q. Which average the least time in the round-house; the electric or the steam locomotive?

A. The electric.

Q. How long is the average steam freight locomotive making say 3,000 miles a month, in the round-house?

A. About 45 per cent. of the time on the road, 30 in the round-house, 25 in the yard awaiting orders, etc.*

*Wm. McClellan.

Q. What two characteristics determine the value of an electric locomotive, other things being equal?

A. The degree to which it is self-contained, and the greatest power that can be got into the space allotted to the motors.†

Q. What frequency is favorable for electric locomotives?

A. 25 cycles, not only for the locomotives (on account of the better ratio of tractive effect to weight on drivers) and the great speed-range adjustment, but also for convenient and effective incandescent lighting of yards and shops, and operation of induction motors in shops.

Q. How are higher speeds attained with the single-phase locomotive?

A. By higher voltages from transformer to motor terminals.

Q. What is the capacity of a single-phase motor of 15 cycles, as compared with one at 25?

A. About 30 per cent. operation.

Q. Which approaches more nearly the efficiency of the direct-current motor?

A. That of 15 cycles:—in most sizes above 90 per cent. throughout its entire load range.

Q. What type does not slow down much with increased load or up grades?

A. The three-phase alternating current.

Q. If at 1,500 H.P. normal output the motors of a given three-phase locomotive have 2 per cent. slip, what will be the slip at five times the normal tractive effort?

A. 10 per cent.

Q. What will the speed drop be?

A. About eight per cent.

Q. How much overloading can a good three-phase induction motor of say 750 H.P. stand?

A. Maximum torque of 6 to 7 times full load torque.

† J. B. Whitehead.

Q. About what proportion of the power generated is available for gearless electric locomotives averaging 20 miles an hour?

A. About 86 per cent.

Q. For freight engines, at 15 miles an hour, with single reduction gear?

A. About 84 per cent.

Q. What considerations affect gross earnings of railways in connection with locomotive types?

A. Principally the following:

(1) Safety.
(2) Reliability.
(3) Capacity of line.
(4) Frequency of stops.
(5) Speed.
(6) Passengers' comfort.
(7) Frequency of service.
(8) Convenient establishment of feeder lines.

Q. Where does electric traction prove safer?

A. In preventing fires in rear-end collisions; doing away with boiler explosions; absence of smoke in tunnels, that prevents seeing signals; no danger from stoves or broken steam pipes in the coaches; elimination of gas tank and oil lamps for lighting; lessened danger of derailment and of broken rails, due to hammer blow of reciprocating parts; adaptability to improved signal systems; ability to cut off power from any given track section and thus prevent collisions.

Q. Where is the electric system more dangerous?

A. On account of the third rail.

Q. As regards reliability; what are the good points of electric traction?

A. Fewer and shorter delays.

Q. The disadvantage?

A. Snow and sleet offer difficulties where the third rail is used.

Q. How about line capacity?

A. More sustained tractive efforts are possible on account of the uniform rotative force; there is no tender to haul; practically the entire locomotive weight is on drivers; electrics can be distributed throughout an excessively long train.

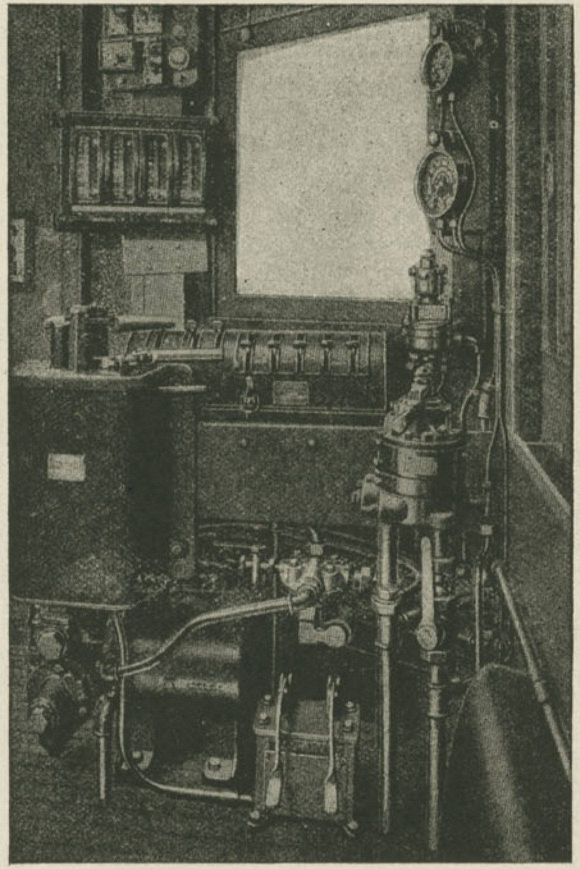


Fig. 403. Cab Interior Showing Engineer's Position and Operating Equipment, Electric Locomotive.

Q. As regards frequent stops?

A. These are rendered possible by the greater accelerative capacity.

Q. How about speed?

A. Electric trains can and do run faster than steam-drawn, owing to the absence of hammer-blow and general racking, due to heavy reciprocating parts. Incidentally, the efficiency does not decrease at high speed as with the steam locomotive.

Q. As regards passengers' comfort?

A. Smoke and cinders are done away with; lighting and heating fixtures may be more conveniently placed.

Q. How about frequency of service?

A. This is rendered possible by using train units of single cars; (especially advantageous on short runs).

Q. What about the establishment of feeder lines?

A. It is more possible to operate short feeder lines, trolley drivers as feeders, at comparatively low cost for power, and local cars or short trains therefrom can be attached to through trains.

Q. How about the saving in fuel transportation?

A. As about ten per cent. of the coal freight of the average steam line is for its own fuel, this item is greatly reduced. Current is cheaper to carry, than coal.

Q. Give an example of an electric traction system?

A. The powerhouse of the N. & W. road generates 25-cycle alternating current at 11,000 volts, stepped up to 44,000 to economize conducting wire, for distribution to substations, where it is stepped down to 11,000 and fed to the contact wires. On the locomotives it is converted and transformed to three-phase current at 725 volts, delta, by a split-phase converter. The locomotive motors are wound for three-phase current, controlled by liquid rheostats.

Q. Describe these water rheostats?

A. There are three boxes 15 feet by 2 by 2, mounted on 44,000-volt pin insulators, placed 4 ft. between centers on the ground, and connected in parallel for adequate carrying capacity. At one end, water is fed in through a fiber pipe, mounted on 11,000-volt pin insulators, and flows out at the other end through numerous small holes in the boxes. (Uniform water velocity is secured by having smaller holes at the bottom, where the pressure is greatest.) The electrodes are 5-inch channel irons 15 inches long, hung from suspension insulators. The high-pressure end is connected by 11,000-volt overhead leads with the power stations; the grounded electrodes connected to the ground plates.

Q. *How is adjustment provided to compensate for the varying conductivity of the water at different seasons?*

A. By shifting the electrodes horizontally in the boxes.

Q. *What is the transmission system?*

A. Two single-phase circuits using four 2/0 seven-strand hard-driven copper wires on pin insulators supported on catenary structure except where the line on wooden poles passes over tunnels. A 3/8-inch steel ground wire is carried above the transmission lines the whole length of the line. All pole crossarms are connected to a wire, grounded every 1,200 feet. At substations, the high-tension lines are sectionalized by air-break switches on the roofs.

Q. *What is the advantage of constant speed, from the train-despatching standpoint?*

A. It enables counting on train arrival to a fraction of a minute. A freight ahead of a 15-mile-an-hour passenger train can not hold up the latter.

Q. *Where are the largest savings in electric traction, over steam?*

A. The traffic can be handled better, in that lost motion is eliminated; there are no stops to take in fuel or water, or to blow up steam.

Q. *What is the schedule speed attainable, in comparison with steam traction?*

A. On given roads, 14 miles as against 7.

Q. *What is done with the regenerated power thrown into the line by electric locomotives on down grades, where no power other than that to overcome friction is required?*

A. There is a regenerative-load rheostat equipment operated automatically by a group of relays, magnetic switches, current transformers, etc., so connected that when the power generated by the locomotives and returned to the powerhouse exceeds the demands on the station, water rheostats cut in successively and absorb excess load, thus preventing reversing and motoring of the generators. Conversely, when the excess regenerated power is all gone, and only rheostat is in service, (all the rheostat load being supplied by the generators) the rheostat is automatically cut out; and when with two rheostats in service the excess regenerated power drops to 200 Kva., one rheostat is automatically cut out, the other remaining in service until the excess regenerated power drops to zero, when this last rheostat cuts out automatically, as before mentioned.

Q. *How many electric railway drive systems are in use?*

A. Three, (1) the continuous or direct current (third rail), (2) three-phase alternating with two overhead trolley wires, (3) single-phase alternating; high-tension, with but one overhead trolley wire.

Q. *Is the powerhouse equipment the same for all three?*

A. Essentially.

Q. *In what do the systems differ?*

A. In (1) the motors, (2) their controlling apparatus, and (3) the methods and apparatus for transmitting the current to the engine.

Q. *What are the essentials of a railway motor?*

A. To start and accelerate quickly, and operate continually at all desired speeds.

Q. What are the characteristics of the direct-current (D.C.) series railway motors?

A. (1) Automatic adjustment of speed to load; (slowing up on steep grades or with heavy loads); (2) definite speed with given load, necessitating inserting a resistance to decrease the speed any desired amount, or connecting the motors in series, (so as to reduce the speed to half with two motors, one fourth with four); (3) decrease in voltage at the end of long lines, thus reducing speed.

Q. What is the inherent quality of the three-phase A.C. motor?

A. Constant speed with various loads and on various grades, despite the increased horse power needed on up grades.

Q. How may it be speeded down?

A. (1) By connecting the motors in pairs as with the continuous motors in series above mentioned; or (2) by introducing resistances with accompanying loss of efficiency.

Q. Of what type are the motors?

A. Induction, without commutators; taking current, usually, from two overhead lines through two collectors.

Q. What can be done with this system on down grades?

A. Use the motors as generators to deliver current to the line.

Q. Where is this of special value?

A. In mountainous districts.

Q. What are the characteristics of the single-phase motor?

A. Series-winding, with speed characteristics like that of the D.C. type; the speed for any voltage decreasing with the load or the steepness of the up grade; but the pressure on the motor may be varied either way to any desired degree by auxiliary connections from the secondary transformer winding on the engine.

Q. What peculiarity has the control lever of this type?

A. It may be hooked up to give any desired speed, as with a steam locomotive.

Q. What advantage has it over the steam locomotive as regards notching up?

A. Notching up the lever on a steam locomotive does not increase the capacity beyond what the boiler can deliver; but on the electric engine the limits are only the capacity of the source and the safe temperature of the motor.

Q. What is the advantage of high frequency in this type?

A. Reduction of motor size for a given capacity.

Q. What members are necessary for the passage of the current from the A.C. generator to the D.C. locomotive motor?

A. (1) Raising transformers ("step-ups") in groups of three, (2) a triple transmission conductor and substations, (3) transformers ("step-downs") in groups of three, (4) rotary converters to change the A.C. current to D.C., (5) a third-rail conductor (sometimes with copper feeder), (6) a heavily bonded track return circuit, sometimes with feeders and "negative boosters."

Q. For the three-phase system what intermediate members are needed?

A. (1) Step-up transformers in groups of three, (2) triple transmission wires, (3) substation step-down transformers in groups of three, (4) two overhead contact wires, (5) a lightly bonded track return.

Q. What is essential with the two trolley wires?

A. To keep them separate, well insulated from each other, at equal height above the rail head.

Q. What intermediates are necessary with the single-phase system for long distances?

A. One step-up transformer, (2) a two-wire transmission circuit with substations each having a single trolley wire and lightly bonded track return.

CHAPTER LXXXV

THE ELECTRIC HEADLIGHT

Q. What are the principal parts of the Pyle electric headlight?

A. The turbine steam engine, the dynamo-electric generator driven thereby, and the arc lamp fed by the current from the latter.

Q. What are the principal parts of the dynamo?

A. The armature, the commutator, the field magnets, and the pole pieces.

Q. What is a magnet?

A. A body having a magnetic field, and two points called poles, and which has the power of (1) attracting the unlike poles of another magnet, (2) repelling the like pole of another magnet, or (3) attracting to either pole readily magnetizable bodies—such, for instance, as iron filings.

Q. Can a magnet have more than two poles?

A. No; but sometimes two or more magnets may be so placed together as to appear like a single magnet having more than one pair of poles.

Q. How many general classes of magnets are there?

A. Two; permanent magnets and electro-magnets.

Q. What is a permanent magnet?

A. One of hardened steel or other "paramagnetic" material, which retains its magnetism a long time after being magnetized.

Q. What is an electro-magnet?

A. One in which magnetism is induced by the passage of an electric current through a coil of insulated wire surrounding a core of magnetizable material.

Q. What name is given to the magnetizing coil?

A. A helix or solenoid; usually the latter.

Q. What is Ampere's rule for determining which pole of a bar magnetized by a coil is north?

A. To imagine yourself lying in the coil with your face towards the bar being magnetized, then the north-seeking (so-called "north") pole will be on your left.

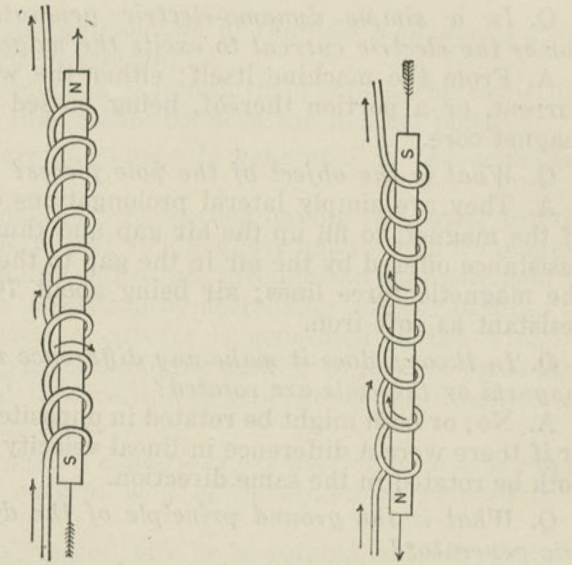


Fig. 404. Right-hand Coil. **Fig. 405.** Left-hand Coil.

Q. Give another rule?

A. With a right-handed coil the north pole will be at the end from which the current flows; with a left-handed coil, at the end toward which it flows. (See Figs. 404 and 405.)

Q. To what is the magnetic strength of an electro-magnet proportionate?

A. (1) To the strength of the magnetizing current (provided the core is not saturated) and (2) to the number of turns of the coil surrounding the magnet.

Q. What is the most usual shape of electro-magnets?

A. The U or horseshoe form, in which, for purposes of convenience, the bar or its equivalent is bent so as to bring the poles beside one another, the effect of the current being the same, as long as the flow is not reversed in passing from one end of the core to another.

Q. In a simple dynamo-electric generator, whence comes the electric current to excite the magnet core?

A. From the machine itself; either the whole of the current, or a portion thereof, being passed around the magnet core.

Q. What is the object of the pole pieces?

A. They are simply lateral prolongations of the ends of the magnet, to fill up the air gap and thus lessen the resistance offered by the air in the gap to the passage of the magnetic force lines; air being about 700 times as resistant as soft iron.

Q. In theory, does it make any difference whether the magnets or the coils are rotated?

A. No; or both might be rotated in opposite directions; or if there were a difference in lineal velocity they might both be rotated in the same direction.

Q. What is the ground principle of the dynamo-electric generator?

A. That when a magnet is moved near a coil of insulated wire forming a circuit, or the latter is moved near a magnet, a current of electricity is induced in the coil during the movement.

Q. What is this principle called?

A. Magnetic induction.

Q. If a bar magnet is moved in a coil, what results?

A. It induces in the coil a current, forming it into a coil magnet, the poles of which are in such position as to attract those of the moving bar magnet in the reverse direction to that in which they are moving, thus opposing the magnet's motion. This opposition must be overcome

by force, and the thus expended energy (less what is dissipated as heat) reappears as an electric current in the coil circuit.

Q. Does it make any difference whether the magnet is moved in the coil, or the coil is moved over the circuit, as far as the generation of the current is concerned?

A. No.

Q. What is the function of the field magnets in a dynamo-electric generator?

A. To produce a magnetic field which the armature coils cut as they rotate between the magnet poles.

Q. How are the currents generated in the armature coils?

A. By induction; magnetism having the power to produce electricity, just as electricity has to produce magnetism. When any coil passes through the magnetic field so as to cut an increasing or decreasing number of lines of magnetic force, a current is generated in the wire, in amount proportionate to the number of lines of force that are cut, and in direction dependent on the direction of motion of the wire.

Q. What partial conditions are necessary in order that the electric current may be generated or induced in a wire?

A. That a ring of wire be so rotated, actually or relatively, between the poles of the magnet, that it will cut the magnetic force lines passing between those poles.

Q. What governs the force of the current?

A. (1) The strength of the magnets, on which the number of force lines for a given area depend; (2) the number of turns of wire in the coil; (3) the rotation speed; that is the number of times the coil cuts the force lines.

Q. In what direction is the current generated in the rotating wire?

A. In both directions alternatively through the coil;

but the direction each time is governed by fixed laws. Suppose, for example, by referring to Fig. 406, the current passes from the north pole to the south pole from left to right, and the coils rotate in the opposite direction to the hands of the clock, the current will be induced from back to front in each wire of the armature coil as it passes before the north pole and cuts the force lines from above, and from front to back when during the next half rotation it passes before the south pole and again cuts the force lines, this time from below.

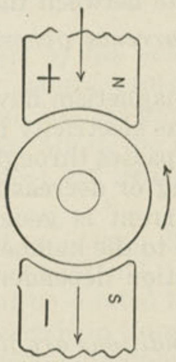


Fig. 406. Generator.

Q. How can these alternate currents be brought into use as a continuous current?

A. By the commutator, in which one end of the wire passing round the coils is attached to one strip of brass or copper lying along the circumference, and the other end to another, which, if there are but two poles to cut, is exactly diametrically opposite. Two metal springs pressing against these strips enable the current to pass from the machine through one outer conducting wire, and back again through the return conductor to the other strip, thus completing the circuit. During one-half rotation of the machine the current flows from the first strip

through the first wire, back through the second wire to the second strip; then during the next half rotation from the first strip to the second wire, back through the first wire to the second strip, thus again completing the circuit, and making of all the short currents one practically continuous one.

Q. How is the commutator attached to the armature?

A. It is on the same shaft and rotates therewith.

Q. Are all dynamos as simple as that just described?

A. No; where there are many armature coils there are as many pairs of commutator strips, insulated from each other by mica.

Q. Of what character is the magnet in the ordinary dynamo?

A. It is of soft iron, in which magnetism is excited by coils of wire surrounding it. Simple machines excite themselves by the current which they generate; in others, there are separate generators for this purpose.

Q. What sort of excitation is desirable where the working is constant, as where there is only one lamp to light?

A. The magnets may be excited either (1) by passing around them all the current from the machine, in which case the machine is said to be "series excited"; or (2) by using separate generators to excite the principal one, thus keeping the magnetic field constant. (Fig. 407.)

Q. What sort of excitation is desirable where the external work is subject to variation?

A. To shunt off a portion of the main current to do the excitation. This may be done either (1) by dividing the current, as it leaves the armature, into two branches, one for the magnets and the other for the external circuit (Fig. 408) ; or (2) by dividing the current into two branches, one of fine wire of high resistance, which goes around the magnets only; the other of larger wire which not only forms the external circuit, but also goes round the magnet.

Q. What is a direct-current dynamo?

A. One which by means of a commutator brings all the currents together into one continuous stream.

Q. What is an alternating-current machine?

A. One in which the currents are generated, constantly reversed in direction, at intervals imperceptibly minute.

Q. What are the principal classes of electric lamps in use?

A. (1) Arc and (2) incandescent.

Q. Which are the most powerful?

A. The arc lamps.

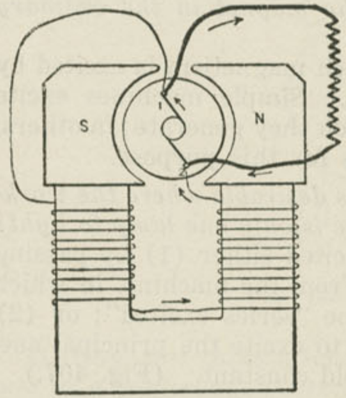


Fig. 407. Series and Shunt.

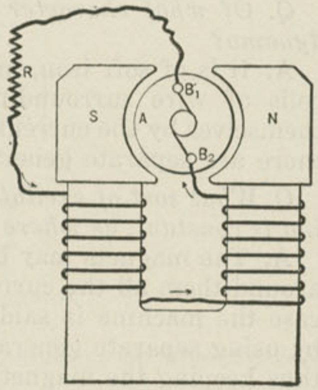


Fig. 408. Series Wound.

Q. How many volts of current are produced when the dynamo of the Pyle electric headlight makes 1800 turns a minute?

A. Thirty-five.

Q. How many amperes?

A. Twenty-three.

Q. What would be the result of short-circuiting?

A. Increased voltage, or tension, of the current.

Q. How may one determine in which direction the current shows?

A. The point of the positive pole is heated up first.

Q. How can the engineman know when the speed is dangerously increased?

A. By the copper point giving off a green light.

Q. What is to be done in such a case?

A. The steam is to be throttled.

Q. What else can cause green light besides excessive speed?

A. Wrong attachment of the wires, that is, the negative wire attached to the positive binding post.

Q. How is the engineman to know whether the green light is caused by too high speed or by wrong connections?

A. Too high speed causes gradual change from green to white light; crossed wires cause green light at once.

Q. On what principle does the Pyle arc lamp work?

A. If a conductor carrying an electric current be divided and the two ends slightly separated, the current will cross the space between them; but as this break offers a resistance to the passage of the current, heat, which is the result of resistance, is produced; the greater the resistance the more the heat. If at each end of the broken conductor a piece of carbon be attached and the two brought close together, the heat generated by the resistance will cause them to glow; there will be formed a so-called Voltaic arc. Part of the carbon will be volatilized, light being caused by the intensely heated carbon vapor, and by the glowing carbon points themselves. The carbon will naturally be gradually consumed. A reflector back of the arc directs its rays, which pass in all directions therefrom, in a parallel beam.

Q. In what direction is the current supposed to pass?

A. From the carbon representing the north pole and marked + (plus) to that representing the south pole and marked — (minus).

Q. Do both carbons burn away equally?

A. No; the positive one burns away twice as fast as the negative, and gets hollow at the end, while the latter keeps its original pointed shape.

Q. In what relative positions are the carbons placed?

A. In a vertical line, with the positive one above; its hollow end serving to throw the light downward.

Q. If the carbons burn away, how is the light maintained?

A. By clockwork or other mechanical arrangement, which keeps them at a constant distance.

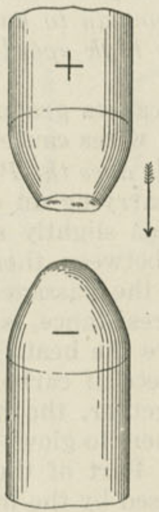


Fig. 409. Carbons.

Q. What may be said of the rate of burning of the two carbons in lamps fed from alternating-current machines?

A. Both burn away equally; there is then neither permanent north nor permanent south pole.

Q. What is an incandescent lamp?

A. One in which the current carried by a copper conductor meets with a resistance in the body of the lamp, in the shape of a fine filament, usually of carbon, which glows by reason of the heat generated by the lamp's resistance.

Q. Why is not the filament consumed by the heat?

A. Because there is no air in the glass bulb, and oxygen, which is contained in air, is necessary to support combustion.

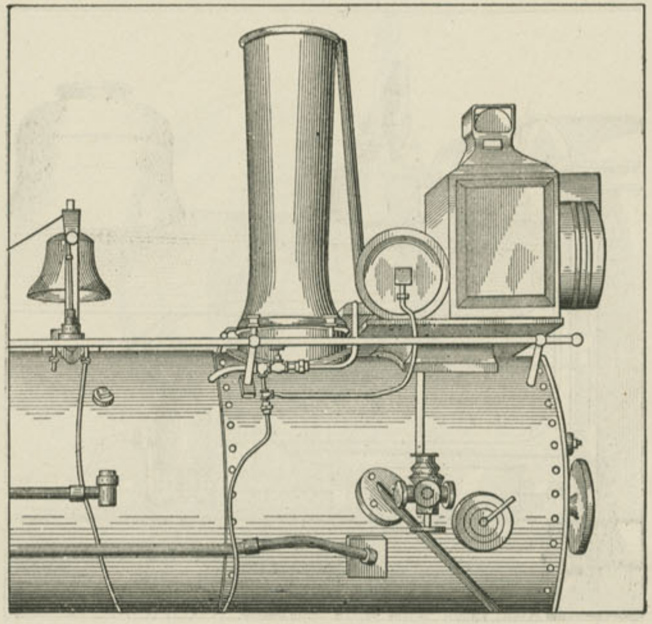


Fig. 410. Pyle Electric Headlight.

Q. How is the arc of the Pyle electric headlight lamp produced and kept up?

A. There is a long spiral called a solenoid, through which passes a soft iron core which is made a magnet by the action of the electric current flowing through the solenoid. When the current flows in the coils and the carbons are being consumed, the arc grows longer, the strength of the magnet in the solenoid lessens, and at a certain degree of weakness the magnet lets go of the clutch which holds the upper or positive carbon, letting it start to drop towards the under one; but before it can reach this, which would put out the light by diminishing the resistance, the magnet is again strengthened, and hinders further downward movement.

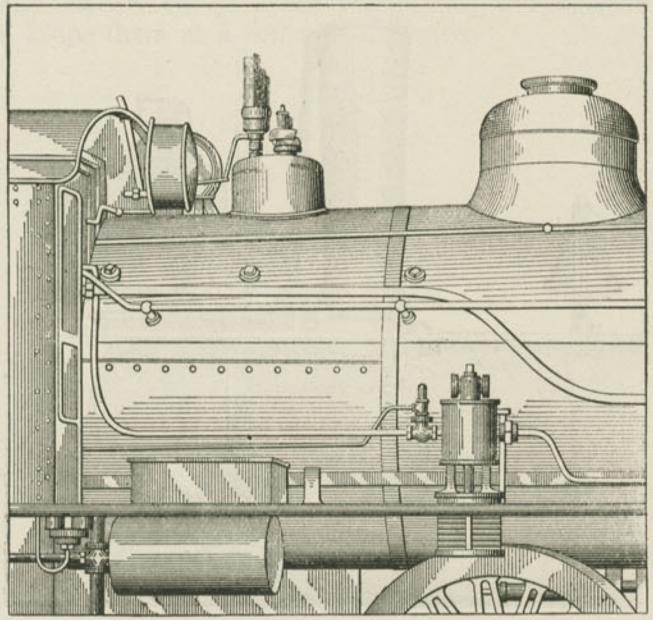


Fig. 411. Pyle Electric Headlight Engine.

Q. Does not this alternating action cause flickering of the lamp?

A. It is softened by the use of a dash pot.

Q. Has the Pyle lamp two carbon poles or electrodes?

A. No; the upper one is of carbon and the lower of

copper, improperly called by the maker "the" electrode. As a matter of fact, both poles are electrodes.

Q. What happens to the carbon electrode in the act of burning?

A. It becomes hard and burns away.

Q. What happens to the copper electrode?

A. It becomes covered with scale, which must be cleared off from time to time.

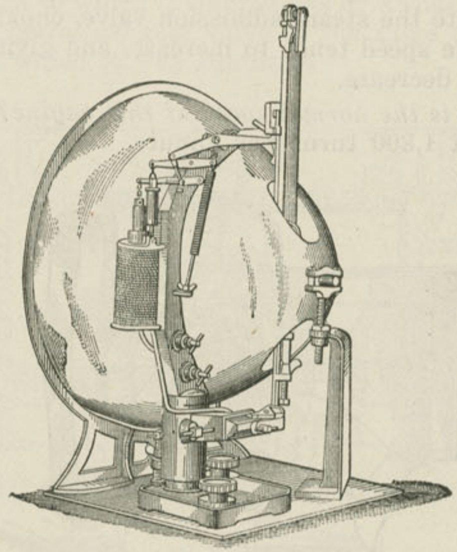


Fig. 412. Rear View of Lamp and Reflector.

Q. Describe the engine which drives the dynamo in the Pyle electric headlight equipment?

A. The principle is the same as that governing the ordinary turbine waterwheel; there is a rotating casing having jets or passages set obliquely to the radii; steam emerging from this at high pressure drives the wheel around at high speed, partly owing to the fact that the jets of steam issuing in one direction at an angle to the radii strike other passages in the casing, inclined in the opposite direction. The general principle is that the steam must enter the wheel at maximum velocity, and leave it with practically none at all, its force and motion being imparted to the wheel.

Q. What controls the speed of this engine?

A. A governor of the so-called centrifugal type, having weights revolving about an axis and tending to separate with increase of speed and close up towards the axis. They operate the steam admission valve, choking off the steam if the speed tends to increase, and giving more if it tends to decrease.

Q. What is the normal speed of this engine?

A. About 1,800 turns per minute.

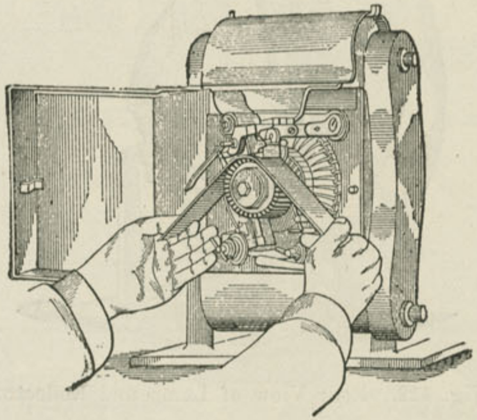


Fig. 413. Method of Smoothing Up the Commutator.

Q. Suppose the speed should reach a point at which the governor could not control it?

A. There would come into play a centrifugal brake, set to act at about 150 turns more than the governor.

CHAPTER LXXXVI

UNAFLOW LOCOMOTIVE

Q. What is a "Stumpf" or unaflow engine?

A. One in which the steam flows in only one direction, instead of reversing its flow and being exhausted out of the same port to which it entered (as by a slide valve) or through a special exhaust valve in the same end of the cylinder by which it was admitted.

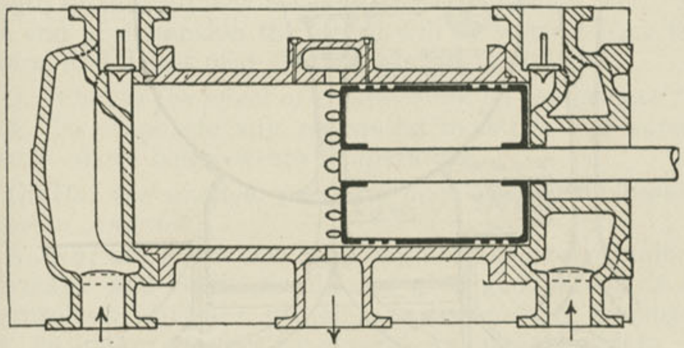


Fig. 414. Lengthwise Section of Unaflow Cylinder.

Q. How is this accomplished?

A. By having the steam enter at one end of a double-ended or double-acting cylinder (preferably after having heated the surface of the head); then pass through an admission valve placed as far as possible from the supply pipe in the cylinder head; then after doing useful work, driving the piston first by direct pressure, then by expansion, exhaust through ports at the far end of the stroke; i. e., at the middle of length of the double-acting cylinder. (See Fig. 414.)

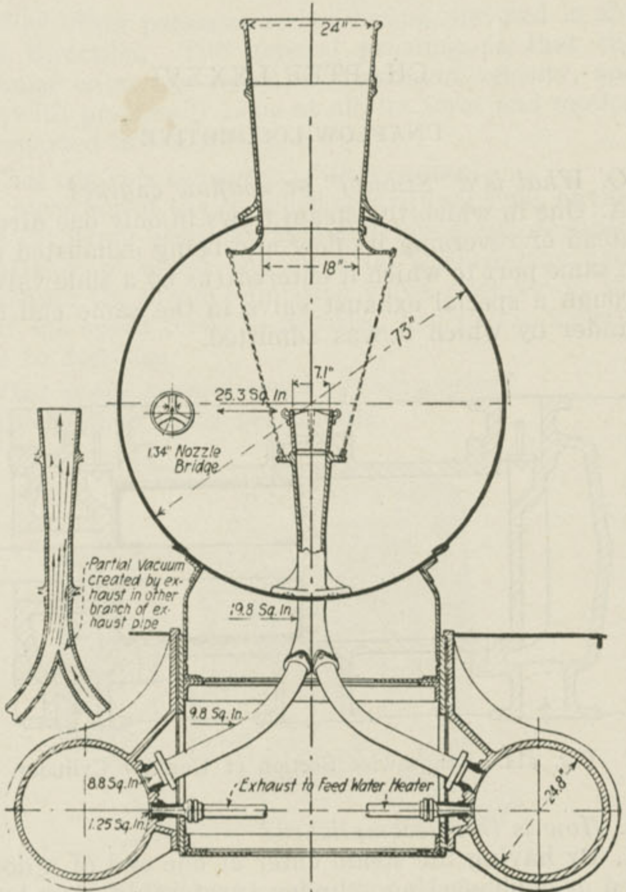


Fig. 415. Unaflow Locomotive Cylinder and Exhaust Ejector Details.

Q. *How are these exhaust ports kept closed except during the exhaust periods?*

A. By having the piston long enough to cover them except during these periods.

Q. *What is the object of this arrangement, as distinguished from the usual "counterflow" system?*

A. To avoid cooling the clearance-space surfaces, hence lessen cylinder condensation.

Q. *What about the steam temperatures during this entire stroke?*

A. The steam nearest each hot admission end gets heat during expansion, exhaust and compression; remaining dry; while that in the exhaust portion in the middle of length of the cylinder becomes correspondingly wet. At the end of expansion the steam will be wettest near the piston and driest near the hot admission end.

Q. *What is the effect of compression on the exhaust?*

A. To evaporate any remaining moisture and superheat it above boiler-steam temperature.

Q. *Has the unaflow principle been applied to locomotives in America?*

A. No; but about 200 such engines have been built in Germany and Switzerland, and give good accounts of themselves. But the principle is successfully employed for stationary engines by several American builders.

Q. *What peculiarity has the exhaust of the unaflow locomotive?*

A. The exhaust pipes are joined at acute angles (see Figs. 415 and 416) so that a jet-ejector action is obtained; because an engine with two cranks and 25-per cent. exhaust lead will produce sufficient overlap of the exhaust periods that the exhaust of one cylinder begins before the other has ceased.

Q. *What is the desirable result?*

A. To diminish back pressure, and the clearance volume.

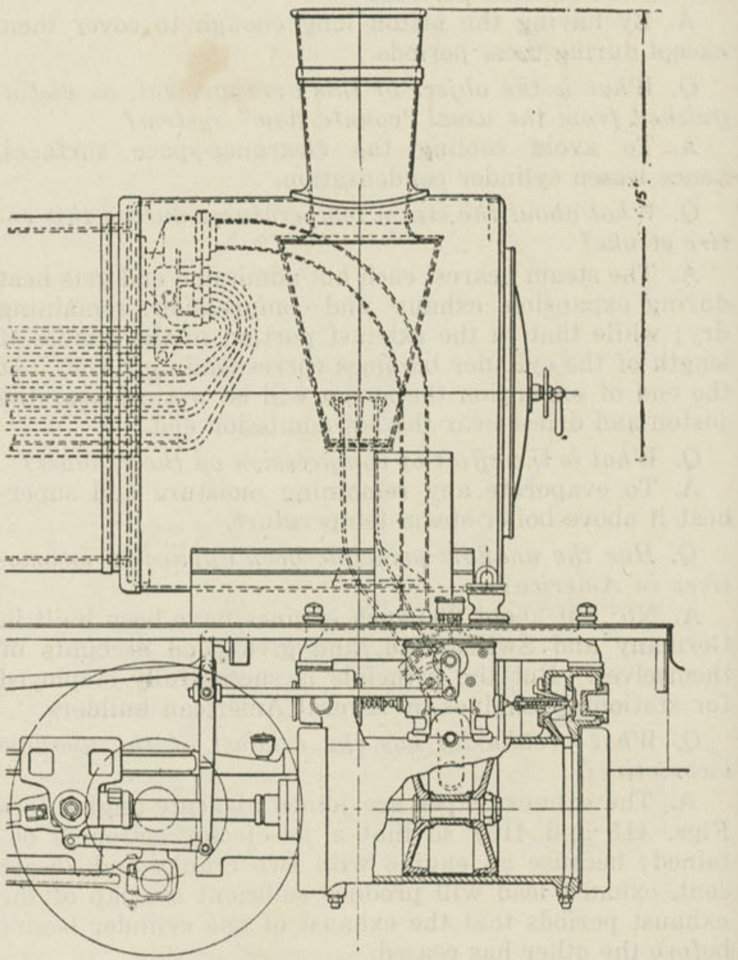


Fig. 416. Unaflow Locomotive Cylinder and Exhaust Ejector Details.

Q. Show graphically the gain in engine efficiency of the unaflow cylinder operating with the exhaust ejector?

A. As given in Fig. 417 in which the shaded areas *A* and *B* combined represent cylinder loss due to incomplete expansion. Since the exhaust ejector is effective during only a part of the exhaust period, the area *A* represents all that loss which can be used to create a vacuum in the other cylinder; area *B* being lost. On the return stroke the shaded area *C* represents the gain due to the reduced back-pressure caused by the exhaust of the other cylinder.

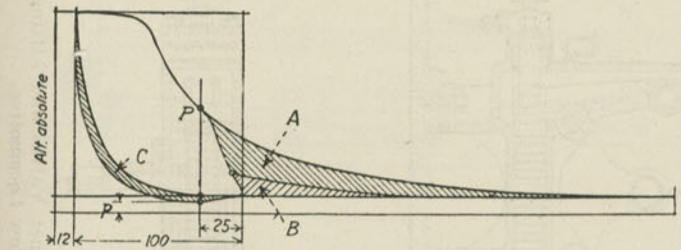


Fig. 417. Back Pressure Diagram.

Q. How is uniform draft secured?

A. By a large exhaust lead and small exhaust port area.

Q. What does this affect?

A. Shortening of the compression.

Q. What is a special advantage of the unaflow principle at very short cut offs?

A. Throttling is never necessary.

Q. What kind of distributing valves are used?

A. Piston valves on some, double-beat poppets on others.

Q. What is the usual objection to a single-beat poppet?

A. It requires a high lift, and a large force to raise it.

Q. Why then can it be used on a unaflow engine?

A. On account of the high compression, that balances the pressure considerably.

Q. How is it given high lift?

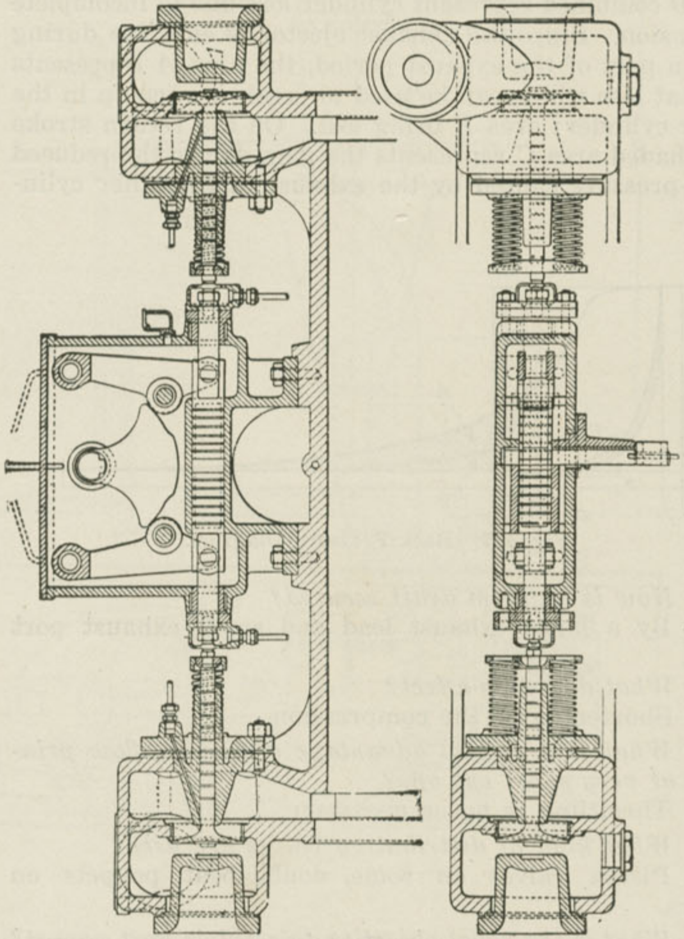


Fig. 418. Details of Poppet Valves and Lifting Mechanism, Unaflow Locomotive.

A. By arranging a cam roller between the valve and the valve-lever fulcrum, as seen in Figs. 418 and 419.

Q. How is coasting managed?

A. By raising the valves from their seats by compressed air admitted between small pistons formed on the valve tappits so that the roller will clear the cam. (See Fig. 419.)

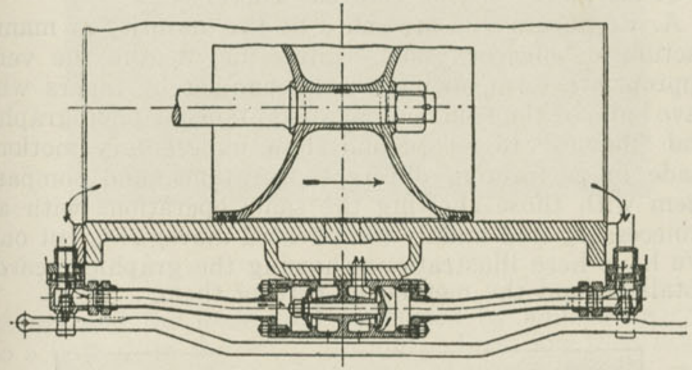


Fig. 419. Compression Release Valve for Unaflow Locomotive Cylinders.

Q. How is this air controlled?

A. By a valve in the cab.

CHAPTER LXXXVII

MOTION RECORDS

Q. How are "motion records" made?

A. Engineers who are called by the majority of manufacturers "efficiency men," altho they loathe the very appropriate term, owing to the number of fakers who have entered the field, employ instantaneous photography and "movies" to record and show unnecessary motions made in performing different operations, and compare them with those showing the same operations with all unnecessary and unduly complicated movements cut out. We have here illustrations showing the graphic records obtained, and the method of getting them.

Fig. 420.

The object here is to demonstrate the advantage of opening and closing a locomotive fire door by steam instead of by hand. A tiny incandescent lamp is attached to various parts of the fireman's person, and to the

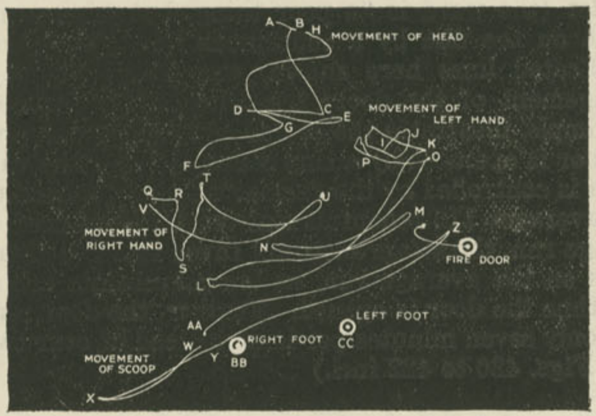


Fig. 421.

shovel and the door, and connected by suitable wiring to a battery in the cab. Motion pictures are then taken of his movements under both sets of conditions; each

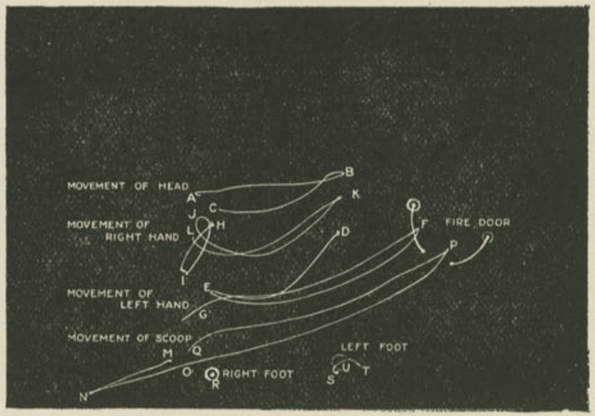


Fig. 422.

lamplet (the word is "a poor thing, but mine own") is shown on the film by a continuous line. The series of complicated lines here shown, was taken during hand management of the door; the other, much more direct and simple, illustrates the course of each tiny lamp where the door is operated by a tiny steam cylinder the valve to which is controlled by the fireman's foot. As each ton of coal averages 115 scoopfuls and ten tons are used on an average run, the steam assistant saves 11,500 body movements on the average run, as ten movements are saved each time the door is opened. Further, the door remains open only seven minutes per hour instead of over twenty. (See Figs. 420 to 422 incl.)

AIR BRAKE
SECTION

BRAKES

CHAPTER LXXXVIII

GENERAL PRINCIPLES OF BRAKING

Q. What forces tend to stop a train?

A. Friction between brake shoes and wheel treads, journals and their bearings, and wheel treads on the rails. Incidentally, the resistance of the atmosphere, if the wind direction is unfavorable.

Q. What is the result when shoe and wheel friction is greater than rail and wheel?

A. Locked wheels and sliding.

Q. What limits the amount of pressure that the shoes should apply?

A. The rail and wheel friction.

Q. What also must a brake do, besides counteracting train momentum?

A. Prevent accumulation of energy, as on down grades.

Q. What momentum must be overcome, in braking, besides that of the train as a whole?

A. That due to the wheels' rotation.

Q. What are called for on a theoretically perfect brake?

A. According to Turner, it "must be automatic, durable, simple, always ready, responsible and flexible; the latter of which involves the elements of power, time and amount of reduction;" and in an emergency the maximum power must be combined with minimum time and reduction. Also, for regular operation trains must be handled without shock, and stops be made accurately; that is, with a medium between full braking and drifting.

Q. What are the measures of brake value?

A. Ability to stop the train quickly when necessary, and to make quick, short, smooth, accurate stops in regular operation.

Q. What use has the brake, other than as a safety device?

A. It permits hauling heavier cars, and faster and more frequent service.

Q. Which is the more powerful—the locomotive, or the brakes; and why?

A. The brake, because it can stop a train in much less time and distance than that required for the engine to attain, from a stop, the speed at which the brake is applied.

Q. What effect on train resistance has the cooling of the car journals at a stop?

A. To increase it.

Q. What are the various sources of resistance to car movement besides that between wheel and rail.

A. Compression of the track, concussions, rolling of the wheels on the rail; oscillations, flange friction.

Q. What other resistances are there besides these and journal friction?

A. Atmospheric resistance, even with still air.

Q. What effect has train speed on journal friction?

A. Little or none, between ordinary limits.

Q. What effect has increased train speed upon resistance between wheel and rail?

A. To increase it.

Q. On atmospheric resistance?

A. To increase it as the square of the speed; that is, twice the speed four times that resistance; three times the speed, nine times (other things being equal).

Q. How may the speed of an engine or of an engine-drawn train be checked?

A. By shutting off steam and by the application of brake shoes to the wheel treads.

Q. How do the usual brakes lessen the train speed?

A. By increasing the friction so that the momentum of the train is checked.

Q. With proper application of the brakes, what should receive the wear?

A. The wheel treads should get some, but these being of steel or chilled iron, the brake shoes get most of it; which is right, as they are the cheaper to renew, and outside of the question of cost their wear is of less consequence.

Q. Are the brake shoes always applied to the wheel treads?

A. Usually; but experiments have been made to apply them to iron drums borne on the axles, and the wear of which would be of less consequence than that of the wheel treads.

Q. What would be the proper place to apply the brakes?

A. To the rails, thus making friction between the train as the moving member of a pair, and the track as the stationary member, and doing away with the possibility of floating the wheels.*

Q. What is the principal difficulty in this?

A. The uneven character of the rails, particularly at the joints.

POWER BRAKES

Q. Into what classes may power brakes be divided?

A. Into pneumatic or air, hydraulic, water (as distinguished from hydraulic) and electric.

Q. Which of these mediums is at present almost universally employed?

A. Pneumatic or air.

Q. What are the sub-classes of this type?

A. The "straight-air" or compressed-air, and the automatic or vacuum, with its various subdivisions.

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* This was first suggested to the writer by the late John C. Trautwine (first of this name), in his time the most eminent of American civil engineers, and received the endorsement of many prominent in practical matters. It has been put into practice by the builders of electrical locomotives.

THE STRAIGHT-AIR BRAKE

Q. What is a straight-air brake?

A. One in which the brakes are applied by pressure from a cylinder and piston under each car, the motive fluid being compressed air in a reservoir under the engine and having a valve controlling the flow of air to the brake pipe.

Q. What were the working parts of the straight-air brake on the engine?

A. An air compressor to compress the air, a main reservoir to contain it, and a three-way cock or engineer's valve.

Q. What parts on each car?

A. Its portion of the continuous brake pipe, and a brake cylinder with its piston.

Q. How were straight-air brakes applied?

A. The three-way cock was placed in such position that the main reservoir pressure flowed into the brake pipe, forcing out all the pistons in the various brake cylinders under the cars.

Q. What are the disadvantages of this class of brake?

A. In a long train it takes too much time for the air to flow from the engine reservoir to the rear cars; and in case the train parts, only the front portion, which least needs control, may be checked by the brake; the rear part being left free, which might lead to danger, as on an up-grade, where there would be nothing to prevent its running down.

Q. What would be the effect of applying the brake first at the head of the train?

A. The slack would run into the head end.

Q. What was the effect of a burst hose with this brake?

A. To throw the brake out of service.

Q. What were the special disadvantages of this brake for long trains?

A. The brake pipe was of so large volume in comparison with the reservoir, that the pressure would be lowered, and it would be necessary to pump up while setting the brakes.

Q. What was the effect of air friction in the brake pipe in a long train?

A. To reduce the speed with which the air was applied, and the pressure obtained on the rear cars.

Q. Where is the straight-air brake now used?

A. On engine and tender, only.

Q. What extra parts are necessary?

A. Reducing valve, engineman's straight-air brake valve, double-seated checks for driver-brake and tender-brake cylinders; a safety valve for each of these last; straight-air hose from engine to tender.

Q. Can it be used in combination with the automatic brake?

A. Yes.

AUTOMATIC BRAKES

Q. What is the difference between automatic and a straight-air brake?

A. The former type will brake the train automatically in case of a burst hose, or if for any other cause the compressed-air supply failed.

Q. What is the difference in the equipments?

A. The automatic type has on each car a triple valve (its essential feature) and an auxiliary reservoir.

Q. What is the difference in action?

A. Owing to the reservoir under each car, that particular car has efficient braking power, irrespective of the length of the train; parting of the train applies the brakes, instead of making that impossible.

Q. How can the automatic brakes be released after they have been applied?

A. By so turning the engineman's valve as to close the opening by which air may escape from the brake pipe, and let air flow from the main reservoir to the brake pipe, this latter moves the triple valves so as to let the air out of the cylinders and release the brakes.

Q. Can a continuous brake system work with some of the cars straight-air and the rest automatic?

A. No; it must be either one thing or the other.

Q. How can the brake on any one car be thrown out of service without affecting those on cars before and back of it?

A. By closing the cut-out cock.

Q. How many kinds of automatic brakes are there?

A. The plain automatic, the quick-action, the high-speed.

Q. Is the plain automatic brake now used?

A. No.

Q. Is the quick-action style used?

A. Yes, for ordinary passenger and freight cars.

Q. On a locomotive with combined automatic and straight-air, what would be the result if the automatic was applied while the straight-air brake was partially on?

A. In releasing the automatic, the air could not escape through the triple, and there would be air connection between the straight-air valve and the cylinder. This would call for putting the straight-air brake valve handle in "release."

Q. What would happen if straight-air was applied while the automatic was partly on?

A. The brakes on engine and tender could not be let off entirely without putting the engineer's automatic brake valve either at "running" or at "release."

"QUICK-ACTION" BRAKES

Q. What is the so-called quick-action brake?

A. The first successor of the plain automatic on both passenger and freight trains.

Q. In what did it differ from the plain automatic?

A. In the triple-valve.

Q. What disadvantage of the plain automatic did it overcome?

A. The trouble with emergency stops on long trains, where the head brakes set comparatively too soon and the slack ran into the front cars.

"HIGH-SPEED" BRAKES

Q. How can an ordinary quick-action passenger car equipment be converted to high-speed?

A. By adding a reducing valve, two feed valves on the engine (one connected with a reverse-cock pipe bracket, the other replacing the feed valve on the G-6 brake valve). A duplex pump governor is also necessary.

Q. Why have two feed valves?

A. One for the high-speed and the other for the ordinary quick-action brake.

Q. What is the cause of the more rapid action as compared with the quick-action type?

A. The pressure is higher, hence the air flows more rapidly from the auxiliary reservoir to the brake cylinder.

Q. How should this type be applied?

A. By two applications.

Q. Why?

A. There can be made two 20-lb. full-service reductions and releases and still leave 70-lbs. pressure.

Q. What are the elements of the high-speed brakes?

A. (1) A special driver and engine-truck brake triple valve; (2) a cut-out cock; (3) an automatic reducer to keep 60 pounds in the brake cylinder; (4) a quick-action triple valve for the tender instead of the usual one; (5) a safety valve for extra cars temporarily attached to high-speed trains and having no automatic reducer; (6) a reversing-cock.

Q. How may the locomotive equipment shown in Fig. 444 be changed from "quick-action" to "high-speed"?

A. By turning the handle of the reversing cock and that of the cut-off cock in the pipe leading to the 90-pound governor. This changes the brake pipe pressure to 110 instead of 70 pounds, and the main reservoir pressure to 130 pounds.

Q. How much faster is the "high-speed" than the "quick-action"?

A. About 30 per cent. quicker stops can be made.

Q. What is the quick-action cylinder cap?

A. A cap used with the distributing valve to get emergency quick-action by venting part of the brake-pipe pressure into the locomotive brake cylinders.

THE LOCOMOTIVE BRAKE EQUIPMENT

Q. What is the purpose of the brake equipment on a locomotive?

A. To safely and adequately control the speed.

Q. On what principle does this equipment operate?

A. Brake cylinders, operated by compressed air, have their piston rod connected, through a suitable system of rods and levers, to brake shoes which in application are pressed against the treads of the wheels, and the friction thus caused by their rubbing tends to retard the rotation of the wheels.

Q. What is the usual arrangement of brake cylinders?

A. The driving wheels usually have one brake cylinder for each side of the engine, making two driver brake cylinders; four-wheel pony trucks have a cylinder mounted on the truck; two-wheel trailer trucks often

have an independent cylinder mounted on the truck; and the tender has one cylinder which takes care of both trucks.

Q. What are the principal parts of the locomotive brake equipment?

A. (1) The air compressors, which compress atmospheric air to the required pressure; (2) the compressor governor, which controls the operation of the compressors and limits the maximum air pressure; (3) two or more main reservoirs which receive and store the compressed air delivered by the compressors and catch the water and oil which condense when the air cools after being compressed; (4) coils of cooling pipe which are placed between the compressor and main reservoirs, and also between the main reservoirs themselves, and which radiate the heat of the compressed air and condense the moisture and oil vapor in the air; (5) brake valves for the operation of the brakes, and the control of the flow of air to the brake system from the main reservoirs; (6) feed and reducing valves for regulating the pressure of the air in the brake system; (7) some type of operating valve, such as the distributing valve, triple valve, etc., which automatically controls the flow of air to and from the brake cylinders to apply and release the brakes; (8) the brake cylinders which transmit the force of the compressed air to the rods, levers and brake shoes; (9) a system of piping which connects these various devices and which contains the necessary cutout cocks, dirt collectors, hose and couplings, pressure gages, and various fittings for proper operation.

Q. What equipments are most usually found on locomotives?

A. The most used is the "ET" which is now practically standard. The "LT" is much like it with a different kind of operating valve. The "A-1" is the old standard automatic brake, to which is often added the "SWA" schedule which is a straight air type. With this older type of equipment, the tender was braked like a car in the train, and to obtain straight air operation on the tender, schedule "SWB" was added.

Q. What are the principal differences among them?

A. In the type of operating valves. The "ET" uses the distributing valve; the "LT," the control valve; while the "A-1" and "SWA-B" uses triple valves like those used on cars.

Q. What devices are common to all brake equipments?

A. The air compressors, governor, main reservoirs, brake cylinders, and many of the fittings in the pipe lines.

THE AIR COMPRESSOR

Q. What is the use of the air pump or compressor?

A. To charge the main reservoirs with air under high pressure, as indicated by the pressure gage in the cab.

Q. How many types of compressor are there?

A. Two: simple or single-stage, and compound. (Very often two are used; either both on the same side of the engine or one each side.)

Q. Whence is their power derived?

A. Their steam cylinders get live steam directly from the boiler.

Q. What is the object of the circular ribs on the 9½″ compressor air cylinder?

A. To facilitate cooling it, as compression generates heat.

Q. How many sizes of the single-stage compressor are there?

A. Two: the 9½″ and the 11″.

SINGLE-STAGE AIR COMPRESSORS

Q. Describe the Westinghouse single-stage air compressor.

A. There is an air cylinder, Fig. 423, surmounted by a double-acting steam cylinder, supplied from the boiler,

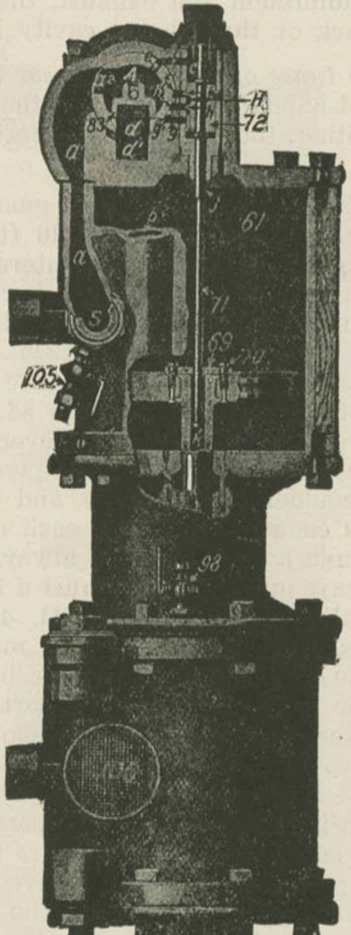

Fig. 423. Section of Compressor Through Reversing Valve.

the two pistons being on the same rod; a valve motion controls steam admission and exhaust, the latter going to either the stack or the exhaust cavity in the saddle.

Q. How many types of this compressor are there?

A. Two: right-hand and left-hand; the latter being applicable on either the right or the left side of the engine.

Q. Describe the steam valve of this pump.

A. As in Figs. 423, 424, 425 and 426 (the two latter being merely diagrammatical) steam enters at the steam inlet, passing through a, a^1 to the chamber A, above the main valve 83 and between the unequal diametered pistons 77 and 79 (connected by stem 81) through e to chamber C, containing the reversing valve 72, that controls these pistons and the main valve 83, and is itself worked by the rod 71, struck by the reversing plate 69 on the main piston 65. This plate engages alternately the reversing shoulder j (Fig. 424) and the button k. A and C always communicate with each other and the steam inlet through a^1 and e; hence always contain live steam. E is always open to the exhaust d through t and t^1 (see main valve bushing, Figs. 424, 425, 426). A balancing port s (Figs. 423, 425, 426) meets a groove down the outside of the reversing-valve bush, where it enters the upper cylinder through a port in the head. Its object is to keep the same pressure above the reversing rod as below. When valve 72 is in lower position (Figs. 423, 425), D is connected (through h, h^1, H [Fig. 423], f and f^1) with the main exhaust passage d, d^1, d^2; so that there is only atmospheric pressure to right of 77. The latter has pulled 79 and main valve 83 with it to position shown in Figs. 424 and 425. The main valve 83 then admits steam below piston 65, through b, b^1, b^2, raising it and causing exhaust through c^1, c, B, d, d^1, d^2, to the connection *Ex;* thence to the outer air. At top stroke end, rod 71 reverses 72 and opens g (Figs. 423, 426). Steam from C enters D through bushing ports

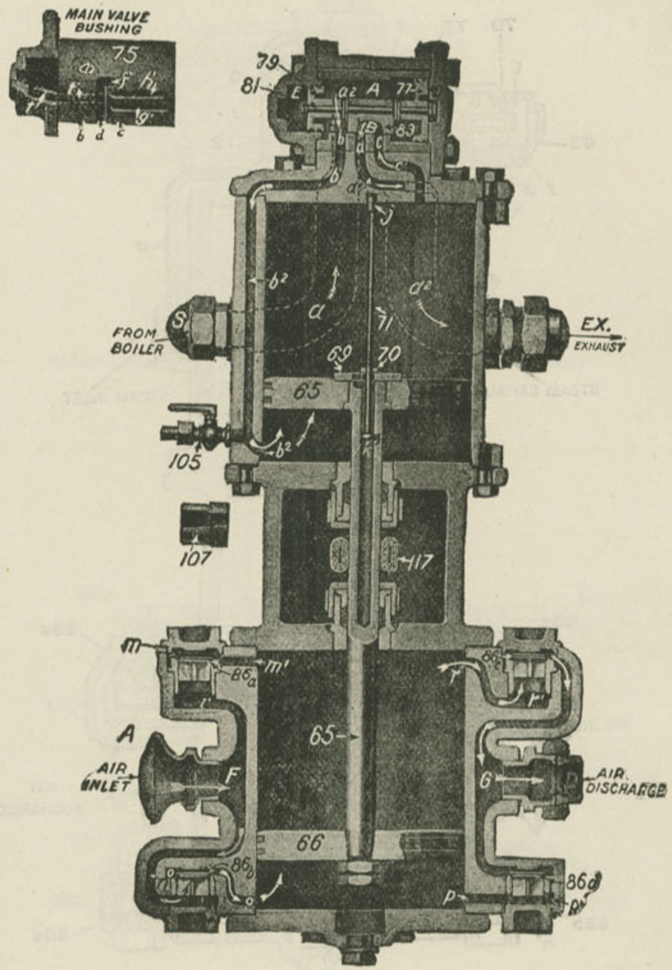

Fig. 424. Section of Compressor Through Main Valve.

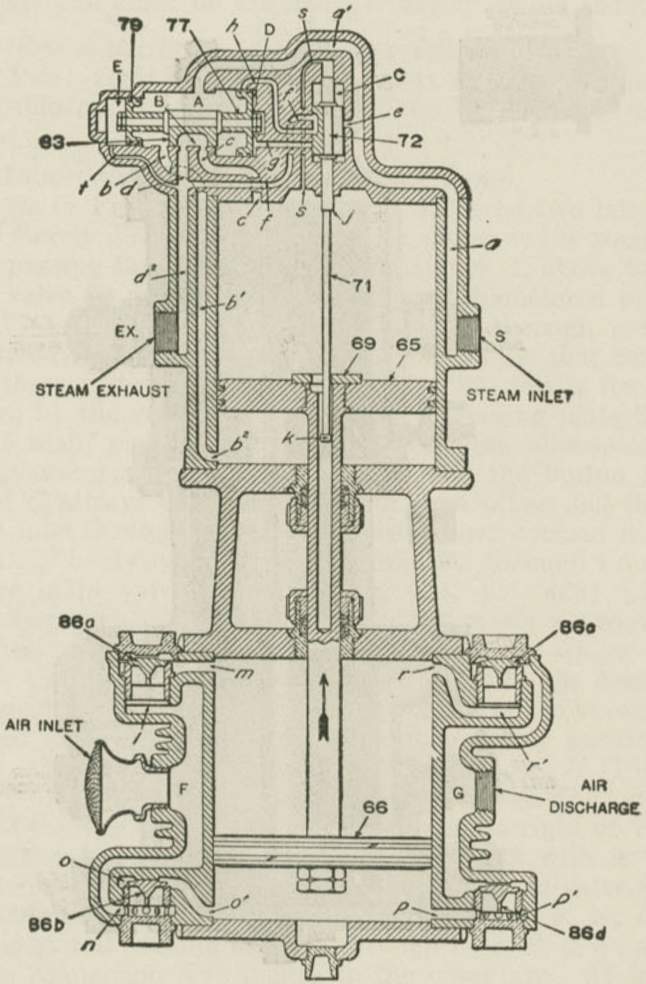

Fig. 425. Diagrammatic View, Up Stroke

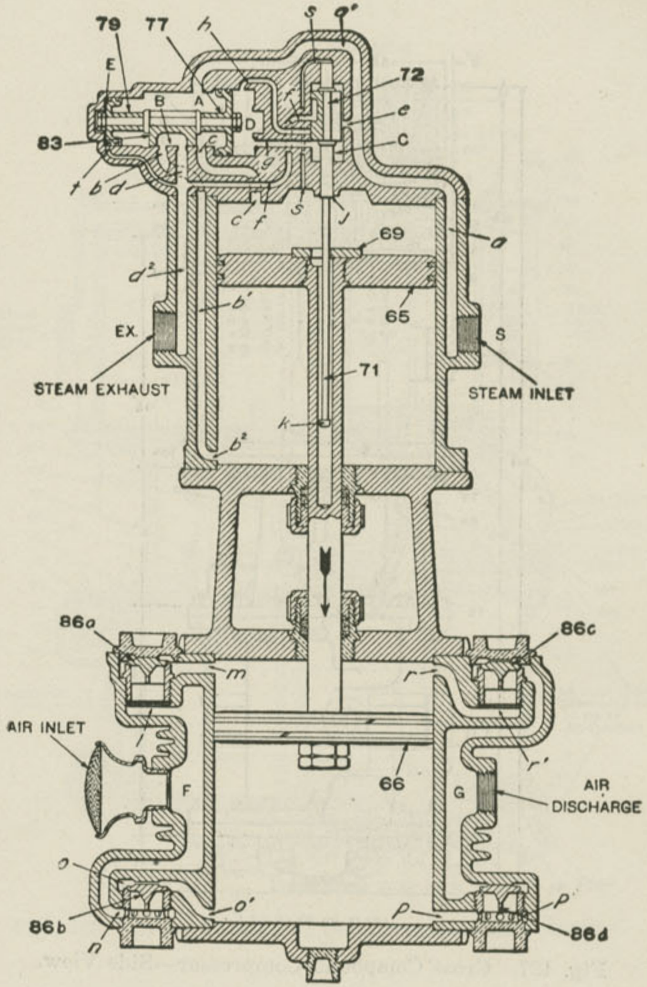

Fig. 426. Diagrammatic View, Down Stroke.

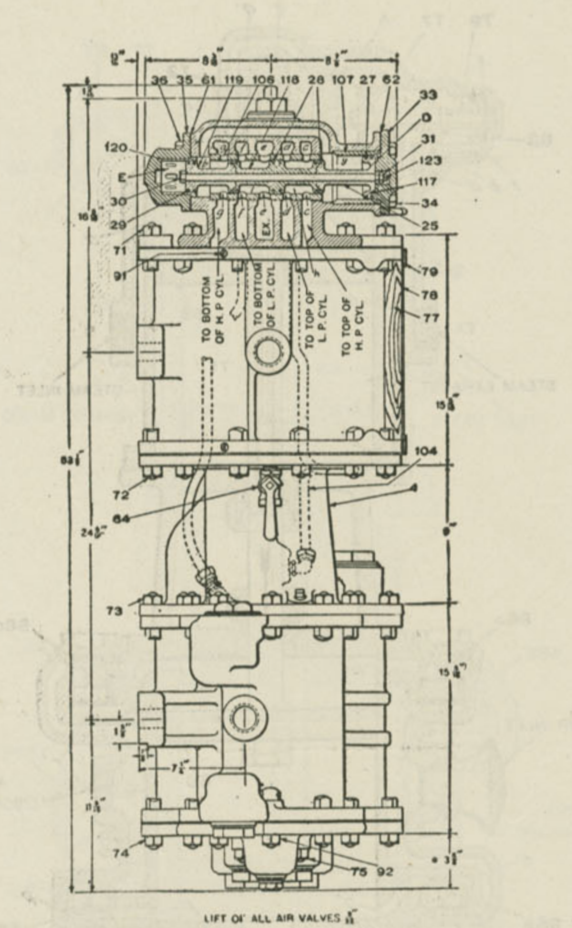

Fig. 427. Cross Compound Compressor—Side View.

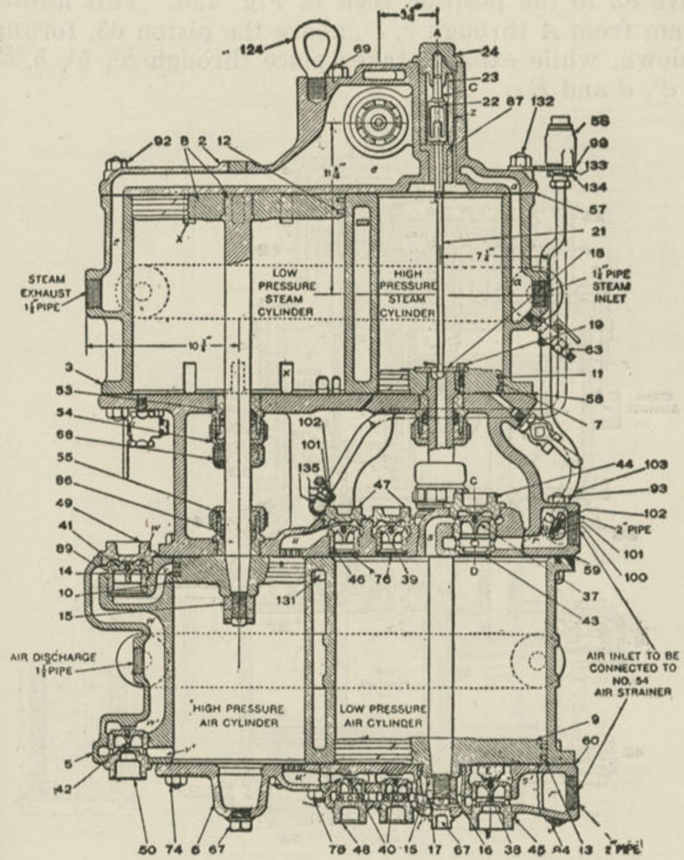

Fig. 428. Cross Compound Compressor—Front Section.

g, g^1, balancing pressures on 77, so that the steam in A forces 79 to the left, drawing with it 77 and the main valve 83 to the position seen in Fig. 426. This admits steam from A through c, c^1, above the piston 65, forcing it down, while exhaust takes place through b^2, b^1, b, B, d^2, d^1, d and Ex.

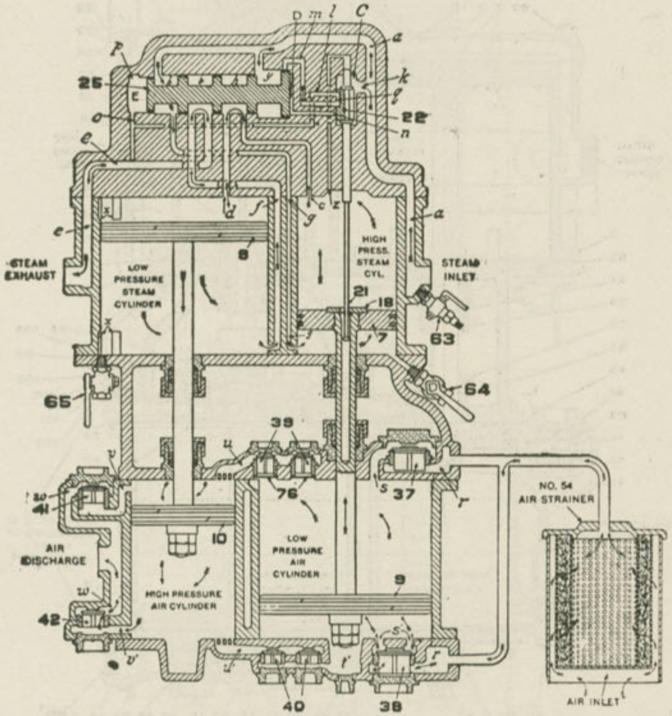

Fig. 429. Cross Compound Compressor, Diagrammatic

Q. What is the construction and operation of the air end of the compressor?

A. As seen in Figs. 423, 424, 425 and 426, its piston is actuated by that of the steam end. On the up-stroke,

the air thereby compressed is confined by the upper inlet valve 86a. When the pressure in r, r^1 is sufficient,

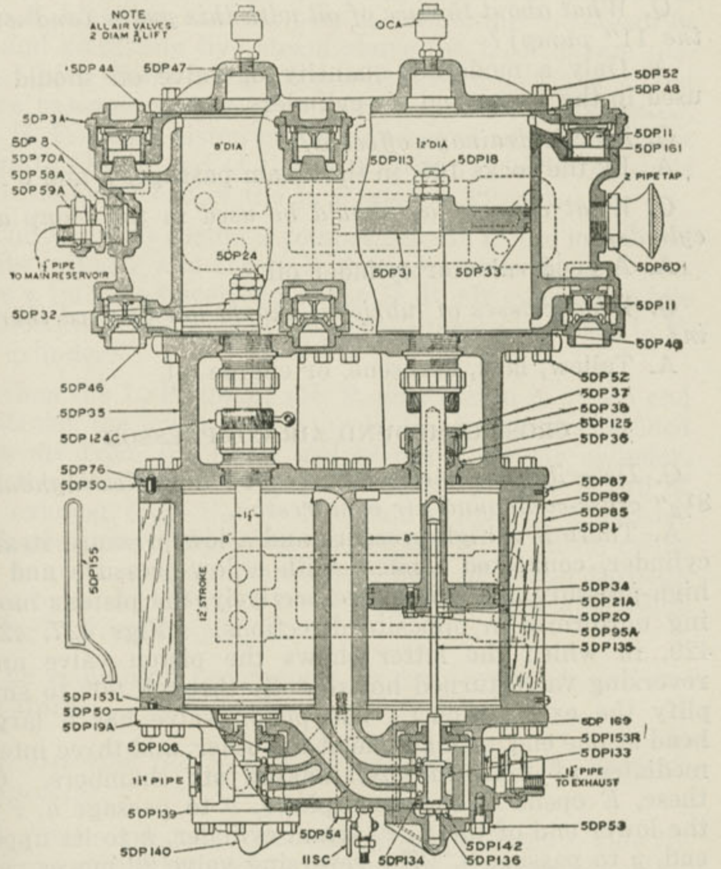

Fig. 430. No. 5B New York Duplex Air Compressor.

the upper discharge valve 86c is lifted, and the compressed air is forced through G and the discharge pipe into the main reservoirs. During this stroke the atmospheric pressure (not the vacuum) lifts the lower inlet valve 86b and air enters through o, o^1 below the piston, to be compressed on the down stroke.

Q. *What about the use of oil with this pump (and with the 11″ pump)?*

A. Only a moderate quantity of valve oil should be used in the steam and air-cylinders.

Q. *How is drainage effected?*

A. By the cocks 105, in the steam passages a and b^2.

Q. *What class of oil should be used in the pump air cylinder?*

A. A good valve or cylinder oil.

Q. *What classes of lubricant should not be used therein?*

A. Tallow, lard, kerosene, or engine oil.

CROSS-COMPOUND AIR COMPRESSOR

Q. *Describe the main features of the Westinghouse 8½″ cross-compound air compressor.*

A. There is a high-pressure and a low-pressure steam cylinder, connected tandem with a low-pressure and a high-pressure air cylinder respectively, the pistons moving uniformly in opposite directions. (Figs 427, 428, 429, in which the latter shows the piston valve and reversing valve turned horizontally through 90° to simplify the explanation.) The piston valve has a large head at one end, a small one at the other, and three intermediates of uniform size, making six chambers. Of these, E opens to the atmosphere, b to passage a, i to the lower end of the L. P. steam cylinder, h to its upper end, y to passage a. The reversing valve 22 moves vertically in chamber C, controlling steam admission and exhaust from the cavity D, moving the piston valve horizontally.

When the H. P. steam (L. P. air) piston has nearly completed its up-stroke, it lifts rod 21 and valve 22,

admitting steam to chamber D; the latter moves the main valve 25 to the left, uncovering grooves in the small piston valve cylinder head, letting live steam pass from b to E, blanking exhaust port o, cushioning the steam in E, and admitting live steam above the H. P. steam piston. Live steam being supplied through a, y and c, and since passage g, chamber i and passage f are connected, the H. P. steam piston moves downward and the exhaust from the lower end of the H. P. steam cylinder expands into the lower end of the L. P. steam cylinder.

The L. P. air piston 9 compresses air in the lower end of its cylinder and forces it through valves 40 and passage u into the lower end of the H. P. air cylinder, while outside air is being drawn into the upper end of the L. P. air cylinder.

When the L. P. steam (H. P. air) piston is at top end of stroke, the lower end of the H. P. air cylinder is filled with air from the lower end of the L. P. air cylinder, and the lower end of the L. P. steam cylinder is full of the exhaust from the H. P. steam cylinder. Excessive back pressure in the lower end of the H. P. steam cylinder is prevented by permissible flow of steam through three by-pass grooves X from the lower to the upper side of the L. P. steam piston.

The remaining occurrences in each cycle are self-explanatory.

Q. *Describe the New York Air Brake Co.'s "duplex" compressor.*

A. There are two equal size steam cylinders, side by side, one coupled tandem with the low pressure air cylinder, the other tandem with the high; when the pistons on the high pressure side are at stroke end, as in Fig. 430, those in the low are at half stroke. The steam valves are actuated by tappets, the rods of which pass centrally into the hollow piston rods.

THE SWEENEY COMPRESSOR

Q. What is the Sweeney compressor?

A. An emergency attachment for re-charging main reservoirs quickly on down grades, when the pressure is low, or the compressor stalls.

Q. Can you describe it?

A. From the steam chest to the main reservoir there is a pipe having a cut-out cock, safety valve and non-return check. Its action, when the cut-out cock is closed and the engine then reversed, is to make the main cylinders and pistons compress air and force it into the steam chest, and pipe connection to the main reservoir.

Q. What fault has it?

A. Hot smoke gets into the main reservoirs and causes dirt and damage. This arrangement is now seldom used.

THE COMPRESSOR GOVERNOR

Q. What does the compressor governor do?

A. Regulates the steam supply to the air compressor, stopping it when the desired air pressure has been attained.

Q. Does this governor control the brake-pipe pressure?

A. No; only that in the main reservoirs.

Q. Where is the governor placed?

A. In the steam supply pipe to the compressors.

Q. How is the adjustment of the governor changed?

A. Referring to Fig. 431, by the adjusting nut 18 regulating the tension of spring 19 on diaphragm 36.

Q. How does it act?

A. Where the spring tension can restrain the air pressure in the chamber *a*, it holds the small pin valve closed; when the chamber pressure lifts this valve, air passes into the chamber above the piston 6 and forces down the latter, thus seating the steam valve and stopping the pump. When the air pressure runs down, the reverse operations take place. Further, when the pin valve is unseated there is an air leak through the relief port *c*, and a steam leak through the steam valve, keeping the

pump slowly running as a guard against condensation. The 1/8-inch drip-pipe lets any steam that may leak past the stem of valve 5, or any air that may leak past piston 6, reach the atmosphere.

Q. Is it necessary to have in the main reservoir the excess of 20 pounds or more, before air can be supplied to the brake pipe?

A. All that the pump governor does is to regulate the maximum pressure in the main reservoir, the amount being regulated by the governor spring.

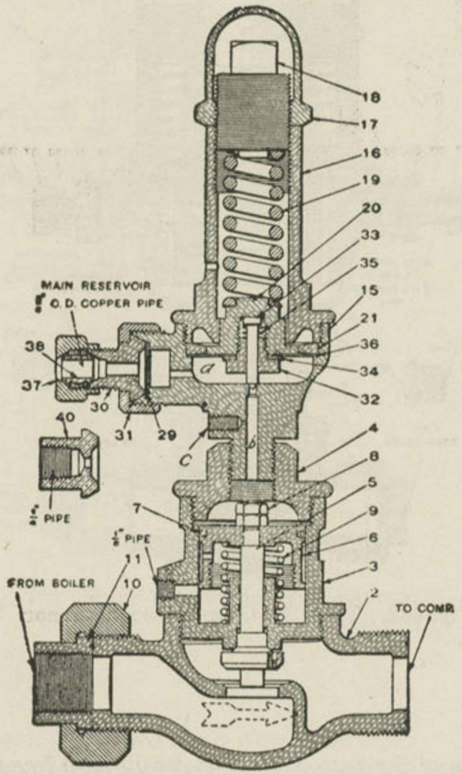

Fig. 431. The Single Pressure Compressor Governor.

THE DUPLEX GOVERNOR

Q. What is the "SD" duplex governor?

A. Two pressure-regulating heads acting with one steam governor body.

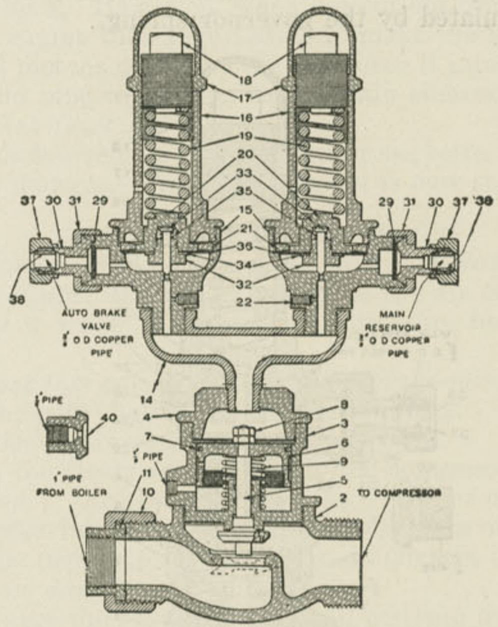

Fig. 432. Type SD Compressor Governor.

Q. What are the two pressure-regulating heads named?

A. "Low-pressure head" and "high-pressure head."

Q. What governor is often used with the "ET" equipment?

A. The "SF" regulating the main reservoir pressure automatically by that in the feed-valve pipe.

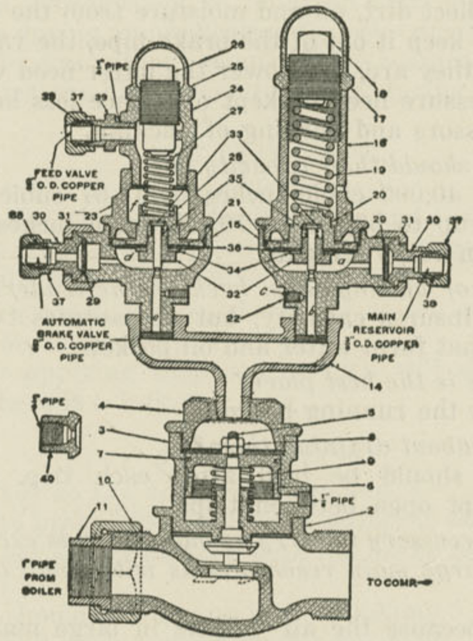

Fig. 433. Type SF Compressor Governor.

Q. What are the regulating heads called?

A. The short one, "excess-pressure head"; the other, "maximum-pressure head."

THE MAIN RESERVOIR

Q. Where do the main reservoirs get their air?
A. From the compressors.

Q. To what do they deliver air?
A. To the engineman's brake valve.

Q. What other use have the main reservoirs than to store compressed air?
A. To collect dirt, oil and moisture from the compressors and so keep it out of the brake pipe, the valves, etc. The larger they are, the slower the latter need work and the less pressure need be kept on, hence less heating of the compressors and burning of packing.

Q. What should their capacity be?
A. From 40,000 cubic inches = 11.57 cubic feet on passengers up to 50,000 to 70,000 cubic inches = 23.1 cubic feet on heavy freights.

Q. What of putting them back on the tender?
A. That insures capacity, but necessitates two extra hose lines that form water and oil pockets.

Q. Where is the best place?
A. Under the running boards.

Q. What about draining them?
A. They should be bled after each trip, and the bleeders kept open between trips.

Q. Is it necessary to carry as many pounds excess pressure with large main reservoirs as with small ones? If so, why?
A. No; because the air volume in large main reservoirs will equalize with the brake pipe and raise it to a higher pressure than a small air volume. To make the small reservoirs as effective to release the brake as the larger ones we add to the pressure of the small ones; for instance, we take main reservoirs of 10,000 cubic inches; with 90 pounds pressure they will expand into a brake pipe of the same volume and equalize at about 38 pounds. If the main reservoirs have 20,000 cubic inches capacity, they will expand into the same brake pipe and equalize at about 55 pounds, so that about 64 pounds in the large reservoirs is as effective in this case as 90 pounds in the small ones. Increased excess pressure adds to the effective "size" of the main reservoirs; the brake can be released with more certainty and speed.

Q. What is the duplex main-reservoir regulation?
A. An arrangement to build up high main-reservoir pressure during an application for releasing and recharging the brakes without requiring the compressor to operate against the high pressure except during brake application.

THE BRAKE PIPE

Q. What is the brake pipe?
A. A line (including flexible hose and their couplings, between vehicles) connecting the engineman's brake valve with each triple valve in the train.

Q. How may leaks in the joints of the air pipes and fittings be discovered?
A. By applying soap suds, which will show bubbles where there is a leak.

HOSE COUPLINGS

Q. What do the hose couplings unite?
A. The brake pipe sections of adjacent cars.

Q. What should be done with the brake hose when uncoupled?
A. It should be hung up in the "dummy," so as to keep cinders and other foreign matter out of it.

THE CENTRIFUGAL DIRT COLLECTOR

Q. What is the centrifugal dirt collector, and where is it placed?
A. It is a substitute for the brake pipe air strainer, put in the branch from the brake pipe to the triples, control valves or distributing valves to catch and hold solid foreign matter.

Q. How does it work?

A. As seen in Fig. 434 it is cone-shaped; the dust-laden air entering at one side strikes the side of the cone and the solid particles are thrown outward and downward by centrifugal force into the lower receptacle of the device where they accumulate around the stem of a central mushroom-shaped deflector that prevents their being carried up and out with the air current.

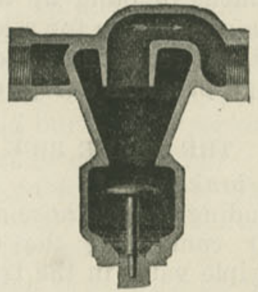

Fig. 434. Centrifugal Dirt Collector.

THE "ET" EQUIPMENT

Q. What is the "ET" (engine and tender) locomotive brake equipment?

A. It consists of one automatic and one independent brake valve (Figs. 435 to 442 inclusive), one feed, one reducing, one distributing valve with its safety valve (Figs. 441 and 442), two pressure gages and the brake cylinders. This equipment replaces the automatic and the straight-air brake valves, two feed valves and reversing cock, straight-air reducing valve, two double check valves, two high-speed reducing valves, two mountain cocks, two retaining valves, three auxiliary reservoirs, two triple valves and tender drain cap of the old standard "A-1" equipment.

Q. Can the "ET" locomotive brake be used both independently of the train brakes and in conjunction therewith?

A. Yes.

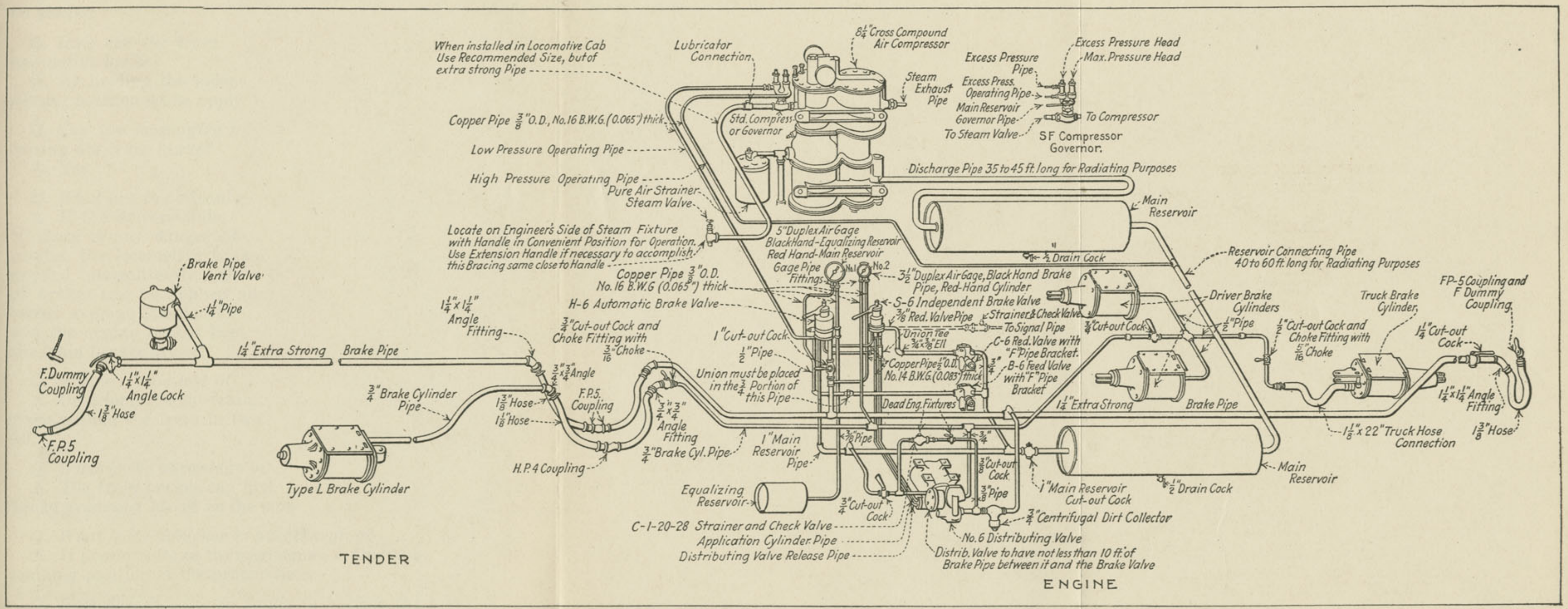

Fig. 435. No. 6 E.T. Brake Equipment, Piping Diagram

Q. Where is this especially advantageous?

A. In switching and handling long trains, especially on grades.

Q. How can the train brakes be applied without the locomotive brake?

A. By holding the independent brake valve handle in release position while applying the automatic.

Q. Can the locomotive brake be released without releasing the train brake?

A. Yes.

Q. What are the advantages of this?

A. If the drivers slide, their brakes can be taken off. If there is any danger of overheating driver tires on grades, the locomotive brake can be either kept off or applied intermittently. On down grades the two kinds of brakes can be applied alternately, thus maintaining better average speed. The train brakes can be let off and the engine brakes kept on to bunch the slack until the train brakes are off.

Q. Where is this last of special advantage?

A. On a long freight train, as it prevents the rear end from pulling the train in two after the hand brakes are off.

Q. What is the advantage in passenger service?

A. The train brakes can first be let off and the engine brake gradually let off as the stop is being completed.

Q. What is its influence in overcharging?

A. It prevents it; as the engineman must come back to running position at the proper time.

Q. How does it come in handy in holding the train a short time on a grade?

A. Because the independent brake can be used alone, letting the train brakes be fully recharged, and enabling prompt starting.

Q. How much more pressure is there on the engine and tender brakes in emergency applications than in service stops?

A. About 30 per cent.

Q. Why is it impossible to leave the brake handle in lap position after releasing the train brake (as in making a two-application stop or in slowing for a signal?

A. The engine brake will remain applied.

Q. What is the advantage of the "ET" brake in double-heading?

A. The man on the second engine can operate his brake independently, as in case of his tires getting hot.

THE H-6 AUTOMATIC BRAKE VALVE

Q. Where is the six-position H-6 automatic brake valve used?

A. With the "ET" equipment.

Q. What are its six positions?

A. Release, running, holding, lap, service application and emergency application (Fig. 436).

Q. What is the peculiarity of the release position?

A. The train brakes can be released, but not the locomotive; the latter can be released only by moving the handle back to running.

Q. What is the use of the holding position?

A. To hold the slack bunched in releasing, on long freight trains, and to make smoother and more exact stops, on passenger trains, by releasing the train brakes just before stopping and gradually letting off the engine brake afterwards.

Q. What is an important difference between the H-6 and the G-6 automatic?

The H-6 can be removed without breaking any pipe joints; has independent locomotive and train brake release; it feeds main reservoir pressure into the application cylinder of the distributing valve in emergency applications.

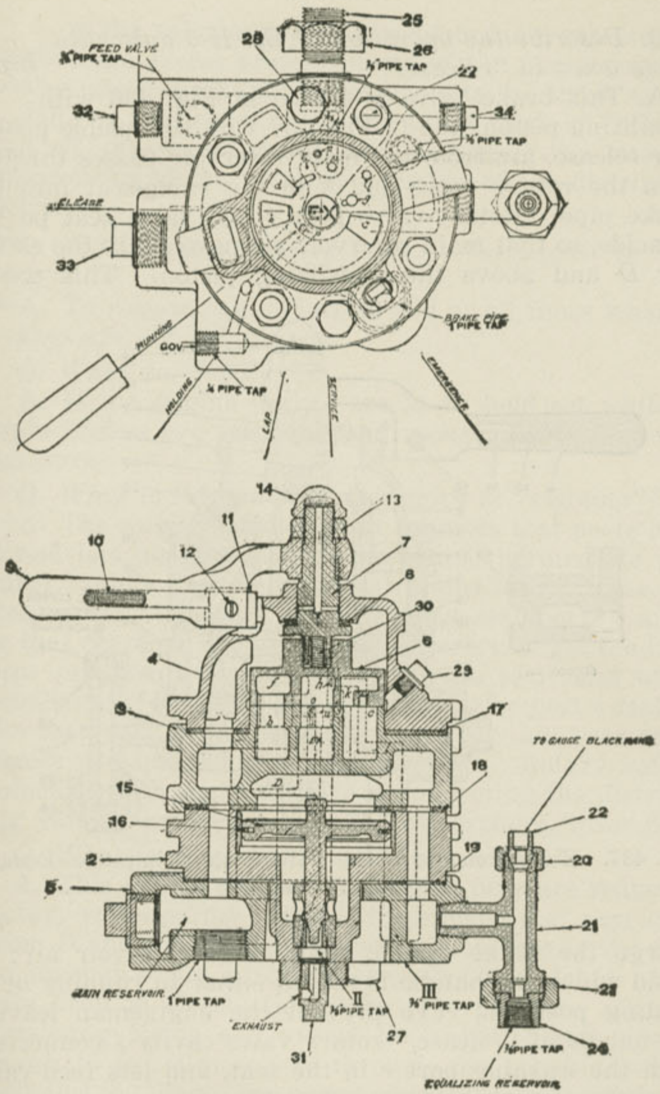

Fig. 436. H-6 Automatic Brake Valve with Plain Equalizing Piston.

Q. Describe the operation of the H-6 automatic brake valve when in "release."

A. This brake valve is shown in Fig. 436 with solid equalizing piston, and in Fig. 437 with collapsible piston. For release, air from the main reservoir passes through *a* in the rotary valve and *b* in the valve-seat into the brake pipe. Rotary-valve port *j* and valve seat port *g* coincide, so that main reservoir air passes into the chamber *D* and above the equalizing piston. This would

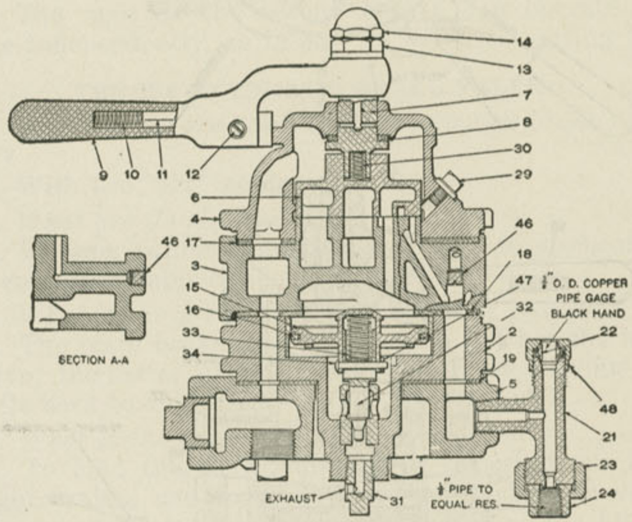

Fig. 437. H-6 Automatic Brake Valve with Collapsible Equalizing Piston.

charge the brake system with main reservoir air; to avoid which the handle is moved either to running or to holding position. (To prevent the engineman leaving the handle at "release," rotary valve cavity *f* connects *d* with the warning port *r* in the seat, and lets feed-valve pipe air escape into the exhaust cavity *ex.*) A small groove in the rotary-valve face connecting with *s* extends to the valve-seat port *p* and lets main reservoir air pass to the excess pressure head of the pump governor.

The rise in brake pipe pressure sets the triple and the equalizing portion of the distributing valve at "release," lets off the train brakes, and recharges the auxiliary reservoirs and the pressure chamber of the distributing valve.

Q. When is it necessary to move the handle to "running"?

A. To release engine brakes and at all times when the brakes are not being used.

Q. When to "holding"?

A. If the engine brakes are to be held set while the train brakes are releasing and recharging to feed-valve pressure.

Q. What is the action of this valve in "running"?

A. The rotary-valve cavity *f* connects seat ports *b* and *d* and lets air pass (up to maximum permissible pressure) rapidly from the feed-valve pipe to the brake pipe. Rotary valve cavity *k* connects valve-seat ports *c* and *g*, so that chamber *D* and equalizing reservoir get the brake pipe pressure and keep those on the two sides of the equalizing piston the same. Rotary-valve port *s* matches the seat port *p* and lets main-reservoir air pass to the excess pressure head of the governor. Rotary valve *h* coincides with seat port *l*, thus connecting the distributing valve release pipe with the atmosphere, through *ex.*

Q. What is the action in service position?

A. This effects gradual brake pipe pressure reduction. Rotary-valve port *h* matches the choked seat port *e*, air from *D* and the equalizing reservoir escapes to the outer air through *o* and *ex;* all other ports being closed. Pressure drop in *D* lets the brake pipe pressure raise the equalizing piston and unseat the valve; brake pipe air passes to the atmosphere through the opening marked "exhaust." When the pressure in *D* drops sufficiently, the handle should be moved to "lap," stopping further reduction. Air discharges from the brake pipe until its pressure is slightly below that in *D*, which latter forces down the piston and stops the discharge.

Q. When is the "lap" position used?

A. In holding brakes after service applications, pending decision as to further reduction or release (all ports being closed); also to prevent loss of main-reservoir air in case of bursts or leaks.

Q. What is the action for an emergency application?

A. Rotary-valve port *x* and seat-port *c* affect free brake pipe communication with the atmosphere, so that triples and distributing valve, by reason of the sudden heavy reduction, go to "emergency." Main-reservoir air is introduced into the application cylinder through *j*, a seat-port groove, *k*, valve port *n* and seat-port *u*, maintaining application cylinder pressure. Equalizing air passes through rotary-valve port *v*, seat-port *g* and exhaust-port *o*, and drops equalizing reservoir pressure to atmosphere.

THE S-6 INDEPENDENT BRAKE VALVE

Q. What is the S-6 independent brake valve?

A. A five-position addition to the automatic valve in "ET" equipment, intended to permit operating the engine brakes independently of those on the train.

Q. What are the five positions of its handle?

A. Release, running, lap, slow application and quick application.

Q. Can you describe it?

A. As seen in Fig. 438 it has a double-return spring to return the handle from "release" to "running" and from "quick application" to "slow application" position.

THE No. 6 DISTRIBUTING VALVE

Q. What is the No. 6 distributing valve?

A. A device to admit air to all brake cylinders on the locomotive, whether in automatic or in independent ap-

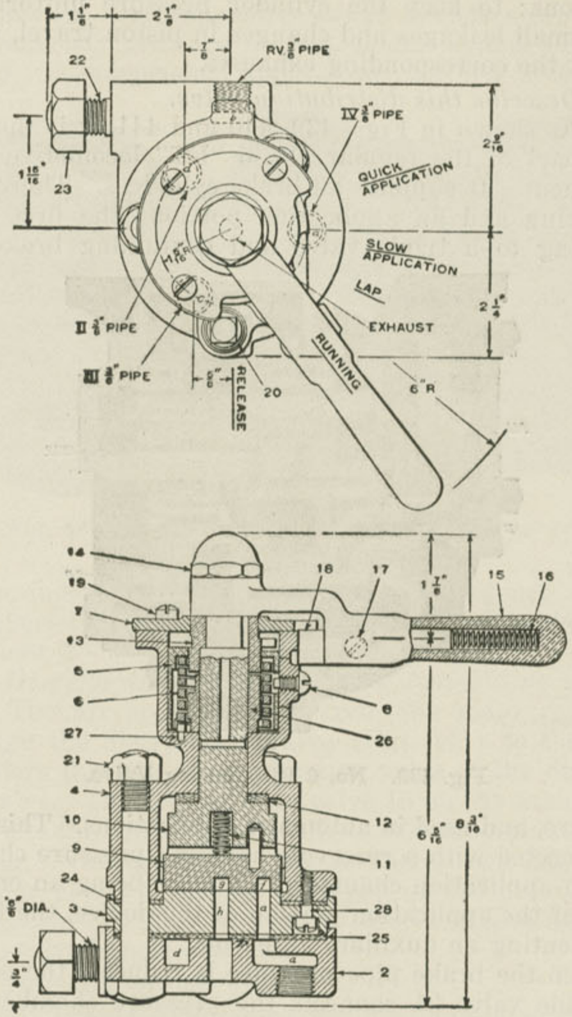

Fig. 438. S-6 Independent Brake Valve.

plications; to keep the cylinder pressure uniform, despite small leakages and changes in piston travel, and to permit the corresponding exhausts.

Q. Describe this distributing valve.

A. As shown in Figs. 439, 440 and 441, it is the principal part of the regular No. 6 "ET" locomotive brake equipment. It supplies all brake cylinders. There is an equalizing and an application portion; the first corresponding to a triple valve and containing brake pipe

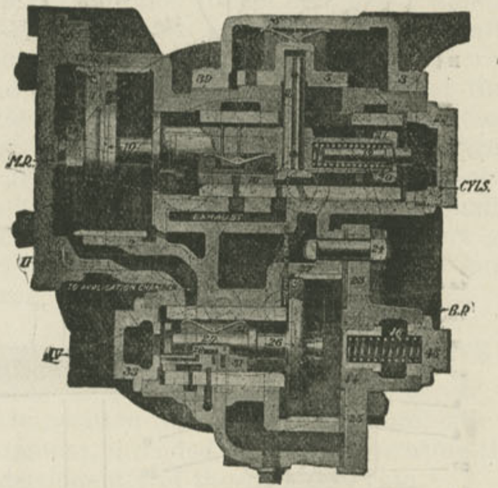

Fig. 439. No. 6 Distributing Valve.

pressure, and used in automatic applications. This valve is connected with a reservoir having a pressure chamber and an application chamber, the latter being an enlargement of the application portion of the device, the former representing an auxiliary reservoir.

When the brake pipe pressure is reduced, the equalizing slide valve 31 connects the pressure chamber with the application chamber and cylinder, and lets air flow into the latter. The upper slide valve 5 (application valve) attached to the application piston 10 lets air in

to the brake cylinders; the lower one, 16 (exhaust valve) releases it. The locomotive brake cylinders always get the same air pressure as that in the application cylinder, *g*. In independent applications, air flow is controlled

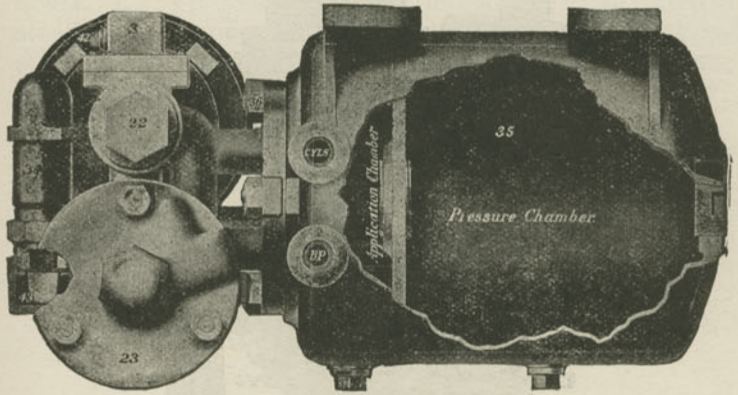

Fig. 440. No. 6 Distributing Valve and Reservoir.

by the independent brake valve. In emergency application there is high braking power; in service applications, sufficient.

Q. Describe the operation of the distributing valve.

A. The air supply comes from the main reservoirs through the distributing valve (Fig. 441) to the brake cylinders through the application valve in the distributing valve. The release slide valve 16 on the same piston stem lets the brake cylinder air to the atmosphere, in releasing. The application piston 10 always has brake-cylinder pressure on one side, and on the other, in the application cylinder, varying pressures according to the brake-valve handle position.

Q. How are brakes applied?

A. By letting compressed air into the application cylinder, thus closing the exhaust ports and opening the application valve. When the pressure in the brake cylinders is more than that in the application cylinder, the piston and its slide valves are brought to "lap," and no more air flows to the brake cylinders, so that it makes no difference how many brake cylinders there are, or

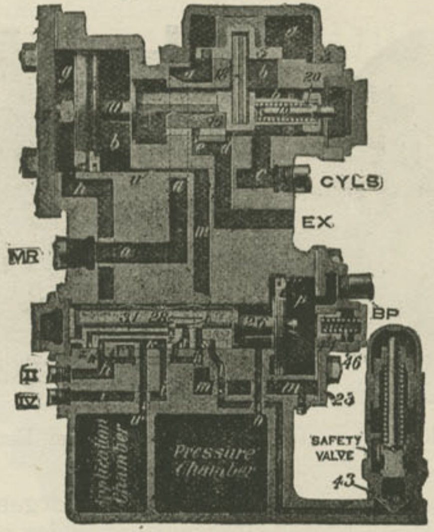

Fig. 441. No. 6 Distributing Valve, Diagrammatic.

whether they may leak a little, they get the desired pressure and keep it as long as there is the required pressure in the application cylinder.

The brakes may be either wholly or partly released, according to the pressure in the application cylinder.

Q. What happens when the independent brake valve is in "application" position?

A. Air flows from the reducing valve to the application cylinder.

Q. When the independent brake valve is on "lap"?

A. Connection with the application cylinder is closed.

Q. When is it in "release"?

A. The application cylinder pipe is open, through the independent brake valve, to the atmosphere.

Q. Describe the New York Co's. "LT" (locomotive and tender) brake.

A. Instead of a distributing valve as in the Westinghouse "ET," it has an automatic control valve; and instead of an independent brake there is a combined straight-air arrangement; it being practically an independent brake.

SAFETY VALVES

Q. Where are safety valves used?

A. On old standard tender, driver and truck brakes, and on the distributing valve.

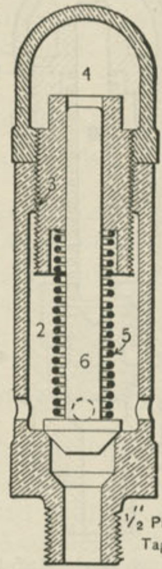

Fig. 442. Old Style Safety Valve.

Q. Why?

A. To let off all pressure over 50 pounds in the first cases, as their tires would run risk of heating by overpressure; to perform the functions of the ordinary brake cylinder relief valve and those of the high speed reducing valves, when on the distributing valve.

THE OLD A-1 EQUIPMENT WITH "SWA" STRAIGHT AIR

Q. What is this equipment?

A. It is the old original locomotive brake equipment.

Q. How was it developed?

A. By using the same type of operating valves as were applied to cars, and adding the brake valves, compressors, governor, main reservoirs, etc.

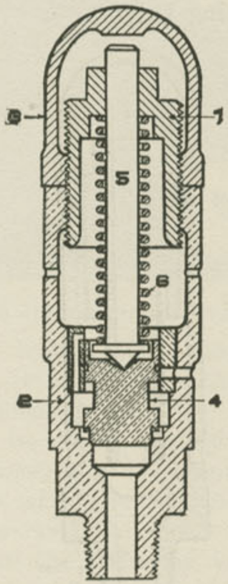

Fig. 443. New Style Safety Valve.

Q. What type of operating valve was used for the driver brake cylinders?

A. The old plain triple valve.

Q. What else was required besides the triple valve?

A. An auxiliary reservoir.

Q. Was this same triple valve and auxiliary reservoir used for the truck brake?

A. The same triple valve was used, but a separate auxiliary reservoir was required for the truck, which reservoir had to be cut out whenever the truck brake was cut out.

Q. What Automatic brake valve was used?

A. The G-6 brake valve.

Q. What is the "SWA" straight air brake?

A. It is a separate straight air brake added to the automatic consisting of an S-3 brake valve supplied by a reducing valve and connected to a double check valve placed in the brake cylinder pipe between the triple valve and brake cylinders.

Q. Could both these brakes be used at the same time?

A. No, only one at a time.

Q. Then the driver brakes could not be released during an automatic brake application?

A. Not by the straight air brake valve. But the brake cylinder pipe had a branch up into the cab with a cutout cock (called a "mountain" cock) on the end, which cock could be opened by the engineman whenever he wished to release driver brakes, or prevent their application.

Q. How was the tender braked?

A. The automatic brake on the tender was just like a car in the train, with a brake cylinder, auxiliary reservoir and triple valve connected to the brake pipe through a tender drain cup. A separate pipe line connected to the straight air brake on the engine by hose and couplings connected to a double check valve on the tender in the brake cylinder pipe just as on the engine, so that the straight air brake valve on the engine also controlled the brakes on the tender when straight air was being used.

Q. Could the tender brakes be released independently during an automatic application?

A. Yes, the brake cylinder pipe in the tender also had a branch running up to the front end of the tender with a "mountain" cock which could be opened to release those brakes or prevent their applying.

Q. What was the object of these "mountain" cocks?

A. In descending long grades, it is often desirable to prevent engine and tender brakes from applying, principally to prevent over-heated driving wheel tires.

Q. What triple valve was used on the tender?

A. On freight and switch engines, the plain triple valve, same as on the engine; on passenger engines, the old quick action triple valve was used on the tender.

Q. What else was used on passenger engines?

A. The high speed reducing valve was attached to the brake cylinder pipe on the engine and another to the brake cylinder pipe on the tender.

Q. What other well-known device was used with this old equipment?

A. Pressure retaining valves were connected to the exhaust of each triple valve and placed in the cab where they could be easily manipulated.

Q. Why was a safety valve placed in the straight air pipe?

A. To prevent building up too high a brake cylinder pressure in case the reducing valve got out of order.

G-6 AUTOMATIC BRAKE VALVE

Q. What is the purpose of the engineman's brake valve?

A. To regulate the air flow from the main reservoir into the brake pipe for charging and releasing the brakes, and from the brake pipe into the atmosphere for putting on brakes.

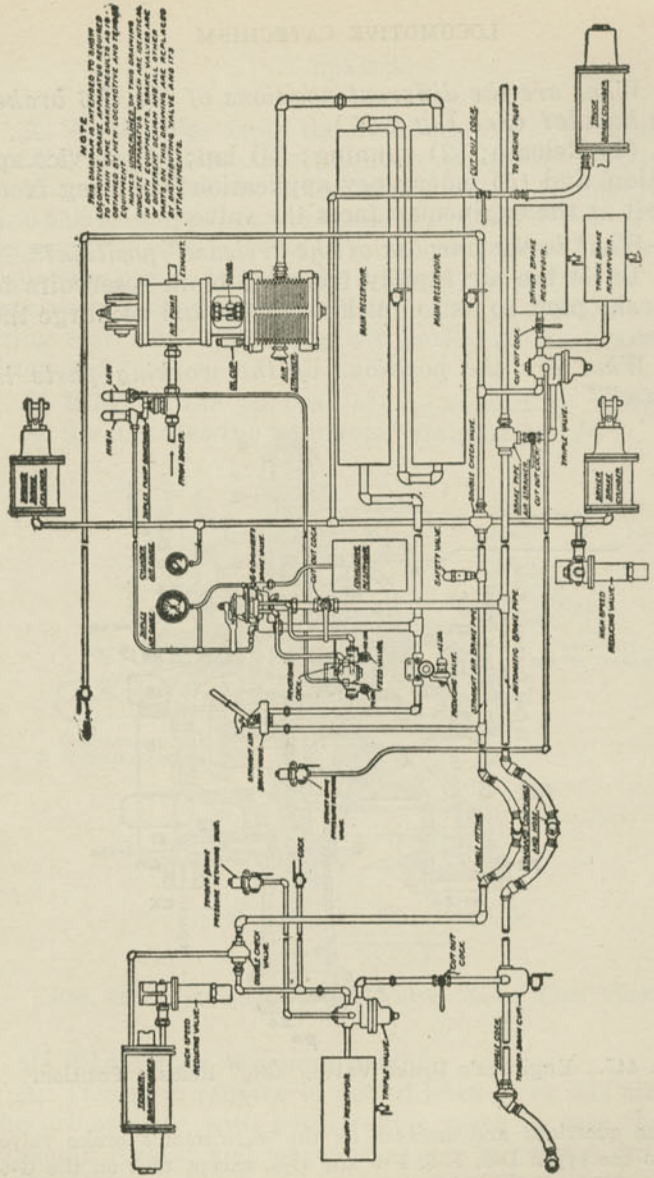

Fig. 444. The Old A-1 Equipment with SWA Straight Air.

Q. What are the different positions of the G-6 brake-valve handle? (See Fig. 446.)

A. (1) Release; (2) running; (3) lap; (4) service application, and (5) emergency application; counting from the left as the engineman faces the valve.

*Q. What is the purpose of the "release" position?**

A. To let the air rapidly from the main reservoirs to the brake pipe, so as to quickly release and recharge the brakes.

Q. What are the positions of the working parts in "release"?

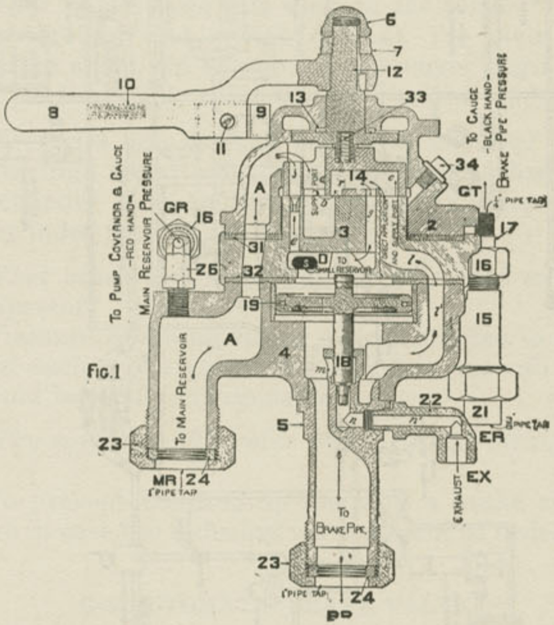

Fig. 445. Engineer's Brake Valve, "G-6," Release Position.

* The questions and answers on the engineman's brake valve refer to the types D-5, E-6, F-6 and G-6, except that on the G-6 type the slide valve supplants the former feed attachment.

A. As the pipe from the main reservoirs is connected at *MR* (Fig. 445), main reservoir air passes through *A*, *A* to the chamber above the rotary valve 14, through this and the passage ll^1 to the brake pipe at *BP*. Port *G* being exposed to cavity *c* lets air into chamber *D* above the equalizer piston 18. Rotary valve *j* registers with *e* and lets air into chamber *D;* so that in this position the equalizing reservoir is fed from two ports and the brake pipe from one.

Q. What is the purpose of the equalizing reservoir?

A. To increase the volume of the chamber *D*.

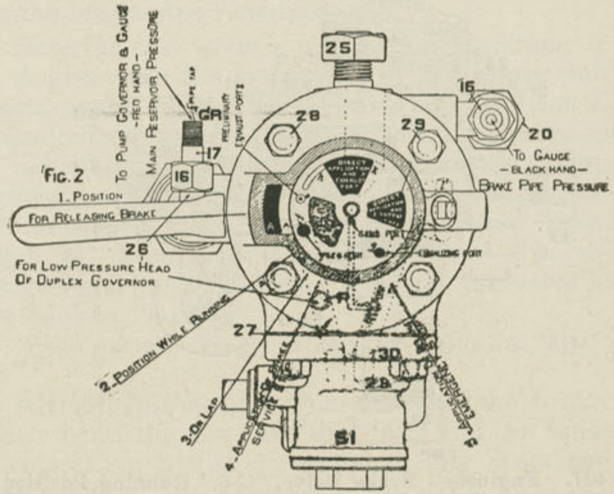

Fig. 446. Engineer's Brake Valve, "G-6," Plan View.

Q. What is the "warning port"?

A. This port (shown in dotted lines at *r*) lets air into the atmosphere with considerable noise in case the engineman forgets and leaves the valve in release position.

Q. What would happen if he kept the valve in "release"?

A. There would accumulate a high pressure in the main and equalizing reservoirs, the auxiliary reservoirs and brake pipe.

Q. When the brake pipe and the auxiliary reservoirs of the brake apparatus are charged, what is done?

A. The handle 8 of the brake valve is moved to 2 (Figs. 446 and 447), "position while running."

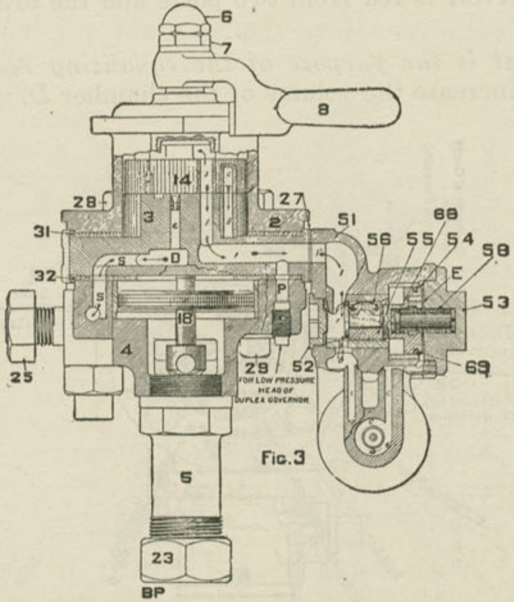

Fig. 447. Engineer's Brake Valve, "G-6," Running Position.

Q. Describe the purpose of the "running" position of the engineman's brake valve?

A. Main-reservoir air goes from the chamber above the valve 14 through port *j* and passages *f*, f^1 into chamber *F*; thence through the feed valve and passages *i*, *l*, l^1 (Fig. 446), into the brake pipe at *BP*. Port *g* still connects *D* with *c*; and as this last overlaps *l*, the equalizing reservoir is in connection with the brake pipe.

Q. When does the feed valve cut off air from the brake pipe?

A. At 70 pounds, in freight service, and 110 pounds in passenger service.

Q. Does the compression then stop?

A. No; it stops when 90 pounds or 130 pounds is in the main reservoir.

Q. What is the "lap" or middle position?

A. One with all ports closed.

Q. What would be the result of starting the compressor when the engineman's brake valve was in lap position?

A. To put 90 or 130 pounds in the main reservoir, while the brake pipe remained empty.

Q. Describe the "service application" position.

A. A groove in the lower face of the rotary valve 14 connects port *e* with groove *h*, and lets air from *D* and the equalizing reservoir, through *k*, into the atmosphere, thus reducing the pressure above piston 18. This lets the pressure below 18 force it up, and unseats the attached discharge valve, so that brake pipe air discharges through *m*, *n*, m^1 into the atmosphere. The desired pressure reduction in *D* being attained, the valve handle is put back to "lap."

Q. What occurs after putting the valve in "lap" position?

A. Air still discharges from 22 until the brake pipe pressure is a little less than that in *D* and the equalizing reservoir; then piston 18 automatically seats the discharge valve.

Q. How much reduction in brake pipe pressure is usually enough for an initial brake application?

A. 5 to 8 pounds.

Q. What is the emergency position?

A. That in which (Fig. 446) the "direct application and exhaust port" *k* and the "direct application and supply port" *l* are connected by a large cavity *c* in rotary valve 14, permitting very rapid brake-pipe discharge.

Q. *How much should the brake-pipe pressure be reduced for an emergency stop?*

A. A very sudden reduction in the emergency position of the brake-valve should be made.

Q. *How are the brakes released?*

A. By moving the valve handle 8 to "Position for Releasing Brake," causing air from the main reservoirs to flow freely again to the brake pipe, forcing the triple valve to "release" position and exhausting the air used in applying the brakes, and recharging the auxiliary reservoirs. When the valve handle is in this position, a small "warning port" discharges air from the main reservoirs to the outer air with considerable noise, thus attracting the attention of the engineman to his neglect to move the valve handle to the "running" position.

Q. *When must the engineman move the brake-valve handle from position 1 to position 2?*

A. Before the accumulation of the maximum pressure of 70 or 110 pounds allowed in the brake pipe, so that the feed valve may properly do its duty of governing the brake pipe pressure; else the pressure in the brake pipe may be rendered excessive.

THE "SWA" EQUIPMENT

Q. *Where is this combination used?*

A. On engines and tenders in yard and freight work; and on road engines with old-style equipment.

Q. *What is added to the old standard engine and tender equipment?*

A. A slide-valve reducing valve, to lower the main reservoir pressure, a straight-air brake valve, a safety valve and a double check valve, on the engine; and on the tender a double check valve and a safety valve, with the necessary hose connections.

Q. *Why do yard engines with old-style equipment find these combinations desirable?*

A. They would otherwise have to make frequent engine reversals, with attendant damage to cylinders and packing. It permits quick straight-air release, also partial release; enables slack-bunching, slow-ups, etc.

Q. *Can each braking element work independently of the other?*

A. Yes.

Q. *What is added therein to the old standard "A-1" equipment?*

A. On the engine, a slide-valve reducing valve, straight-air brake valve and double check; on the tender, a double check valve, safety valve, and hose and connections.

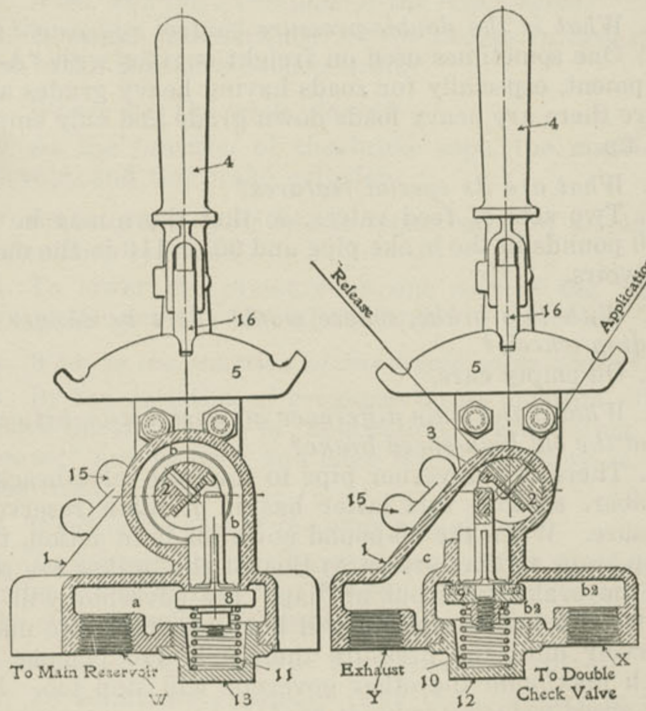

Fig. 448. S-3 Straight Air Brake Valve.

Q. To what pressure are the safety valves set.

A. Both at 53 pounds.

Q. What is their object?

A. To blow off if the reducing valve is out of order, or if the automatic is used before the straight air is released.

Q. What is the object of the slide-valve reducing valve in this combination.

A. To reduce the main-reservoir pressure to standard straight-air pressure of 45 pounds in the brake cylinders.

THE DOUBLE-PRESSURE CONTROL EQUIPMENT

Q. What is the double-pressure control equipment?

A. One sometimes used on freight engines with "A-1" equipment, especially for roads having heavy grades and where there are heavy loads down grade and only empty cars up.

Q. What are its special features?

A. Two sets of feed valves, so that there may be 70 or 90 pounds in the brake pipe and 90 or 110 in the main reservoirs.

Q. With this brake, where would there be danger of skidding wheels?

A. On empty cars.

Q. What is the main difference in construction between it and the old high-speed brake?

A. There is a governor pipe to the feed-valve bracket chamber, so that this latter has in it main reservoir pressure. When the 90-pound governor is in action, the pump stops at that pressure; then if the brakes are set, and the brake-valve put at "lap," the governor will be thrown out and the pump will keep on filling the main reservoir until the pressure therein is 110 pounds, at which maximum the other governor will stop too. No high-speed reducing valve is used.

THE TRIPLE VALVE

Q. What are the functions of the triple valve, from which it derives its name?

A. To charge the corresponding auxiliary reservoir, close communication between auxiliary reservoirs and brake cylinders, as long as there is pressure in the brake pipe; but when this is lowered, as by train parting, or purposely by the engineman, with his valve, to let air into the brake cylinders and apply the brakes; and to release the latter.

Q. What was the advantage of the triple valve?

A. It would automatically set the brakes in case of a burst brake hose or a broken train.

Q. Where was the triple placed?

A. At the junction of the brake pipe, the auxiliary reservoir, and the brake cylinder.

Q. What is the effect on the triple valve, of a leak in the auxiliary reservoir?

A. To lower the pressure on one side of the triple valve piston and thus let off the brake in question.

Q. What is the function of the triple valve piston?

A. By the variation of pressures on its opposite sides, to move the slide valve to "application," "graduating" or "release;" and to open and close the feed groove in the piston bush.

Q. What is the use of the slide valve?

A. To connect the auxiliary reservoir with the brake cylinder, thus setting the brake; and to connect the brake cylinder with the outer air, thus releasing it.

Q. What is the feature of the graduating valve?

A. To admit air gradually from the auxiliary to the brake cylinder, in response to pressure reductions in the brake pipe.

THE AUXILIARY RESERVOIR

Q. What is the use of the auxiliary reservoir?

A. To store, for use on that vehicle, air received from the main reservoirs through the brake pipe and triple valve.

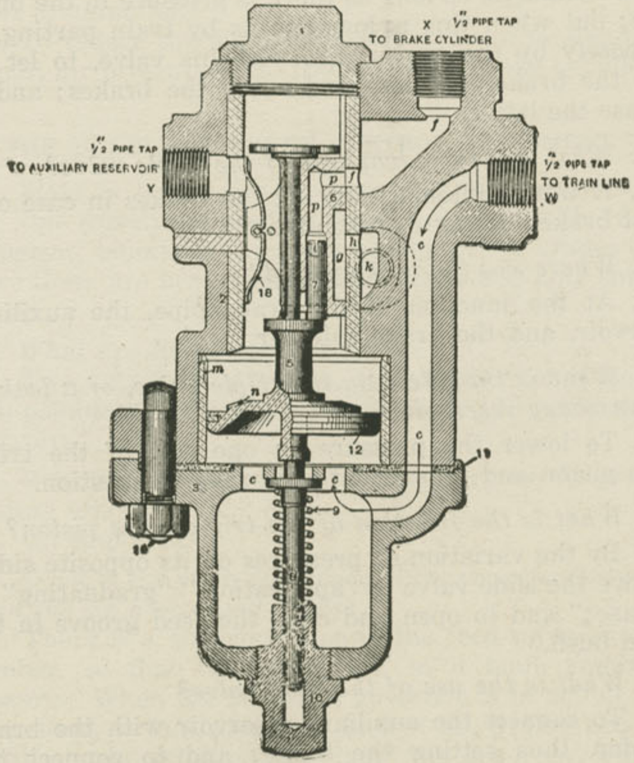

Fig. 449. Plain Triple Valve.

Q. From what is it charged?

A. From the triple valve.

Q. How long?

A. While the brake pipe air pressure is greater than that in the auxiliary; until the pressures on both sides of the triple valve piston are equal.

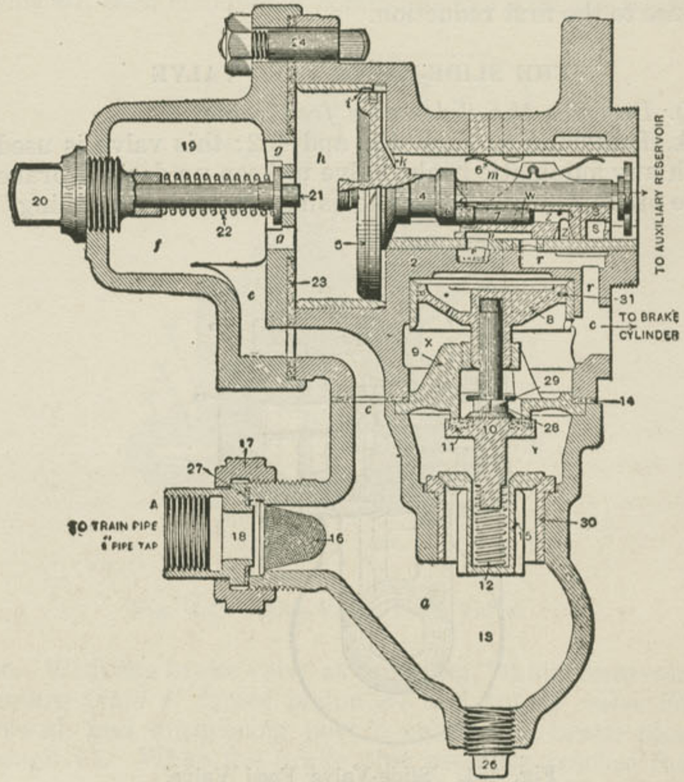

Fig. 450. Quick Action Triple Valve.

Q. What are the two triple valve piston sides called?

A. One is called the brake pipe side; the other the auxiliary or slide-valve cavity side.

Q. What could prevent charging the auxiliary?

A. Clogged strainer, or clogged feed port; cut-out triple; leak in the reservoir itself.

Q. Suppose the auxiliaries charged unequally fast?

A. Those not fully charged would hinder prompt response to the first reduction.

THE SLIDE-VALVE FEED VALVE

Q. Describe the slide-valve feed valve.

A. Referring to Figs. 451 and 452: this valve is used with any automatic brake valve to keep up desired brake pipe pressure while the brake handle stands at "running."

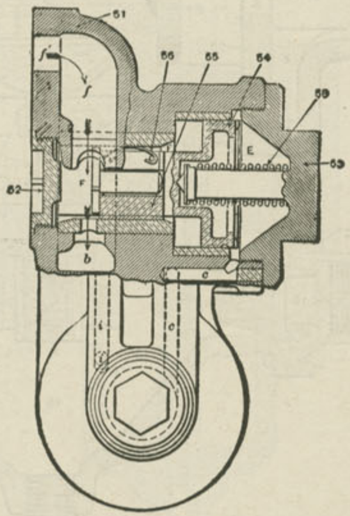

Fig. 451. Slide-Valve Feed Valve.

Fig. 451 is a central section through the supply-valve case and governing device; Fig. 452 one through the regulating valve and spring box and a cross section through the supply-valve case. Ports *f* and *i* register with brake-valve ports (similarly lettered in Fig. 447), and in the

running position main reservoir pressure can reach *F* through *f* and f^1. Chamber *E* (separated by piston 54 from chamber *F*) is connected with the brake pipe by passage *i, c. c.* port *a* (controlled by the regulating valve 59) and chamber *G* over diaphragm 57. Valve 59 is normally held open by diaphragm 57 and regulating spring 67, then chamber *E* communicates with the brake

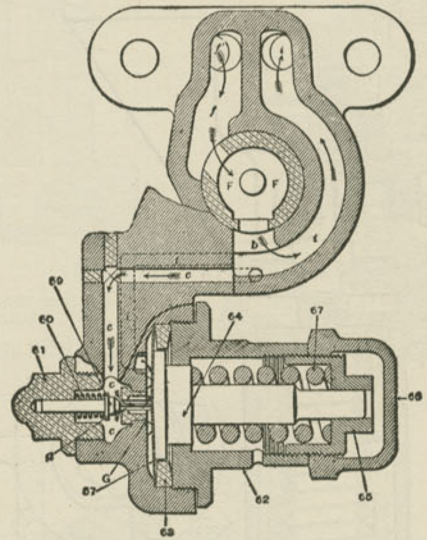

Fig. 452. Slide-Valve Feed Valve.

pipe. With the brake valve at "running," main reservoir pressure from *F* forces piston 54 and supply valve 55 forward, and uncovering port *b* enters the brake pipe through *i i*. When the brake pipe pressure reaches the proper pressure, say 70 pounds, diaphragm 57 allows regulating valve 59 to seat closing *a* and cutting communication between *E* and the brake pipe. Pressures in *E* and *F* equalizing (through leakage past supply-valve piston 54) spring 58 reacts and seats valve 55, closing *b* and cutting brake pipe off from the main reservoirs. Further reduction of brake pipe pressure reduces the pressure in *G*, opens regulating valve 59 and lets *E* discharge into the brake pipe. The supply-valve piston 54 being thus unbalanced the main reservoir pressure in *F* forces it and supply valve 55 forward and recharges the brake pipe through *b*.

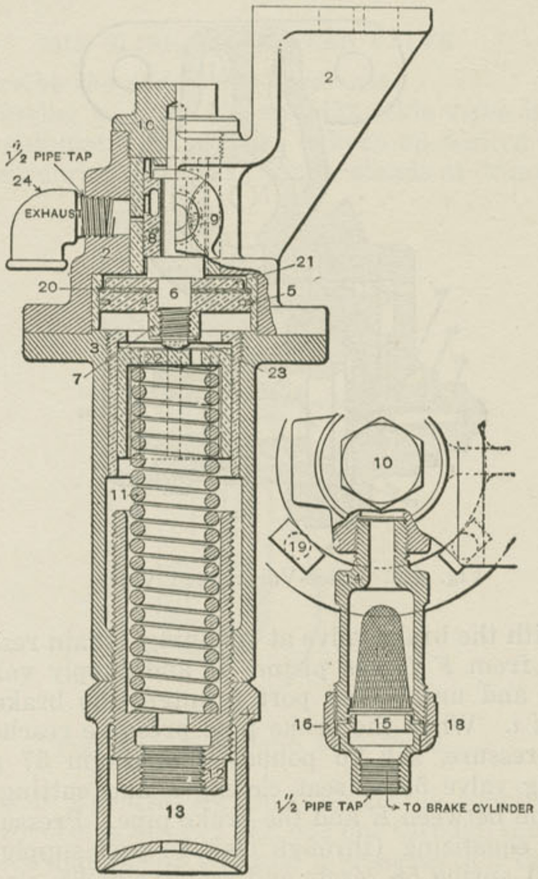

Fig. 453. Automatic Reducing Valve.

AUTOMATIC REDUCING VALVE

Q. Describe the automatic reducing valve.

A. It is shown in vertical cross section in Fig. 453 and Figs. 454, 455 and 456 are vertical cross sections of the

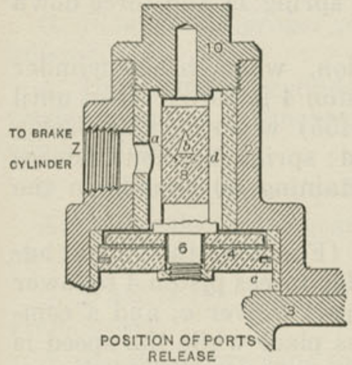

Fig. 454. Release.

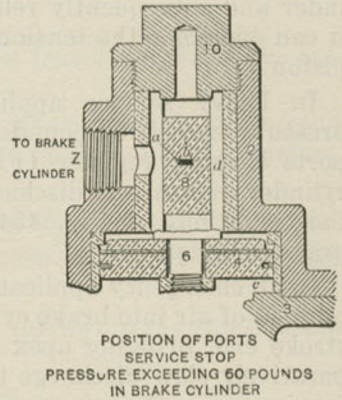

Fig. 455. Service.

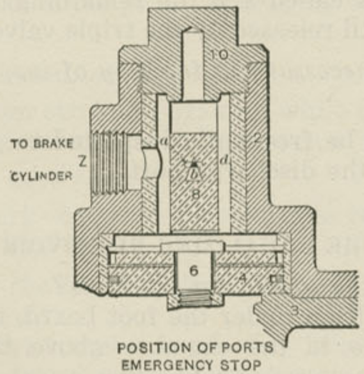

Fig. 456. Emergency.

upper part, showing the various slide-valve positions for release, service stop, and emergency stop respectively.

The triangular port *b* leads to the chamber *d;* port *a* to the atmosphere, through the exhaust opening *Y* (Fig. 453). Referring to the release position (Fig. 454), the port *b* of slide 8 does not register with port *a* of its seat. On brake application the pressure is held in the brake cylinder and subsequently released in the usual way unless it can overcome the tension of spring 11 and force down piston 4.

In heavy service application, when brake-cylinder pressure exceeds 60 pounds piston 4 is moved down until ports *b* and *a* register (Fig. 455) when surplus brake-cylinder pressure is discharged; spring 11 then restores the conditions of Fig. 454 retaining 60 pounds in the brake cylinder.

In an emergency application (Fig. 456) the violent admission of air into brake cylinder forces piston 4 to lower stroke end, bringing apex of port *b* over *a*, and a comparatively slow discharge takes place while the speed is maximum; as the pressure reduces above piston 4 it permits it to rise. When the braking pressure is down to 60 pounds, *a* is closed and the remaining braking pressure is held until released by the triple valve.

Q. *What is necessary in the way of inspection of this device?*

A. It should be frequently inspected to guard against leaks through the discharge port.

THE EQUALIZING RESERVOIR

Q. *What is the equalizing reservoir?*

A. A small drum under the foot board, to furnish additional volume to the chamber above the equalizing piston in the engineer's brake valve.

Q. *What other names has this drum?*

A. "Equalizing auxiliary," "chamber D," and simply "little drum."

THE BRAKE CYLINDER

Q. *What is the function of the brake cylinder?*

A. To press its piston and rod against the brake levers when the piston is forced outward by air pressure, and put on the brakes.

Q. *What is the proper piston travel for the brake cylinders?*

A. Driver-brake cylinders, four inches; truck and trailer cylinders, six inches; and tender and car cylinders, eight inches.

Q. *Of what is a greater travel than normal a sign?*

A. Of weak brake gear, worn shoes, or undue lost motion.

Q. *What is the effect of not taking up the slack in the brake gear?*

A. It takes more time to stop.

Q. *What is standing travel?*

A. The stroke of the piston in braking when the engine is at rest

Q. *What is running travel?*

A. The piston stroke in braking while running; being greater than standing travel, by reason of lost motion.

Q. *What is false travel?*

A. Temporary excessive travel while running, due to uneven track, etc.

Q. *What of the brake cylinder pressure with long and with short travel?*

A. With short travel it is greater; it is in inverse proportion to the travel.

Q. *What of uniformity of travel?*

A. All pistons in the train should have the travel within certain fixed limits, to lessen the trouble from flat wheels and to make braking smoother.

Q. *Where are the driver-brake cylinders located?*

A. Usually between the frames either just back of the cylinder saddle, or just in front of the fire box. On some locomotives, they are attached on the outside of the frames under the cab.

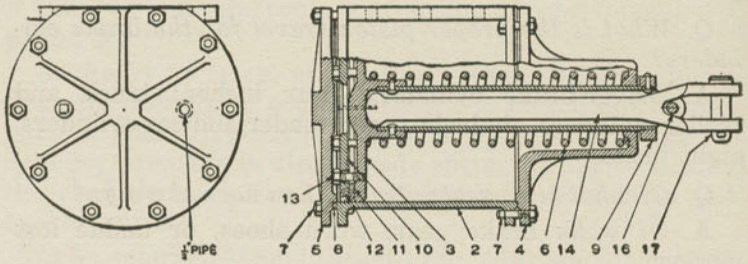

Fig. 457. Driver Brake Cylinder.

Q. *Where is the tender brake cylinder located?*

A. Under the tender underframe about midway between ends.

Q. *When truck or trailer brake cylinders are used, where are they located?*

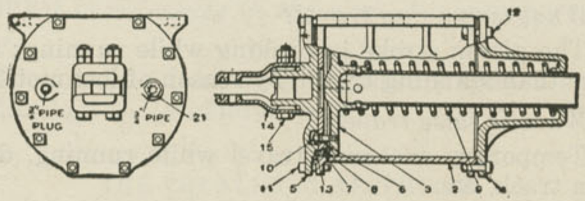

Fig. 458. Tender Brake Cylinder.

A. On their respective trucks.

Q. *How is the air connected to these cylinders?*

A. By flexible hose connections in the brake cylinder pipe.

Q. *How can these various brake cylinders be cut out if necessary?*

A. There is one cut out cock to control the two driver brake cylinders, and another cut out cock for each of the others. The driver brake cut out cock is located in the brake cylinder pipe branch to the two driver brake cylinders; the truck and the trailer cut out cocks are near the upper end of the flexible hose connections; and the tender brake cut out cock is under the cab at the back end of the engine with "ET" equipments, or in the brake pipe branch to the triple valve on the tender with "A-1" equipments.

BRAKE CYLINDER PISTON TRAVEL

Q. *What limits the brake cylinder piston travel?*

A. Brake-rigging slack, lost motion in the car itself, caused by the brake action.

Q. *How is it adjusted?*

A. Either by altering the position of the top hole in the dead truck levers, or by the use of a slack adjuster provided in the rigging for that purpose.

Q. *Does the amount of travel affect the brake cylinder pressure; if so, how?*

A. The pressure in the brake cylinder is built up from atmosphere as the reservoir pressure falls, by an amount depending on the piston displacement; the greater the travel, the less the increase in pressure, for a given reservoir pressure.

Q. *Which is then the more powerful, other things being equal:—long or short travel?*

A. Short.

Q. *If the rear cars of a train had longer piston travel than the front, what would be the result?*

A. The slack part of the train would run into the front cars.

THE PRESSURE-RETAINING VALVE

Q. What are the functions of the pressure-retaining valve?

A. To cause a slow reduction of brake cylinder pressure, and finally retain a certain pressure in the brake

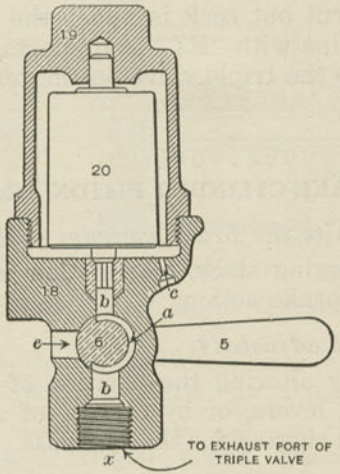

Fig. 459. Single Pressure Weight Type Pressure-Retaining Valve.

cylinder when the brakes are released for recharging the auxiliary reservoirs on a grade.

Q. In what service is this mostly used?

A. On heavy freight; and on heavy grades, as on mountain sections, on engines, tenders and passenger cars.

Q. What is its use?

A. To keep the speed of train from increasing too rapidly while recharging the auxiliaries.

Q. How is it connected?

A. To the triple valve exhaust port, through x (Fig. 459).

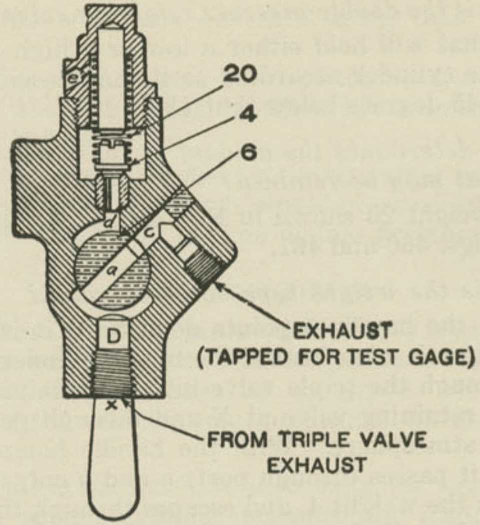

Fig. 460. Single Pressure Spring Type Pressure-Retaining Valve.

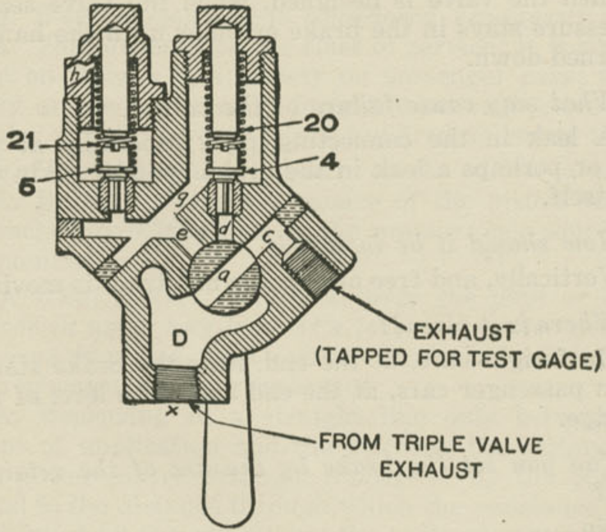

Fig. 461. Double Pressure Spring Type Pressure-Retaining Valve.

Q. What is the double pressure retaining valve?

A. One that will hold either a low or a high pressure in the brake cylinder according as its handle is set horizontally or 45 degrees below that (Fig. 461).

Q. What determines the amount of the brake cylinder pressure that may be retained?

A. The weight 20 shown in Fig. 459, or the spring as shown in Figs. 460 and 461.

Q. How is the weight type valve operated?

A. When the handle 5 points downward it is inoperative; and in releasing brakes the brake cylinder air discharges through the triple valve into the retaining-valve pipe to the retaining valve at *X* and through ports *a*, *b*, *e*, into the atmosphere. With the handle horizontal as in Fig. 459 it passes through ports *a* and *b* only (*e* being closed) lifts the weight 4, and escapes through the port *c* until the brake cylinder pressure is down to the pressure for which the valve is designed, when the valve seats; the pressure stays in the brake cylinder until the handle 5 is turned down.

Q. What may cause failure of the valve?

A. A leak in the connecting pipe, especially at the union, or perhaps a leak in the brake cylinder or in the valve itself.

Q. How should it be installed?

A. Vertically, and free of access when train is moving.

Q. Where is it placed?

A. On freight cars, at the end, near the brake standard; on passenger cars, at the end about the level of the hood edge.

Q. Can you set the brake by the use of the retainer handle?

A. No.

Q. What other use has this valve, than those mentioned?

A. When brakes have been set too hard, a few retainers can keep the slack bunched after releasing, when drifting before a stop.

Q. What pressures are retaining valves made for?

A. 10, 15 and 25 pounds single pressure type; and 10-20, 15-30, and 25-50 pounds double pressure type.

BRAKING POWER

Q. What is braking power, and how is it expressed?

A. The pressure of the shoes against the wheel treads, expressed in percentage as compared with the light weight of the vehicle; only the braked wheels being considered.

Q. What is the uniform basis supposed pressure?

A. 50 pounds cylinder pressure for engines, tenders and freight cars, and 60 pounds for passenger cars.

Q. What percentage is considered necessary?

A. That depends on the class of service; it is sixty per cent on freight cars; ninety on passenger cars; fifty to sixty on engine drivers; forty-five on engine truck and trailer wheels; seventy to one hundred on empty tenders.

Q. How is the total pressure on the piston calculated?

A. By multiplying the square of the piston diameter in inches by 0.7854 and by the pressure per square inch in pounds.

Q. What general rule will cover the gain or loss of power in using any kind of a lever no matter where its fulcrum is placed, with relation to the points of application of power and of resistance?

A. Measuring in a straight line only between each point of application and the fulcrum, the distance that the power moves through, multiplied by the power, is equal to the distance through which the resistance moves, multiplied by the resistance; the units of power and distance being the same for the two points of application. Thus (not allowing for friction) ten pounds moving ten inches would move 100 pounds one inch, or twenty pounds five inches, or five pounds twenty inches.

Q. How does this rule apply to a series of levers acting one after the other?

A. The power of each can be figured independently of the others, and the effect of the power of the first acting on the resistance of the second being considered as the power of the second, and so on.

Q. How much braking power is required to stop a 700-ton passenger train in 20 seconds, from a speed of 60 miles an hour?

A. About 15,330 horse power (H. P.).

Q. How much is a horse power?

A. The equivalent of the work done in raising 33,000 pounds one foot high in a minute, or 550 pounds one foot high in a second, or 1,980,000 pounds one foot high in an hour.

THE BRAKE SHOES

Q. Should the brake shoes be harder or softer than the wheel tread?

A. Softer, on the general principle that of two rubbing parts, the one cheapest to replace should be the softer. Further: wear of the wheels might prove more dangerous than that of the shoes.

Q. But what quality should the shoes possess?

A. Toughness, to guard against breakage.

Q. Is the coefficient of friction—that is, the measure of the amount of friction between the two rubbing surfaces—the same at all speeds?

A. No; at high speeds it is less than at low.

Q. Is this entirely an advantage?

A. On the contrary; as it is just at high speeds when friction is most desirable.

Q. Then in what respect is it advantageous?

A. It permits more severe braking at high speeds without causing shocks by slack action.

Q. How about the friction between the wheels and the rails at various speeds?

A. It is about the same, regardless of speed.

Q. What are the advantages of the clasp brake over the single-shoe type?

A. Shorter, more accurate and smoother stops; reduced brake shoe pressures; lower brake shoe maintenance cost; fewer slid flat wheels; fewer hot journals bearings, and smoother riding cars.

Q. Why shorter stops?

A. Because of uniform braking force, uniform piston travel and reduced brake shoe duty.

Q. Why more accurate and smoother stops?

A. Due to more flexible brake manipulation.

Q. Why less brake shoe pressure?

A. Twice the number of shoes to develop the same braking power.

Q. Why reduced brake shoe maintenance?

A. Less shoe wear.

Q. Why fewer slid flat wheels?

A. No stuck brakes, shocks, or transfer of load from one wheel to another.

Q. Why fewer hot journals?

A. Journal side pressure due to braking is eliminated.

Q. Why smoother riding?

A. Journal boxes play more freely in the pedestals.

THE AIR SIGNAL SYSTEM

Q. What other safety system has been developed along with that of the automatic brake?

A. The air-whistle system for passenger trains.

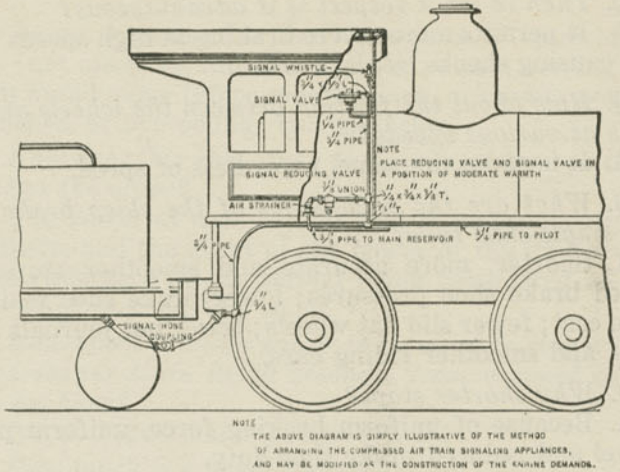

Fig. 462. Signal Equipment for Engine.

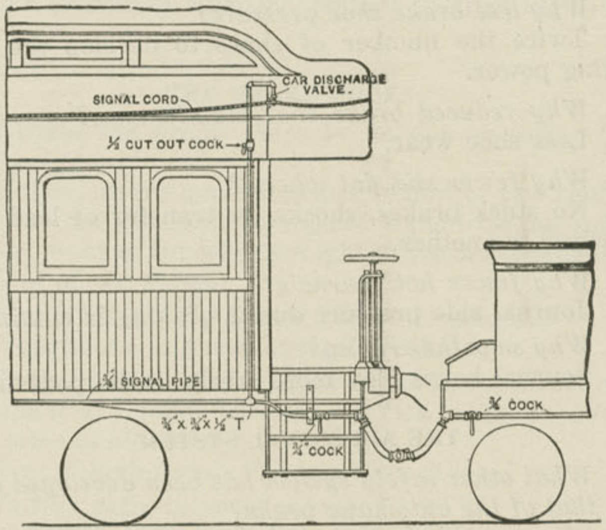

Fig. 463. Location of Signal Apparatus on Coach.

Q. What parts of the air-signal apparatus are placed on the engine?

A. The reducing valve (Fig. 466), signal valve (Fig. 465), whistle (Fig. 462), pipe connections (Fig. 462), and strainer.

Q. What parts are on the car?

A. The discharge valve (Fig. 464), signal cord and signal pipe and connections (Fig. 463).

Q. How is the car discharge valve operated?

A. By pulling the signal cord, forcing the valve 3, and letting the whistle-line pressure escape to the outer air.

Q. Where is the signal valve located?

A. In the cab.

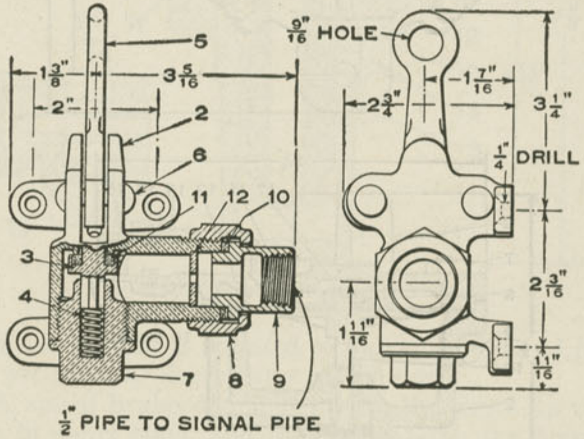

Fig. 464. Car Discharge Valve.

HAND BRAKES

Q. What is the disadvantage of hand brakes?

A. Their application is slow, even after once commenced; the pressure obtainable is not so powerful; time is lost when commencing to apply them; a system of such brakes cannot be automatic—that is, will not brake the train in case it parts; nor can they be made continuous throughout the train; also they heat the wheels unevenly and cause their breakage.

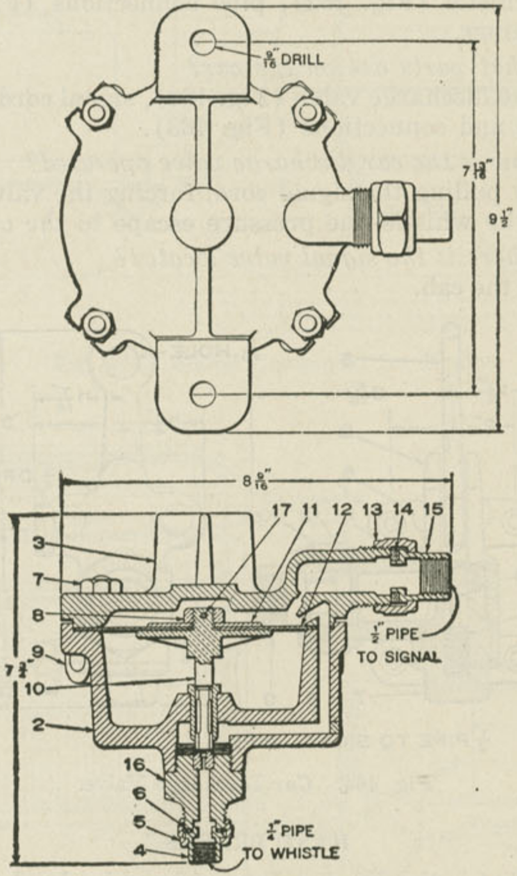

Fig. 465. Signal Valve.

Q. What is the first requirement of a good hand brake?
A. Harmony of operation with the power brake.

Q. What is the result when this is lacking?
A. Hand braking while the air brake is set tends to force the brake piston back to release position and hold it there.

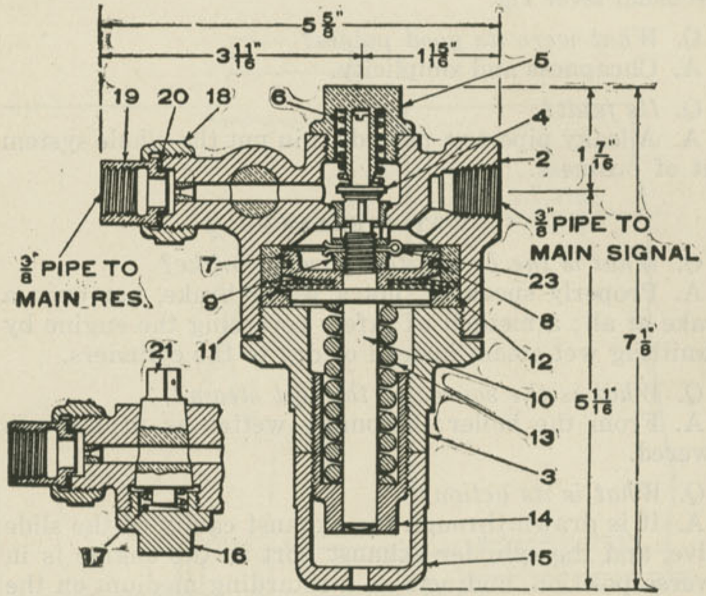

Fig. 466. Signal Reducing Valve.

Q. What method is adopted to quicken the hand brake action yet without decreasing the power?
A. A spiral brake drum, bringing the shoes up to the wheels in short time, and then increasing the leverage.

THE HYDRAULIC BRAKE

Q. What was the hydraulic brake?
A. One in which power was applied from the engine to the various brakes by the pressure of water, glycerine or other liquid, in pipe connection with suitable compressing

apparatus and reservoirs, at one end, and chambers with flexible rubber diaphragm under the various cars; pressure of the liquid on one side of each diaphragm forcing out its push rod and applying the brake cylinder through the usual lever rig.

Q. What were its good points?

A. Cheapness and simplicity.

Q. Its fault?

A. A leaky pipe or a parted train put the whole system out of business.

WATER BRAKES

Q. What is the Le Chatelier water brake?

A. Properly speaking, not a water brake, nor even a brake at all; a method of safely reversing the engine by admitting wet steam instead of dry to the cylinders.

Q. What is the source of the wet steam?

A. From the boiler; becoming wetter as pressure is lowered.

Q. What is its action?

A. It is drawn through the exhaust cavity of the slide valve, and the cylinder exhaust port as the engine is in reverse position, and acts as a retarding medium on the locomotive.

Q. Is it applicable for high-speed?

A. No, not for over 20 miles an hour.

Q. Describe the Baldwin water brake for compound engines.

A. Referring to Figs. 467 and 468, water entering the pipe *A* goes to *a a* and the exhaust passages. The valve *D* regulates the back pressure against which the piston will operate; *E* is a safety valve in the live steam ways; *C*, air-inlet valves preventing smoke and cinders being drawn into the working cylinders; *B*, a lid to close the exhaust nozzle.

Q. How is this brake applied?

A. The cylinder cocks are opened, the reverse lever put into full backing position; the water valve and the air valve *C* opened, and the exhaust lid *B* closed.

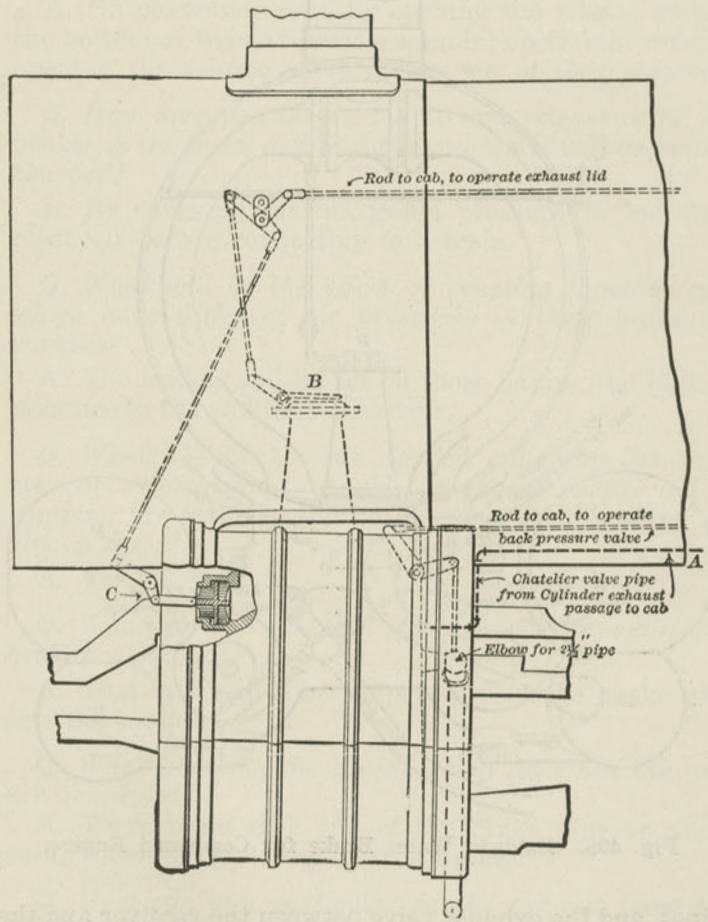

Fig. 467. Baldwin Water Brake for Compound Engine.

Q. Is this brake applicable to all compound engines?

A. No; in two-cylinder compounds having great difference in the cylinder diameters there must be two water

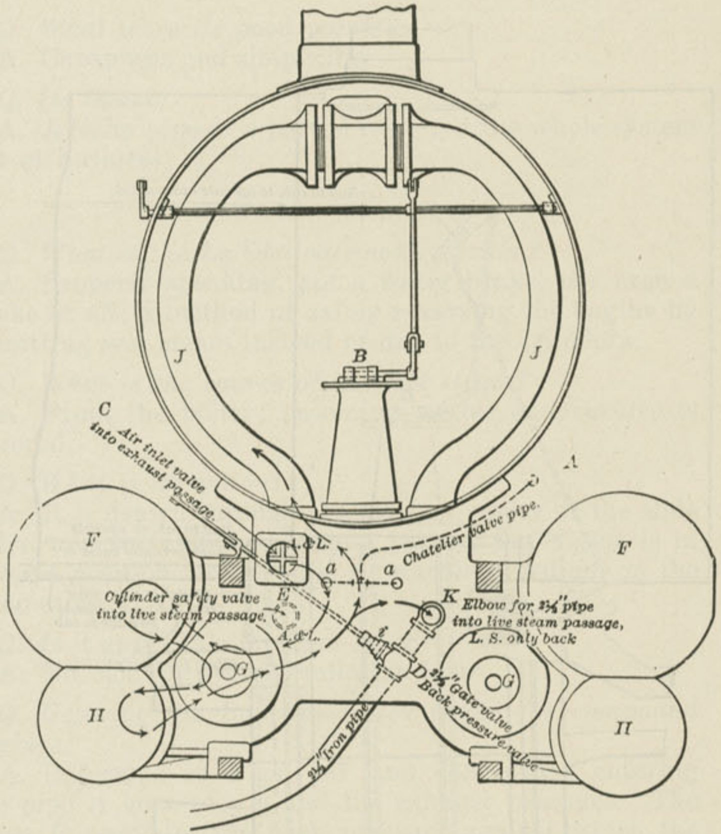

Fig. 468. Baldwin Water Brake for Compound Engine.

pipes, and the exhaust valve between the receiver and the "LP" cylinder must be closed.

TRAIN HANDLING

Q. Suppose that the brakes are set when the engine is not attached to the car, how may they be released?

A. On passenger cars, by opening the release cock in the bottom of the auxiliary reservoir; on freight cars, by opening the release valve in the top of that reservoir.

Q. How may you insure the certain release of all the brakes in the train, and that the reservoirs will be quickly charged?

A. By carrying the maximum pressure in the main reservoir before connecting to a train.

Q. What will be the effect of coupling together cars which have different air pressures in their brake apparatus?

A. The brakes will be set on those having the highest pressure in the auxiliary reservoir.

Q. When the brakes are applied either by the train men or automatically, should the engine runner aid in stopping the train by the brake valve, as in making ordinary stops?

A. Yes.

Q. What is the essential feature of the automatic brake?

A. That any reduction of pressure in the brake pipe sets the brakes.

Q. What prevents the brakes being set when the cars are uncoupled?

A. There is on each end of the brake pipe an angle cock, which is closed before uncoupling.

Q. How can any particular car be cut out from the braking action?

A. By a stop-cock in the branch pipe from the main brake pipe to the quick-action triple valve.

Q. How is the engineman's brake valve cut out from any but the leading engine, when there are two or more engines coupled in the same train?

A. By stop cock in the main brake pipe near the engine runner's brake valve.

Q. What should be done in making up trains, as regards the couplings and connections?

A. All couplings should be united so that the brake system extends to every car in the train, unless the brake is defective on one or more, in which case only this should be cut out. All cocks in the main brake pipe should be opened, except that on the rear of the last car, which should be closed. All cut-off cocks in the branch pipes between the main brake pipe and the triple valves should be opened (except in the case of cars with disabled brakes).

Q. What should be done in the matter of couplings in detaching engines or cars?

A. The main brake pipe should be closed at the point of separation, to prevent setting the brakes, and then the couplings should be parted by hand.

Q. How is the train speed best controlled on long down grades, while maintaining a good working pressure?

A. On ordinary grades, by running the compressors at a fair speed so that a comparatively high pressure will have been accumulated in the main reservoirs while the brakes are on, which will, when released, enable the auxiliary reservoirs to be recharged before the speed has increased to any considerable extent.

Q. How should the compressors be started?

A. Comparatively slowly, until they get warm.

Q. What is the object of this?

A. To have an air cushion in the air cylinders and let the condensation escape through the exhaust.

Q. What about lubricating the air compressors?

A. The lubricator should be used as soon as possible after starting, but only moderately; using valve oil only. The piston rod should be swabbed with oil.

Q. Should the emergency brake be used except in a case of absolute emergency?

A. No; it is unpleasant to passengers and does the rolling stock no good.

Q. Should the brake pipe pressure be exhausted to atmosphere in putting on the brakes?

A. No; it is just a waste of air. They cannot be put on any harder than full on, and pressures are calculated so that they will be full on long before the brake pipe is fully exhausted.

Q. How about testing and inspecting brakes on leaving a terminal station?

A. They should be tried then, to be sure that they are in perfect condition and that they will work on the first regular stop or on the first emergency.

Q. How should very accurate passenger train stops be made?

A. With two brake applications.

Q. How can shocks to passengers in stopping be avoided?

A. By releasing just before train stops, letting the trucks right themselves. If on a heavy grade, apply again to prevent drifting.

Q. When should freight-train brakes be released to avoid parting?

A. Never, at a slow speed, before the train stops.

Q. How about braking for stops to take water on a freight train?

A. The train should be stopped short of the water supply, engine uncoupled and run alone to that point.

Q. *What should be observed in setting out cars?*

A. To leave the brakes applied on the train when quitting it; then after recoupling the angle cocks must be opened.

Q. *What should be done before starting?*

A. The brakes should be tested and the number and weight of cars and the number of brakes in good order ascertained.

Q. *How should the engine be coupled to an empty or a partially-charged train?*

A. With reduced engine and brake pipe pressure.

Q. *What rule about opening the throttle at once after releasing freight-train brakes?*

A. It may part the train; the train slack should first adjust itself.

Q. *What about emergency application on turntables and at water cranes with the old "A-1" equipment?*

A. It strains the turntables. At these and water cranes there should be two applications, aided if necessary by a little steam.

Q. *What is the best way to brake heavy freight trains on grades and fast passenger trains?*

A. With heavy initial application.

Q. *What should be done at the top of a down grade?*

A. The brakes should be applied, to see if capable of controlling the train.

Q. *What rule about descending a grade?*

A. To keep the brake pipe pressure to the standard by frequent recharging.

Q. *Where hand brakes are necessary, on which cars should they be applied first?*

A. Those with no air brakes; then those immediately back of the engine.

Q. *Is the full air-brake power available when the hand brakes have been put on?*

A. No.

Q. *What rule about using the pressure retainers?*

A. All should be used, unless the train runs too slowly.

Q. *What rule about release position on long trains?*

A. It should be used, regardless of the train length.

Q. *How is recharging to be done, with freight trains, on down grades?*

A. It should be done in release position, returning the handle to running position when standard brake pressure is reached, unless a higher pressure is necessary. If the train is long, stay at "release" a few seconds, then return to "running," and back to release momentarily to let off any brakes on the forward cars which may have charged too rapidly.

Q. *What about using sand?*

A. It should be used before the wheels are liable to slide; otherwise it may cause flatting.

Q. *Which will hold best—driver and tender brakes in good condition, or reversing the engine?*

A. The brakes.

Q. *How much braking power have these two brakes on heavy freight engines?*

A. About the same as from five to seven 60,000-pound capacity cars with 30,000 pounds light weight.

Q. *What is the effect of reversing after applying the engine and tender brakes?*

A. Flatting.

Q. *Where is slight brake pipe leakage dangerous?*

A. On grades, unless the air gage is sharply watched.

Q. *Should the brakes apply suddenly when not intended, what should be done?*

A. The brake valve put at "lap" to hold the main-reservoir pressure and be able to release brakes and recharge auxiliary reservoirs.

Q. *What are causes of such sudden unexpected braking?*

A. (1) Broken hose, (2) conductor's application.

Q. In case of parting between air-braked cars on a partially equipped train, what is to be done?

A. Throttle closed.

Q. What is the principal cause of flatting?

A. Trying to release by putting the valve handle at "running."

Q. What should be done with passenger trains after leaving terminals or changing engines?

A. A running test should be made.

Q. In backing a train only partially equipped with air brakes, what should be done?

A. Hand brakes put on at the rear.

Q. Where else is this advisable?

A. To hold slack when parts of the train are on each side of a summit.

Q. Where is this not advisable?

A. To avoid shocks in the caboose when the air brakes are put on at a head of a partially equipped train.

Q. Why?

A. The hand brakes tend to stretch out the train and make more slack.

Q. In actual emergency cases what should be done?

A. The handle held at "emergency application" until the train is still; if a passenger train, until the danger is by.

Q. What relations between train length and discharge at the brake pipe exhaust port?

A. The shorter the train, the shorter the discharge for a given reduction.

Q. Of what use is this fact?

A. It informs the engineman whether or not the angle cocks are open between tender and cars.

Q. Suppose there are "empties" to be hauled up grades and the same number of "loads" down; should the brake pipe pressure be the same?

A. No; say 70 pounds for the "empties" (to avoid wheel flatting) and 90 for the "loads."

Q. What brake cylinder pressures will 70 pounds brake pipe pressures give in emergency stops?

A. About 60 pounds with the Westinghouse brake.

Q. What for service stops?

A. About 50 pounds.

Q. With 90 pounds brake pipe pressure how much brake pipe reduction is necessary to equalize the auxiliary and brake cylinder pressures?

A. About 25 pounds.

Q. In air-brake parlance, what is meant by excess pressure?

A. The difference between main-reservoir and brake pipe pressure; usually 20 to 30 pounds.

Q. Does the length of the train have anything to do with the amount of excess pressure carried?

A. To insure a quick release of the brakes the brake pipe must be charged its whole length as quickly as possible, so that all the brakes will release as uniformly as possible, to avoid jerking the train. It will take more air to charge a long brake pipe than a short one, therefore, with the same reservoir less excess will do the work with a short train.

Q. What is a service application?

A. Gradual braking.

Q. What is an emergency application?

A. Practically instantaneous application of full brake power by sudden reduction of brake pipe pressure.

Q. Does the friction between brake shoe and wheel vary with the rotation speed of the wheel?

A. Yes.

Q. Does the adhesion between wheel and rail vary with the speed?

A. No.

Q. To what does this point?

A. To the possibility—indeed, the necessity—of greater brake cylinder and brake shoe pressure with high speeds; provided this increased pressure can be reduced down as the speed decreases.

Q. How is this reduction effected?

A. By the automatic reducing valve.

Q. What effect does it have on a bridge to apply brakes when the train is thereon?

A. There is a force produced which tends to push the rails in the direction the train is running.

Q. What effect does it have on a bridge to apply brakes before reaching it, and to hold them on while the train is passing over the bridge?

A. Same as preceding answer.

Q. Will a cam driver-brake set the brake harder with a long or short piston travel, provided the air pressure is the same in the brake cylinder in both cases?

A. The brake will set tighter with the longer piston travel. The cam screws are brought more nearly horizontal where the greatest power of the brake is obtained. In other words, with the short travel the cams stand higher, and have a downward thrust as well as one towards the wheel center.

Q. Why is it that an engine air gage will show 70 pounds brake pipe and 90 pounds main reservoir with engine when not coupled to any cars, but as soon as coupled up to the train, the brake pipe hand may drop 5 pounds or more? When the engine is cut off afterward, the hands stand all right again. It is a D-5 (1892 model) brake valve.

A. As the brake pipe pressure approaches 70, the supply valve begins to close making a smaller opening through the brake valve to the brake pipe. If the brake pipe is tight, the supply valve will finally close and the brake pipe pointer on the gage will register full brake

pipe pressure. However, should the brake pipe leak, the supply valve cannot close, but must remain open and feed the leaks. If the leaks are heavy the valve will stay open, and the gage register short of full brake pipe pressure, in proportion to the leakage.

Q. What are the various causes for wheel sliding, which particularly concern the train and engine men?

A. (1) Too high (over 70 pounds) brake pipe pressure. (2) Hand brake, especially if used with air brake. (3) Sticking brakes (triples, with poorly fitting packing rings). (4) Leakage by rubber seat of emergency valve. (5) Plugged up exhaust port of retaining valve in either of its positions. (6) Heavy brake applications, especially with empty cars or on a slippery rail. (7) Too short piston travel. (8) Unequal distribution of brake power where rigging has a short equalizing lever and same strikes, under brake application, on rod jaw by reason of slack being taken up too much on one end of the car. (9) Brake shoes freezing to wheels.

Q. What pressure should be carried in the signal line?

A. Forty-five pounds.

Q. How would you know whether or not there was main reservoir pressure in the signal line?

A. (1) By the whistle blowing when brakes were released; (2) by the inspection gage.

Q. How would you repair a broken signal pipe line?

A. Usually, plug it.

Q. How much of the weight of a passenger car should be braked?

A. 90 per cent for full service application.

Q. Is this usual?

A. Yes; in freight service 60 per cent of the light weight of the car is usually braked.

Q. With the very best brakes, how do stops at different speeds compare?

A. On a level, directly with the square of the speed.

Q. At 60 miles an hour, how many feet a second will a train move?

A. Eighty-eight.

Q. What is the effect of cutting out the engine-truck brake?

A. The train will run considerably farther before a stop can be accomplished.

Q. What about the position of the shoes and angle of the brake-beam hangers?

A. Practice in this respect is reasonably correct; but incorrect angle of the hanger may cause either considerable loss of power or such an increase as may slide the wheels.

Q. In what position will the best results be obtained?

A. If when the brakes are on, the hanger is parallel to a tangent to the wheel at the middle point of the brake shoe contact.

Q. What may be said about loss of brake efficiency by reason of low brake and reservoir pressures?

A. This is getting to be less, by reason of the pressure used being increased; now where the road passes through a hilly country, over 70 pounds are used, generally 110 pounds.

Q. What may be said of piston travel in connection with the brake?

A. It is often too great, and more often unequal in the various cars; some may have six inches and some ten; which makes smooth stopping difficult.

Q. What about the tension of the cylinder release spring, as causing loss of brake efficiency?

A. This is quite considerable, and probably can never be eliminated.

Q. How about the loss of efficiency from beam release springs?

A. This is the least excusable of all; the shoes should fall off from the wheels by their own weight. Their tension should be made and kept as low as possible.

Q. How about the loss by friction in foundation brakes?

A. The amount of such loss has never been properly determined.

Q. What about insufficient leverage?

A. This comes from one of two causes; either the adoption of low standards of brake power, or mistakes in putting up foundation brakes.

CHAPTER LXXXIX

EXAMINATION OF FIREMEN

Q. By whom will the examination of firemen for position as enginemen be conducted?

A. By the road foreman of engines on the subjects given hereafter; and the trainmaster on such subjects as are under their respective jurisdictions; and by such other persons as the superintendent may direct.

Q. From whom will candidates be selected?

A. From those who have served as firemen at least three years.

Q. By seniority?

A. No; firemen must not rely upon seniority; the best interests of the company demand that vacancies shall be filled with men who have shown themselves most worthy of promotion; loyal, faithful, intelligent, and economical performance.

Q. Are the examinations in writing?

A. The examination will be either written, oral, or both, as the examiners may elect.

The examiners may vary the arrangement of the questions, or add to them, as they see fit, and if any answers of the candidate are not satisfactory, he will be questioned further on the doubtful points.

Q. On what else will the candidate be examined?

A. In addition to this, he may be required to pass a practical examination on the locomotive, its operation, and the uses of its parts and attachments. He may be required to disconnect certain parts, such as rods, crossheads, links, and eccentrics, and put them together; to explain the uses of the shoes and wedges and the proper

manner of making adjustments of the same, and to show familiarity with the construction of pistons, slide valves, etc. He may then be required to operate injectors, to take them apart, and to point out the parts that are likely to be affected in service. He will be called on to explain the construction and uses of the throttle valve and connections, dry pipe, steam pipes, etc. He will be required to understand the Westinghouse air brake and train signal. He may be taken to an air-brake apparatus and required to operate it; to name the principal parts and explain their uses; to explain the manner of producing the supply of air, its storage, and its course when applying and releasing the brakes. He must also understand the uses and manner of operating the sight-feed lubricators.

A locomotive engineman will not be considered competent to properly care for and handle a locomotive, who does not have a general knowledge of the uses of its parts and the manner in which they are put together and secured in place. When smaller parts break, he must have the necessary knowledge to remove and replace them properly, and must be competent to locate defects that may develop. Candidates must pass the examinations referred to above to the satisfaction of the examiners. If successful, the examiners shall certify to the result of the examination upon a blank form, to be delivered to the superintendent and kept on file in his office for future reference.

Q. Should a candidate fail to pass a satisfactory examination may he be given another opportunity on a future occasion, when further promotions are to be made?

A. Yes. If so, he will be furnished with a memorandum of the subjects on which he displayed insufficient knowledge, in order to assist him in making the necessary investigations preparatory to the second examination.

Q. If he fails to pass the second examination, what will be done?

A. His record, with the result of the two examinations, will be forwarded to the superintendent, who will determine whether or not the candidate will be retained in the company's service.

Q. What is required of applicants for position as firemen?

A. They must meet the following requirements before their applications are filed:

They must be able-bodied; not less than 21 nor more than 26 years of age; able to read printing, such as in the Book of Rules, and writing, such as train orders; and write sentences of their own composition or from examiner's dictation. They must be able to solve problems in addition, subtraction, multiplication, division, and elementary fractions and decimals, so as to be able to compute speed, time, and distance. They must pass the standard test for sight, hearing, and color sense, and the examination for physical fitness.

These examinations and written papers, together with the Form of Application for Employment, when satisfactorily filled out, will be filed in the office of the road foreman of engines, or such other place as the superintendent may direct.

When employing firemen, the most suitable men for the service will be selected from this file, without regard to the date of application.

All firemen will be given instruction and opportunity to learn the road, before being regularly assigned to duty.

After six months' service, the fireman must pass an examination on such questions relating to his duties as may be put to him by his instructor (and most, if not all, of which will be found, with correct answers thereto, in these pages). He may be required to pass further examinations on more advanced matters, at such periods of service as the superintendent may designate.

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* Denotes Illustration † Denotes Table

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