Twenty-Fourth Edition

Locomotive Catechism

By ROBERT GRIMSHAW, M.E.

A COMPLETE TREATISE ON THE LOCOMOTIVE, CONTAINING 1,600 QUESTIONS AND THEIR ANSWERS, COVERING THE DESIGN, CONSTRUCTION, REPAIR AND RUNNING OF ALL KINDS OF LOCOMOTIVES. BEING INTENDED AS EXAMINATION QUESTIONS FOR ENGINEERS, FIREMEN, AND ALL OTHER RAILROAD MEN.

Includes the latest Official Forms for Examination of Firemen for Promotion, and of Engineers for Employment, and Detailed Descriptions of Compound Locomotives up to date.

Illustrated by 222 Engravings and 12 Folding Plates.

Twenty-Fourth Edition

NEW YORK
THE NORMAN W. HENLEY PUBLISHING CO.
132 Nassau Street
1905

MACGOWAN & SLIPPER
PRINTERS
30 Beekman Street
New York
U. S. A.

TO

Theodore N. Ely,

Superintendent of Motive Power, Pennsylvania Railroad,

IN APPRECIATION OF HIS

ENGINEERING AND EXECUTIVE ABILITY

AND HIS

COURTESY AND MANLY QUALITIES.

PREFACE.

IT HAS for many centuries been the custom to give a book a preface at the last moment. For this there is probably some good reason. Sometimes it affords the author opportunity to excuse himself for his temerity, or to apologize for his shortcomings, or to repeat to the public the hopes which he and his publishers have so often exchanged, as to the book's success.

On this occasion, however, there appears to be no great amount of presumption in doing for locomotive engineers and for those who wish to become such, what I have already done for stationary engineers, actual and prospective, and what the technical press and those for whom my other Catechisms were written, have thanked me for doing. As for the hopes of success, there is not even that excuse, for the sales in advance of publication indicate that the publishers' venture will be profitable, and my own pride and author's royalties stand in no need of sympathy. There might remain the apology—but as I have done the best I could under the circumstances, and as angels could do no more (than their best, be it understood) that excuse for an excuse falls through.

Yet there must be a Preface—and a reason therefor.

Well, the reason why this is a Catechism instead of something else shall furnish the reason for the Preface.

There are some classes of information which are like unto that triumph of modern ingenuity, the six-shooter, which, when wanted, is wanted like—well, *like everything*, and wanted right away. The Catechetical form gives each question (hurried or leisurely) its answer, very largely independent of any other question or matter, leaving out "ifs" and "buts" and "considerings." If there are only enough such questions and answers, and if the former are properly chosen (which includes being up to date) and the latter correct, this Catechism ought to be useful and satisfactory to those who buy it. As to the number of queries—as there are nearly thirteen hundred, the ground may be said to be reasonably well covered. As to their selection—novices and expert locomotive engine-runners have chosen many of them, and examining engineers many more. Many of the rest have come to me in the line of my regular work as consulting engineer in this country and abroad. As far as able I will answer, free by mail and promptly, any question of general interest concerning the locomotive, the answer to which does not appear in the current edition.

There only remains the item of correctness in the replies. While I am a long way on the blind side of infallibility (and have the compositor and the proof reader as scapegoats anyhow, where errors are found), the reader ought to get out of the book his money's worth and his time's worth.

I hope to make and keep, through this work, as many friends as by my other Catechisms—and friends are better than money any day—and that, through my efforts, my readers may increase in knowledge and in earning power.

ROBERT GRIMSHAW.

PREFACE TO THE NEW EDITION.

The success of previous editions warrants this issue in enlarged and improved form. The principal special features added are two Appendixes, with a separate index, the first giving the latest official Forms for Examination of Firemen for Promotion and of Engineers for Employment, and the second, detailed matter up to date, concerning compound locomotives, with instructions for running and for action in emergencies. There are also two large folding plates giving details of the famous "Webb" compounds on the L. & N. W. R. R., England, and one showing how to effect general locomotive repairs on the road.

ROBERT GRIMSHAW.

Locomotive Catechism.

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

A. Boiler, engines and running-gear.

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

A. Horizontal tubular with internal fire-box.

Q. What name might be applied to the class of 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; there are some, however, that have the cylinder on one side of different diameter from that on the other; and some have one cylinder on each side and one in the center; some have four cylinders.

Q. Are all locomotive engines horizontal?

A. Nearly all; but there are some that are slightly inclined downwards towards the crank-pin, and while nearly horizontal are not strictly so.

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

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

Q. Are all locomotive engines double-acting?

A. Yes.

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

A. It is a misnomer. The term "high pressure" 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 principally without one) 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 engine the steam which is exhausted from one cylinder is passed into another, there to do more work as it expands further. In a non-compound engine the steam after being exhausted from one cylinder does not go into any other cylinder.

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

A. Yes; many engines, particularly marine ones, 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 cer-

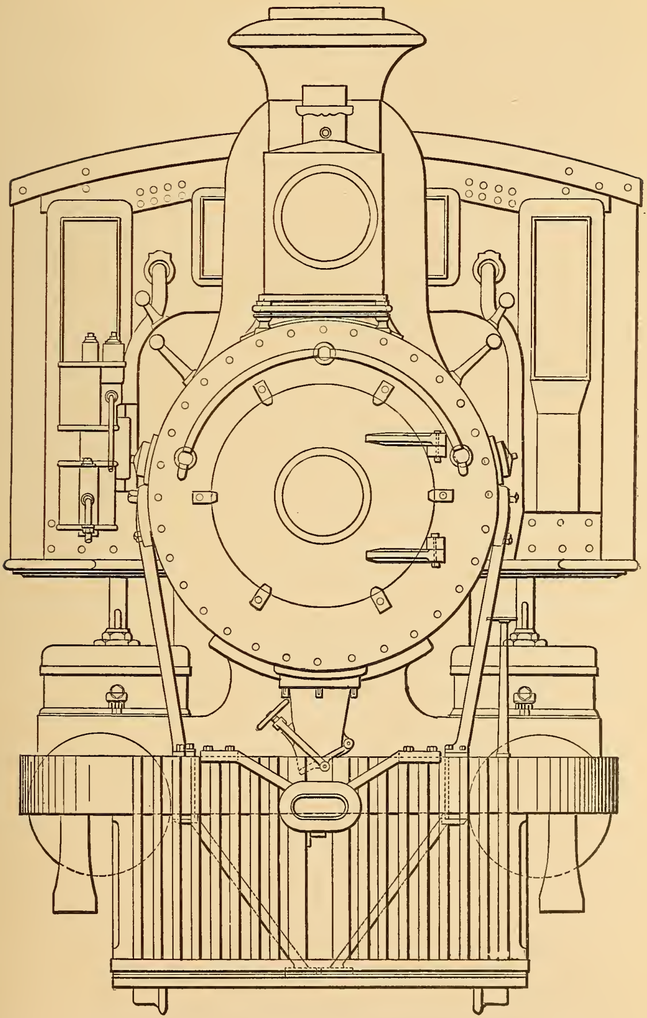


Fig. 1. Front End View, Pennsylvania R. R. Engine, Class "O."

tain 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 which are cooled by cold water circulating on the other side of such sheets or tubes.

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.

Q. Are all locomotives non-condensing?

A. Yes; it would be impossible, at least in the present state of the art of steam engineering, to carry on a train that would pay expenses, enough water to cool the exhaust from its engines. The time may come when by greater efficiency of the engine itself, calling for less steam per horsepower; by decreased friction of the engine and of the train, calling for less horsepower; and by increased efficiency of condensers themselves, calling for less water per horsepower—a locomotive may be run with condensing engines; but that time is not yet.

Q. What is meant by 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 piston of the engine itself; 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

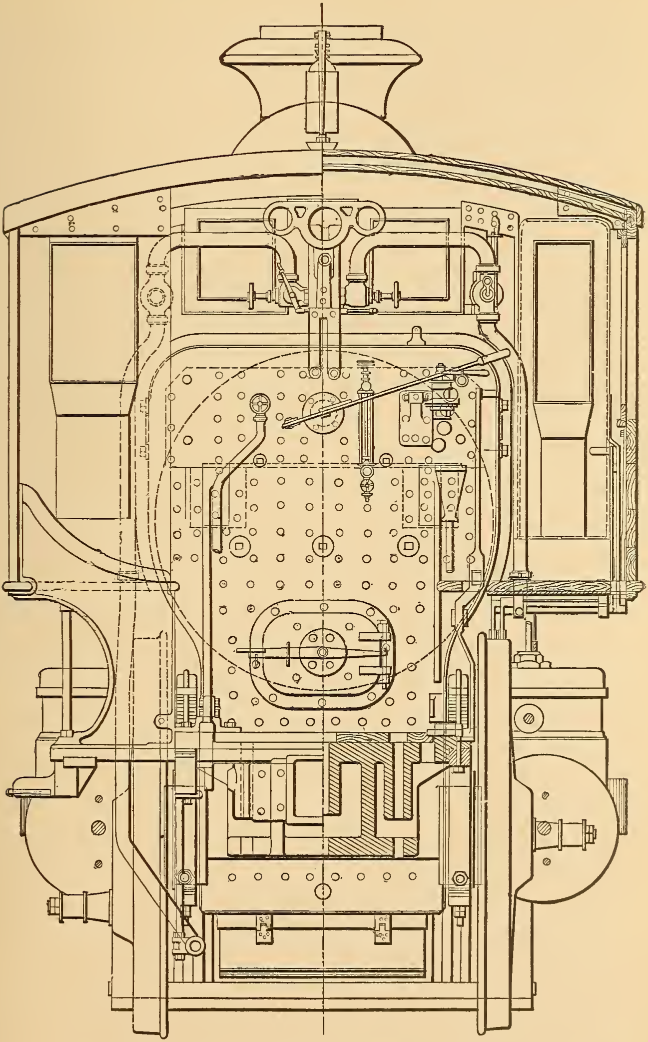


Fig. 2. Rear View, and Part Section through Cab, Pennsylvania R. R. Engine, Class "O."

have been made to use other types, but in general they have been failures, not having the simplicity, durability, and range of work of the ordinary slide.

Q. What is meant by 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 a strap surrounding an eccentric disk set on the driving-shaft or axle of the engine. There are usually two such disks for each cylinder, to enable the engine to be reversed. The position of the link being varied, the amount of motion that it imparts to the valve may be varied at will.

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

A. Most of them are, but there is a system in which motion is imparted to the valve 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 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 hav-

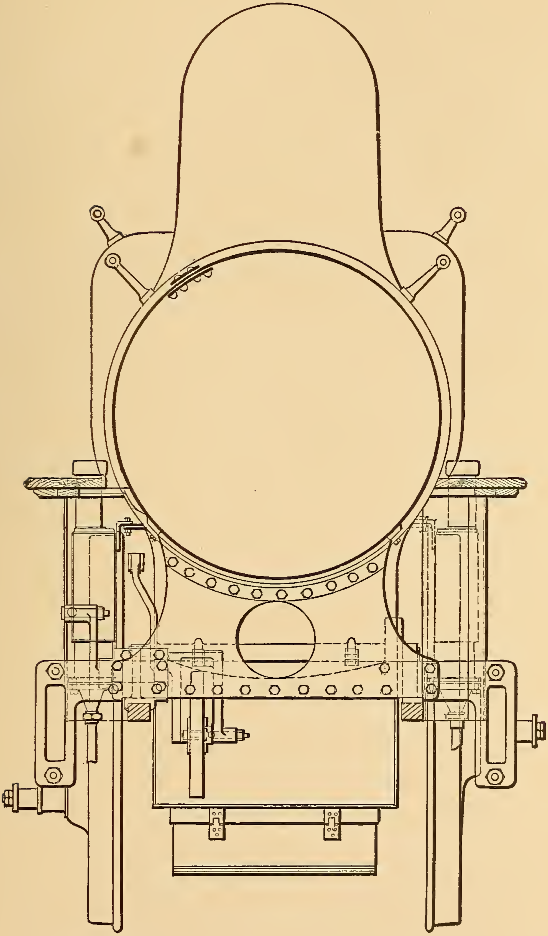


Fig. 3. Cross Section, Pennsylvania R. R. Engine, Class "O."

ing a crank and connecting-rod is difficult to get started in case the 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 one used.

Q. Are the engines of all locomotives reversible?

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

Q. What are the essential parts of the boiler?

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

Q. What materials are used for boilers?

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

Q. What are the advantages of steel for boilers?

A. It is stronger and more ductile, thus enabling a boiler to stand more pressure for a given weight, or to be lighter for a given pressure.

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

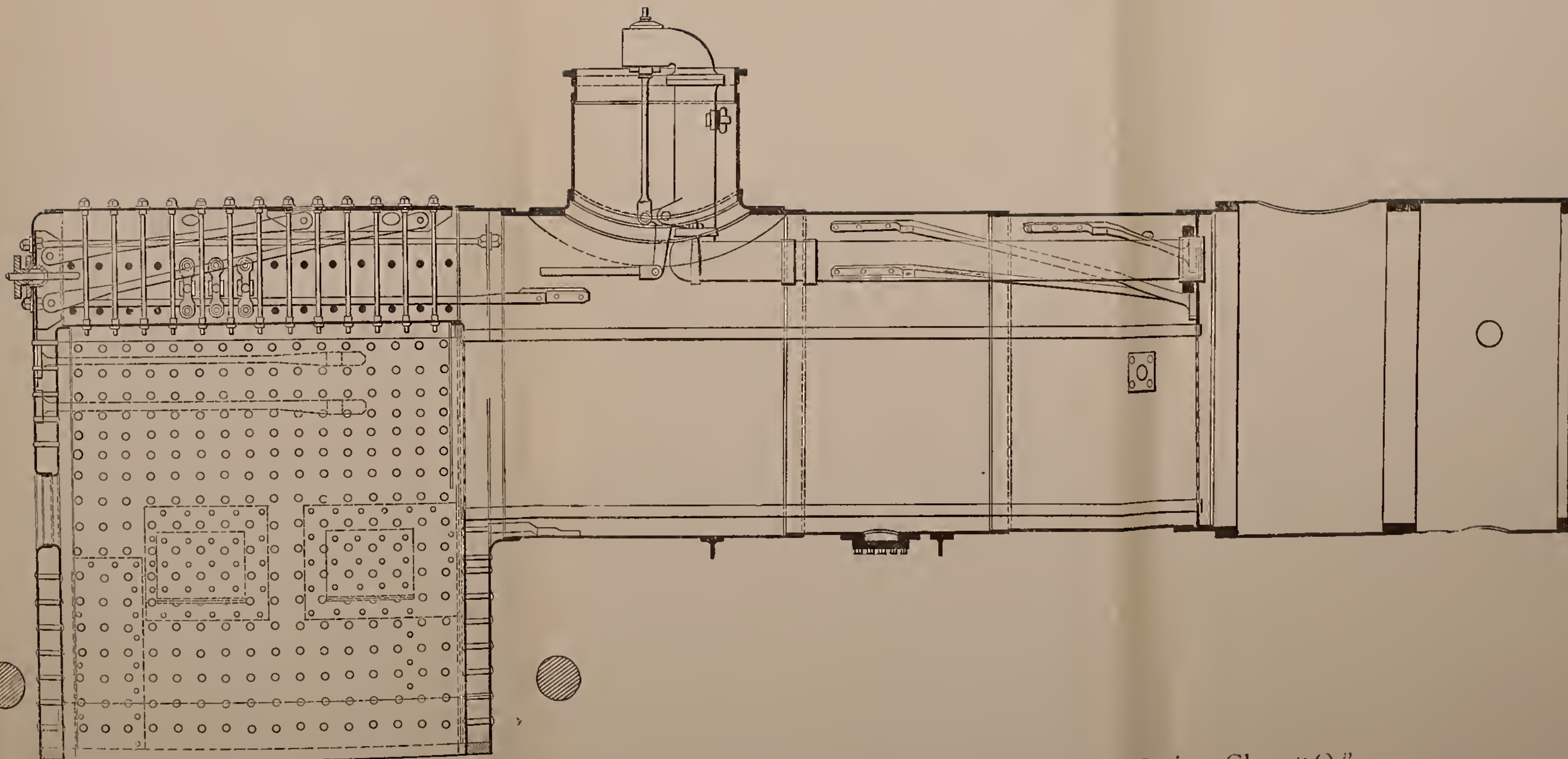


Plate II. Central Lengthwise Vertical Section, Boiler of Pennsylvania R. R. Engine, Class "O."

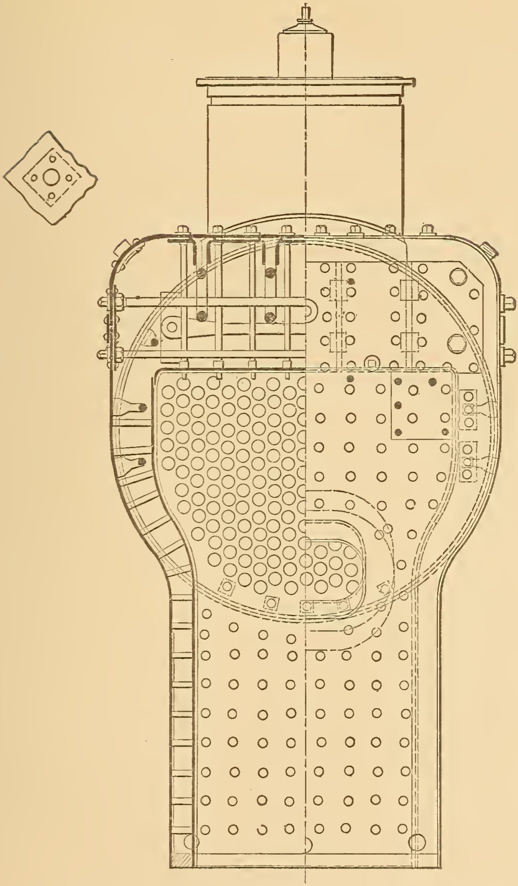


Fig. 4. Cross Section, Pennsylvania R. R. Boiler, Class "O."

ash-pan which receives the ashes that fall through the grate, and which is supplied with suitable dampers to regulate the amount of air which may be 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 and sometimes flat—usually the former. (See figures 5 and 6.)

Q. What materials are used for fire-boxes?

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

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

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

Q. What kind of 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.

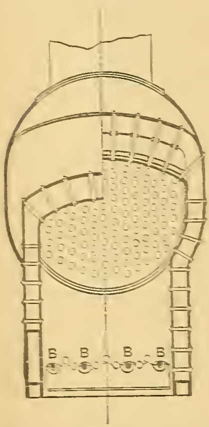


Fig. 6. Milholland Fire-box.

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

A. It is shown in figures 6 and 7. The furnace top slopes downward from the barrel of the boiler, and the crown-sheet is stayed with screw stays, except for a short distance back of the tube-plate; water-grates being used, as shown in the cut.

Q. What sort of fire-box is ordinarily used for burning bituminous or soft coal?

A. One quite deep and rectangular, with vertical

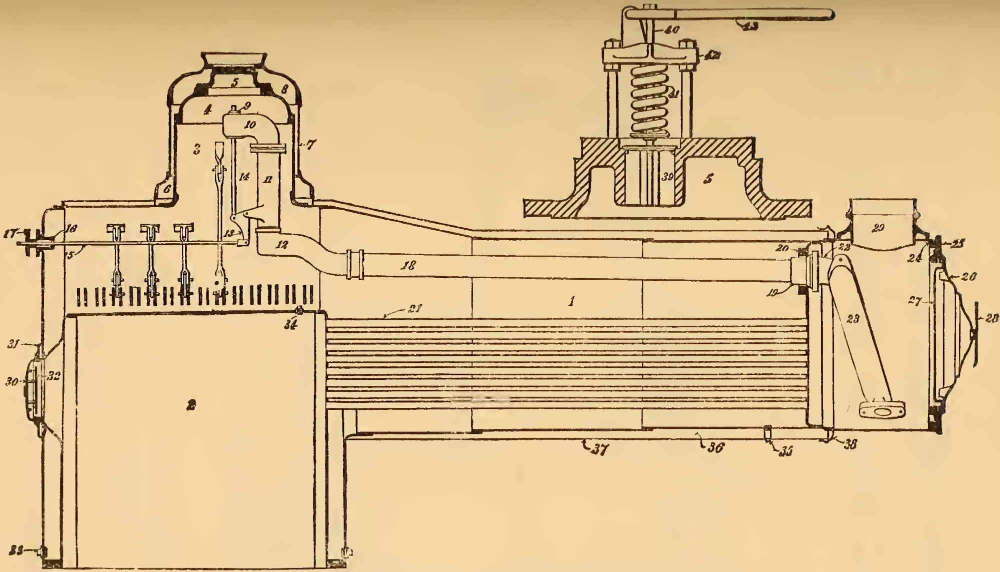


Fig. 5. Lengthwise Section, Locomotive Boiler.

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. Smoke-stack 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.

walls and a flat top very slightly sloping; 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 width of the boiler-barrel.

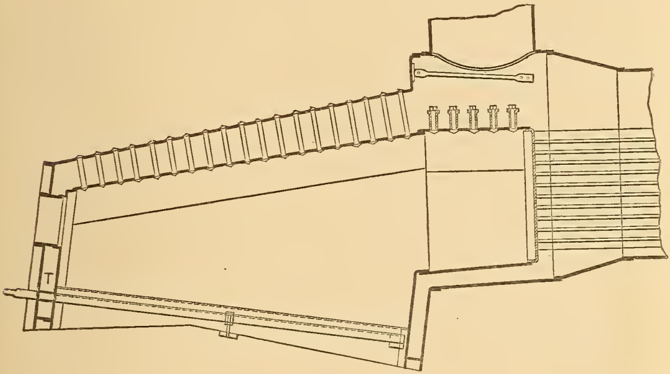


Fig. 7. Milholland Fire-box, P. & R. R. R.

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

A. Because soft coal first burns into coke, and this 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.

Q. What is the Wootten fire-box?

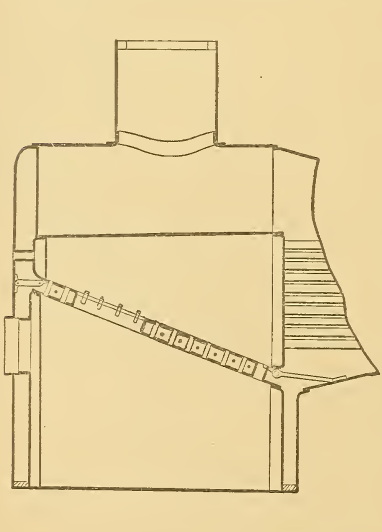
A. It is a wide and shallow fire-box, and has a combustion-chamber, and a brick bridge across the fire-box end of this chamber; is above the frames, and extends over the rear driving-axle.

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.



Figs. 8 and 9. Buchanan Fire-box, C. V. R. R.

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 the use of a water-table, as shown in figure 8, inclining from the back plate downwards to the tube-plate just below the bottom row of tubes, 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 gases of combustion, smoke and air, the intention being to cause them to mingle before they strike the tubes. There are also four tubes in the front end and four in the back, just above the fire, to supply air above the grate. Each of these has a conical nozzle through which there may be passed a jet of steam which will draw in a current of air.

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. That it necessitates raising the entire boiler, and thus raising the centre of gravity of the machine.

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. Besides this, the steam-dome is added for the same purpose. (See figure 5.)

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

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

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

Q. Is this same principle applied to the side sheets?

A. Sometimes.

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

A. To give the fireman a 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 with 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. How may fire-boxes be lagged?

A. On the L. S. & M. S. Railway a sheet of asbestos was placed next the hot surface, and over that was placed a covering of hair felt one inch thick, the whole being kept in place by a sheeting of kalamein or planished iron; the boiler-heads being done the same way.

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

A. A strain tending to crush it in.

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

A. To a very slight extent their own stiffness; to a very great extent the stay-bolts, extending from the inside fire-box sheets to the outside fire-box sheets. (See figure 10.)

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

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

Q. How are these stay-bolts fastened?

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

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 centres; what will be the strain on each bolt?

A. There will be 16 square inches held by each bolt, making 19,600 pounds that the bolt will have to hold.

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

A. To "make assurance doubly sure"; because sometimes the screw-threads strip, 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. 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; and rivets extend through the outer sheet, the mud-ring, and the inner sheet.

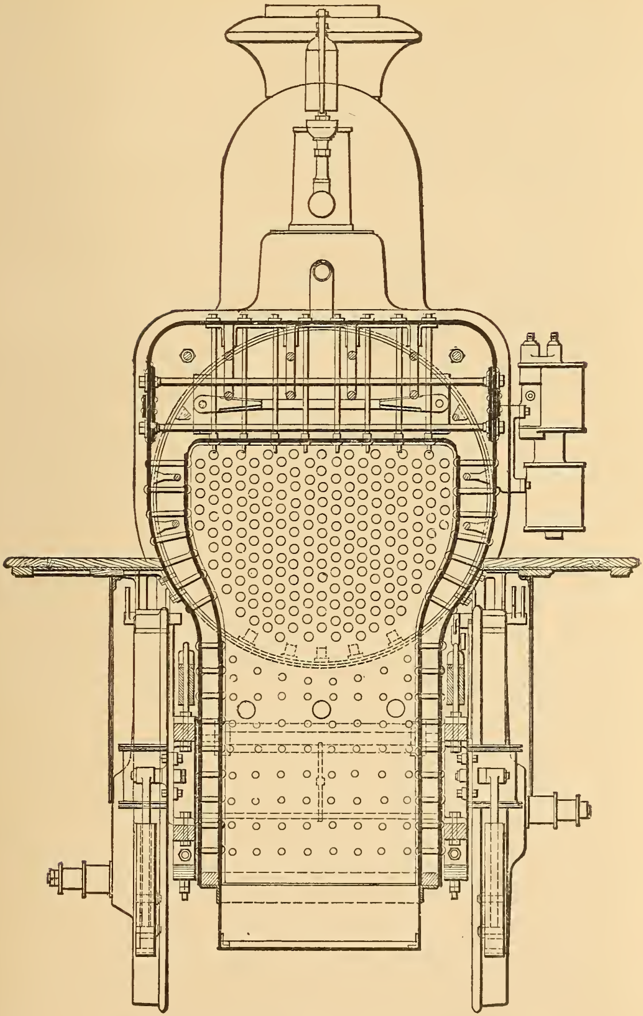


Fig. 10. Cross Section, Pennsylvania R. R. Engine, Class "O."

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

A. Instead of the solid mud-ring as in figure 11, there may be a ring of boiler-plate flanged over so as to have a section as in figure 12, with both the inner and the outer sheets riveted to this.

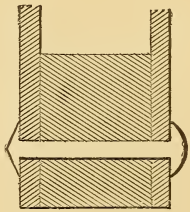


Fig. 11. Solid Mud Ring.

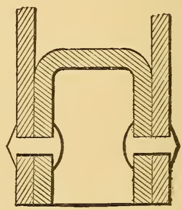


Fig. 12. Flanged Mud Ring.

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

A. The foundation-ring.

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

A. Simply a plain flap hinged on the left, outside the doorway, and having a chain by which to raise its latch and swing it open and shut.

Q. What is the objection to this type of furnace door?

A. That, 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 current of air downwards on the fuel instead of letting it go through the flues; still more thoroughly by a sheet-iron deflecting-plate placed on the inside of the box and hinged at its upper edge, with a contrivance by which it may be thrown up when coal is to be laid on.

Q. Describe the Hudson furnace-door deflector?

A. It is shown in figures 13 and 14. D is a deflector hung from a hook H attached to the fire-

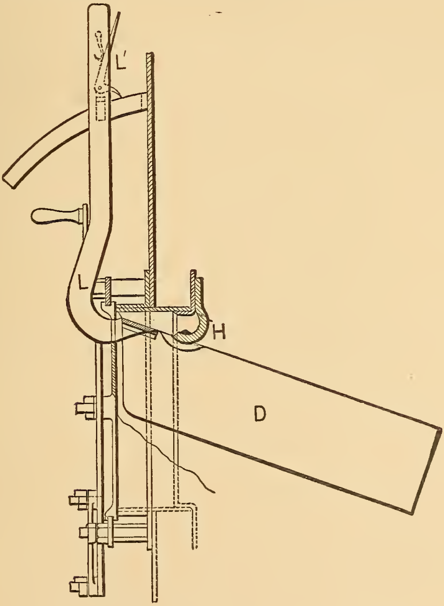


Fig. 13. Hudson Furnace-door Deflector.

box over the furnace door; a lever L is fastened to the deflector, by which to move it out of the way when coal is thrown on the fire. The position of the deflector is regulated by the lever and a latch L at its

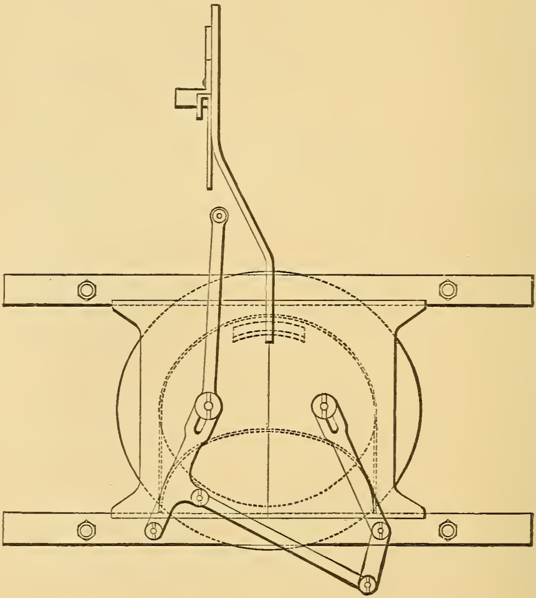


Fig. 14. Hudson Furnace-door Deflector.

upper end. A pair of sliding doors is usually employed in connection with the deflector.

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

A. By a jet of steam sent up the chimney from a pipe connected with the steam-space of the boiler 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. Its use is to direct a jet of live steam up the stack, causing, by friction between that jet and the surrounding air in the stack, a current of air 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 cause cold air to be drawn 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 ash-pan?

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

Q. How are the ash-pan dampers worked?

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

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 the spaces between them with ashes or cinders.

Q. What class of grates do we find used for wood?

A. They have stationary bars, ordinarily placed close together.

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

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

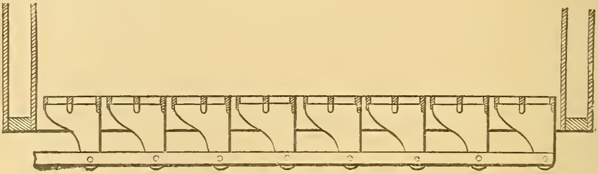


Fig. 15. Rocking Grate.

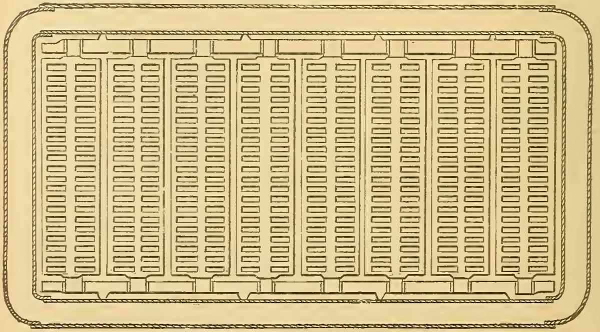


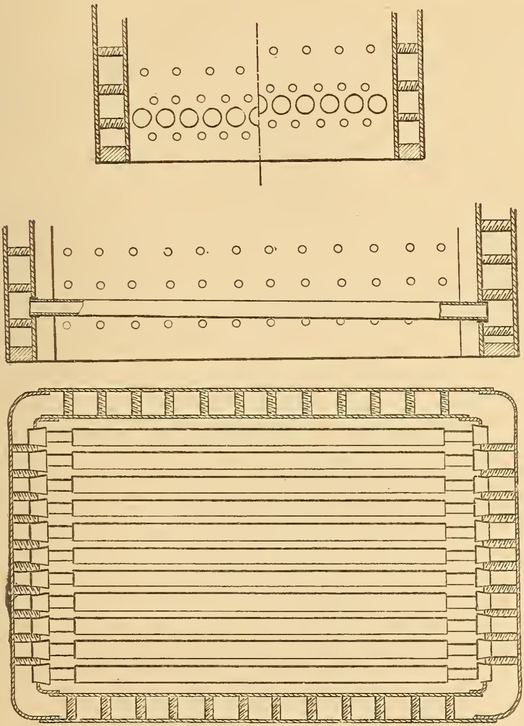
Fig. 16. Rocking Grate.

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

A. Hard, because the fire must be shallower.

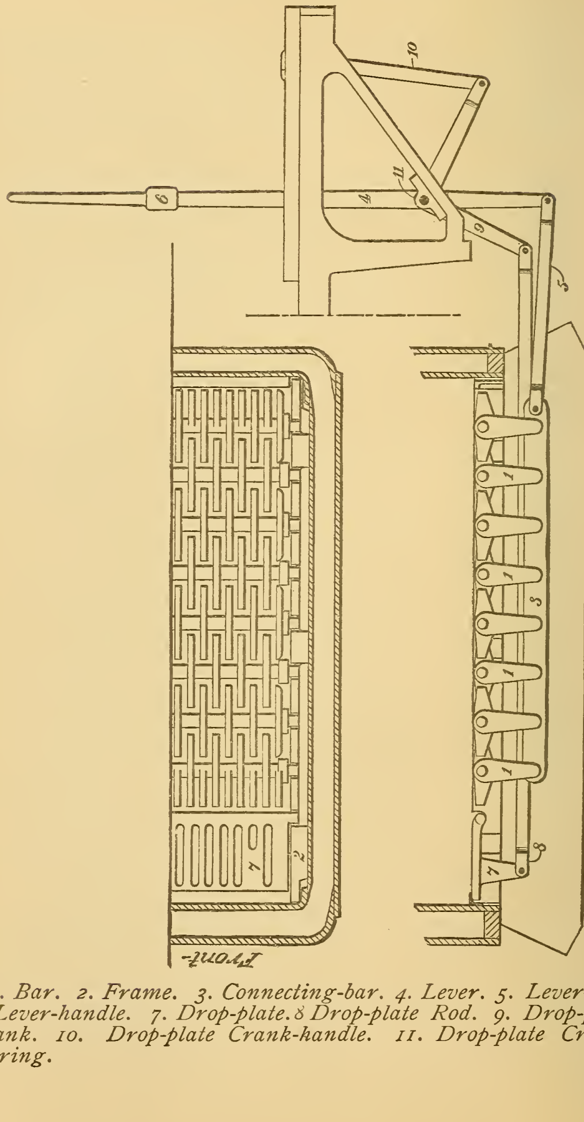
Q. What is the character of grate usually employed for anthracite or hard coal?

A. It is usually long, and has, instead of ordinary



Figs. 17, 18 and 19. Water-grate for Bituminous Coal.

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.



Figs. 20 and 21. 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.

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WESTINGHOUSE NINE-AND-ONE-HALF INCH IMPROVED AIR PUMP

PLATE III.

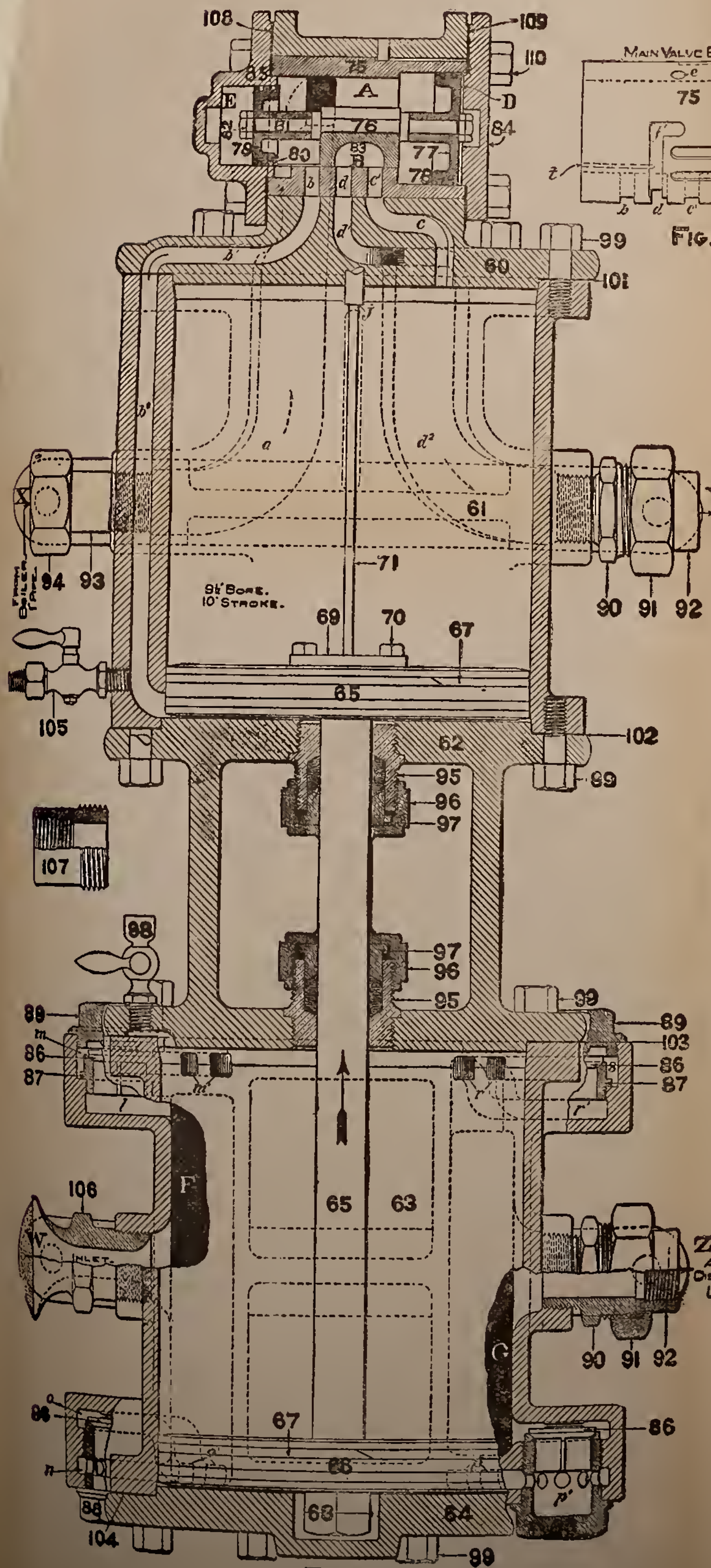


Fig. 1

Fig. 3

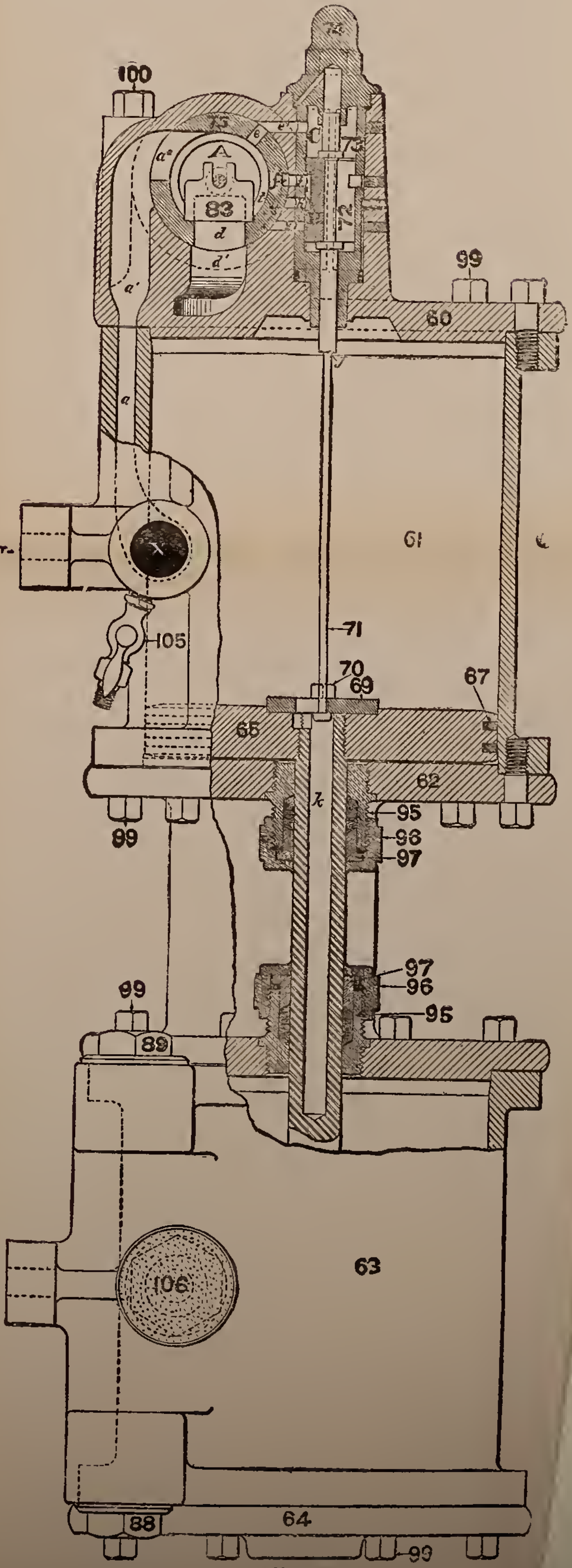


Fig. 2

The fire may be drawn 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 T (fig. 7) provided for that purpose, and have on their back ends rings by which to draw them out. At the front end they rest on a bearing-bar. Figures 6 and 7 show the type used on the Philadelphia and Reading road.

Q. How are the tubes of a water-grate 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 largely upon the fuel; anthracite coal taking more grate surface than soft coal or wood.

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

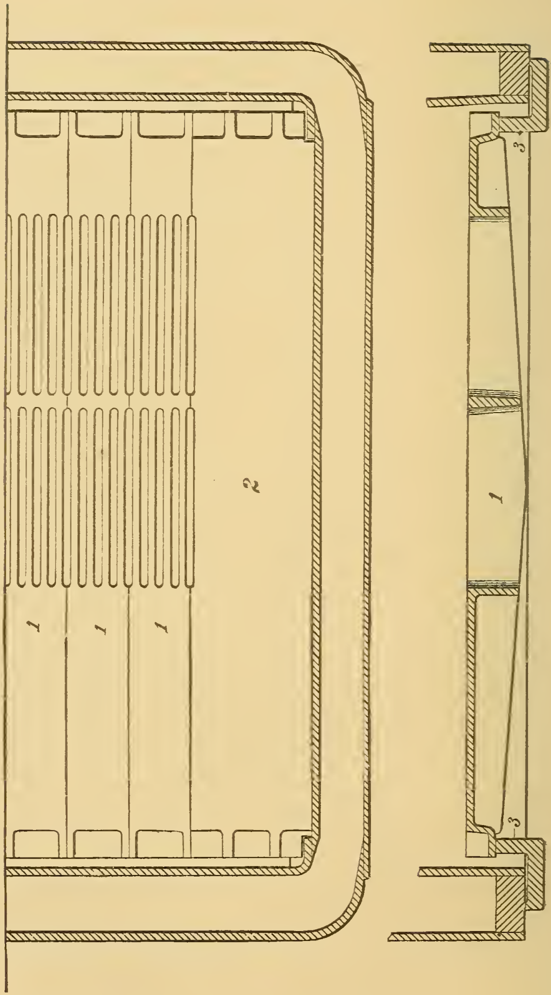
A. In soft-coal engines, by a drop door held up by arms controlled by a lever outside the fire-box; when this lever is turned, the arms which hold up the drop door are removed, and the weight brings down the door so that the coals may be taken out by a suitable opening, and, by raising the ash-pan damper, may be raked out. (See figures 24 and 25.)

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

A. Cast iron.

Q. What material is usually employed for water-grates?

A. Wrought iron.



Figs. 22 and 23. Plain Grate for Wood.

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

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.

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 its 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 also serves to distribute the fuel evenly over the grate.

Q. Of what material are locomotive tubes made?

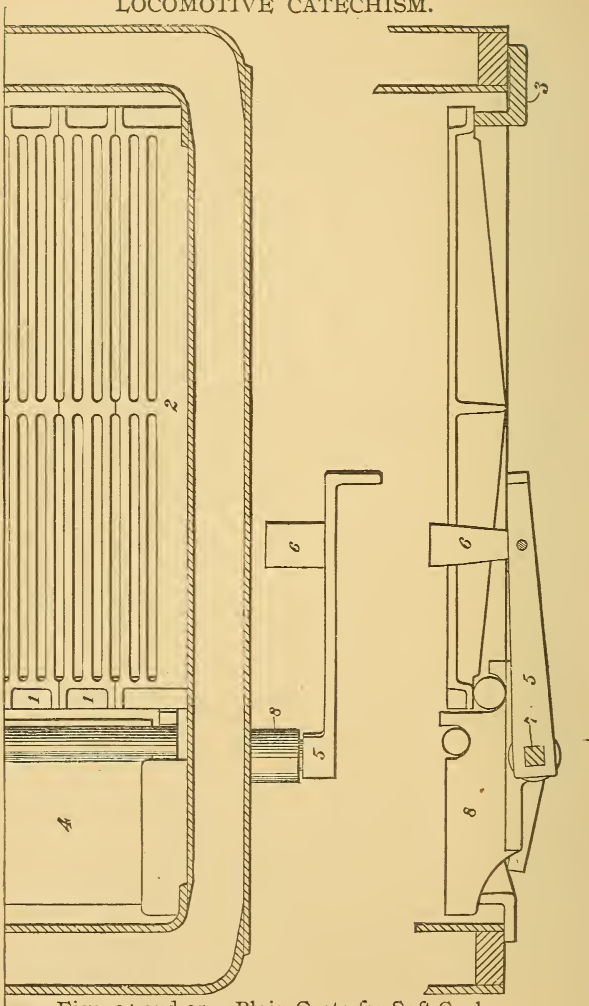
A. In America, of iron and of Bessemer steel; in Europe, of these metals and also of copper and of brass.

Q. When was the use of copper and brass tubes abandoned in this country?

A. Only after coal was substituted for wood as fuel.

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

A. Ten to twelve feet long, and two inches in diameter.



Figs. 24 and 25. 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. Why not use tubes of a larger diameter?

A. Because it is best to divide the current of combustion-gases into small streams each of which has its outer surface next a surface of metal on the other side of which there is water to be heated. If the tubes were four inches in diameter, nearly all the heat of the central portions (say two inches in diameter) would be wasted, not having time to be delivered to the metal of the tubes 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.

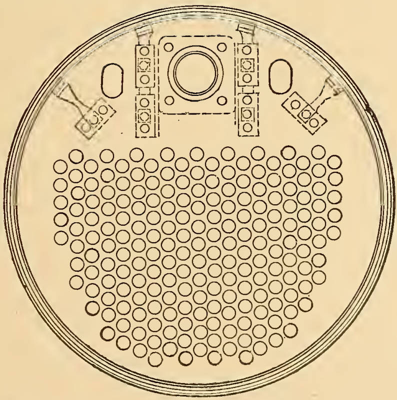


Fig. 26. Cross Section, Pennsylvania R. R. Boiler, Class "O."

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

A. Too slow draft, causing deposit of soot.

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

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

Q. What is the disadvantage of too long tubes?

A. They vibrate too much and are liable to leak.

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 to 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 stoppage of the flues?

A. There are two results: (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 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 made thinner to stand the same external pressure on them; this of course makes them cheaper, lessens the weight of the engine, and makes the engine raise steam rather more quickly.

Q. Why is the tube-plate made 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. In vertical, some think, as that gives the water better chance to ascend among them. Others again think that it is no advantage to have the water rise too fast; that it is better to have it delayed a little in its passage upward so as to be longer in contact with the tubes. But then it must be remembered that the bottoms of the tubes are not their hottest portion.

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

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

Q. In what direction do sling-stays extend?

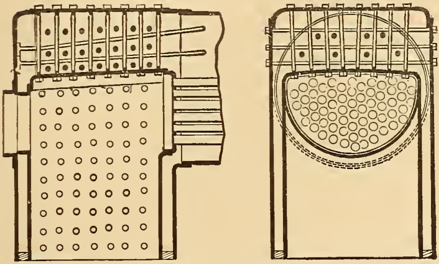
A. As nearly as possible at right angles to the surfaces which they connect. (See figure 5.)

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

A. That in order to be of the greatest effectiveness, they should be perpendicular to both the surfaces which they connect. Now ordinarily, if they are 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-



Figs. 27 and 28. Belpaire Fire-box, Matanzas R. R.

bolt will be at right angles to both the surfaces which it connects, as shown in figures 27 and 28.

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

A. The Belpaire.

Q. What other advantage has the Belpaire 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 top of a fire-box curved?

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

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

A. They necessitate 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 a lodgment for scale.

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 end will be lower than the front so as 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 towards 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 centre of 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. (See figure 7.)

Q. How are the crown-bars fastened?

A. They have at each end, feet resting on the side-sheet seam, 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, there goes a bolt; then the bars are slung from the boiler-shell; so that the bars support the crown-sheet and the boiler-shell holds up the bars.

Q. What is the advantage of the crown-bar system of 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; is not easy to inspect, and does not afford good facilities for washing out mud and scale.

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 towards the sheet?

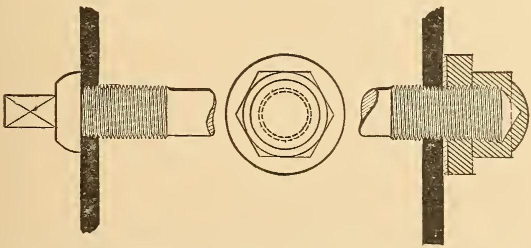


Fig. 29. Crown-stay Bolts and Nuts, Pennsylvania R. R., Class "O."

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

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. Tubes also act as lengthwise stays. (See plate 2.)

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

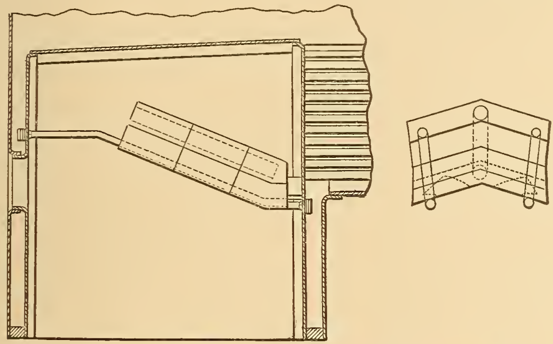
A. They should be as strong as the stays themselves.

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

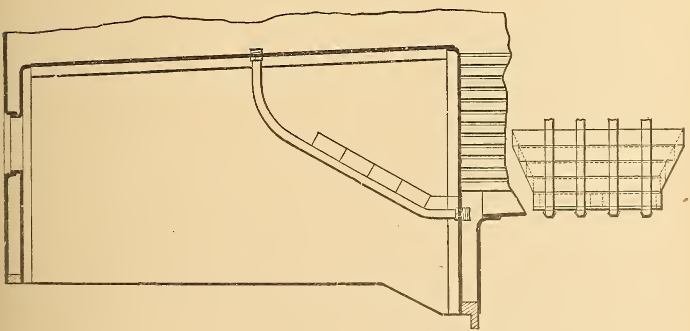
A. It is built across the front of the fire-box, from side to side of the box; and extends forward and upward, forming a diagonally-placed baffle-plate above the grate, preventing the flames and gases of combustion from the front of the grate going directly into the lower tubes and compelling them first to flow backward and upward, thus not only giving the gases 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 products of combustion; 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



Figs. 30 and 31. Brick Arch on Water-tubes.



Figs. 32 and 33. Brick Arch on Water-tubes.

between the water-leg and the water on the crown-sheet; or by tubes between the front and the back leg. (See figures 30 to 33, inclusive.)

Q. Have any experiments been made as to measuring 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, and 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 of the engines 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 ran 58.22. For the preceding month the advantage was about the same. The train-weight was 160 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. Have English engines as a general rule more or less heating and grate-surface than Americans?

A. Less. The Gladstone, on the L. B. and S. C. Railway, has only 1485 square feet of total heating surface and 20.65 square feet of grate (with a ratio of 72 to 1). The maximum indicated horsepower of the Gladstone being 1040, we have 50.35 horsepower per square foot of grate, and 1.43 square feet of heating-surface per horsepower, or 0.7 horsepower per square foot of heating surface.

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

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

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

A. To afford an easy passageway in which the

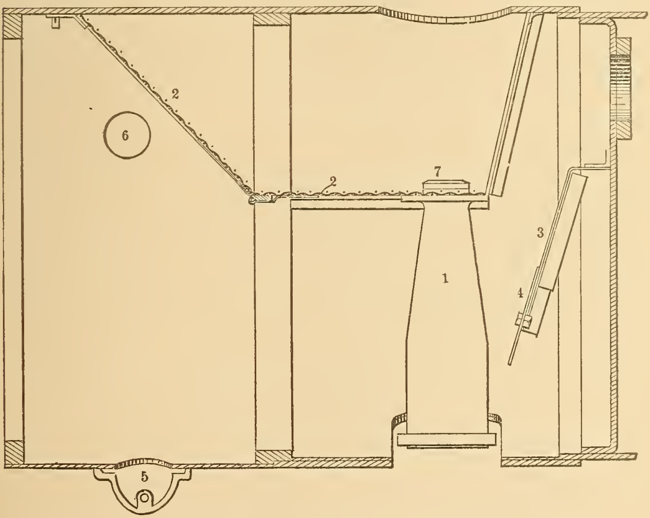


Fig. 34. Smoke-box and Fittings, (Lengthwise View.)

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

combustion-gases may turn from a horizontal to a vertical course in leaving the tubes and entering the stack; and to serve as a receptacle for solid particles that have been drawn along through the tubes from the fire-box; also to serve as a place in which the exhaust-nozzles may be given proper inspection and adjustment; to keep the live steam hot on its way to the cylinders, and to prevent the exhaust being chilled on its way and losing its power of entraining air with it.

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

A. Of cast iron, having in its centre a large outward-opening door which permits inspection and repair of parts inside the smoke-box. (Figure 34.)

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

A. Usually by diamond stacks having cones and nettings against which the sparks and cinders are thrown and which deflect them and throw them down, while permitting the gases of combustion to go out.

Q. What is the objection to a very deep cast-iron cinder-box?

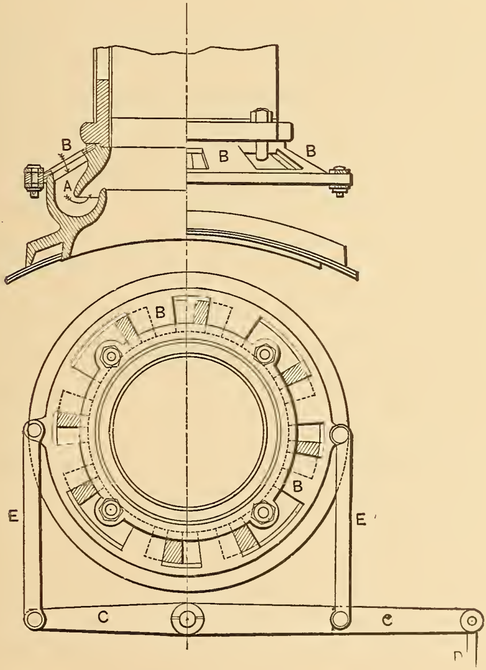
A. If it once gets afire inside it may get red hot and crack or break off.

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 figures 35 and 36. It admits air at the base of the stack, thus doing away with the necessity for opening the fire-door and admitting cold air into the box.

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.



Figs. 35 and 36. Luttgens' Damper for Coal-burners.

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-sheet, slightly above the tubes, about half way down.

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. 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 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. It runs from 250° to 650° or even 700° F.

Q. How is the locomotive boiler given the strong draft that distinguishes it from other types of boiler?

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 gases of combustion by friction with the steam-jets which they discharge. Of course the greater the steam-consumption the greater 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 and 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 supposed to be of cylindrical section; whether it is or not it has not smooth sides and there is 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 from which air can get into the stack to supply the place of that which the blast has drawn out, is through the grate, the fire-boxes and the tubes, we have a supply of air entering the fire-box through the grate, at every puff of the exhaust.

Q. Of what material are the exhaust-pipes made?

A. Of 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 of them 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 on 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 diameter of the exhaust orifice may be changed without change of the nozzle itself; but these are usually too complicated.

Q. What is the disadvantage of too large exhaust?

A. Insufficient draft without the use of the blower, which 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 the combustion-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 the disadvantage of the double nozzle?

A. That the blast is not quite concentric with the stack.

Q. How can these troubles be got around?

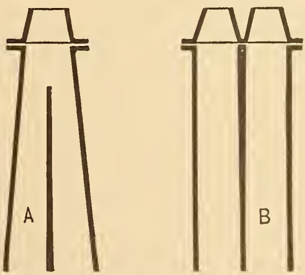
A. Usually by having one nozzle surrounding the other.

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 a locomotive boiler generate enough steam for practical purposes?

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 engines with sharp blast.



Figs. 37 and 38. A Single and a Double Exhaust Nozzle.

Q. As between the two kinds of exhaust nozzles *shown in A and B, figures 37 and 38, what are the relative advantages and disadvantages?*

A. Style A has the advantage of giving a central jet through the stack, but does not divide one cylinder from the other exactly, so that 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 it does not give a central jet.

Q. What is the object of the stack?

A. To make a draft and to remove the hot combustion-gases, and cinders to a height which will enable them to clear the train and other objects near the ground-level.

Q. What is the object of making the stack larger at the top than at the bottom, when it is so done?

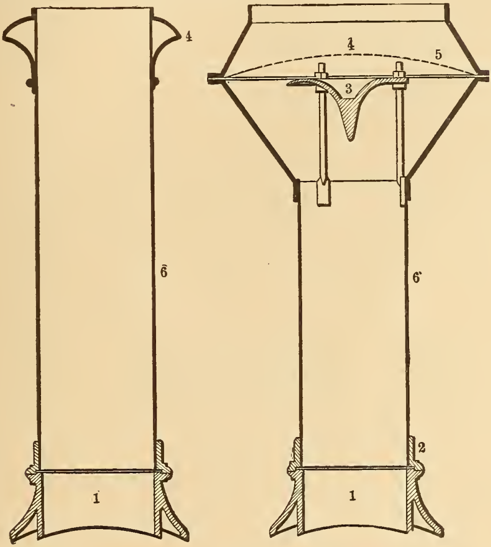
A. It makes a better passage for the combustion-gases and at the same time make it possible to throw sparks to a less distance; thus it helps the draft.

Q. What kind of a stack is usually given with the long front end?

A. A plain cylindrical stack like a straight pipe. (Figure 39.)

Q. What is the diamond stack?

A. It has a central pipe above the axial line of which there is a cast iron cone-like deflector, against which the sparks and cinders strike, which act causes 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 in order to keep live cinders getting into the open air. Below the cone there is a chamber into which the sparks may fall and where they may cool. (See figure 40.)



Figs. 39 and 40. Smoke-stacks.

1. Base. 2. Base-flange. 3. Cone. 4. Top. 5. Netting. 6. Body. 7. Chamber. 8. Inside Pipe. 9. Hand-hole and Plate.

Q. What gives its name to the diamond stack?

A. The outline of its top.

Q. What name is given to the conical plate that is suspended in the axis of the diamond stack, near its top?

A. A 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?

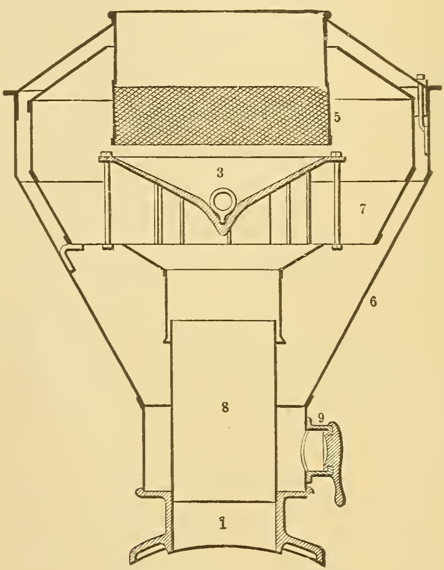


Fig. 41. Stack for Wood.

A. The form shown in figure 41, in which there is a very wide double cone-top surrounding a cen tral cylindrical pipe, a cone deflector, and a central wire netting. The space around the central pipe serves as a receptacle for cinders and is supplied with a hand-hole through which they may be removed.

Q. Of what material are smoke-stacks usually made?

A. For ordinary requirements the outsides are of sheet iron; sometimes with cast-iron tops to prevent wear by 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.

Q. How big should the inner pipe of a smoke-stack be?

A. About an inch smaller than the cylinder-diameter, for non-compound engines; sometimes of the same diameter as the cylinders.

Q. What is the disadvantage of having 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 all along its 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 name is given to the cylindrical part of a locomotive boiler?

A. The waist or barrel.

Q. What about the diameter of straight boiler-sheets as compared with that 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 the more circulation-room for water between the flues, with an equal number of flues?

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

Q. Of what material are locomotive boilers now most often made?

A. Of soft steel.

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

A. Great tensile and compressive strength, ductility, and uniformity of structure.

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 fibre; 54,000 across the fibre.

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

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

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 should stretch about one-eighth of its length before breaking; and 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 down 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. Because 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 to ream or drill them to the required size; as this gives smoother walls and also cripples the fibres 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 the edge of the plate; or (3) by the rivet itself being sheared off.

Q To what does the first method of giving way point?

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

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

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

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 it is not tight it will lose strength by corrosion.

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

A. The smaller number further apart.

Q. Why not then go as far as possible in this direction?

A. Because then 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 them 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, so as to insure absolute equality of spacing. Also, there is more likelihood of the rivets filling and fitting the holes, where they are drilled or reamed, than with punched holes.

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

A. That 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 the wide spacing of rivets?

A. The fact that the shearing strength of the rivet increases as the square of its diameter, while the crushing strength of the metal increases 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 three-eighths inch plates?

A. Seven-eighths inch.

Q. What would be the strongest seam that we could get with a single row of seven-eighths inch rivets in three-eighths inch plates?

A. One and three-quarter inches between rivet-edges, or two and five-eighths inches between rivet-centres.

(The foregoing applies to iron plates and iron rivets.)

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 the use of 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 the 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 kind of a 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 calking-tool having a square end?

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 x 12 x 12 x 160 = 1,152,000 pounds.

Q. What is the use of the dome?

A. Theoretically it is 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 it usually weakens the shell by reason of the large hole cut in the latter. Practically it is only a convenient place of attachment for throttle-valve, safety-valve and other fittings; and many engines are without them, without appearing to have lost anything by the omission.

Q. Where is the dome usually placed?

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

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

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

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

A. From three and one-half to seven and one-half 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 amount of coal required to evaporate six to eight tons of water per hour in such an engine?

A. One ton per hour is the average, as one pound of average coal will make from six to eight pounds of steam with the boiler in average condition.

Q. How is the engineer 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 movement is indicated by a pointer traveling about a circular dial graduated to indicate the pressure in pounds per square inch above the 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 of the steam is made to straighten more or less a curved flattened elastic metal tube. (Figure 42.)

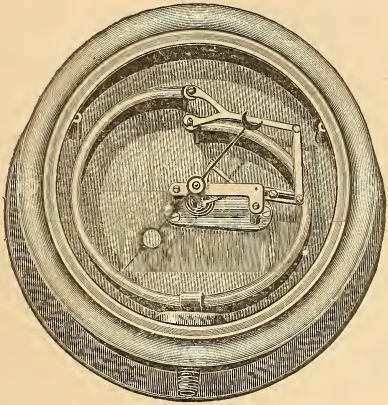


Fig. 42. Interior of Crosby-Bourdon Steam-gage.

Q. What precaution is taken to prevent the steam taking the temper out of the disks or tubes of steam-gages?

A. They are put on with a turn or two of pipe between the boiler and the disk; the bend of the pipe gradually filling with condensed steam, which prevents the live steam from touching the elastic disks or tubes.

Q. To what should the handle of the steam-gage point when the connection between it 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 correct?

A. No; if it points 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 it might point to 90 when there was 100 pounds pressure on it, and to 160 when there was 170 pounds. Gages may be "fast" at some steam-pressures, and "slow" at others.

Q. Which is the most dangerous gage to have: one that is "fast" or one that is "slow"?

A. One that is "slow."

Q. How should the gages be tested?

A. Against a standard mercury column, and by competent persons.

Q. How can the engine-runner know the height 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 of them where it is desired to keep the water level, one about four or five inches above this, and another about four or five inches below it.

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 indications of the try-cocks?

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. Describe a water-gage or water-column?

A. There are two openings in the end of the boiler, one above the desired water-level and the other below it. Into each of these 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 there 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 it is in connection. There is a drip-cock from the lower one, by which the tube may be drained when the valves are closed; and suitable rods guard it from accidental breakage from outside. This tube may be either vertical or inclined; in either case the water-level should be at the same height in the tube as in the boiler.

Q. In order to prevent 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.

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. 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 higher than 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, then, should they be renewed?

A. Say every two or three months.

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 there projects a central discharge-pipe leaving around it an annular air-chamber. Between the suction-chamber and the barrel there is an upward-opening valve; between the discharge-chamber and the barrel there is another upward-opening discharge-valve or pressure-valve; each of these valves 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 (if the joints are tight) there is formed 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. There is at the end of the feed-pipe furthest from the pump 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 figure 43) 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.

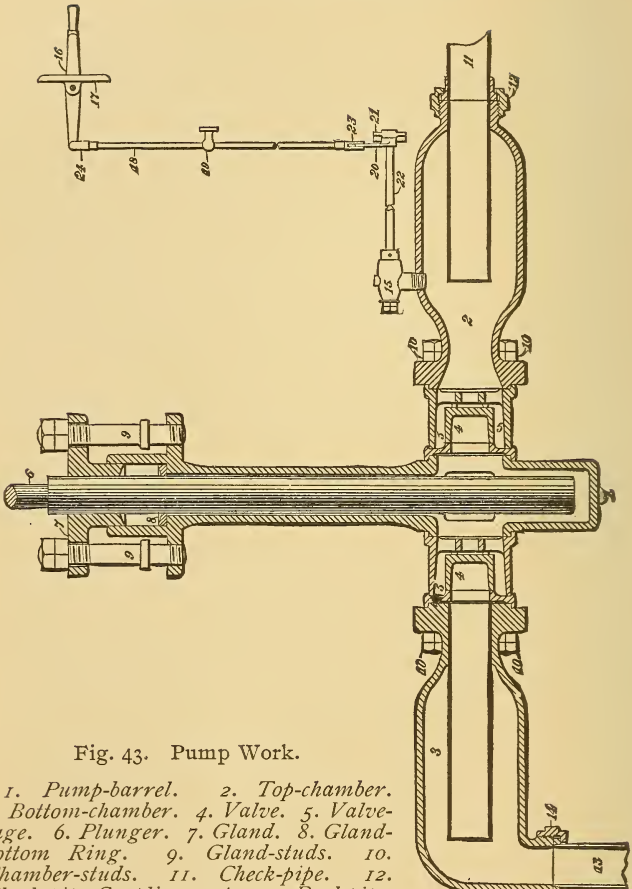


Fig. 43. Pump Work.

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. Where are the pumps usually placed and driven?

A. On the frames back of the cylinders, and driven direct from the crosshead; although sometimes they are inside the frames and are driven by a small eccentric on one of the axles; and 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 pumps driven by the crosshead?

A. Full-stroke pumps.

Q. What name is given to those which are 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 the air-chamber are bolted together; breaking this joint and removing the air-chamber exposes the pressure-valve and gage. 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.

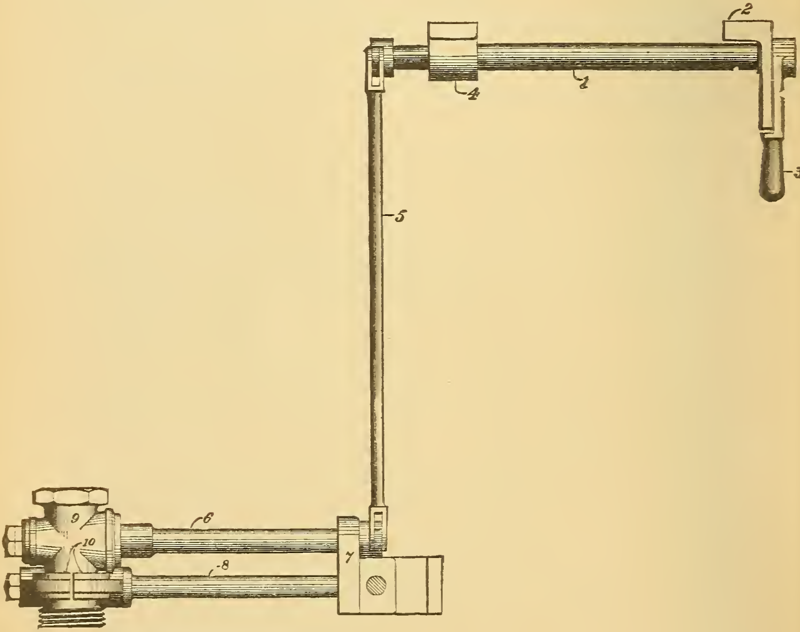


Fig. 44. Feed-water Work.

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. 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 engineer to judge as to the amount of feed-water that is passing.

Q. How is the supply of feed-water supplied by the pump regulated?

A. By a feed-cock in the suction-pipe, regulating the amount that can pass to the pump (see figures 44 and 45); also by the valve opening from the tank to the tender-hose.

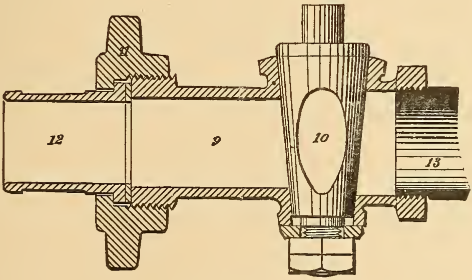


Fig. 45. Feed-cock.

9. Feed-cock Body. 10. Feed-cock Plug and Nut. 11. Hose-coupling Nut. 12. Hose-swivel. 13. Feed-pipe.

Q. What would be the result of over-feeding the boiler?

A. The steam-space would be filled and this water would get into the steam-pipes and be likely to wreck the cylinders.

Q. What would be the result of under-feeding the boiler?

A. The crown-sheet and upper flues would be left uncovered with water and liable to be overheated, or as it is called, burned.

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 about one and one-half to 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 also.

Q. How is the water in the pump, suction-pipe and tank prevented from freezing without being bled out?

A. By heater-pipes communicating with the steam in the boiler or with injectors, and discharging into the suction-pipe.

Q. What keeps the suction-hose from flattening either under external pressure or by reason of short bends?

A. It is often lined with a stout wire spiral.

Q. What enables the pump to be removed for inspection or repair, while steam is on the boiler, or the boiler 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 that direction. Figure 46 shows a pump-check composed of a check-body 1 and flange 2, held together by check-flange studs 3.

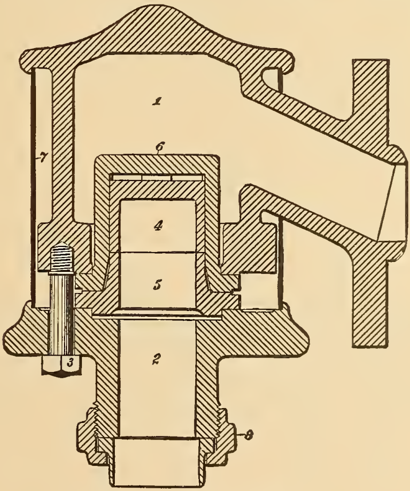


Fig. 46. Pump-check.

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.

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 will 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.

Q. Where then should the check-valve be placed?

A. Just inside the shell, where the feed-pipe discharges into it.

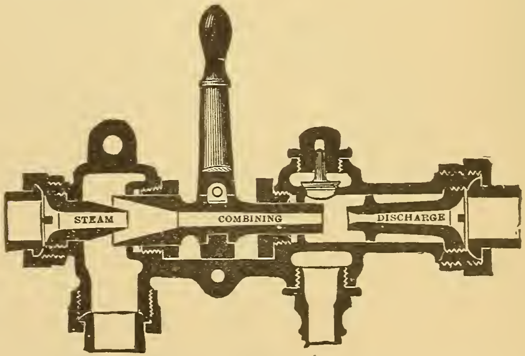


Fig. 47. Lengthwise Vertical Section, "Little Giant" Injector.

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 and the other when standing still; say, in the latter case the one on the left-hand side.

Q. Where should an injector get its steam supply?

A. Over that part of the boiler or dome which will give the driest steam.

Q. How may loose mud and other loose dirt be removed from a locomotive boiler?

A. Through large blow-off cocks placed 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 of the mud and dirt 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 is 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 to prevent the boiler blowing up in case steam is made faster than it is 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; and this would continue until all the water was evaporated, or until the pressure got too great for the boiler to stand. In order 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, which is 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 discharging capacity enough to let through all the steam that the boiler can make, there will be no explosion. And in order to diminish the chances of explosion there are often two of these valves side by side, and set to blow at the same or about the same pressure. (See figure 5.)

Q. What is to prevent the engineer 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 exploding 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 ensure that the disk is not corroded on the seat, or that it is not otherwise inefficient.

Q. How may the pressure of steam 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. That without leaving the cab it may be readily adjusted, to blow at any desired pressure.

Q. What are the advantages of the pop safety-valve?

A. That it gives larger discharging-area than the ordinary 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 figure 48.)

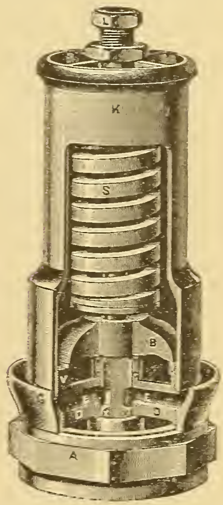


Fig. 48. Crosby Locomotive Pop Safety-valve.

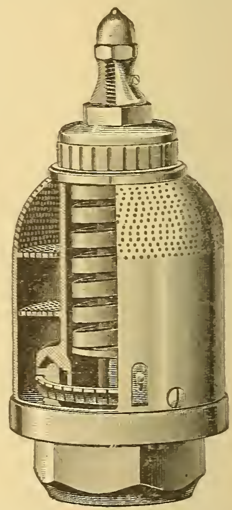


Fig. 49. Meady Muffled Locomotive Pop Safety-valve.

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, consisting of a coil of wire 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 a large discharging-area. Some have a central vertical pipe with a large number of L-shaped tubular branches pointing upwards. 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. (Figure 49.)

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 is radiation from the boiler lessened?

A. By lagging the boiler and dome with wood strips and then 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 and Russia iron.

Q. How may hard mud and scale be removed?

A. Either 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 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.

Q. How does the steam-whistle act?

A. There is an inverted cylinder or cup 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. (Figure 50.)

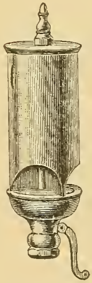


Fig. 50.
Chime Whistle.

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 a dome; although sometimes placed 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 they are 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 is ended. Moving the valves and the stem lengthwise of the latter, either closes the disks against the circular openings or removes them from them, leaving annular openings through which the steam flows.

Q. When they are 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 pressure of the steam 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.

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 of them 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. It is enabled to work in a straight line through the stuffing-box by a small vibrating link. (See plate 21.)

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 type of 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.

Q. What would be better than the clamping-rig?

A. A notched sector or quadrant such as is used with the reverse-lever, except that the notches are of saw-tooth style so as to permit the throttle to be

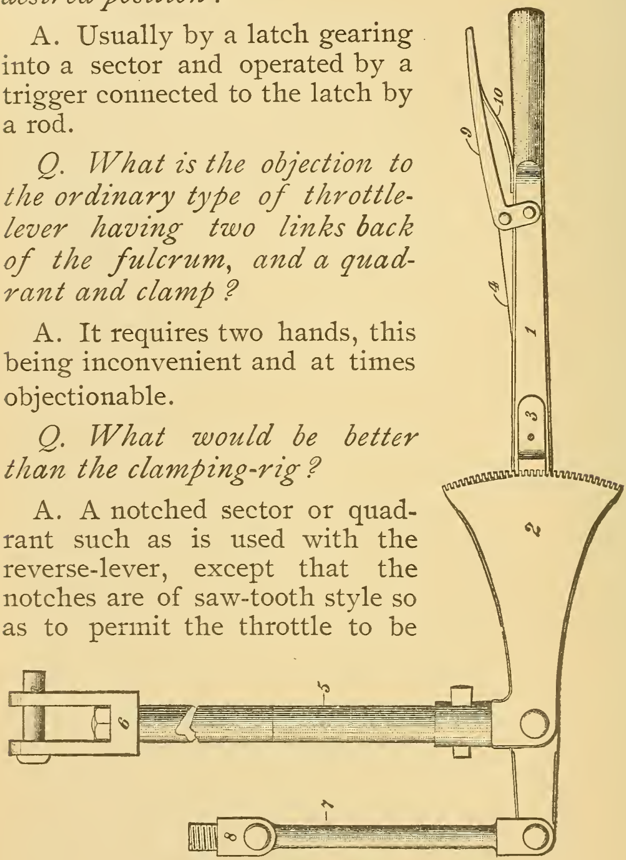


Fig. 51. Throttle Work.

1. Lever. 2. Quadrant. 3. Latch. 4. Latch-link. 5. Rod. 6. Jaw. 7. Link. 8. Link-stud. 9. Handle. 10. Handle-spring.

very quickly closed and prevent it from being jarred open. (See figure 51.)

Q. What is the disadvantage of such a throttle?

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 pipe called a 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. (See Plate 2.)

Q. Of what material are throttle-pipes made?

A. Of cast-iron.

Q. Why not make the throttle-valve of brass?

A. Because the pipe being of cast-iron the difference of expansion in the two metals would make a valve leak under high-pressure steam if it was tight under low, or *vice versa*.

Q. What is the disadvantage of having 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. 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, and which extends along through the steam-space in the shell of the boiler, 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 branches of the T-pipe?

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 the question of expansion and contraction.

Q. How are flexibility and expansibility provided for in the steam-pipes?

A. By connecting them with 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.

Q. How is movement in an up-and-down direction provided for?

A. By having a false end to 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.

Q. What causes foaming in the boiler?

A. Oil, alkali, or other matter, causing the water to froth, like suds.

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 of finding out whether the show of water was due to overpumping or to foaming.

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 should be done to stop foaming?

A. The feed should be put on, and the surface blow 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 the use of the heaters.

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. Where is the feed 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 the feed-water right on the fire-box sheets?

A. To crack them by sudden cooling and contraction.

Q. What is usually the best height to carry water in the boiler?

A. At such a height 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 in such case there would be no knowing whether there was 1-4 inch or 3 inches of water above the cock.

Q. How should water be carried in approaching a down grade?

A. There should be enough water 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. I should put on the feed, and see that the fireman kept the fire 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. It makes a great deal. If it is acid it tends to corrode the boiler on the inside; if it has much mineral matter in solution this is dropped from it when evaporation takes place, and becomes baked on the shell and tubes as a stony scale; if there is undissolved vegetable or mineral matter, this is deposited on the bottom as slush and sometimes is baked on also.

Q. How can acid get in the water?

A. The water from streams in the Pennsylvania coal-mining regions is impregnated with sulphuric acid; and the same or similar causes produce similar results elsewhere.

Q. Would alkaline water be an advantage?

A. No, 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. What has been the experience with feed-heaters?

A. That their cost has been greater than the saving which they effected; so that their use has been abandoned.

Q. Where there are three cylinders, as for instance in a compound locomotive where there is one cylinder between the frames and two outside, as shown in figure 52, how are the cranks arranged?

A. 120°, that is, one-third of a circle, apart.

Q. Where are the cylinders of a two-cylinder American locomotive placed?

A. On the outside of the frames.

Q. Where are the cylinders of most two-cylinder European locomotives placed?

A. Inside, between the frames.

Q. What are the advantages of the American arrangement of the cylinders?

A. There is no necessity for cranking the axle, and the steam chests are more readily got at.

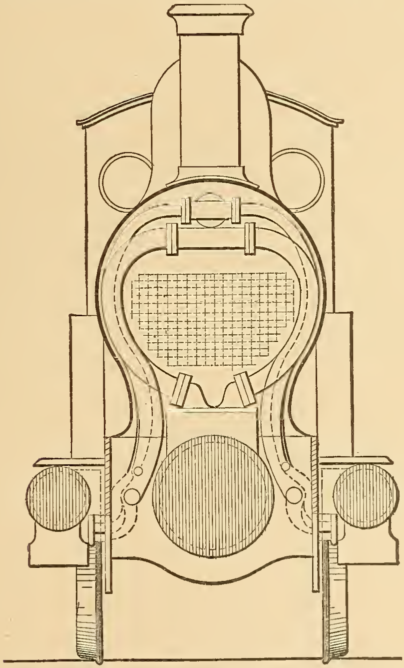


Fig. 52. Arrangement of Cylinders, Webb Compound Locomotive.

Q. What are the advantages of inside-cylinder engines?

A. They run more steadily, where the wheel-base is short, by reason of the outside cylinders having greater leverage to twist the entire machine from side to side; and there is less loss of heat from the cylinder, by radiation, than where they are exposed outside the frames; the engine takes up less room

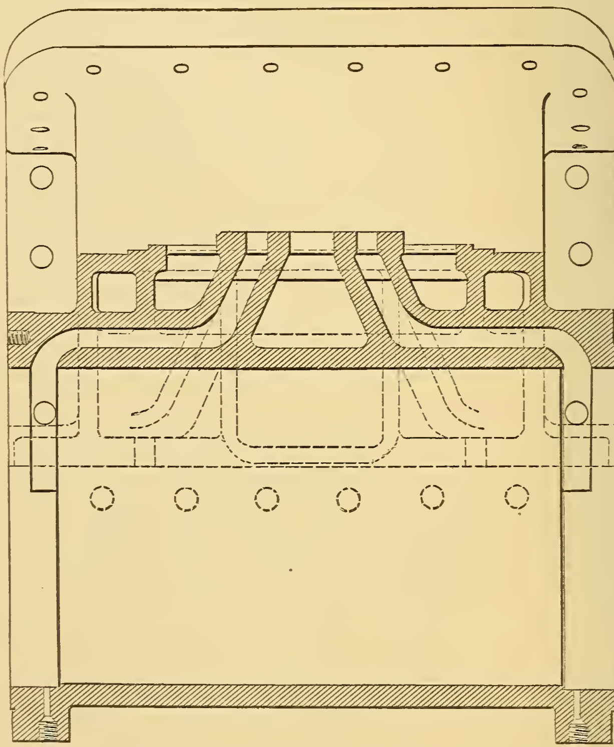
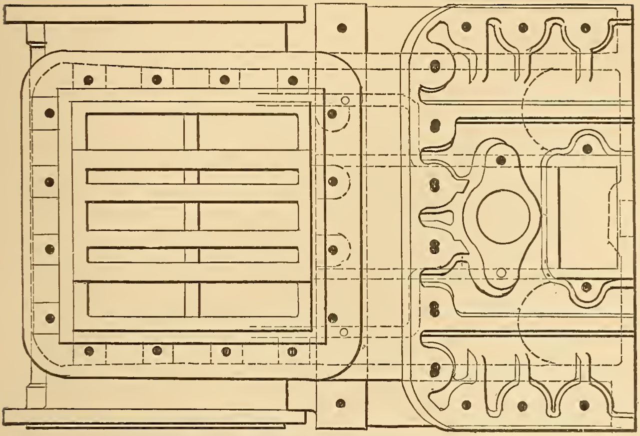
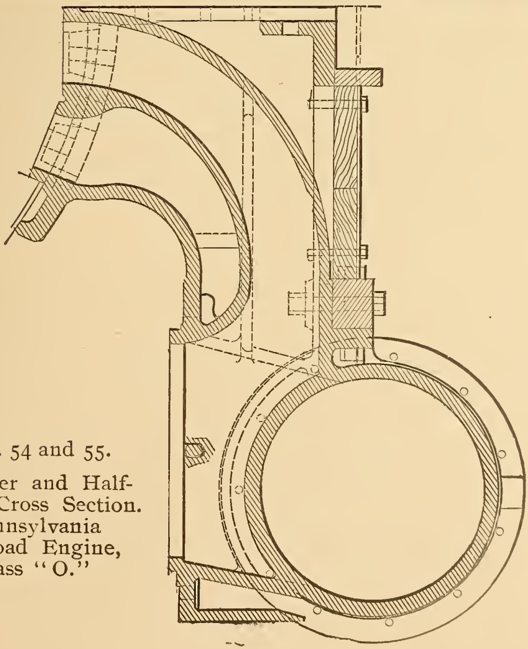


Fig. 53. Cylinder, Pennsylvania Railroad Engine, Class "O." Lengthwise Vertical Section.

laterally, hence narrower tunnels and bridges suffice for a given power of engine.





Figs. 54 and 55.

Cylinder and Half-saddle Cross Section. Pennsylvania Railroad Engine, Class "O."

Q. What are the disadvantages of the inside-cylinder type?

A. The danger from broken crank-axles; the difficulty of getting at the cylinders for inspection, adjustment and repair, and the inability to use cylinders of very great diameter.

Q. Where there are two cylinders in a compound locomotive, where are they generally arranged?

A. If it is an outside-cylinder engine, the high-pressure will come on one side and the low-pressure on the other. If it is 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 length of engine.

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 cylinders outside.

Q. In the Vauclain compound locomotive what is the arrangement of the cylinders?

A. Two on each side, one above the other; where the conditions will permit the high-pressure cylinder being put on top as is shown in figure 56, but where the wheels are low, as with consolidation engines, the low-pressure cylinder is above as shown in figure 57.

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 on each side.

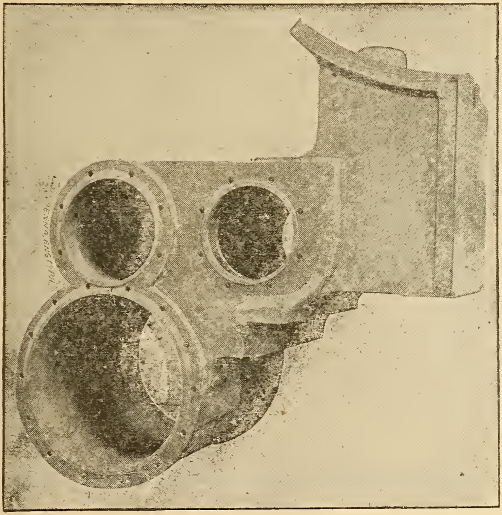


Fig. 56. Cylinders, Valve Chest and Half-saddle, Vauclain Eight-wheeled Compound.

Q. Is it possible to balance the weight of the connecting-rod 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.

Q. Suppose that it is balanced horizontally, what will be the effect?

A. That which is ordinarily observed; there will

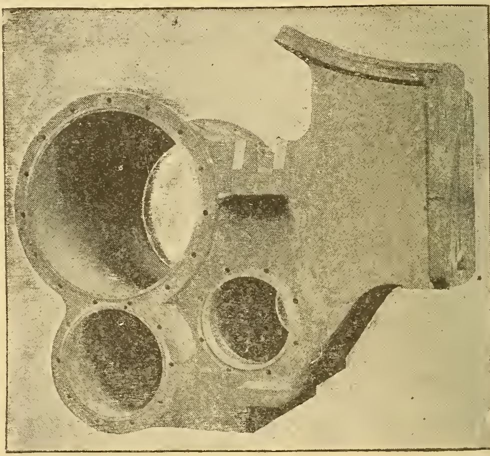


Fig. 57. Cylinders, Valve Chest and Half-saddle, Vauclain Consolidation Compound.

be a series of vertical movements corresponding to the upward and downward motion of the cranks, and the engine will sway from side to side, and will 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.

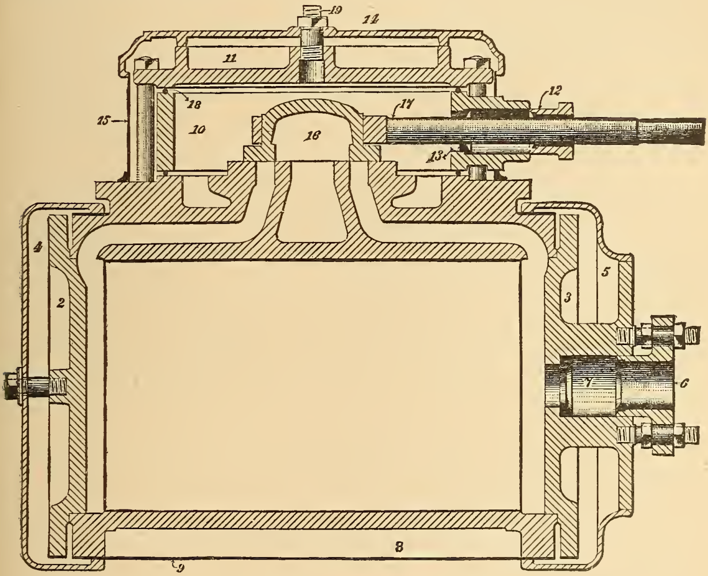


Fig. 58. Cylinder, Steam-chest and Attachments.

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. What is the disadvantage of steeply-inclined outside cylinders?

A. They cause a rolling motion.

Q. How are the steam-cylinders made?

A. Their convex walls are cast with the bottom of the steam-chest in one piece with them, and the passages from the steam-chest to the 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 flanges of the cylinder-ends. The steam-chest is sometimes in one piece with the cylinder, sometimes bolted to it.

Q. To what are the cylinders fastened?

A. To bed-plates or bed-castings placed between them; these sometimes forming two separate pieces which are bolted together in the centre 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 centre-line of the engine.

Q. To what are the bed-castings fastened besides to the cylinders?

A. To the smoke-box.

Q. To what are the cylinders fastened besides to the bed-castings?

A. To the frames.

Q. Which arrangement of cylinder is the most popular in America?

A. The cylinder and half-saddle cast in one. (See figure 59.)

Q. In this type, what is the difference between the cylinders for the two sides of the engine?

A. They are practically alike, in present practice, to save expense in making patterns and in keeping spare parts at various shops.

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 in order to replace that bolt; whereas a stud may be drilled out in place without unlagging.

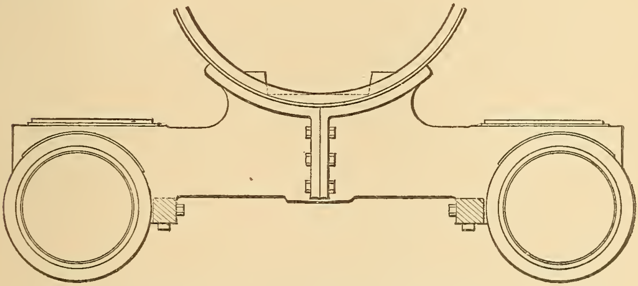


Fig. 59. Cylinder and Half-saddle.

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 position of the piston 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.

Q. How is the joint between the steam-chest case and the cylinder, between it and its cover, made steam-tight?

A. One way is by an ordinary gasket; but a preferable one is by a 1-4 inch soft copper rod of proper outline, the ends being scarfed and hard-soldered.

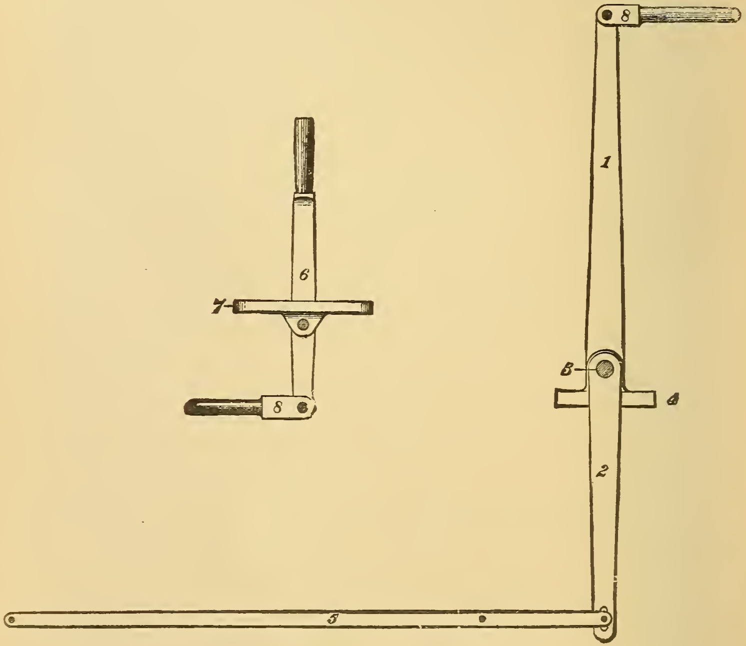


Fig. 60. Cylinder-cock Work.

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.

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. How is the joint between the cylinder and its 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 ends of the cylinder 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 reason of water carried over from the boiler or left by condensation, lessened?

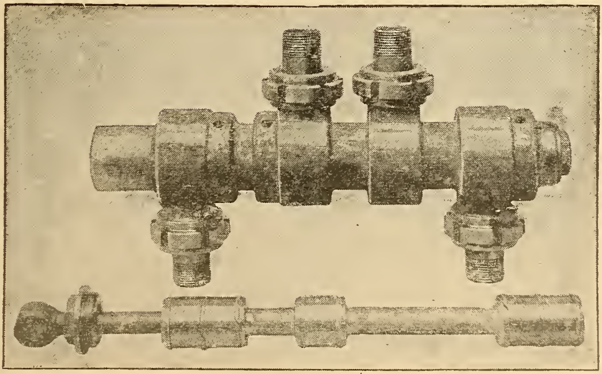


Fig. 61. Combination Cylinder-cock and By-pass Valve, Vauclain Compound Locomotive.

A. By cocks at each end of the cylinder, 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 figures 60 and 61.)

Q. What precaution is taken to lessen the loss of heat and lowering of pressure due to internal condensation by reason of radiation from the steam-chest and cylinder walls?

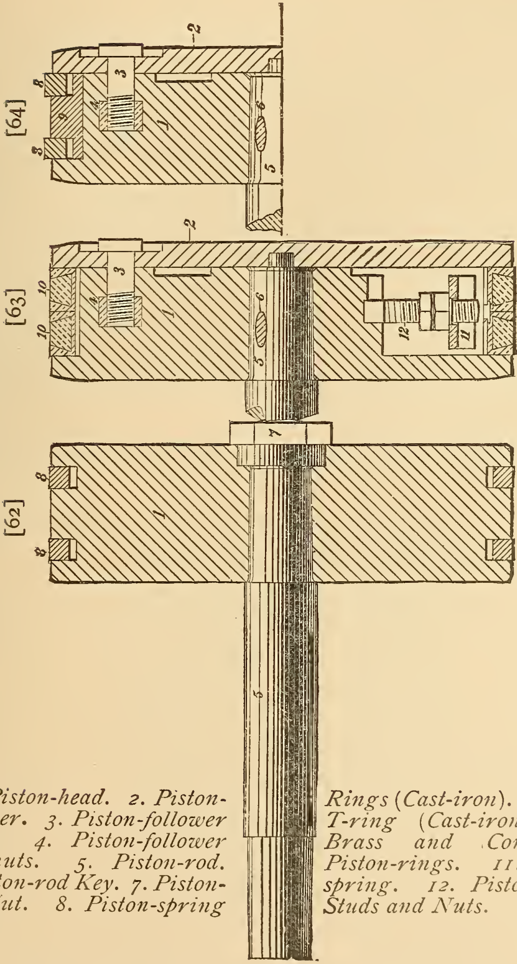
A. They are lagged with a non-conducting substance, as wooden strips, and usually have an air-jacket or double wall; the cylinder-heads are in the same way double. Sometimes instead of wooden strips, hair felt is used as a non-conductor.

Q. What 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 ways is to have a spider consisting of a ring, hub, and radial arms, and a follower-plate or follower which is bolted to the spider by the follower-bolts. This built-up head works slightly loose in the cylinder, but has a pair of rings which are 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 so as to permit being opened out by the packing-bolts. The joint or cut in one ring is placed on the opposite side of the piston-head from that in the other ring, so as not to make a continuous cut through which steam might pass. Figure 62 shows a piston-head made in one solid piece with two cast-iron spring rings 8, 8, let into grooves in its periphery. Figure 63 shows a head made of a spider 1 or head proper, and a follower 2, fastened thereto



1. Piston-head. 2. Piston-follower. 3. Piston-follower Bolts. 4. Piston-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.

Figs. 62, 63 and 64. Pistons and Packing Rings.

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 the spring-studs and nuts 12. In figure 64 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 figure 62, the piston is fastened on with a nut 7; in figures 63 and 64, by a key.

Q. Of what material are these rings made?

A. They may be of cast-iron, or of brass or gun-metal, or of either of these two with babbitt-metal run in to lessen friction.

Q. What material is used for follower-bolt nuts?

A. Brass, to prevent the bolts being rusted tight in them, 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 pressure of the steam in the cylinder, so that the greater the steam-pressure in the cylinder, tending to pass the piston, the greater the pressure by which the piston-rings are pressed against the cylinder-walls to prevent leakage past the head. Also, they are often held out solely by their own elasticity; being made 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 the greatest possible spring to them, 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. There are two classes of rings; one set of L-section and the other of plain rectangular section; each of these extends all the way around, but they break joints; each ring being in six circumferential sections.

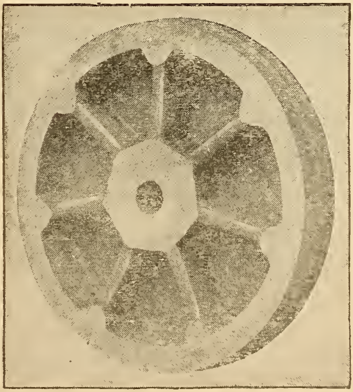


Fig. 65. Half of Vauclain Two-part Cast-iron Piston-head.

Q. What method is there of making pistons *which will permit of having them hollow and yet do away with the uncertainty of coring?*

A. By casting them of two sections and riveting them together; the sections being of the character shown in figure 65.

Q. How is the piston-rod fastened to the cross-head?

A. Usually it is tapered to fit a tapering hole in the crosshead, and is 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 which are absolutely parallel with the cylinder-axis, thus protecting the rod, the stuffing-box, and the cylinder and piston from undue wear. (See figures 66 to 70, inclusive.)

Q. How is the piston-rod fastened to the piston-head?

It may be passed clear through and riveted over or passed through and supplied with a nut on the front end, or tapered and keyed; or tapered and riveted, or tapered, riveted and keyed. (See figures 62, 63 and 64.)

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, Indiarubber and cotton, etc ; this material being pressed against the walls of the stuffing-box and the outside of the rod by the stuffing-box cover having a tube which 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 the box and the rod. There are also split packing-rings of antifriction metal which are pressed against the rod and the box by springs.

Q. What are the essential parts of a cross-head?

A. A socket for the reception of the piston-rod end ; a journal on which the connecting-rod may turn, and slides which may play between the guides.

Q. Which is it best to have cut by wear ; the slides, (gibs) or the guides?

A. The slides or gibs.

Q. What is the objection to having the 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 cross-head?

A. It is usually cast solid with it.

Q. What class of crosshead may be used for compound engines having two cylinders on a side?

A. As shown in figure 66, having two sockets, one for each piston-rod; the entire block being of

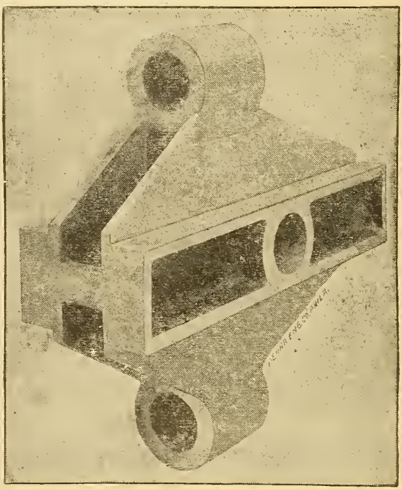


Fig. 66. Crosshead, Vauclain Compound Locomotive.

cast steel in one piece and having its wearing-surfaces covered with block tin 1-16 inch thick.

Q. What forms are given to guides?

A. Their form is legion. There may be only one guide-bar, above the piston-rod and crosshead, and which is embraced by the latter, or there may be two, one above and the other below, the crosshead having bearing surfaces on both, but not embracing either, or two above the crosshead, or two pairs, one

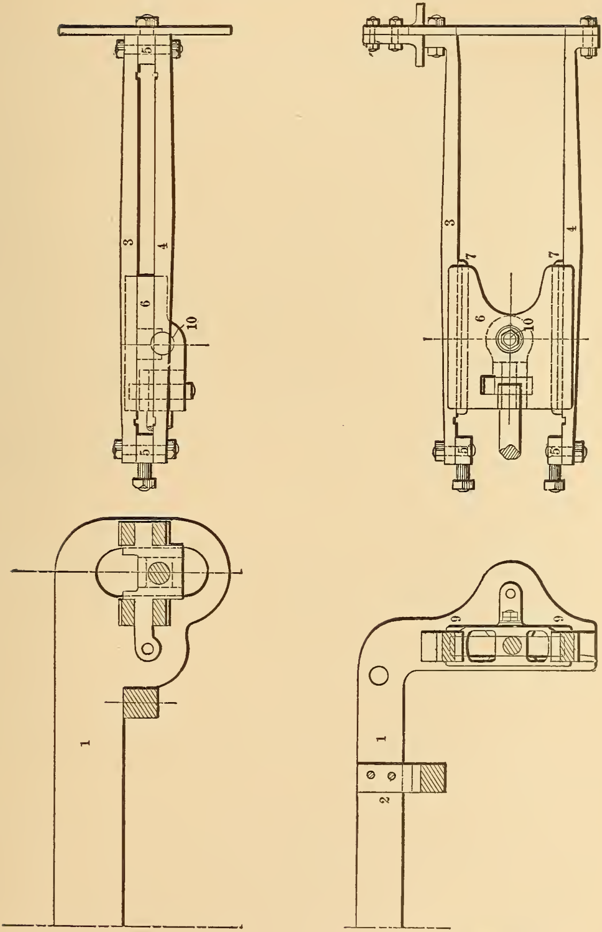


Fig. 67, 68. Guide-bearer, Guides and Crossheads.

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.

pair above and one pair below the crosshead. Figure 67, page 109, shows an arrangement in which the crosshead has four guide-bars, two upper and two lower, the wrist-pin centre being about in line with the lower ones, as shown in the cross section. Figure 68, page 109, shows two guides, one upper and one lower, the wrist-pin coming about half way between them, as shown more clearly in the cross section. In figure 69, page 111, there is but one guide-bar and that is surrounded by plates bolted to the crosshead proper. In figure 70, of page 112, there are two guides, having between them what is called the crosshead filling-piece which is bolted between the two cheeks of the crosshead.

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 to the guide-bars, as with mogul and consolidation engines?

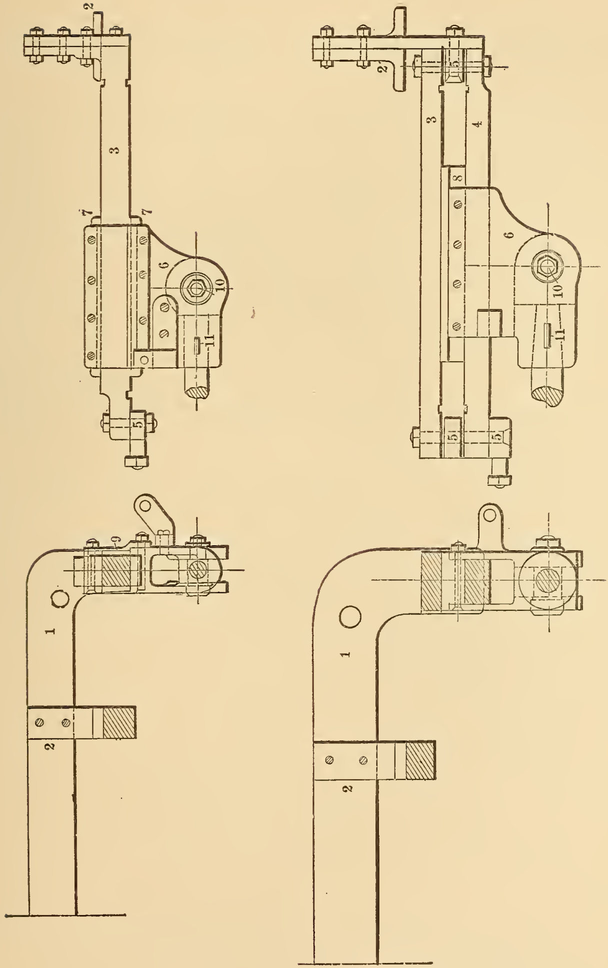
A. There are two bars above the crosshead and none below or on the sides.

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 end to the guide-yoke attached to the frame of the engine, and usually, also, to the boiler.

Q. What other name is often given to the guide-yoke?

A. The guide-bearer.



Figs. 69 and 70. 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. What provision is there to reduce the wear of the guides and slides to a minimum?

A. The guides are hard and finely finished, and the slides are 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 they may be set out quite readily, by liners or otherwise.

Q. Is there any provision for bringing the guide-bars nearer together when they are 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; or 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.

Q. Where is there the greatest strain on a slide-bar?

A. At the centre 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 one.

Q. Why is this?

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 slide, 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 slide.

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 its 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: and 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 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 in its rotation.

Q. How much power have the piston and crosshead to turn the crank-pin when the centres 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 set quartering so that when one side is on the dead centre the other is about at its maximum power.

Q. Is there no means of preventing this difficulty of having dead centres?

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 (towards the stuffing-box) it is in compression; and on the return or in stroke, it is in tension.

Q. What is the most common-shape of connecting-rod?

A. As now made most frequently, there are flat wrought-iron bars, larger at the crank-pin end 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 centre-line, where material gives the least strength.

Q. Why are they made larger at the crank-pin end than at the wrist-pin end?

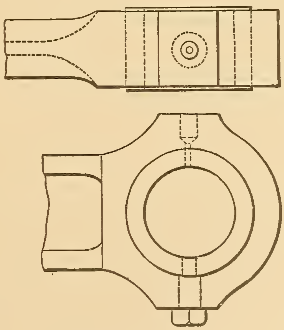


Fig. 71. Rod Ends.

A. Partly because the crank-pin should be larger than the wrist-pin, and partly because experience has shown that that end is most liable to break.

Q. What class of bearing is given the wrist-pin and crank-pins, in the ends of the rods?

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

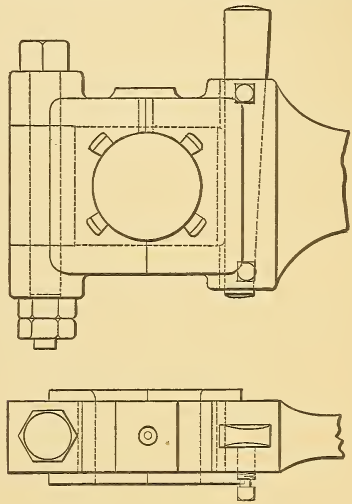


Fig. 72. Rod Ends.

pin, and which may be set up as desired. In the other, the pins turn in bushes which are hydraulically pressed into the eyes in the ends of the rods, and which have no capability of adjustment; in fact cannot be taken out except at the shop.

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 to enable them to be further set up.

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 semi-circle.

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 leg of the strap.

Q. What material is employed for the brasses?

A. Sometimes brass, sometimes bronze; these being sometimes plain, but generally supplied with babbitt plugs or strips cast in them 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. What is the use of the 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 of coupling-rods?

A. They lengthen the rigid wheel-base and somewhat complicate the difficulties of balancing the engine.

Q. What other names are given to the coupling-rods?

A. Parallel rods, side-rods.

Q. What is the form given to the coupling-rods?

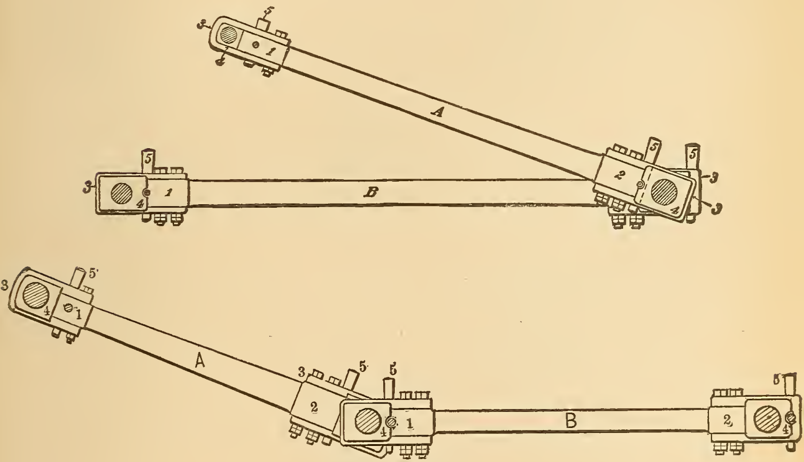
A. Usually they are flat wrought-iron bars enlarged at the ends to receive the pin-brasses, usually with the side milled out so as to remove material where it gives less strength. Plain flat rods of rectangular section are common, but modern designs usually have the fluted or I-section.

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 the parallel rods or side-rods?

A. About the same cross section as the connecting-rods or main rods, but of equal width at each end, or even slightly wider in the middle of their length than at the ends. Figure 73 shows the main rod outside the coupling-rod; in figure 74, it is inside. In figure 75, the crosshead is outside



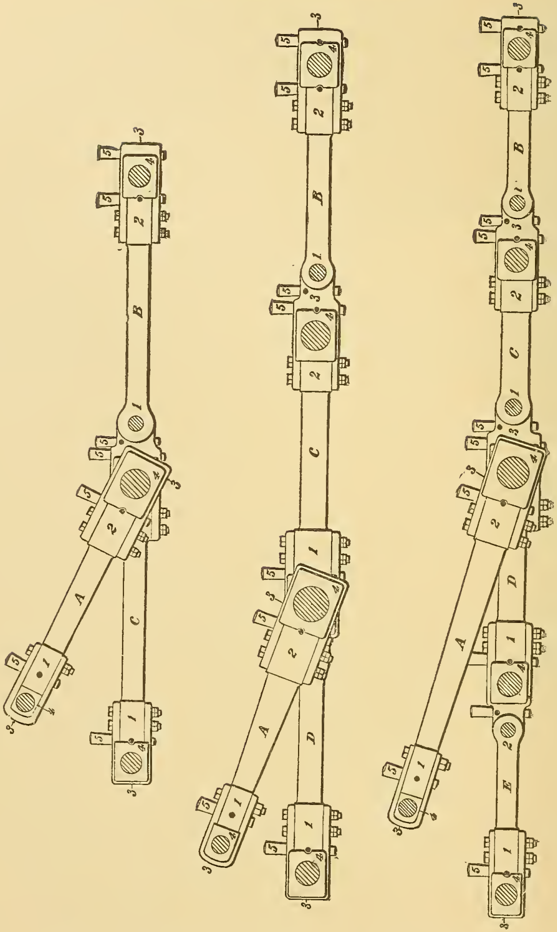
Figs. 73 and 74.

A. Main Rod. B. Parallel Bar or Coupling Pin. 1. Front Stub-end. 2. Back Stub-end. 3. Strap. 4. Brass. 5. Key.

both the back and the second coupling-rods. In figure 76, there are back, second and third coupling-rods, the connecting-rod being outside of all of them and between the second and third. In figure 77, there are back, second, third and fourth coupling-rods, the connecting-rod being outside of all of them and between the second and third.

Q. What classes of wear and stress do side-rods get that main rods do not get?

A. There is play between the axle-boxes and



Figs. 75, 76 and 77. 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.

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 having a coupling-rod wider in the middle than at the ends?

A. To give increased stiffness in the vertical plane.

Q. What is the advantage of having a coupling-rod thinner in the centre than at the ends?

A. To give it lateral flexibility.

Q. In consolidation engines, which coupling-rods have the most work to do?

A. The centre ones.

Q. Why are the side-rods of a Mogul engine made 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 put 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. (See figure 75.)

Q. Should the pin between the front and the *back coupling-rods be put near to the main pin or far from it?*

A. Near to it, 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 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 figure 76.)

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 and another in front of the coupling-rod pin; or back of the pins in the third pair of drivers and close to them, 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-wheel engine?

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. What name is given to such cranks as are used on the ordinary English inside-cylinder locomotive?

A. Centre 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 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 bending the axle by hydraulic pressure to the required throw and similarly turning the pins.

Q. What is the objection to the inside-crank locomotive?

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 of locomotive engine, how are the cranks arranged?

A. One of them at right angles to the other, in order that when one of the two cranks is on its dead centre, the other can start the engine.

Q. Of what material are the crank-pins made?

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 for them 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 ends of the pins are conical or 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 length of crank-pin?

A. They 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 it gets a bending stress and also one tending to shear it off at the point where it is 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 to 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 54° 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 their maximum work; when one is in front and the other back of the axle, one is at the best advantage and the other at the poorest; and when both are back of the axle, both of them are at their minimum power.

Q. What other advantages is there in working steam with cut-off, besides saving steam?

A. There is a tendency to equalize the action of the connecting-rod on the crank all through the rotation, there being greatest steam-pressure where the rod has least leverage on the crank-pin, and *vice versa.*

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. In what position are the steam-chests?

A. In American engines, on top; (see figure 1, page 11;) in British engines, or at least on those which have inside cylinders on the sides next the centre line of the locomotive.

Q. What are the advantages of having the chests on top?

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 of a locomotive on the sides of the cylinders, as in the 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 cylinder. (Figures 56 and 57.)

Q. How are the steam-chests 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 they are 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 most simple and usual type of slide-valve used for an American standard locomotive?

A. The valve consists in effect of a plate or block, such as is shown in section figure 58, page 97, having in its under surface a cavity which extends at right angles to the direction of travel 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 figure 53, page 92, and in figures 58 and 81, it consists of a plain surface having in it three ports, all of which are at right angles to the direction of motion of the piston and of the valve. The central one of these communicates with the exhaust-passage, and the end ones with the cylinder, at the counterbore. 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 was given a short amount of travel and wore itself a low place in the seat, there would be either a smash-up or a leak between the steam-chest and the cylinder, if the travel was increased or the valve was adjusted so as to be brought nearer to or further from the crosshead end of the cylinder.

Q. What are the functions of the valve?

A. To admit steam from the steam-chest into each end of the cylinder, up to a certain point in the stroke; then to cut it off from that end of the cylinder; then to release it from that end into the exhaust-pipe; and in some cases to close the exhaust before all the waste steam that has done work has been exhausted.

Q. How is the position of the valve 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 these things?

A. The arch of the valve must be of such a 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 travel of the valve?

A. It may be more or less according to the points at which it is desired to cut off the admission of the steam and to close the exhaust.

Q. What is the character of the valve of the Vauclain compound engine ?

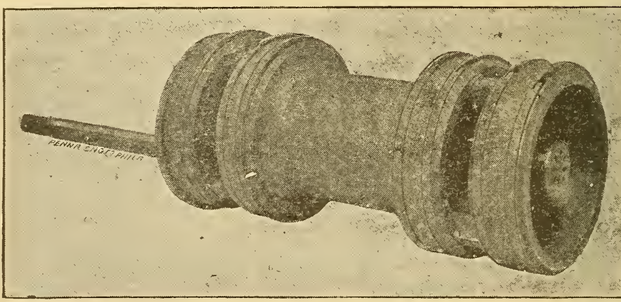


Fig. 78. Hollow Piston Valve, Vauclain Compound Locomotive.

A. It is a hollow piston having cast-iron rings sprung into place just like ordinary piston-rings ; it

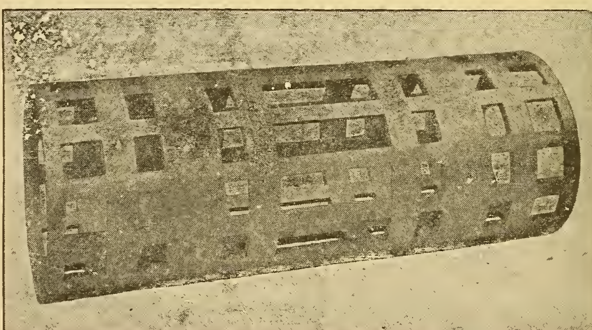


Fig. 79. Bushing of Piston-valve Seat, Vauclain Compound Locomotive.

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 the same for the low. Figure 78 shows the valve; figure 79 shows the ported seat or bushing in which it plays.

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 is necessary to seal the end ports, and by so timing the position of the valve with respect to the piston, that after opening the end port for admission of steam it 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 or outside lap, or simply lap.

Q. What is the relation between the 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 degree of expansion.

Q. What is the relation between the valve-travel and the 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 degree of expansion.

Q. If the valve had its lips just long enough to cover the end ports when in mid-position, was at mid-position when the piston was at stroke-end, *and was given an equal degree of travel in each direction from its mid-position, what would be the effect upon the steam-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 in order to give the full degree of steam-admission without choking?

A. That depends upon the length of the port as well as upon its width; also upon the piston-speed. The narrower the port and the higher the piston-speed, the greater the valve-travel should be.

Q. Is there any usual rule for port-area?

A. There is one, but it is "more honored in the breach than in the observance." It is to give, for 600 feet piston-speed, a port-area of 1-10 the piston-area.

Q. What is the effect of giving the valve-legs or lips a certain lap inside the inside edges of the end ports?

A. To cause the exhaust to be closed before the piston gets to stroke-end, thereby giving what is called cushion or compression.

Q. What are the advantages of compression or cushion?

A. To enable a fast-running engine to get over the centres 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 the new stroke.

Q. What is the travel of a valve?

A. The entire distance that it moves along the valve-face, 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 late cut-off.

Q. What is the relation between the travel of the valve and the throw of the eccentric?

A. If the rocker-arm has arms 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.

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 centre of the axle and the centre of the eccentric-sheave.

Q. What effect has inside lap upon the time of exhaust commencement?

A. It delays it.

Q. What effect has outside lap upon the time of opening for exhaust?

A. It makes it take place earlier than it would if there was no lap.

Q. What effect has outside lap upon exhaust-release or opening?

A. It causes it to take place earlier.

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.

Q. What is the effect upon the steam distribution, of inside lap or exhaust lap?

A. To prolong expansion, and to hasten compression or cushion.

Q. What is the effect upon the steam distribution of inside clearance or negative inside lap?

A. To shorten expansion, and to delay compression or cushion.

Q. By what means is the 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 down or planed down without bringing the valve-rod too low in the stuffing-box.

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, (figure 53.) The raising of the valve-seat above the bottom of the chest also allows for wear and permits planing off without trouble.

Q. What would be the disadvantage of having 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 laid and 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 is the effect of great valve-travel?

A. Great friction between the valve and seat, unless there is some way of counteracting it.

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 figure 80. 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 end, and passes it over to be discharged into the same port, beside the stream of steam coming by the outside edge of the valve.

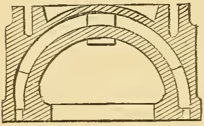


Fig. 80. Allen Balanced Valve, Pennsylvania Railroad, Class "O." Lengthwise Vertical Section to one side of Centre.

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 they were equipped with the ordinary plain D slide-valve, have been able to go on

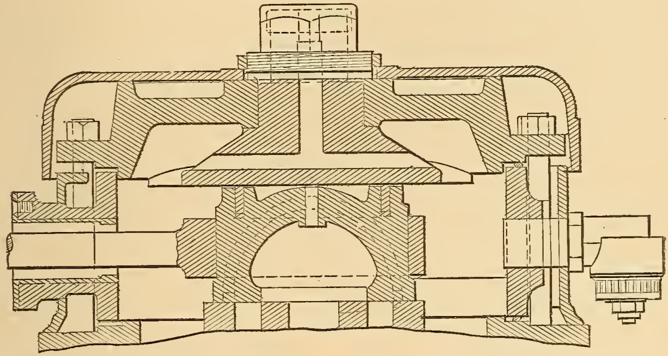


Fig. 81. Allen Balanced Valve, Pennsylvania Railroad Engine, Class "O." Central Lengthwise Vertical Section.

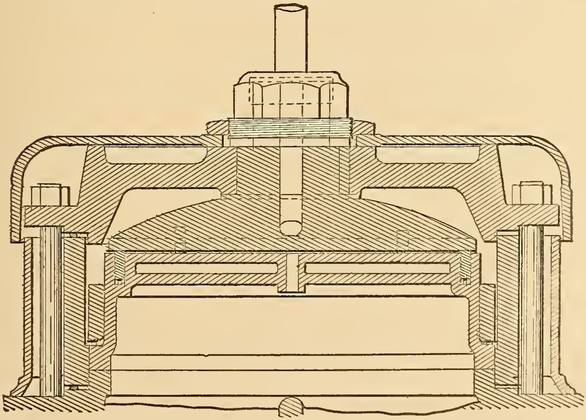


Fig. 82. Allen Balanced Valve, Pennsylvania Railroad Engine, Class "O." Vertical Cross Section.

to the next one when the valve was changed to the Allen.

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. That 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 amount of 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 of full size and may have smooth walls.

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.

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 plain; 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. Figures 80, 81 and 82, show the balanced Allen valve in class "O" engines, Pennsylvania Railroad.

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 inwards into the chest, and thus permitting air to enter the chest through it, instead of coming by way of the exhaust-pipes and drawing cinders with it.

Q. How was the Bristol roller slide-valve made?

A. The valve rested on a number of small rollers RR (figures 83, 84), each side connected to a frame, their axles having a little play in their journals. Steel plates were attached to the valve on each side and others to the valve-seat, so that the rollers rested on the latter below and the valve was carried by the upper plates, which in turn rested on the rollers. The pressure of the valve was carried on the rollers;

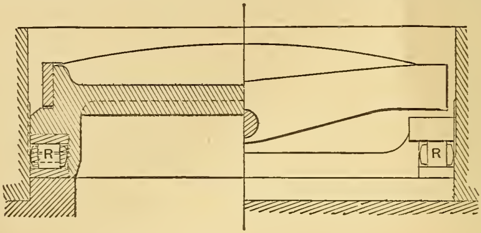


Fig. 83. Bristol Roller Valve.

and as it wore there was little or no contact between its face and seat.

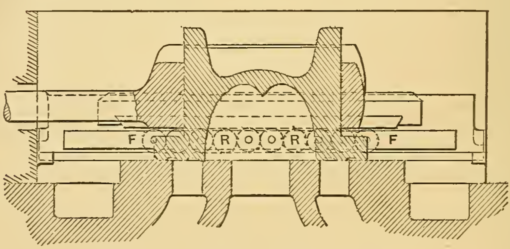


Fig. 84. Bristol Roller Valve.

Q. What is 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 centre.

Q. What is meant by lead-angle?

A. The angular distance of the crank from its zero-point when the port commences to open.

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 small.

Q. What are the limits of lead-angle for stationary engines?

A. Between zero and 8°.

Q. What are the objects of lead?

A. To conceal and neutralize a 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 enable the exhaust to be made more easily.

Q. What effect has lead upon the various elements of distribution: admission, cut-off, release, and cushion?

A. It causes all of them to take place earlier, other things being equal, than if there was 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-pin.

Q. How is the valve given lead by the setting of the eccentric?

A. The eccentric is advanced still further beyond the point 90° from the crank, which it would have if there was no lead. Thus, if there is no rocker-arm, the eccentric is run still further ahead of the eccentric 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 ends of the cylinder?

A. No; the reason being that the connecting-rod introduces irregularities between the piston movement and the valve movement.

Q. What is the nature of these irregularities?

A. When the crosshead is at C, the out end of the stroke (see figure 85,) the crank-pin will be at *c*, on the outboard dead centre. When the crosshead is at B, in the middle of its stroke, the crank-pin will not

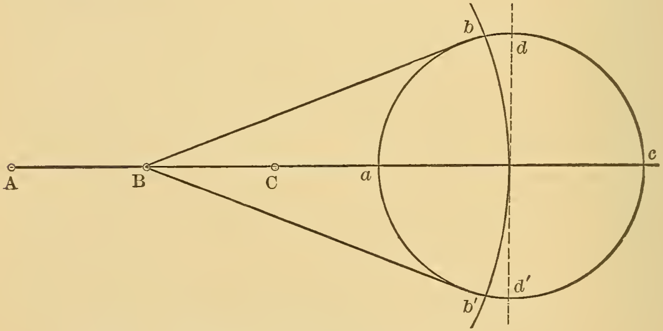


Fig. 85. Effect of Angularity of Connecting-rod.

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 length of main rod in order to lessen the irregularity?

A. It would increase the necessary length of the engine, and also the amount of unbalanced weight.

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 ends of the valve.

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 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 backing eccentric; of course experimenting with the angular advance given, until the lead is seen to be 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. 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 it be reduced?

A. In four ways: by increasing the angular advance; by reducing the valve-travel; by increasing the length of the link, or by shortening the eccentric-rods.

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 rods.

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. Where there are no rockers and links, what will the travel of the valve be?

A. Equal to the eccentric-throw.

Q. Does the lead vary with a shifting link?

A. Yes.

Q Does the lead vary with a stationary link?

A. No.

Q. What is the valve-gear?

A. The mechanism by which the slide-valves are operated by the main driving-axle.

Q. Under what two principal classes may locomotive driving-gears be divided?

A. Into link-motion gears and radial gears.

Q. What is a link-motion gear?

A. One in which the valve receives its motion from a piece driven by a strip, 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 derives its motion from the crosshead or from the connecting-rod, instead of from a rotating piece as an eccentric or an axle.

Q. What are the requisites of a locomotive valve-gear?

A. It must be capable of driving the engine in either direction, forwards or backwards, 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 these two classes of valve-gears is most common with American locomotives?

A. The link-motion is almost universal in this country, and the principal one employed in other countries also.

Q. In the most common form of American locomotive, what is the character of the link?

A. It is a curved piece of metal, having in it a slot of circular curvature, the concavity of which is towards 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 figure 91, 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 may be raised and lowered, carrying the link with it, by a nearly vertical arm, which is connected by a nearly horizontal reverse-rod to a nearly vertical reverse-lever in the cab. Moving the upper end of the reverse-lever forward and backwards lowers and raises the link. The weight of the link and of otherwise unbalanced parts of the gear is balanced by a spring. In England these same otherwise unbalanced parts are balanced by a weight.

Q. What name is given to this link-motion?

A. The Stephenson or shifting-link gear.

Q. What is the effect of raising the link so that the link-block and rocker-pin will be below both the eccentric-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 motion of the valve, of placing the reverse-lever in such a position as to bring the block at the centre of the link?

A. The motion of one eccentric and its rod will counteract that of the other, and either at or near the centre 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 the other way, the valve will be in such a position as to run the engine neither way.

Q. Are the eccentric-rods of the Stephenson valve-gear ever so arranged as to be crossed instead of open or uncrossed, when both the 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 figure 86, in which F is the centre of the forward-eccentric sheave, and B the centre of the backing-eccentric sheave, A being the axle centre, and M being the lower rocker-pin. In figure 87, which is the ordinary method of arrangement in

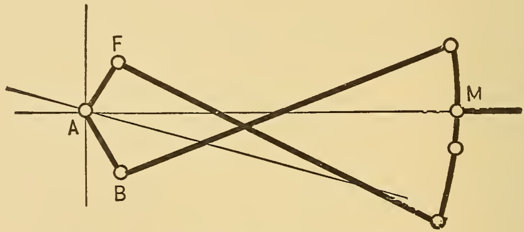


Fig. 86. Stephenson Link, Crossed Rods.

American locomotives, it will be seen that when both the eccentrics are on the same side of the axle as the link, the rods are not crossed.

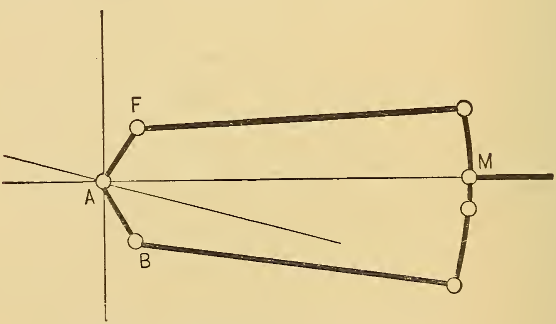


Fig. 87. Stephenson Link, Open Rods.

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 centre 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 centre 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. What name is given to the motion with a link having a curved slot concave towards the driving-axle?

A. The Stephenson link-motion or shifting-link motion.

Q. With this ordinary link-motion, how late can steam be cut-off in 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 which is 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 the ordinary link-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 the Stephenson link-motion affect the point at which release or exhaust takes place?

A. The greater the travel of the valve, the later the release or exhaust.

Q. With the Stephenson shifting-link motion, and open rods, how does the lead vary with the position of the link?

A. The lead increases with the grade of expansion; that is, the earlier the cut-off the greater the lead.

Q. With the Stephenson shifting-link motion, as ordinarily made, but with crossed rods, how does the link-position affect the lead?

A. The greater the degree of expansion, or the earlier the cut-off, the less the lead.

Q. Can the Stephenson shifting-link motion be so constructed that the lead will be constant with varying grades of expansion?

A. Yes; if the link is short, and the eccentric-rods long, and the two eccentrics are properly set with different angles of advance, the variations of lead become practically nothing.

Q. In the shifting-link or Stephenson link-motion, what must be the radius of the link-slot?

A. It must be equal to the length of the eccentric-rods.

Q. How long has the shifting-link motion, ordinarily known as the Stephenson gear, been used on locomotives?

A. Since 1843, at which time it was invented by Howe, and applied to the locomotives of Robert Stephenson & Co.

Q. Has it been much changed since its original invention and application?

A. No.

Q. At which end does the angularity of the connecting-rod tend to make cut-off later than the average or desired amount?

A. At the forward end.

Q. How then can the link be arranged so as to equalize the gear?

A. By giving it 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 revolution of the crank the link will slip backward and forward a certain distance upon its block; if this slip should be very great with the engine linked up in any particular position, and the engine should run a long time in that gear, the link-faces would be worn, there would be lost motion, and the distribution would be irregular 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 it is desired to have a minimum of slip at a certain point of suspension, the saddle-stud should be placed as nearly as possible over that point.

Q. What is an "open link"?

A. One in which the the eccentric-pins instead of being back of the link as in figure 88, are as in figure 89.

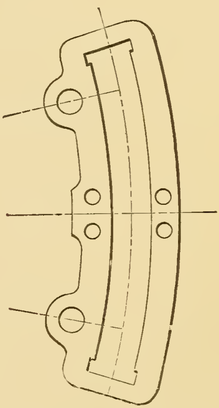


Fig. 88. Usual Link.

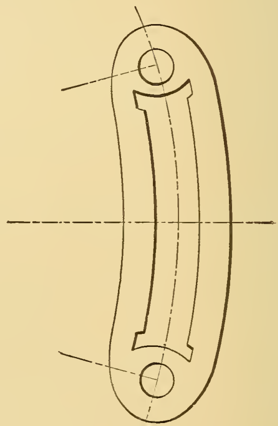


Fig. 89. Open Link.

Q. What are the peculiarities of the open link 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 in order 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 seen in figure 90, the pins are in the line of the slot itself.

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 a short eccentric-throw is desired.

Q. Why is this?

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?

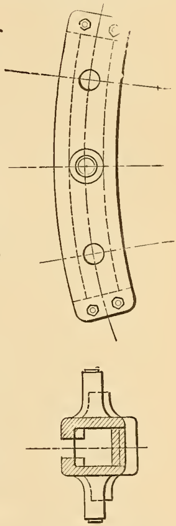


Fig. 90. Box Link.

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 reverse-link or link ordinarily made?

A. In two main parts, the front and the back half (as shown in figure 91), with filling-piece 9 between them, and a saddle, 10, by which it is suspended by the link-lifter 12, which is raised by the reverse-shaft 13; its weight being counterbalanced by the counterbalance-spring 14.

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.

Q. How is the weight of the shifting link and attached parts neutralized?

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, causing damage to the valve-gear or other parts.

Q. Where a flat spiral spring is used to balance the weight of the link, 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, figure 91.

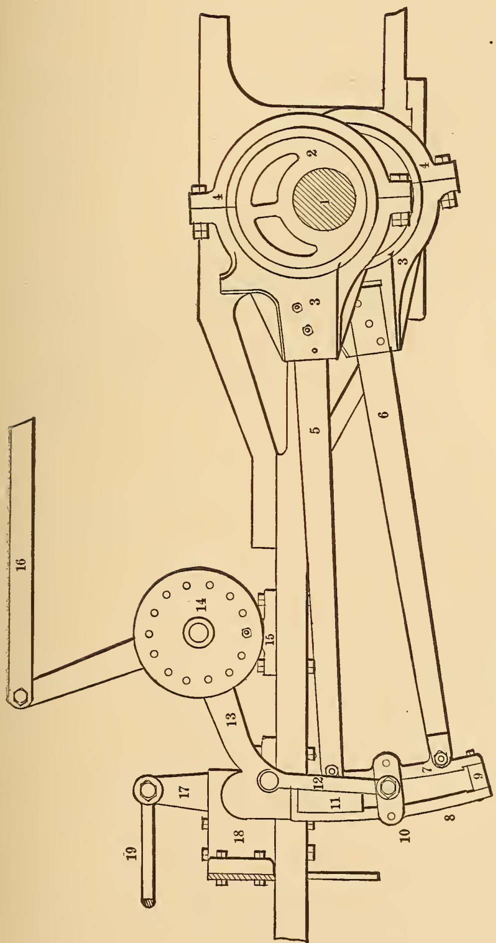


Fig. 91. Valve Motion Work, Shifting Link.

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. Counter-balance-spring. 15. Reverse-shaft Bearing. 16. Reverse-lever Rod. 17. Rock-shaft. 18. Rock-shaft Box. 19. Valve-rod.

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 gives the motion to the slide-valve.

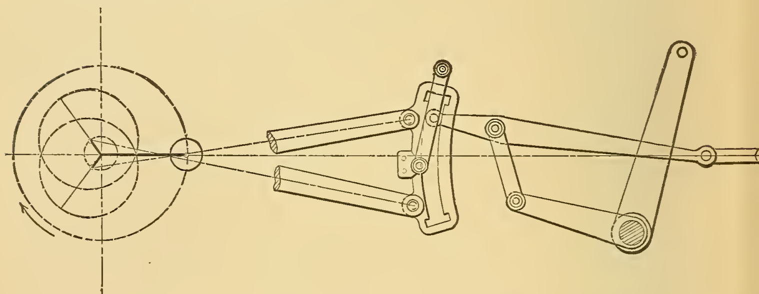


Fig. 92. Stationary Link.

Q. Would the same effect be produced if the link-block was raised and lowered and the height 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 curvature of the link-slot is towards the axle and eccentric, instead of the concavity being so turned. One of such motions, known as the Gooch gear, is outlined in figure 93, with the links uncrossed. In B is the centre of the backing eccentric; F that of the forward eccentric; S being the saddle and the point of suspension of the link; P being the block, which is attached to the radius-rod PV, that is 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.

Q. Can the links of the Gooch or stationary-link motion be crossed?

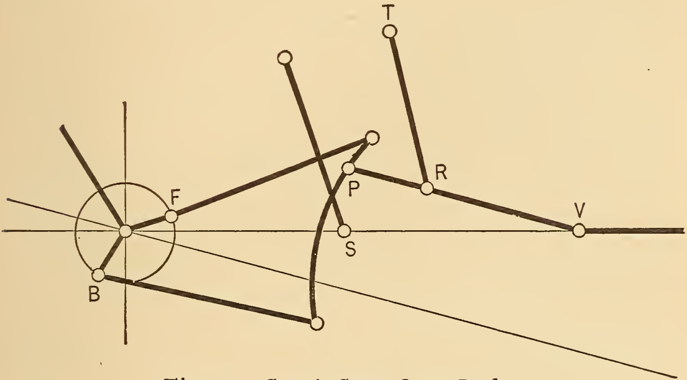


Fig. 93. Gooch Gear, Open Rods.

A. Yes; they are so shown in figure 94 (in which the hangers of both the link and the radius-rod are omitted).

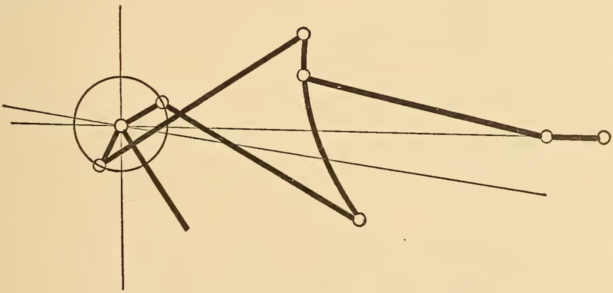


Fig. 94. Gooch Gear, Crossed Rods.

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, towards the axle.

Q. Is this desirable?

A. No; it causes irregularities in the movement of the link so that the sliding-block slips up and down in the slot.

Q. May this trouble be removed?

A. Partly, by placing the point of suspension of the link near the centre of the chord or straight line joining the extremities of the slot.

Q. To what cases is the stationary-link motion, figure 92, page 156, 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 the 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 in order 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; which will be best effected, in practice, by a suspension-rod having a radius equal to the length of the radius-rod.

Q. Are these facts concerning the points and manner of suspension of the Gooch link and radius-rod correct for crossed rods as well as for open ones?

A. Yes.

Q. What must be the length of the radius of the slot in the link of the Gooch gear?

A. It must equal that of the radius-rod, as shown in figure 93.

Q. What is the objection to the Gooch gear for locomotive purposes?

A. It requires too great a distance between the driving-axle and the cylinder, by reason of the great length of radius-rod between the link and the 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 centre of motion of the valve moves farther and farther from the centre of the driving-axle, as the Stephenson link or the Gooch radius-rod is raised or lowered, the distribution of the steam is different in the forward stroke from what it is in the return or backward stroke.

Q. By what style of valve-motion may this trouble be got around?

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; both Allan and Trick having invented it independently, the former

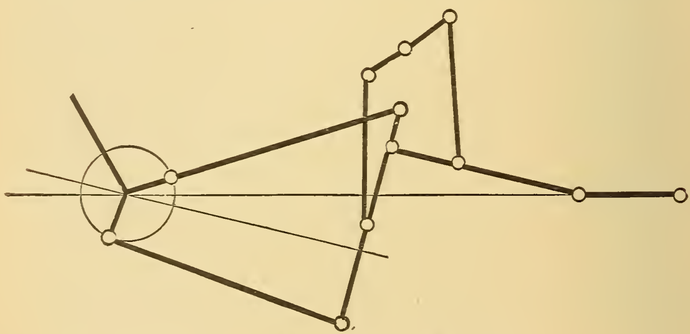


Fig. 95. Allan Gear, Open Rods.

slightly before the latter. It is shown in outline in figure 95, with open rods.

Q. Can the Allan link-motion or gear be used with crossed rods?

A. Yes.

Q. What is the effect of the position of the link upon the lead, with the Allan gear?

A. With crossed rods, the lead decreases with increase in the grade 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. That its parts are more perfectly balanced than the Stephenson, and it dispenses with the counter-weight or spring peculiar to the latter.

Q. What is the objection to the Allan gear?

A. The great distance required between the steam-chest and the driving-axle, by reason of the long radius-rod required.

Q. Can you describe a locomotive valve-gear having variable expansion, and reversing-motion, with but one eccentric?

A. Yes; such a one is the Heusinger von Waldegg gear, shown in figure 96. There is on the driving-axle, the centre of which is represented by O, a crank shown by the line OR, and a single eccentric the centre of the sheave of which is shown at E, and which is set at right angles to and following the crank. The eccentric-rod EC takes hold of the lower end of the curved link CC, which turns upon the fixed pin P, and the convexity of which is turned from the driving-axle. In the curved slot in this link a sliding-block K has up-and-down motion, being raised and lowered by a lifting-link, which varies the degree of fore-and-aft motion given the block by the oscillation of the link. The radius-rod BK extends from this block nearly horizontally towards the driving-axle, and its end B is pivoted to two levers MS, the upper ends of which are jointed to the valve-stem VV, while their lower ends turn in bearings S, below the crosshead W. Thus the levers

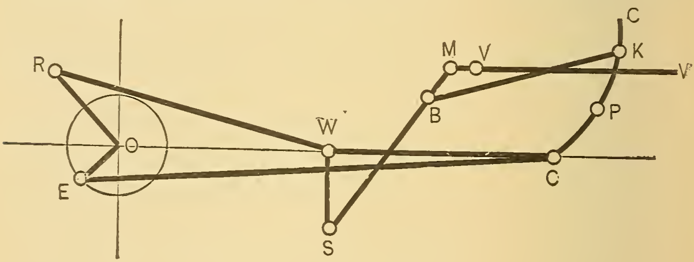


Fig. 96. Waldegg Gear.

MS get at their lower ends S a to-and-fro motion from the crosshead W, to a downward projection of which they are pivoted; the point B gets an oscillating motion from the link, and the upper ends M get a peculiar motion which is quite favorable to giving the valve a movement which will ensure good distribution, favorable expansion, and reversibility of engine.

Q. How about the lead on the Heusinger von Waldegg gear?

A. It is constant at all grades of expansion.

Q. What is the objection to this gear?

A. It is too complicated.

Q. Is there any other link-motion by which *variable expansion and reversibility of engine may be got with a single eccentric?*

A. Yes, the Pius Fink motion, the most simple of all. It is shown in outline in figure 97, in which the radius-rod is moved up and down by a bell-crank lever. O is the driving-axle, OR the crank, and D the eccentric, which stands 180° from the crank; that

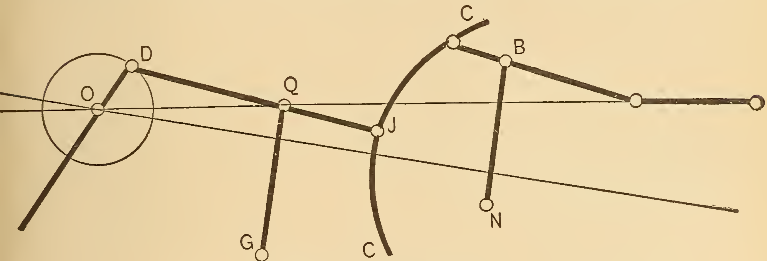


Fig. 97. Fink Gear.

is, directly opposite it; the sheave being fastened immovably to the link CC. A sustaining-arm GQ is pivoted below, at G, at such a point that Q moves almost exactly along the line of stroke and the link oscillates around this point as the axle turns. NB is the radius-rod, connected at B with the valve-stem; and it is raised and lowered in the link-slot by a bell-crank lever, fastened to a lifting-link. The dead-point in the link is at J; the direction in which the engine runs depends on whether the block is above or below J; and the distance of the block from this dead point covers the grade of expansion; the greater the distance the less the expansion, and the later the cut-off, and *vice versa*.

Q. What must be the radius of the arc of the Fink link?

A. It must be equal to the length of the radius-rod.

Q. What are the disadvantages of the Fink link-motion?

A. Unequal steam-distribution, at various points of cut-off.

Q. Is it a desirable gear for locomotive use?

A. No.

Q. Might the curved link in the Fink gear be replaced by a straight one?

A. Yes; provided the link were lowered when the radius-rod was raised, and *vice versa*, as in the case of the Allan gear.

Q. Is there any way by which the variability of lead with the Fink gear may be practically neutralized, and the cut-off points may be practically symmetrical?

A. Yes; by the judicious use of compression or cushion; as has been proved with the Porter-Allan stationary engine, where only half the link is used (reversibility not being necessary).

Q. Are link-motions very common, in which when the centres of the eccentric 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. What is the Walschaert link-motion?

A. One in which there are two distinct motions, one from a single eccentric, and the other from the crosshead; the eccentric usually being like a return-crank from the main crank-pin as shown in figure 98, with its centre at right angles to the crank-arm.

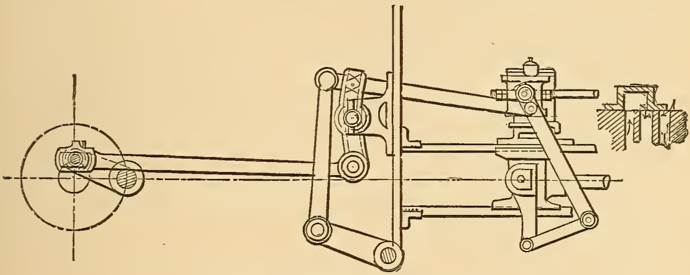


Fig. 98. Walschaert Gear.

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 cross-head motions are combined so that the crosshead motion gives the angular advance which the eccentric would not give, and thus enables the valve to have constant lead.

Q. To what classes of engines is the Walschaert motion best adapted?

A. To those with outside cylinders.

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 of the stroke, but there will be less width of port-opening with the small throw.

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.

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 to a great extent with the irregularities in cut-off and exhaust closure, due to the angularity of the connecting-rod.

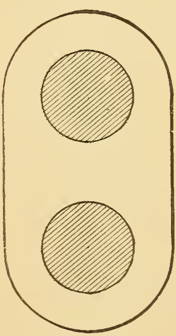


Fig. 99.

Q. Is there any other way by which the valves could be given sliding motion from a rotating axle, than by eccentrics?

A. Yes, cranks may be used, the eccentric being in effect a crank the pin of which is enlarged so as to include the shaft. Thus, ordinarily, the crank-pin is smaller than the shaft and at some distance from it; in figure 99, it is of the same size; in figure 100, the pin is larger than the shaft, but does not enclose it; in figure 101, the pin not only is larger than the shaft but encloses it and has become an eccentric.

Q. What would be the simplest way of getting the motion of the eccentric to the valve?

A. By an eccentric-rod direct from the strap.

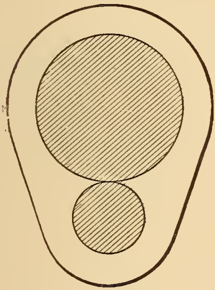


Fig. 100.

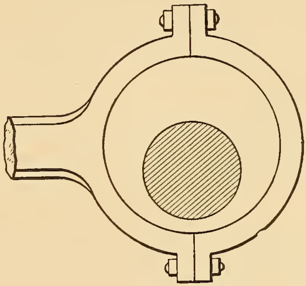


Fig. 101.

Q. Why cannot this be done in the case of a locomotive?

A. Because it is necessary to have two eccentrics in order to be able to reverse the engine, and to have a link in order to be able to vary the throw for the purpose of varying the period of admission and degree of expansion.

Q. With the use of two eccentrics and of the link-motion, is the valve driven directly from the link?

A. No; there is a rocker-arm for the purpose of transferring the motion from the lower plane to the higher one; also from within the frames to outside.

Q. What other effect has the rocker-arm upon the motion?

A. It reverses it, making it necessary to set the eccentrics differently from what would be the position were there no rocker-arm.

Q. Suppose that there was a valve without steam lap, driven by one eccentric, how would this have to be placed on the axle, supposing that no lead was used?

A. If there was no rocker-arm it should be placed

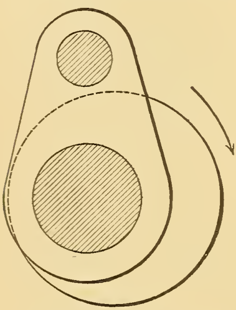


Fig. 102. Single Eccentric, Lapless Valve, no rocker.

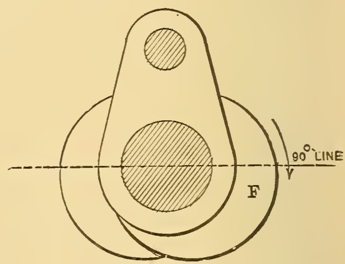


Fig. 103. Two Eccentrics, Lapless Valve, no Rocker.

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; that is, if there was a single eccentric it would be as in figure 102.

Q. How should the eccentrics be set, where there are two of them with shifting link and uncrossed rods, driving a lapless valve without rocker-arm (no lead being required)?

A. As shown in figure 103, each one being 90° ahead of the crank-pin in the direction in which the engine is to run. (The forward eccentric is marked "F.")

Q. Suppose the case of 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 would the eccentric have to be set, if no lead was desired?

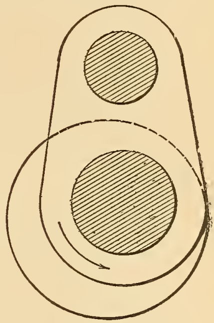


Fig. 104. One Eccentric, Lapped Valve, no Rocker.

A. As shown in figure 104, in which the eccentric is set 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 was at beginning of stroke.

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 shown in figure 105, where the forward eccentric is set 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° posi-

tion, necessary to make the steam edge of the valve-lip line with the outside edge of the end port, be determined?

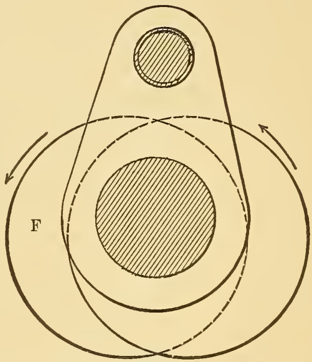


Fig. 105. Two Eccentrics, Lapped Valve, no Rocker.

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 the manner of setting the latter (when no lead is desired)?

A. As the rocker-arm reverses the direction of motion of the valve 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

* This is fully described and illustrated under the head of Valve Setting.

direction in which it is to run the engine, as shown in figure 106.

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?

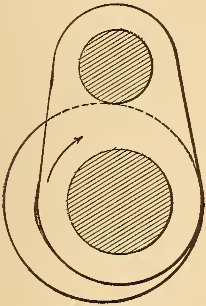


Fig. 106. One Eccentric, Lapless Valve with Rocker.

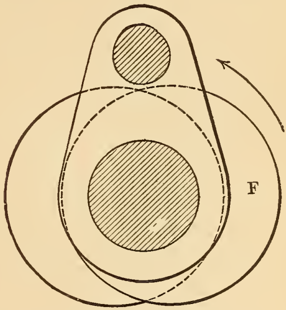


Fig. 107. Two Eccentrics, Lapless Valve with Rocker.

A. Each should be run back of the crank-pin (in the opposite direction from that which it is required to run the engine) 90°. (See figure 107, in which the forward eccentric is marked "F.")

Q. Where there is a rocker-arm and a lapped valve, 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 turn to bring the valve line-and-line for admission at stroke-end; the eccentric belly being towards the crank. The more lap the more such excess. (See figure 108.)

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?

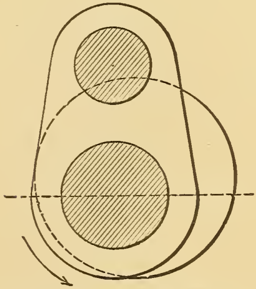


Fig. 108. One Eccentric, Lapped Valve, with Rocker.

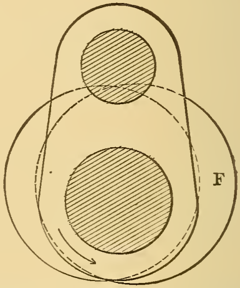


Fig. 109. Two Eccentrics, Lapped Valve, with Rocker.

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 towards the crank. (See figure 109, 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. (This rule is good for either one or two eccentrics.)

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 of it 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 "lead" or "advance."

Q. In how many pieces is the eccentric-sheave?

A. Sometimes in one, sometimes for convenience of repairs, in two.

Q. How are these parts fastened together?

A. Sometimes by bolts or studs, sometimes by keys and cotters.

Q. What is the advantage of the latter system?

A. There is less trouble in fastening them 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 key-way, and again without cutting key-ways, 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 key-way?

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 end; and the lifting-shaft will have to be in front of the link instead of back of it. The eccentric-strap is made in two halves, a front, shown in figure 91, and to which the eccentric-rod is bolted, and a back which is bolted to the front half.

Q. Is the eccentric-strap always divided in a line at right angles to the centre line of the rod?

A. No; some builders make the part at an angle of 45° or so with the rod.

Q. What is the advantage of having the part at right angles to the centre line of the rod?

A. That there will not be required one pattern for the right side and another for the left.

Q. What is the advantage of having the part at more than a right angle to the centre 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 on it?

A. To avoid the necessity of having a right and a left-hand pattern.

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. 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. 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 which lies alongside the handle of the lever; the latch working in notches on the upper side of the quadrant.

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

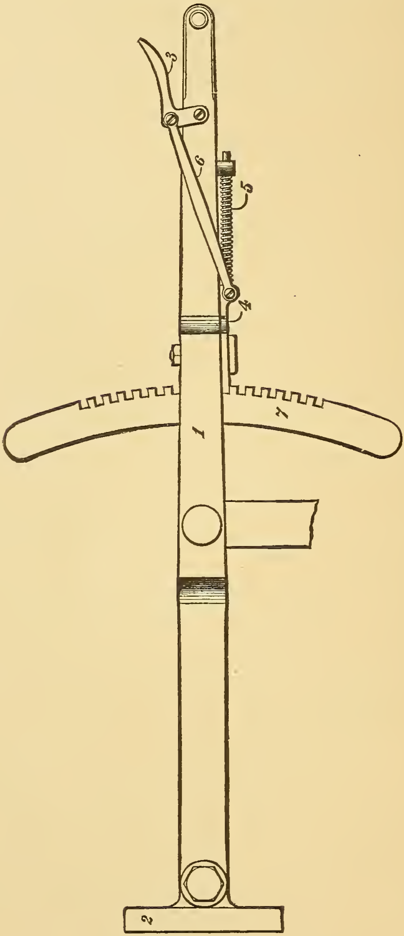


Fig. 110. Reverse-lever and Attachments.

1. Lever. 2. Fulcrum. 3. Handle. 4. Latch. 5. Latch-spring. 6. Latch-rod. 7. Catch.

of piston-stroke; as 6, 9, 12, etc., or 6, 8, 10, etc. Besides these, there is one notch corresponding to mid-gear.

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. What is the most desirable position for the tumbling shaft?

A. When it holds the hanger in such a way as to guide its vibrations in arcs that are practically parallel to the central 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 gear to another.

Q. Why not curve the eccentric-rods?

A. That would produce the desired results, but would introduce an element of weakness into the design.

Q. What point must be noted in connection with the hanger?

A. It must be of such length that the end of the link 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?

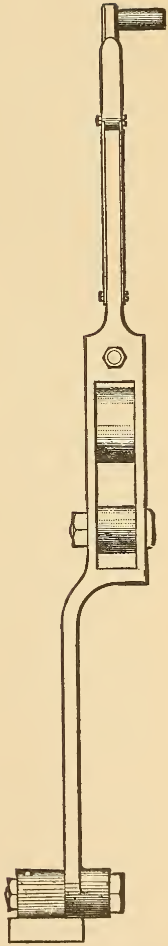


Fig. 111. Reverse Lever and attachments.

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 gear back, what will have to be done?

A. There are two remedies; one to put the tumbling-shaft below the link motion, and the other to lengthen the rocker so as to lower the entire motion.

Q. What will be necessary in the second case?

A. To change the relative positions of the rocker-arms 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 vibration of the valve-stem and the slip of the link-block.

Q. Of what material are the rocker-arms usually made?

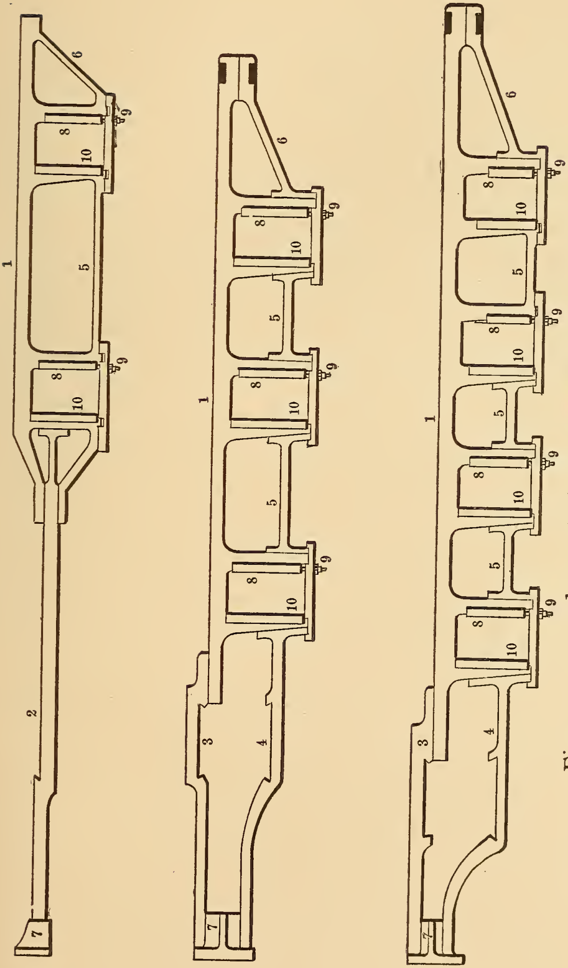
A. Of wrought iron.

Q. Why are the holes in the rocker-arms usually made tapering?

A. To enable the pin to be driven out more readily.

Q. How are the frames of the ordinary American engine made?

A. Divided into two parts, a front and a back frame, or main frame. The main frames are built up of wrought-iron bars, say four inches square in cross section, arranged in pairs, one some distance above the other on each side, with double connecting-pieces at each end, so as to form a sort of truss, the distance-pieces being the pedestals, between the



Figs. 112, 113 and 114. 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.

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, which 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 cow-catcher 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 figures 113 and 114).

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 ends of which are 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. Then cross-braces attached to the lower bars each side of the engine unite the right and the 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 by reason of difference of 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. (Figures 113 and 114.)

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 they are tapered they will hold the frame together better; this being particularly true if they are long.

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 form 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.

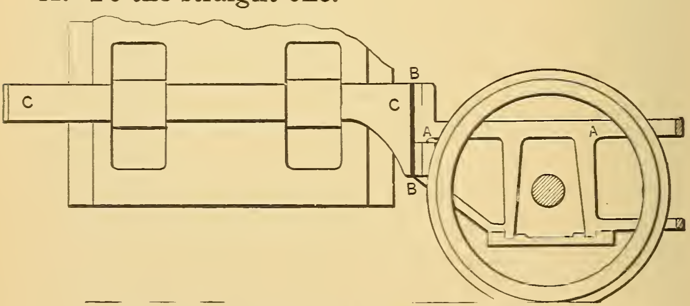


Fig. 115. Frame for Narrow-gage Engines.

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 figures 115 and 116, in which B B is the cross-plate, bolted to the back ends of the arms; two

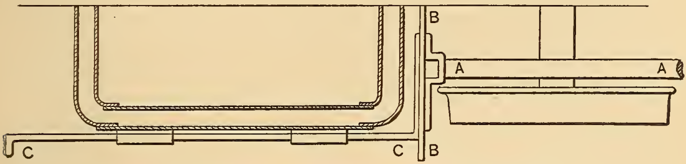


Fig. 116. Frame for Narrow-gage Engines.

flat bars C C are bolted to it 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.

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 the springs and equalizing-levers.

Q. How do the equalizing-bars distribute the weight of the engine equally on all the drivers?

A. Because if there were more weight put on the rear end 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 the rear ends 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 part 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 centre-pin. Three-point suspension is the most suitable way that is known, as witness the great stability of a three-legged over a four-legged stool.

Q. What forms the front point of support in an eight-wheel passenger engine?

A. The centre-pin.

Q. What is the front point of 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 one, and the fulcrums of the equalizing-levers between the driving-wheels being the other four.

Q. How many points of support has a ten-wheel engine?

A. Five; the truck centre-pin in front, and the fulcrums of the equalizing-bars between the driving-wheels.

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 in the track, or a pedestal, some of the strain is taken off its springs and thrown on the front driving-springs.

Q. What is to prevent the irregularity of the 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 the injury to the parts by the pounding and vibration that would thus ensue?

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 their proper position; and when the weight comes down on that side, the springs lessen the shock which would tend to injure the axle-box, axle, wheel, and rail; to say nothing of the substructure, as on a bridge.

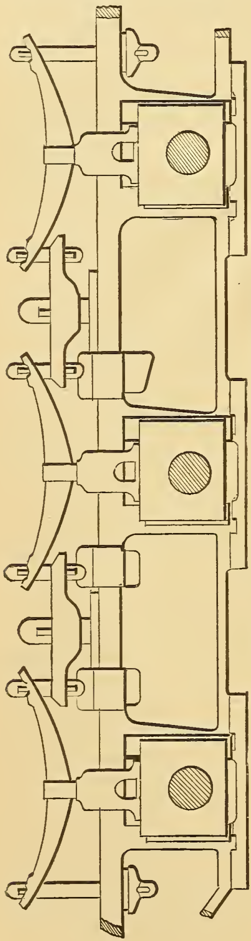
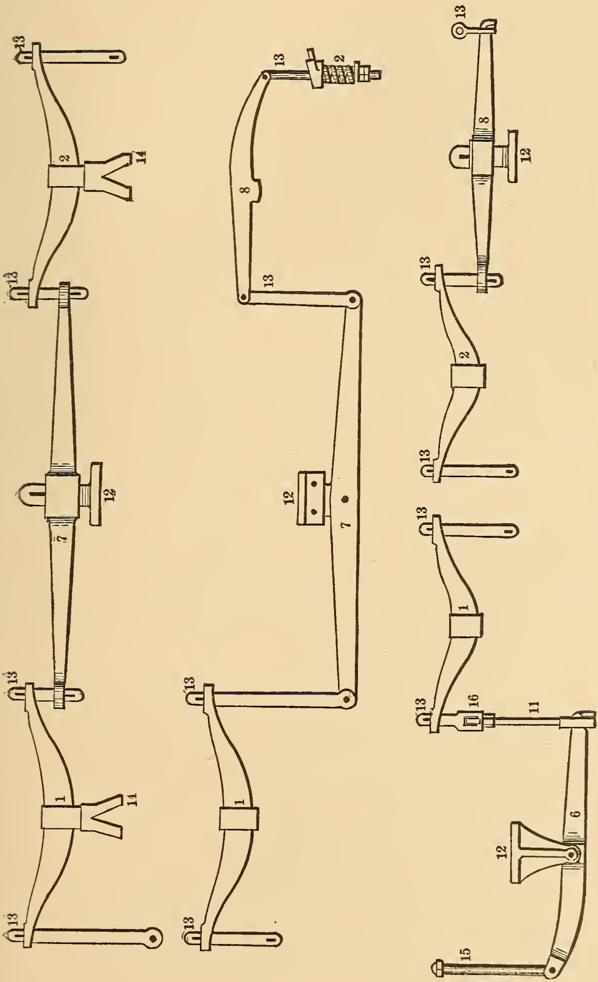


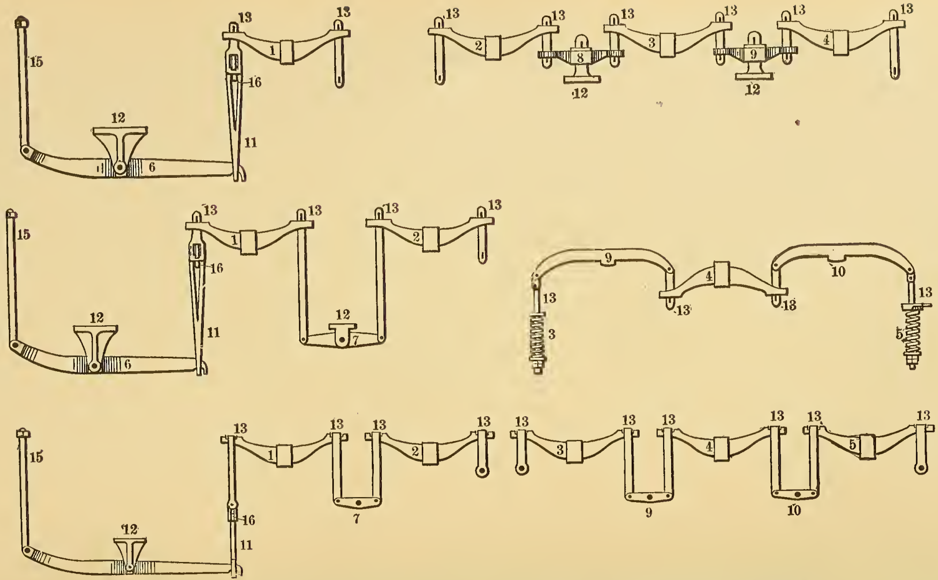
Fig. 117. Spring Arrangement for Consolidation Engines.

Q. What is the usual method of connection between the springs and the axle-boxes and the frames?

A. There are U-shaped saddle-pieces which bear on the tops of the axle-boxes and surround the upper bars of the frames; these are attached to the centres of the two bottoms of compound leaf springs, running lengthwise of the engine and of the frames. From one end of each of these springs there is a hanger, to the lower end of which the frame is attached, 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 there is attached one end of an equalizing-bar the centre of which is bolted to the upper frame bar, between the driving-axles. Thus most



Figs. 118, 119, 120 and 121. Springs and Equalizer Work. (See legend, next page.)



Figs. 122, 123, 124, 125, 126 and 127. Springs and Equalizing 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 Centre-pin Bolt. 16. Transverse Equalizing-beam.

of the weight of the engine (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 back end of the front driving-axle spring to the front end of the rear driving-axle spring, aids in distributing the weight so that neither spring gets an excess of weight; 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.

Q. What is the character of the driving-axle springs?

A. Each is made up of a series of leaves, of equal width but successively decreasing lengths, bound together in the centre by a clip so as to act as though they were a single bar, slightly curved, and thicker in the centre 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 and 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. How many driving-axles has the ordinary English passenger locomotive?

A. One only, having of course but two driving-wheels.

Q. How many driving-axles 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 the 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 of the engine 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 centres of the cylinders and parallel with all the other axles.

Q. What is the effect of not having the driving-axle true with respect to the cylinder-axles and the other axles?

A. A snaky motion, tending to make the engine wear more to one side of the track than the other and thus wear the flanges on one side more than on the other.

Q. What is the advantage of large driving-wheels?

A. They enable high speeds to be attained and keep the piston-speed down, thus enabling the steam to be properly exhausted.

Q. What are their disadvantages?

A. They set the engine too high; they are more liable to jump the track at high speeds and on curves, or by reason of obstructions.

Q. How are driving-wheels usually constructed in this country?

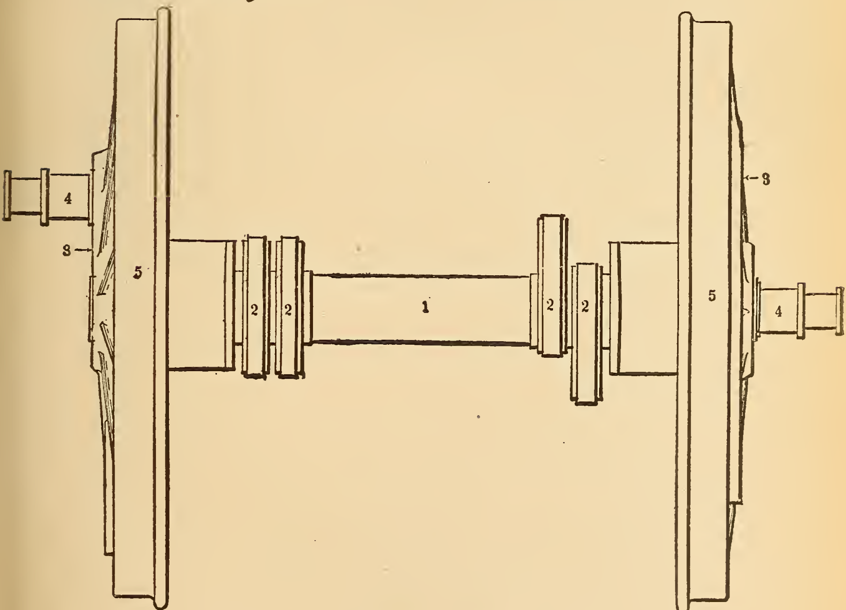


Fig. 128. Wheels, Axle and Tires.
1. Axle. 2. Eccentrics. 3. Wheel-centres. 4. Wrist-pin. 5. Tires.

A. They are made with a single-piece iron casting as a centre, about which a wrought-iron or steel tire, usually the latter, is shrunk; the hub and rim, (sometimes the spokes also,) being cored out to lessen their weight and to give the wheel 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.

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 yet, grooves are turned in its flat sides and in these are placed the projecting fillets of retaining-rings which are bolted to the wheel-rims; so that if the tire should break the parts will be clamped to the wheel-centre by these retaining-rings.

Q. How are the driving-wheels fastened to the driving-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 key-ways in the 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-centre 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-centre turned off. This is shown in figure 129.

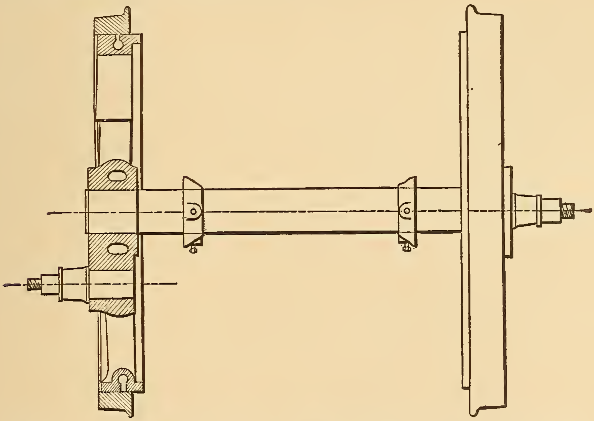


Fig. 129. Wheel-centre to Permit Narrowing the Gage.

Q. What is flange-friction?

A. The friction of the flanges against the insides of the rails, due partly to slewing.

Q. How may it be lessened?

A. By lubrication, as is practiced on some of the European railways usually by a block of tallow pressed 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 pair of wheels which do not turn with their 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 treads of the wheels 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 only be effective in case the amount of taper or cone given the treads is directly proportionate to the radius of the curve. Each degree of curvature requires a different amount of taper; furthermore the action in passing around a curve at high speed is to throw the entire machine towards the outer rail, which is just in 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 usually gets the worst of it.

Q. Is the influence of cone or taper on the wheel treads increased or lessened with the distance between axles?

A. Diminished.

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 bearings do these journals have?

A. Usually brasses with semi-circular 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. Octagonal and cylindrical.

Q. What are the objections to octagonal brasses?

A. They are more difficult to fit than the cylindrical ones, 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 in this case.

Q. Should oil-cellars be straight or tapering?

A. Tapering, in order to facilitate their removal.

Q. Are all the driving-wheels always supplied with tires?

A. No, some builders leave the front pair without them.

Q. What name is given to a driving-wheel tire that has no flange?

A. It is variously called plain, mulay and blind.

Q. In Mogul engines, which pair of tires is made blind?

A. The middle pair.

Q. In ten-wheel engines, with six drivers, which wheels are without flanges?

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. What pair should have flanges and which should be blind, on consolidation engines?

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 any way; then the two centre pairs may be left without flanges.

Q. What is the object of having 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 of the shoulder on the rim of the wheel-centre in some wheels against which the tire is pressed?

A. To prevent the tire from slipping inwards 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 because 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 heavy a weight without the intervention of springs.

Q. What name is given to the distance between axle-centres?

A. Spread.

Q. What name is given to the total distance between the centres of the front and back wheels?

A. Total wheel-base.

Q. What name is given to the distance between front and back driving-wheel centres?

A. Rigid wheel-base.

Q. What is the effect on the resistance to rolling, of lessening the distance between truck-axles?

A. To diminish it up to a certain point.

Q. What is the advantage of placing the driving-axles between the furnace and the 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 (see figure 148, page 221,) is the distance greatest 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 an undue amount of 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 of an engine?

A. The distance from the centre 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-centres of the parallel rod; or where there are more than one on each side, the total lengths of such rods on one side.

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 figure

133, page 203,) 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 Mogul engine as compared with the ten-wheeler, in tractive power?

A. It has greater hauling power by reason of having a greater proportion of its weight on the driving-wheels.

Q. What is a truck?

A. A frame bearing one or more pairs of non-driving wheels and attached to the frame of the engine, one end of which it supports, by a vertical centre-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 pairs of wheels in the front truck of an engine, instead of one?

A. In order 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 pairs of truck-wheels, where is the centre-pin placed?

A. Equidistant from each axle.

Q. Where there is but one pair of truck-

wheels as in the so-called pony or Bissell truck, where is the centre-pin placed?

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 axle-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 there is

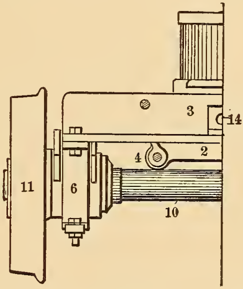


Fig. 130. Four-Wheel Truck (one half). (See legend next page.)

a leaf spring with its convex side up. On each axle-box there rests the ends of a pair of equalizing-levers, (one inside and the other outside the frame, on each side) and to these the ends of the springs are hung by hangers. On the spring-strap the truck-frame rests: 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 centre-plate. (See figures 130 and 131.)

Q. How is the centre-plate fastened to the truck?

A. Sometimes it is bolted to it, and sometimes it is hung by swing links permitting it to vibrate crosswise of the track.

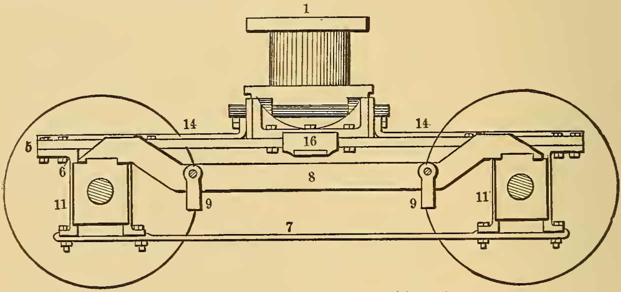


Fig. 131. Four Wheel Truck.

1. Centre-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. What keeps the engine from being jolted off the centre-pin in case of a very rough track or of a derailment?

A. A key passing through the pin prevents this.

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 there is a V-shaped frame, the point of which has a centre-pin passing into the main frame, and about which the truck may swing. There are usually swing-bolsters, as on some four-wheel trucks. Sometimes the pony truck is equalized with the driving-axles to make

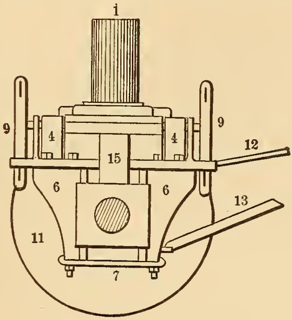


Fig. 132. Pony Truck.

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 centre-pin,

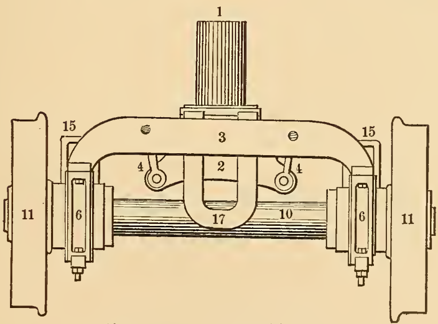


Fig. 133. Pony Truck.

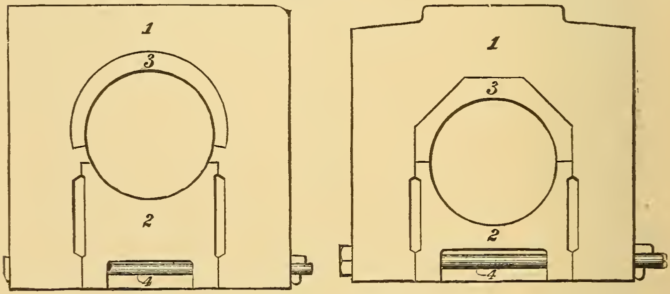
the centre of which is fulcrumed in a horizontal pin attached to the main frame, and the rear of which is borne by a cross-bar suspended from the front ends of the front driving-axle springs. This rig gives the truck a share of any excessive downward thrust or weight that is put over the driving-wheels, and *vice versa*. (See figures 132 and 133.)

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 and 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-



Figs. 134 and 135. Driving and Truck Journal-boxes.
1. Box. 2. Cellar. 3. Brass. 4. Cellar-bolt.

iron centres are used and given wrought-iron or steel tires, in the same way as driving-wheels are made; sometimes again there are two webs or wrought-iron plates between the hub and the rim, the space between them being filled up with compressed paper.

Q. What character of bearings and journal-boxes have the truck axles?

A. About the same as those of the drivers, except that they are smaller.

Q. What keeps the trucks from getting across the track in case of derailment?

A. Check-chains or safety-chains.

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 placed?

A. Usually on top of the boiler; but in recent practice one has been put lower down, each side, between the drivers, so that the sand may be nearer where it is wanted and have less chance to stick in the pipe in case it gets frozen. (See figure 136.)

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 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 the friction of its journals in their bearings, which is really sliding friction.

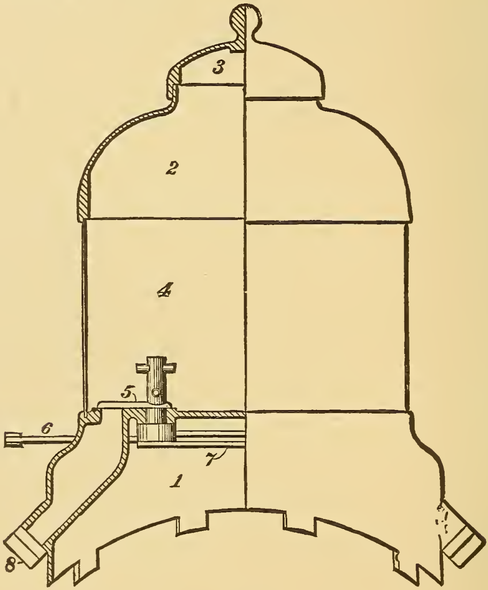


Fig. 136. Sand-box Work.

1. Base. 2. Top. 3. Lid. 4. Body. 5. Valve. 6. Lever. 7. Valve Connecting-rod. 8. Pipe-flange.

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 the track, kind and quantity of lubricant supplied, etc.; say 3,750 pounds for average conditions.

Q. How can this 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. What is adhesion or traction?

A. The tendency of the driving-wheels to cling to or "bite" the rail so as to give a good leverage, tending to drive the whole engine ahead instead of letting the wheels spin around.

Q. What increases this adhesion or traction?

A. Weight on the driving-wheels. The greater the weight on them the greater the tractive effect, other things being equal.

Q. Why not make all the wheels 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. Because that would necessarily lengthen the rigid wheel-base. While it would do for slow speeds on straight roads it would not do at all for curves, by reason of the long wheel-base, or for high speeds by reason of the greater tendency of large wheels to leave the track.

Q. Cannot 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. 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 they are 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. 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-wahing" or swinging of the entire engine from side to side of the track.

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 centre of gravity from the centre of the axle, will equal the weight at the crank-pin multiplied by half the stroke of the piston.

Q. Can the lack of balance in the reciprocating parts of a locomotive 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 one coming back at the same time and speed.

Q. Suppose that you have a segment-shaped counterweight; how can its centre of gravity be found?

A. By cutting out a wood or card-board templet of even thickness, of the same size and shape as the weight, and suspending it from several points in its surface, near its rim, by a brad-awl 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 face of the templet. Where two of these lines intersect will be the centre of gravity of the templet, and should be that of the piece which it was made to match.

Q. Where there are two segment-shaped counterweights separated by a spoke, will their common centre of gravity be at the same distance *from the axle-centre 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 centres of gravity by a chord at right angles to the radius or spoke. Where this cuts the centre-line of the spoke will be the common centre 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 centre of gravity be found?

A. By laying them down as directed for two segments, connecting the centres of gravity of the two outside ones by a chord at right angles to the spoke-radius, and stepping off from this chord, towards the centre of gravity of the middle weight, one-third the distance between the chord and that weight. The point thus found will be the common centre 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. What means are employed to signal the approach or intended starting of a train from the train itself?

A. The bell (figure 137) and the whistle (figures 138 and 139).

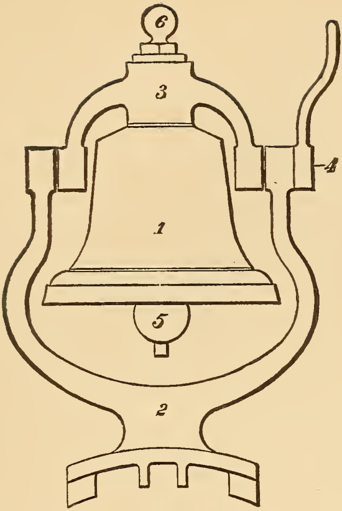


Fig. 137. Bell and Frame.

1. Bell. 2. Frame. 3. Yoke. 4. Crank. 5. Tongue. 6. Acorn.

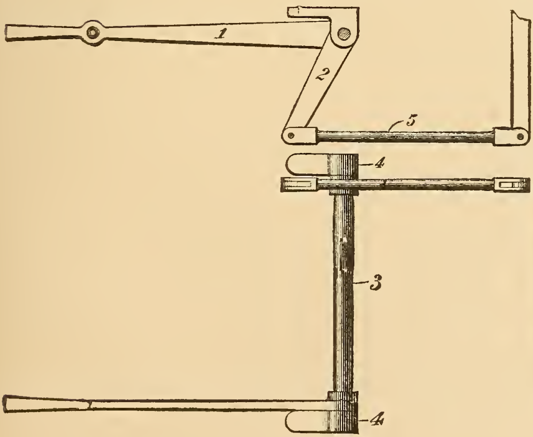


Fig. 139.
Chime Whistle.

Fig. 138. Whistle Work.

1. Lever. 2. Arm or Crank. 3. Shaft. 4. Shaft-bearing. 5. Link.

Q. Where is the bell usually placed?

A. On top of the boiler, in the yoke; it is rung by a rope passing into the cab.

Q. How is the engineer signalled 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 is the engineer enabled to see ahead of the engine, on the track, at night?

A. By a head-light of about 40 to 75 candle-power placed in front on a bracket having a parabolic mirror by which its rays may be directed in a practically parallel beam striking the track in an elliptical area at some distance ahead of the engine.

Q. How do the engineer 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.

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 end of the frame.

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.

Q. How is the engine enabled to push a train, without injury to the cow-catcher?

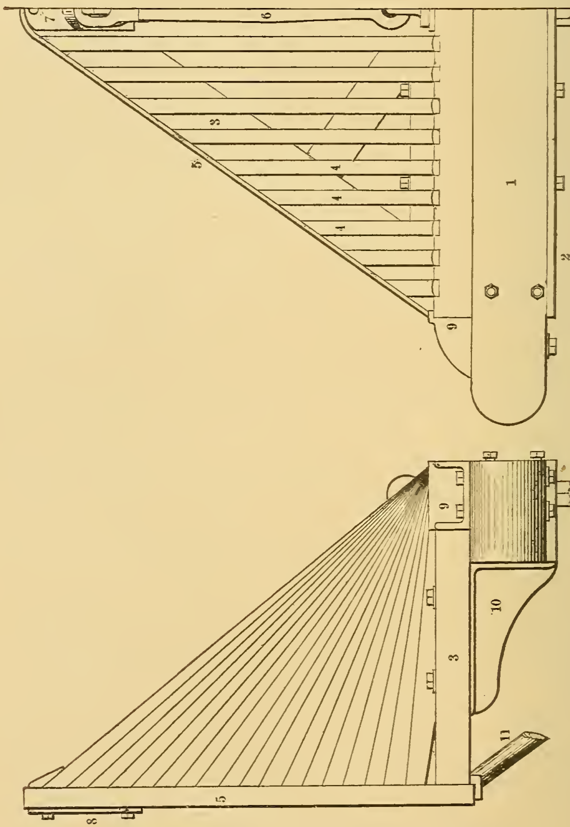
A. By a pushing-bar hinged to the centre of the bumper-timber, in front, and which, when not in use, lies along the front edge of the cow-catcher.

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.



Figs. 140 and 141. 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.

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 required for freight service?

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

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

A. For hauling freight trains, small drivers and 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 engines are required for suburban business?

A. Engines that can start heavy trains and run them at high speeds; and usually it is well for them to be double-enders or to have valve-gear, etc., permitting them to be run equally well in either motion.

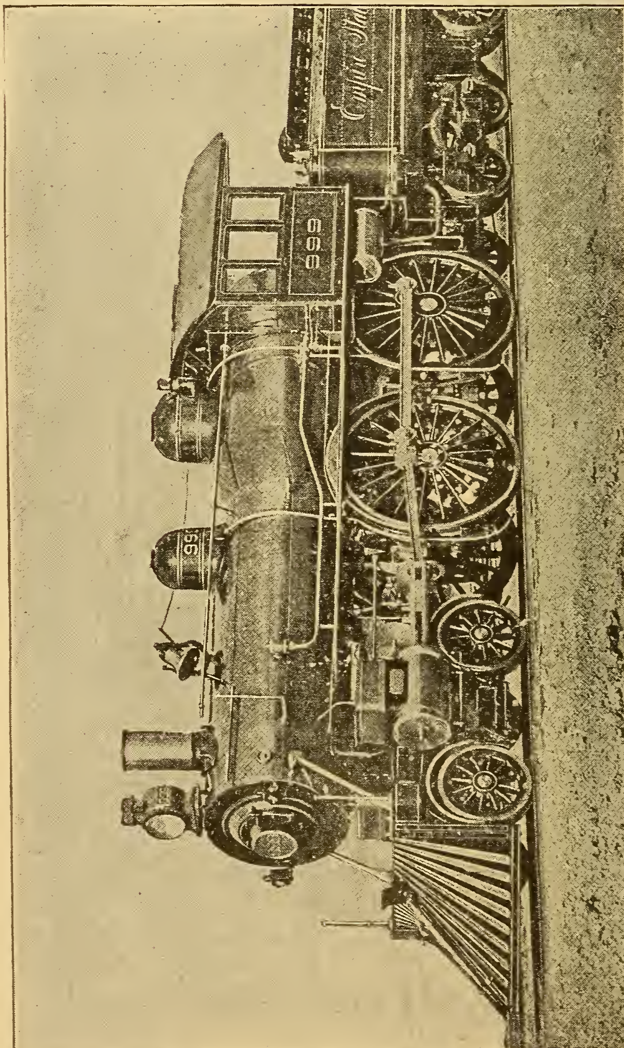


Fig. 142. "999," Latest Engine on New York Central. Speed, One Hundred Miles an Hour.

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 swivelling truck.

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 is the idea of having the fire-box over both pairs of drivers?

A. In order 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 having 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 figure 143, then a modification of this has also four wheels coupled, but instead of having a four-wheeled truck in front there is a pony truck there and another in the rear, as shown in figure 144.

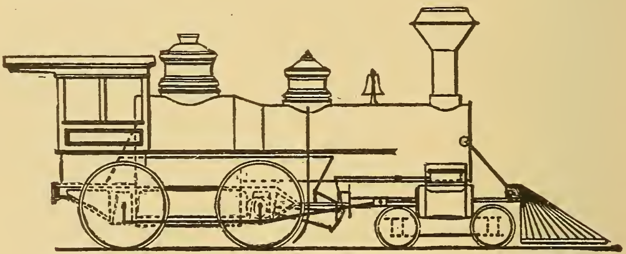


Fig. 143. Express Passenger Engine, American Type.

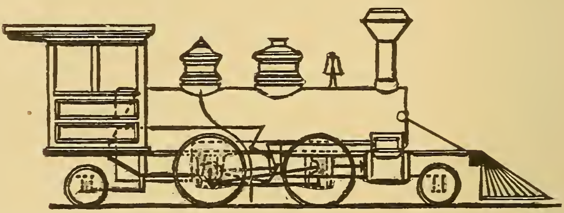


Fig. 144. Express Passenger Engine, with Pony Truck.

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 the rear pair of drivers the main pair, and have a two-wheel or Bissell truck in front of the cylinders so as 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 figure 145.)

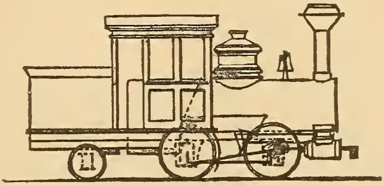


Fig. 145. Switching and Local Passenger Service, with Back Tank. (Modified Forney Type.)

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 service?

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 a greater tractive power is desired than can be had with only two pairs of drivers, what arrangement is made?

A. More drivers are added, as in the Mogul, (figure 146, page 220,) in which there are three pairs of drivers and a pony or two-wheel truck, the consolidation, in which there are four pairs of drivers and a two-wheel truck, the ten-wheeler, in which there are three pairs of drivers and a four-wheel truck, the twelve-wheeler, in which there are four pairs of drivers and a four-wheel truck, and the decapod, in which there are five pairs of drivers and a two-wheel truck. (See figures 146, 147, 148 and 149.)

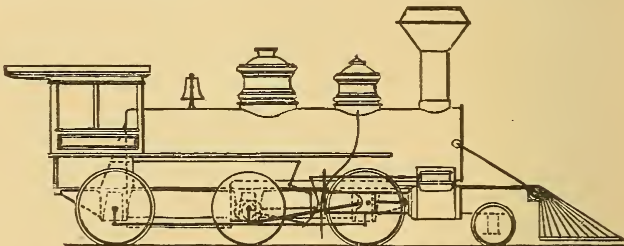


Fig. 146. Mogul Freight Engine with Tender.

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

A. The ten-wheeler is coming into great favor for

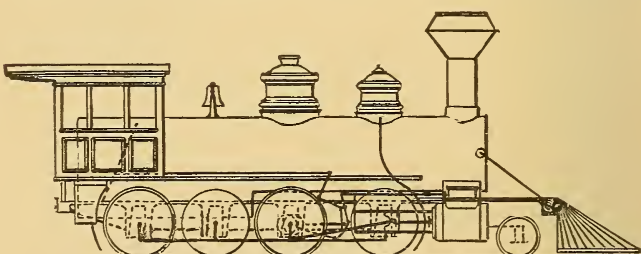


Fig. 147. Consolidation Engine for Heavy Freight.

this purpose; having six wheels coupled and a four-wheeled truck, as shown in figure 148, page 221.

Q. For heavy freight what seem to be the best adopted types of engine in this country?

A. The consolidation, having eight wheels coupled and a pony truck in front as shown in figure 147, page 220, and the decapod, having ten wheels coupled and a pony truck, as shown in figure 149.

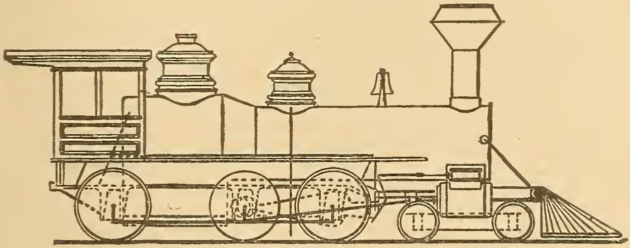


Fig. 148. Ten-wheeler for Fast Freight.

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

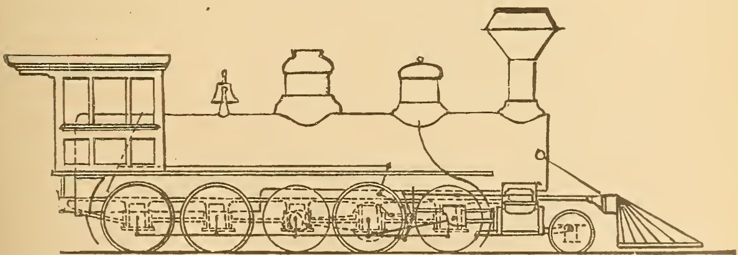


Fig. 149. "Decapod" for Heavy Freight.

drivers are; in the ten-wheeler, by reason of the back-truck wheels which are in the rear of the cylinders. the front drivers are quite close to the middle pair, and thus get proportionately less of the weight.

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

A. It enables adding to the weight of the engine, 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 pairs of drivers, short wheel-base and no truck, if for switching only, and seldom have tenders, the fuel and water

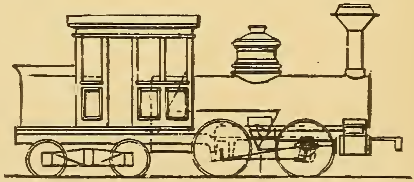


Fig. 150. Engine for Switching and Local Service, with Back Tank. (Forney Type.)

being carried on the engine; if they do, the tenders have instead of two trucks, only two pairs of wheels. Such an engine with three pairs of drivers may be seen in figure 155.

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

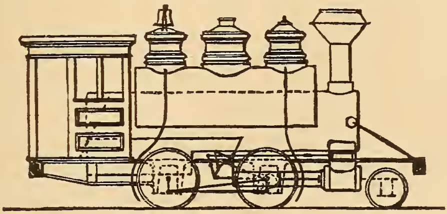


Fig. 151. Switching Engine, Saddle Tank.

truck under it; this being the Forney type. (Figure 150, page 222.) Another has two pairs of wheels coupled, and a pony truck in front, with a four-wheel tender, as in figure 153, page 224. A third class is of

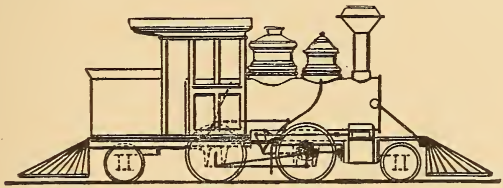


Fig. 152. Switching and Local Passenger Engine.

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 figure 145, page 219. 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. (Figure 152.) A fifth class has four wheels coupled, a pony truck in front, and a saddle tank, as shown in figure 151. A sixth type, which is for very heavy switching, has six wheels coupled, a saddle tank, and no truck.

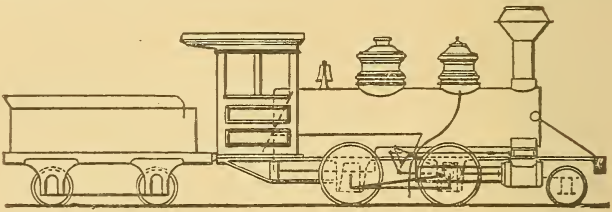


Fig. 153. Switching-engine, with Four Wheeled Tender.

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 mentioned, as used for light switching, etc.; or a

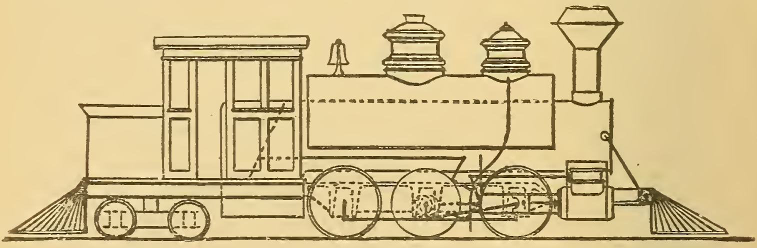


Fig. 154. Heavy Switching and Local Freight Engine, with Saddle Tank and Back Tank.

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 figure 154.)

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

A. In order to utilize for tractive purposes every pound of weight of the engine.

Q. Why are the fuel and water borne by the engine?

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

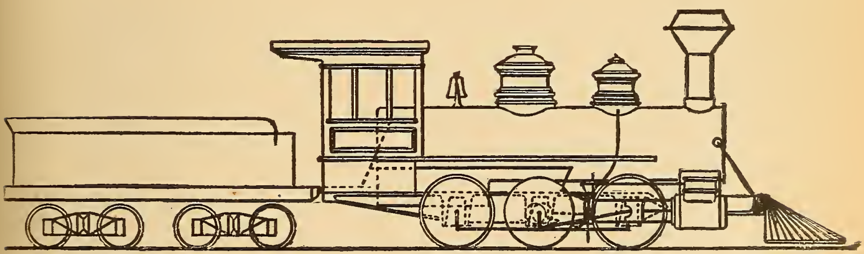


Fig. 155. Heavy Switching Engine, Six Wheels Coupled, with Tender.

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

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

Q. What is the disadvantage of having 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 are 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.

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. That 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 the reduction of the height and width without reducing power.

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 by safety chains. Most commonly the water-tank is of U-shape with the opening towards the cab, and the coal in the space between; sometimes also 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 man-hole 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 centre of the track for a mile or so, and a scoop-tube which is 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. 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; it has not room enough 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, in order to give greater facilities for oiling, or for renewal of the bearings.

Q. How are the tender-axle boxes made?

A. About like car-axle boxes, the journal being in a cast-iron box open front and rear and having a cover. (Figure 156.)

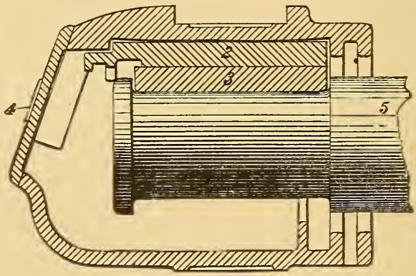


Fig. 156. Tender Journal-box.

1. Box. 2. Wedge. 3. Brass. 4. Lid. 5. Axle.

Q. What keeps the oil from leaking out of the box, past the journal, and dust from getting in?

A. A wood 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 centre-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.

Q. How may the speed of an engine or train be suddenly checked?

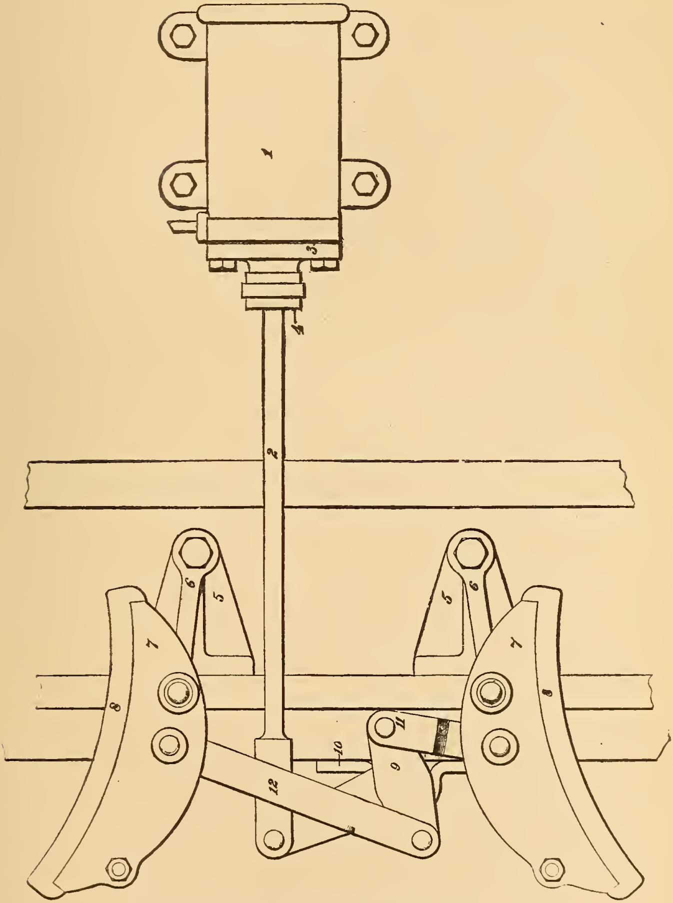


Fig. 157. Steam Brake Work.

1. Cylinder. 2. Piston-rod. 3. Cylinder-head. 4. Cylinder Stuffing-box Nut. 5. Hangers. 6. Links. 7. Heads. 8. Shoes. 9. Shaft. 10. Shaft-support. 11. Upper Arm-rod. 12. Lower Arm-rod.

A. By shutting off steam and by the application of brake-shoes to the wheel-treads.

Q. How do the brakes lessen the train speed?

A. By increasing the friction so that the momentum of the train is usually taken up in overcoming this excess of friction; just as in a similar case the speed would be checked by the application of the brakes even although the engine continued hauling.

Q. What is the effect of too sudden and hard application of the brakes?

A. The wheels are prevented from turning at all, and then skid or slide along the track, causing wear of both rails and wheel-treads, especially the latter.

Q. In case of proper application of the brakes, what should receive the wear?

A. The wheel-treads get some of it, but these last being of steel or chilled iron, the brake-shoes should 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 flatting the wheels.*

Q. What is the principal difficulty in this?

A. The uneven character of the rails, particularly at the joints.

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.

Q. What are the principal classes of power brakes?

A. Those operating by compressed air, and those operating by vacuum.

Q. Into what two classes are compressed-air brakes divided?

A. Into those using straight air, and automatic.

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 cylinder under the engine or tender, and having a valve controlling the flow of air to the train-pipe.

Q. What are the disadvantages of this class of brake?

---

* This was first suggested to the writer by the late John C. Trautwine, in his time the most eminent of American civil engineers, and has received the endorsement of many prominent in practical matters.

A. In a long train it takes too much time for the air to flow from the engine or tender 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. How does the automatic brake work?

A. There is a compressed-air reservoir on the engine or tender, and a cylinder and piston under each car in the train, operating the brake-levers as with the straight-air brake; but there is a separate or auxiliary reservoir on the engine or tender. The air-pump discharges into the main reservoir; in connection with this is the engineer's brake-valve, with which is connected the brake-pipe, which with its continuations, extends back under the train, communicating with the auxiliary reservoirs. Other pipes communicate with the auxiliary reservoirs by the "triple-valves." In charging the brakes the main reservoir is filled with compressed air; then the engineer's valve is opened to let air through the brake-pipe and triple-valves and into the auxiliary reservoirs. The triple-valves close communication between the auxiliary reservoirs and the brake-cylinders, as long as there is pressure in the brake-pipe; but when this pressure is lowered, as by the breakage of the train, or purposely done by the engineer, they open and let air from the auxiliary cylinders to the brake-cylinders, thus applying the brakes. The engineer's valve permits letting air out of the brake-pipe at will, and thus applying the brakes when desired.

Q. How can the automatic brakes be taken off after they have been applied?

A. By so turning the engineer'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 closing the triple-valves, letting the air out of the cylinders, and releasing the brakes, which are forced from the wheels by springs.

Q. When is it desirable to use the automatic brake with straight air?

A. Where the system leaks.

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 the four-way cock, which closes communication between the brake-cylinder and the auxiliary reservoir on that car; leaving the main brake-pipe unobstructed.

Q. What other use has the four-way cock?

A. To enable the automatic brakes to be used with straight air; its handle being turned into another position than that required to throw the brakes out of service, and leave a communication from the main brake-pipe to the brake-cylinder, so that the brakes may be applied by letting air into the main brake-pipe and not having any in it when the brakes are to be off.

Q. Where is the air-pump for working the air-brake placed?

A. On the right side of the fire-box, or on the right side of the boiler a little in advance of the fire-box.

Q. What are the essential parts of the Westinghouse quick-action automatic brake?

A. A pumping apparatus to furnish compressed air; a main reservoir for storage of compressed air; the engine-runner's brake and equalizing discharge valve, to regulate the flow of air from the main reservoir into the brake-pipe for releasing the brakes, and from the main train or brake-pipe to the air for applying them; the main train-pipe or brake-pipe running from the main reservoir to the engine-runner's brake and equalizing discharge-valve and along under the train, supplying air to the apparatus under each car; the auxiliary reservoir, on each car, taking a supply of air from the main reservoir, through the brake-pipe, and storing it; the brake-cylinder on each car, having a piston-rod so attached to the brake-lever that when its piston is forced out by air pressure the brakes are put on; the quick-action automatic triple valve, connected to the main train-pipe, to the auxiliary reservoir, and the brake-cylinder, and operated by the variation of pressure in the brake-pipe; the couplings with their flexible hose, between cars, connecting the sections of the train-pipe; the duplex air gage, showing the pressure in the main reservoir and that in the train-pipe; and the pump governor, regulating the supply of steam to the pump, so that when there is sufficient air pressure in the train brake-pipe and in the reservoirs, the pump shall stop working.

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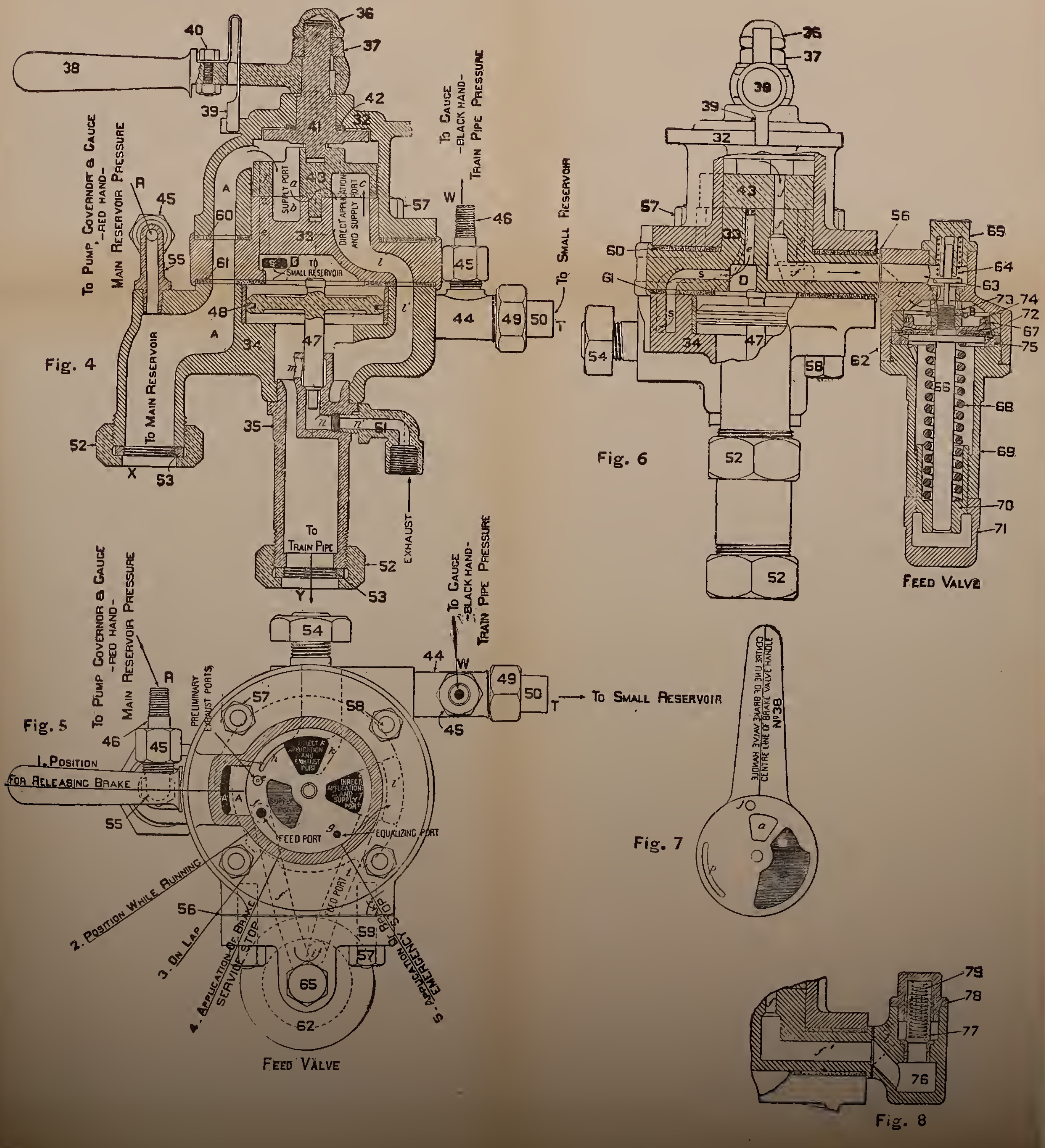
WESTINGHOUSE IMPROVED ENGINEER'S BRAKE AND EQUALIZING DISCHARGE VALVE WITH FEED VALVE ATTACHMENT. 1892 MODEL.

PLATE IV.



Q. Describe the valve-motion of the 9 1-2 inch improved air pump of the Westinghouse automatic brake?

A. The valve motion consists of two pistons (see 77 and 79, figure 1, plate III,) of unequal diameter, mounted on a rod 76 and having between them a D valve 83, to distribute steam to the upper or to the lower side of the main steam piston 65, as required. Steam enters the pump at X (where a stud and nut admit of the direct attachment of the pump-governor) and by passages *a* and a^1 and port a^2 is admitted to the slide-valve chamber between the two pistons 77 and 79. As the piston 77 is larger than 79, the action is to force the two to the right as shown in figure 1, thus letting steam under the main piston 65 through the port *b* to the passages b^1 and d^2, forcing the main piston upwards; the steam that has forced the main piston downward being exhausted to the atmosphere through the passage *c*, port c^1, and cavity B to the slide-valve 83, port *d* and passages d^1 and d^2 at the connection Y, whence it is taken by a suitable pipe to the smoke-box.

Q. What is the arrangement of the main-valve bushing of this pump?

A. This is shown in figure 3, port *t* communicating between the chamber E in the main-valve head 85 and exhaust-passage f^1, and hence being in constant communication with the atmosphere taking the pressure off that surface of the main-valve piston 79, which is exposed to the chamber E. The reversing-valve 72 works in the chamber *C* in the centre of the steam-cylinder head, taking steam from the slide-valve chamber *A* through the ports *e* and e^1; this valve being moved by a rod 71 extending into the space K of the hollow piston-rod. This valve is to admit steam to and exhaust it from the space D between the main valve piston 77 and the head 84. It is shown in figure 1 in position to exhaust the steam before used, from the space *D* through the port *h* (figures 2 and 3), port h^1, reversing valve-cavity *H* and ports *f* and f^1 to the main exhaust-ports *d*, d^1 and d^2.

Q. What is the effect when the main piston approaching the upward termination of its stroke, strikes the shoulder f of the reversing-valve rod 71, and forces this rod and its valve 72 upwards?

A. Steam is let in from chamber *C* to chamber *D* through the ports *g* and g^1 (figure 3), thus balancing the pressure on both sides of the main-valve piston 77, when the steam in chamber *A* acting on the effective area presented to it, of the main-valve piston 79, forces it to the left, and lets live steam to the upper side of the main steam-piston 65, exhausting from the piston side, and forcing it downward until at the lower end of its stroke the button head on the lower end of the reversing-valve stem 71 comes in contact with the reversing-valve plate 69, again moving the reversing-valve 72 to the position shown in figure 2, thus completing a full double stroke.

Q. What happens in the air-cylinder as the steam and air-pistons are making their strokes?

A. Air from outside is drawn into first one end and then the other of the air-cylinder 63, through the screened inlet 106 at *W*, chamber *F*, and the receiving-valves 86 to the left (figure 1), and thence discharged under pressure through the discharge-valves 86 to the right (figure 1), to the chamber *G* and the main reservoir to which the pump should be connected by a 1 1-4 inch pipe at *Z*.

Q. What about the use of oil with this pump (and with the eight-inch pump)?

A. Only a moderate quantity of oil should be used in the steam and air-cylinder.

Q. How is drainage effected?

A. By the cocks 105, in the steam-passages a and b^2.

Q. Describe the new Westinghouse engineer's brake and equalizing discharge-valve (three-way cock) with feed-valve attachments?

A. As shown in figures 4, 5 and 6, plate IV, the valve is so arranged that when the handle is in "running position" the pressure in the train-pipe is cut-off automatically at 70 pounds, no matter what higher pressure there is in the main reservoir; and any loss in the train-pipe, from leakage, is automatically supplied. The amount of excess pressure to be carried in the main reservoir to permit the re-charging and releasing promptly, is regulated by the pump-governor, which will stop the pump when the maximum pressure is reached. The pump-governor does not control the train-pipe pressure. It is not necessary to have in the main reservoir the excess of 20 pounds or more, before air can be supplied to the train-pipe to make up for leakages when the handle of the valve is in running position. All that the pump-governor does is to regulate the degree of excess pressure in the main reservoir; the amount of this excess being regulated by the governor-spring.

Q. What is the distribution of the air when the handle is in position 1, "for Releasing Brakes"?

A. Air from the main reservoir enters the brake-valve at *X*, passing through the port *A*, *A*, through the port *a* in the rotary valve 43 to the port *b* in its seat 33, thence upward into the cavity *c* of the rotary valve, and finally to the ports *l* and l^1 and the train-pipe at *Y*. The ports *j* in the rotary valve and *e* in its seat are not reduced in this position, and let air to the chamber *D* above, equalizing the piston 47 and passing thence through the ports *s* and *s*, charging the small equalizing reservoir connected at *T*.

Q. When the train pipe and the auxiliary reservoirs of the brake apparatus are charged, what is done?

A. The handle 38 of the brake-valve is moved to 2, "position while running," in which position the ports *a* and *b*, and *j* and *e* are no longer in communication, and air then reaches the train-pipe through the port *j* in the rotary valve 43, and the ports *f*, f^1 in its seat 33, passing thence through the feed-valve 63 to the port *i*, ports *l* and l^1, to the train-pipe, and continuing to flow thereto until the pressure in the chamber *B* on the diaphragm 72 exceeds the resistance of the spring 68, and, forcing the diaphragm 72 and its attachments downward, the feed-valve 63 closes until such time as by reason of any leaks in the train-pipe the pressure therein has been reduced below 70 pounds, when the valve 61 is again automatically pushed open by the diaphragm rising, replenishing the train-pipe pressure. The equalizing port *g* is now in communication with the chamber *D*, maintaining the train-pipe pressure therein, through the ports *l* and *l*, to the cavity *c* in the rotary valve 43.

Q. How is the adjustment of the spring 68 accomplished?

A. By the adjusting-nut 70, to which access is had by the removal of the cap check-nut 71.

Q. How are the brakes applied?

A. The handle 38 of the valve is moved to position 4, "Application of Break Service Stop," bringing into conjunction the port *p* (a groove in the under side of the rotary valve 43) and the ports *e* and *h* (the latter also a groove) in its seat, causing air to any desired extent to be discharged to the atmosphere from the chamber *D* above the piston 47 and the equalizing-reservoir, through the large direct-application and exhaust-port *k*, thus reducing the pressure above the piston 47 and causing that in the train-pipe below to force it upwards from its seat, letting air flow from the train-pipe through the ports *m*, *n* and n^1 to the atmosphere, through the exhaust-connection 51. When the desired reduction of pressure in the chamber *D* is made, the valve-handle is moved backward to position 3, "on lap;" air still continuing to flow from the exhaust fitting 51 until the pressure in the train-pipe has been reduced to an amount about equal to that in chamber *D*.

Q. How much reduction of pressure from chamber D should be enough to apply the brakes slightly?

A. About six to eight pounds; piston 47 rising slightly and then being forced to its seat automatically by the excess of pressure on its upper surface from the air remaining in chamber *D*.

Q. How are the brakes released?

A. By moving the valve-handle 38 to "Position for Releasing Brake," causing air from the main reservoir to flow freely again to the train-pipe, forcing the triple valve to "released" 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 reservoir to the outer air with considerable noise, thus attracting the attention of the engine-runner to his neglect to move the valve-handle to the "running" position.

Q. When must the engine-runner move the brake-valve handle from position 1 to position 2?

A. Before the accumulation of the maximum pressure of 70 pounds allowed in the train-pipe, so that the feed-valve attachment may properly do its duty of governing the train-pipe pressure; else the pressure in the train-pipe may be rendered excessive.

Q. How are the brakes put on for an emergency application?

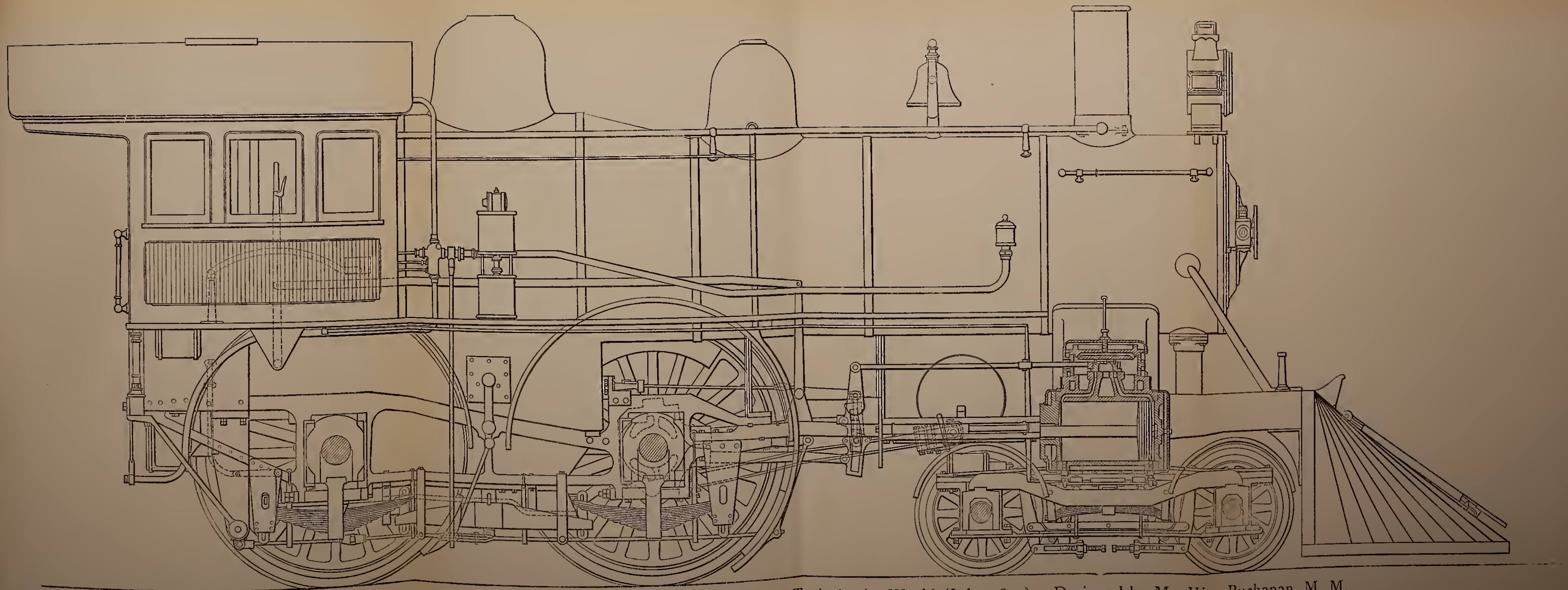


Plate V. Engine No. 999, N. Y. C. & H. R. R. R., Drawing the Fastest Train in the World (July, 1893). Designed by Mr. Wm. Buchanan, M. M.

PRINCIPAL DIMENSIONS:

Cylinders, 19 in. x 24 in. Driving Wheels, 86 in. Diameter of Boiler, 58 in. Total heating surface, 1,930.37 sq. ft. Grate surface, 30.7 sq. ft. Weight, working order, 124,000 lbs. Weight on drivers, 84,000 lbs. Boiler Pressure, 190 lbs.

A. The brake-valve handle 38 is moved to the extreme right (position 5, "Application of Brake, Emergency Stop"), when the direct-application and exhaust-port *k* and the direct-application and supply-pipe *l* may be brought together by a large cavity *c* in the under surface of the rotary valve 43, thus discharging from the train-pipe to the atmosphere a large volume of air, and putting the brakes on very quickly.

Q. How much should the train-pipe pressure be reduced for an emergency stop?

A. Twenty to twenty-five pounds only.

Q. What are the functions of the quick-action automatic triple-valve?

A. To let air from the auxiliary reservoir (and under certain conditions from the train-pipe) to the brake-cylinder, thus putting on the brakes and cutting off connection between the brake-pipe to the auxiliary reservoir, and restoring the supply from the train-pipe to the auxiliary, while permitting the escape of the air from the brake-cylinder and releasing the brakes.

Q. What are the principal parts of the triple-valve?

A. The piston and the slide-valve.

Q. What is the effect on the triple-valve of a moderate reduction of air pressure in the train-pipe?

A. To force the triple-valve piston and its slide-valve to such position as to let the air in the auxiliary reservoir pass directly into the brake-cylinders and apply the brakes.

Q. What is the effect of a sudden reduction of air pressure in the train-pipe, as by the parting of the train?

A. The same as is effected by a moderate reduction, besides opening supplemental valves in the triple valve, and letting the compressed air in the train-pipe enter the brake-cylinder, so as to increase the pressure on the brakes about 20 per cent.

Q. What is the effect of restoring to the brake-pipe an excess of pressure over that remaining in the auxiliary reservoir?

A. To force the piston and the slide-valve of the triple valve to their normal position, making connection between the train-pipe and the auxiliary reservoir, and letting the air in the brake-cylinder escape into the atmosphere, thus letting off the brakes.

Q. What is the essential feature of the automatic brake?

A. That any reduction of pressure in the train-pipes sets the brakes.

Q. What prevents the brakes being set when the cars are uncoupled?

A. There is on each end of the train-pipe an angle valve, 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 train-pipe to the quick-action triple valve.

Q. How is the engine-runner'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 train-pipe near the engine-runner's brake-valve.

Q. Can the Westinghouse "quick-action" automatic brake be used in connection with the plain automatic form?

A. Yes.

Q. Can it be used as a non-automatic or "straight air" brake?

A. No.

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 left out. All cocks in the main train-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 train-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 train-pipe should be closed at the point of separation, to prevent setting the brakes, and then the couplings should be parted by hand.

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 the auxiliary reservoir.

Q. What are the limits of travel of the brake-cylinder pistons?

A. They should not travel more than eight inches nor less than four.

Q. Of what is a greater travel than eight inches a sign?

A. Of weak brake-gear or worn shoes.

Q. How can the brakes be thrown out of use on any particular car?

A. By closing the cut-out cock.

Q. How can the plain automatic triple-valve that is used for the locomotive driver and tender-brake be rendered inoperative?

A. By turning the handle of the four-way cock downward to a point midway between a horizontal and a vertical position, or until a lug on the handle prevents further movement.

Q. How may the automatic brake be rendered inoperative?

A. By turning this handle to a horizontal position.

Q. How may triple-valves be drained?

A. By unscrewing the plug in the lower case.

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.

Q. What class of oil should be used in the air-cylinder of the pumping apparatus?

A. 32° gravity West Virginia well oil.

Q. What classes of lubricant should not be used in the air-cylinder of the pumping apparatus?

A. Tallow, lard or kerosene.

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 stoppages?

A. Yes.

Q. How much travel should the pistons of driving-wheel brakes have?

A. From three to five inches.

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. 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. How is the train-speed best controlled on *long down grades, while maintaining a good working pressure?*

A. On ordinary grades it is best done by running the pump at a good speed so that a comparatively high pressure will have been accumulated in the main reservoir 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. Should the engine be reversed when the brakes are applied?

A. No.

Q. How should the brake-pump be started?

A. Comparatively slowly.

Q. Is it right to attempt to stop a train of 50 or 60 cars with only six or eight braked?

A. No.

Q. Should the emergency brake be used except in a case of absolute emergency?

A. No; it is unpleasant to passengers and does not do the rolling stock any good.

Q. How about the number of applications of the brake in stopping at a station?

A. It should be done with one if possible; certainly with not more than two.

Q. Should the train-pipe pressure be exhausted to zero 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 train-pipe is fully exhausted.

Q. How about testing and inspecting brakes on leaving a terminal station?

A. They should be tried then, so as 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. What is the effect of not taking up the slack in the brake-gear?

A. It takes more time to stop.

Q. What should be done with the brake-hose when it is uncoupled?

A. It should be hung up in the "dummy" so as to keep cinders and things out of it.

Q. What is the vacuum brake?

A. One in which instead of operating the brake-cylinders by compressed air they are applied by removing the pressure from one side of a piston or diaphragm. In the Eames brake, such as is used on the New York elevated railways, there is a simple steam-jet ejector which exhausts the air from the train-pipe and the brake-cylinders, giving much more rapid control than is possible by the straight-air or the automatic system, as there would not be time to pump up between stations or stops, with the stations so close together and the trains running on such a short headway.

Q. How are the locomotive and tender braked?

A. There are brake-shoes which bear against their wheels and which press against them by crosswise brake-beams hung from the frame by brake-hangers, and having attached to their centres by pivoted fulcrums, brake-levers operated by compressed air cylinders, or sometimes, in the case of the tender, by hand-wheels. (See figure 157.)

Q. What is the effect of driver-brakes on the driving-boxes?

A. If improperly constructed and used, they will do them harm; but if properly designed, made and used, and the wedges are kept up, there should be no trouble.

Q. Should the driver-brake be used as an emergency brake only?

A. No; for two reasons: the first being that if no brake is applied on the engine the car-brakes will have to do extra work in stopping it; and the second, that in an emergency you will perhaps not be used to applying it, and you may forget it.

Q. How can a locomotive be turned around on the track?

A. By a turn-table, a loop, or a Y.

Q. How is a turn-table usually constructed?

A. There is a circular pit of a diameter rather greater than the combined length of the engine and tender; 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 turn-table 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 turn-table 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 centre-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. There is a pear-shaped or kite-shaped siding which is led out from the track and returned to it, so that the engine which starts on it 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 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.

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, instead of escaping directly into the stack.

Q. How many cylinders may a compound locomotive have?

A. There may be two, one high-pressure and the other low; or two high-pressure and one low into which they both exhaust, or one high-pressure and two low into which it exhausts, or two high-pressure, each exhausting into a separate low-pressure.

Q. What are the advantages of compounding?

A. To enable the steam to be expanded more times without causing such a great range of temperature in one cylinder; to distribute more evenly the pressure due to expansion instead of having the pressure on the crank-pins vary so greatly 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; perhaps 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.

Q. Which should have the greater volume, the high-pressure or the low-pressure cylinder?

A. The low.

Q. How is this greater volume usually obtained?

A. By having the stroke the same in both the high-pressure and the low-pressure cylinders and giving the latter greater diameter; or by having two low-pressure cylinders to one high.

Q. What is the usual rule for the ratio (proportion) between the high and the low-pressure cylinder volumes?

A. There is no general rule; there is a limit placed by the maximum diameter that it is possible to give the low-pressure cylinder. In two-cylinder compounds the low-pressure cylinder may have from one and three quarters to two and three quarter 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. What is the arrangement of pistons in compound locomotives?

A. In some the low-pressure pistons travel in the same direction and at the same time as the high, both being sometimes fastened to the same crosshead. In others they are connected at right angles to each other. Where they are connected at right angles they have a receiver or chamber between the two cylinders.

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 there is less coal pulled.

Q. Is there any preference as to which crank should lead, in compounds?

A. There does not seem to be any reason why there should be, but most put the low side 90° back of the high for going ahead.

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 make the high-pressure cylinder large enough to take care of the heaviest work, what then?

A. The engine will have too large cylinders for ordinary running.

Q. What will be the disadvantage of having too much cylinder?

A. When on straight levels, the mean pressure needed will be got with earlier cut-off than is considered good practice with ordinary valve-gear, and the final pressure in the large cylinder will be so low that it may be under that of the atmosphere.

Q. If we have the high-pressure cylinder about the same size as for an ordinary locomotive, and the low-pressure cylinder properly proportioned to this, what should be the increase in capacity *and economy in the compound over the non-compound engine?*

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 high-pressure cylinder larger inside clearance (negative exhaust lap) by reason of its having ordinarily so considerable a 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 low-pressure cylinder a cushion pressure higher than the receiver pressure, the same excessive inside clearance is needful for the low-pressure cylinder also.

Q. In order to keep the steam as dry as possible, what should be done with the receiver, where there is one?

A. It is well to enclose 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. How does the turning power of the ordinary non-compound engine vary?

A. From about three-fourths that of the maximum for one cylinder, to nearly 1.5 times such maximum, according to the crank-positions.

Q. Where does the lowest power come?

A. In that position at which no steam can be let into one side.

Q. How may compound locomotives be classified, as regards the number of cylinders?

A. Into two-cylinder, three-cylinder and four-cylinder.

Q. Into what principal divisions may two-cylinder compound locomotives be classified?

A. Into those which may be worked non-compound all the time if desired, and those which may not; the latter usually having an automatic device by which they are worked non-compound during at least part of a rotation.

Q. What designs are included in those which may be worked non-compound all the time if desired?

A. Those of Mallet, the originator of compounding for locomotives.

Q. What designs are included in those which are workable non-compound only in starting?

A. Those of Worsdell and of Von Borries.

Q. What is the essential characteristic of the Von Borries system?

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 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.

Q. How much of a rotation takes place before *the high-pressure exhaust opens the intercepting-valve and closes the starting-valve?*

A. From 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.

Q. What characterizes the Worsdell system?

A. The intercepting-valve is a flap which when the engine 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 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.

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.

Q. In this type of engine, supposing that the

PLATE VI.—Express Passenger Engine, American Type, No. 858, Baltimore and Ohio Railroad. Built by Baldwin Locomotive Works.

Fuel, Bituminous Coal. Actual Total Weight in Working Order, 116,360 lbs. ; on Drivers, 75,210 lbs. Total Wheel-base, 21 ft. 11 in. ; Rigid Wheel-base, 7 ft. 6 in. Cylinders, 20 x 24 in. Driving-wheel Diameter, outside of Tires, 78 in. Grate-surface, 24.75 sq. ft. Heating-surface, Fire-box, 149 sq. ft. ; Tubes, 1544 sq. ft. ; Total, 1693 sq. ft.

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 done?

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.

Q. What is the advantage of the Mallet two-cylinder compound system over the Worsdell and the Von Borries?

A. That it has a starting power or emergency power at least as great as that of a non-compound engine of the same cylinder dimensions.

Q. What is the essential peculiarity in the Mallet two-cylinder system?

A. There is a high-pressure cylinder on one side and a low on the other, with a receiver-pipe between them. The main steam-pipe runs from the boiler to the high-pressure cylinder; there is a starting-valve connected with the boiler by a pipe, and an intercepting-valve which may either throw the exhaust of the high-pressure cylinder up into the stack or pass it into the receiver, thence to reach the low-pressure cylinder. The intercepting-valve is composed of two circular valves and a piston, making a balanced double poppet. The central opening in the intercepting-valve connects with the high-pressure exhaust, the left (say) with the usual exhaust-nozzle, and the right one with the receiver-pipe. By opening the starting-valve, steam from the boiler is let into the receiver-pipe, and of course serves the large or low-pressure cylinder with steam at boiler pressure instead of with exhaust steam. This excess of pressure in the receiver puts on the large valve-piston which opens into the receiver sufficient pressure to close it, at the same time opening that valve-piston (on the same stem) between the high-pressure exhaust pipe and the exhaust pipe to the stack; so that the machine will under these circumstances work as a simple engine with two high-pressure cylinders, and will keep on doing so until the starting-valve is closed by hand. Closing the starting-valve causes the valve-piston to move over, so that one closes the communication for the high-pressure exhaust to the stack, and the other opens it for this exhaust to get to the receiver and of course to the low-pressure cylinder. At the same time, the boiler-pressure steam is shut off from the receiver.

Q. Suppose that we have a Mallet compound engine with the high-pressure cylinder the same area as one of the high-pressures in an ordinary engine, and the low-pressure twice as large; with a given boiler-power what will be the quantity of steam necessary to start the train, as compared with the simple engine?

A. The low-pressure cylinder need have only one half the pressure on it, to give the same starting-power of the entire machine.

Q. If we give the low-pressure 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 low-pressure cylinder is on the dead center, or the low-pressure valve is in such position that it cannot be moved to let steam in.

Q. What is the Hughes or Linder starting-valve?

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 effective 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 have the result of lessening the power of the high-pressure cylinder in the same proportion as that in the low-pressure was increased.

Q. With this arrangement, is it advisable to use the higher power in starting?

A. That depends on where the cranks are.

Q. If the low-pressure side is on the dead center, will it be desirable to use the extra pressure?

A. No; it will be better not to let boiler-pressure steam into the receiver just at starting, but to let it in when the engine has made not quite one-eighth turn.

Q. If the high-pressure side is on the dead center, will it be better to use the extra steam on the low-pressure side, or not?

A. Yes, because as the low-pressure pistons will be about half stroke, there will be a very high rotative effect, say about four times as great as with a simple engine starting with the same crank-positions; but this pressure should be reduced almost at once, to prevent throwing the high-pressure pistons out of effective action, and thus risking stalling the engine.

Q. With this safety-valve, how about the power of the engine?

A. It is less than that of the simple engine having two cylinders each as large as the high-pressure cylinder of the compound, and boiler pressure of 150 to the compound's 170 pounds per square inch.

Q. Suppose that there is no safety-valve?

A. Then it is necessary to have all the parts on the low-pressure side strong enough to bear full boiler-pressure; and the engine-runner must have considerable judgment in order to tell whether or not to use the extra steam on the "low" side.

Q. What is the special advantage of the two-cylinder type?

A. Simplicity.

Q. What are the objections to it?

A. The immense size necessary for the low-pressure cylinder.

Q. How can the total work 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. What is the advantage of having three cylinders, say two low-pressure and one high?

A. Expansion may be carried further than with only one low; the work may be more evenly distributed; weights may be better placed.

Q. What are the disadvantages?

A. Complication, and high first cost and subsequent maintenance.

Q. What is the difference between a three-cylinder locomotive and the triple-expansion stationary or marine engine?

A. In the locomotive there are but two sets or stages of expansion; the exhaust of the high-pressure engine splits and goes into two separate low-pressure cylinders which act alike. In the marine or stationary triple-expansion engine, which has three cylinders, there are three successive stages of expansion; the high-pressure cylinder exhausting into the intermediate, and this in turn exhausting into the low-pressure cylinder, which in turn may discharge either into the air or into a condenser.

Q. What type of compound has two low-pressure cylinders and one high?

A. That in use on the Northern Railway of France.

Q. What is its general arrangement?

A. The high-pressure cylinder is between the frames, the low-pressures are outside, the latter with their valve-chests on top, the former with its chest below. The low-pressure cylinders are horizontal, the high is inclined one in ten. The engine is a Mogul and the middle axle is the driving-axle for all three cylinders. The low-pressure cranks are at right angles, and the high-pressure crank being midway between them makes 135° with each. The high-pressure distribution is caused by a main valve with a cut-off valve sliding on its back on the Meyer or the Ryder plan; the cut-off valve having its edges oblique to the cylinder-axis, and the passages in the main valve being skewed so as to open into the cylinder as usual; but the exhaust-port in the cylinder-casting, and the cavity in the main valve have their edges skewed. The main valve can slide crosswise in its driving-yoke. A second yoke holds it crosswise, but permits lengthwise traverse. This yoke is operated by a stem controlled from the cab, to vary the cut-off. In its extreme positions the valve will let steam blow through without doing work. This permits starting the engine with boiler steam in the two low-pressure cylinders with their cranks at right angles; the high-pressure cylinder being left out.

Q. Is the "one high-pressure and two low" type common in marine work?

A. Yes.

Q. With such a system is it possible to get the work divided equally among the three cylinders?

A. Yes.

Q. Is there any necessity for coupling-rods in this arrangement of three-cylinder compounds?

A. Yes.

Q. What system has two high-pressure cylinders and one low?

A. The Webb, in use on the London and North-Western Railway. (See figure 52, page 91.)

Q. How are the cylinders, etc., arranged in the Webb type?

A. The high-pressure cylinders are outside the frames and have their centers about four feet back of the front tube-sheet. Their pistons are connected to the second pair of drivers. The low-pressure cylinder is between the frames, and its piston is connected to the forward drivers by a cranked axle. The exhaust from the outside cylinders passes around the smoke-box to the low-pressure steam-chest, which is on top. There are no coupling-rods, where there are but two pairs of drivers.

Q. Where there are three driving-axles, what is the connection?

A. The first driving-axle is driven by the low-pressure cylinder, the others are coupled and driven by the high-pressure cylinders; but there is no connection by coupling-rods between the high-pressure cylinders and the low.

Q. Has the type with two high-pressure cylinders and one low been used in marine practice?

A. No.

Q. What is its principal advantage?

A. That there are no parallel rods.

Q. Would they be of any use in this type with only four drivers?

A. No; they would only complicate matters.

Q. What are the objections to this type?

A. That one of the principal reasons why three cylinders are used instead of two is usually to do away with large low-pressure cylinders; and where there are two high to one low, this calls for an excessively large low-pressure cylinder; other disadvantages are the crank-axle for the middle cylinder; increase in number of parts, in first cost, and in keep.

Q. In the Webb compound is there any way of letting steam from the boiler to the low-pressure cylinder?

A. No.

Q. What effect does this have on the starting power?

A. It is limited to that of the ordinary type having merely two cylinders the same size as the Webb high-pressure cylinders.

Q. How great is the starting power of the Webb engine?

A. It may run from about one-fifth to one-third that due to the weight on the high-pressure driving-wheels; although the probability is that it will be from one-fourth to one-third; and if this be enough to slip the drivers, steam will be automatically let into the receiver and thus into the low-pressure cylinder, until the receiver pressure rises so high that the high-pressure pistons cannot slip their drivers; then the engine will be in shape to start as a compound.

Q. What are the two principal classes of four-cylinder compounds?

A. One in which there is used a very large receiver, and in which the crank-angles do not play much part, and another (the "continuous-expansion" type) in which the high and the low-pressure pistons are rigidly connected, so that there is but small dead space between the cylinders.

Q. What are the engines of the first class?

A. Those having two inside-connected high-pressure and two outside-connected low-pressure cylinders and the Mallet "double-bogy" type.

Q. What engines comprise the second class?

A. Those of the Baldwin (Vauclain) type, having the high and the low-pressure cylinders on the same side, with their pistons connected to the same crosshead.

Q. In the four-cylinder receiver type, how many receivers are there?

A. Only one.

Q. What is the arrangement adopted on the Paris, Lyons and Mediterranean Railway for passenger service?

A. There are four pairs of drivers coupled. All four cylinders are beneath the smoke-box and have horizontal axes. The two high-pressure cylinders are between the frames and drive the forward axle. The two low-pressure cylinders are outside, with their centers lower than those of the high-pressure cylinders; and are connected to the rear axle. The high-pressure crank on each side leads the low on that side 198°, to give the greatest possible minimum starting-power.* The Walschaert valve-gear is used, outside only; the cut-off points are adjusted by a complicated cam arrangement. The starting-gear consists of an auxiliary steam-pipe and cock to let boiler-steam into the receiver-pipe, which has a safety-valve.

Q. What is a tandem compound locomotive?

A. One in which the high-pressure cylinder is in direct axial line with the low, and there is no receiver; the high and low-pressure 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; and no complications in the matter of starting.

Q. What parts are saved?

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 high-pressure cylinder up to a certain point, then there will be expansion in that up to the point of exhaust-opening or

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* The last Paris, Lyons and Mediterranean engines have cranks 135° apart.

release, when there will be a drop in pressure as the high-pressure exhaust mixes with that in the passages between it and the low-pressure cylinder; then there will be further expansion in the high-pressure cylinder in the passages between the two cylinders; then (the low-pressure valve opening) there will be another drop in pressure, up to that point at which the cylinders are in communication; then there will be expansion until the low-pressure admission-valve closes; from this on there will be compression in the connecting passages and in the high-pressure cylinder; and when the high-pressure exhaust closes there will be more compression in the low-pressure cylinder.

Q. What is one of the principal troubles in the steam-distribution in this type?

A. The compression in the high-pressure cylinder, requiring for its reduction large volume of clearance-space therein (which will make a drop in pressure at one point in the stroke) or giving the high-pressure 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. Does not the requirement of late cut-offs in the high-pressure cylinder with this type of engine cut into the steam economy?

A. No, because high expansion may be got by having a comparatively large low-pressure cylinder.

Q. How about the starting-power of tandem compound locomotives?

A. As ordinarily built, by letting live steam into the low-pressure cylinders, this steam acts as forward or driving pressure on the low-pressure pistons and as back pressure on the high; so that there would be no use in keeping the starting-valve open after the high-pressure cylinder had exhausted once.

Q. Where have tandem compounds been used?

A. On the Northern Railway of France, by Du Bousquet, and on the Boston and Albany Railway.

Q. What was the peculiarity of the French tandem locomotives?

A. The high-pressure cylinder was directly on the end of the low, its front* head practically forming the back head of the latter; the latter had two piston-rods which passed by the walls of the high-pressure cylinder; one balanced Allen slide-valve which was inclined served both cylinders, its seat having five ports.

Q. What difference is there between this and the type adopted for freight service?

A. In the latter the second driving-axle is connected to the low-pressure cylinders and the third

* The words "front" and "back" are here used in the special sense corresponding to locomotive practice, and are employed in just the reverse sense in stationary engine work. The words "crank" and "out" ends and heads are best, for all kinds of engines.

to the high; and the high-pressure crank on each side leads its low by 232°48′.

Q. What is the advantage of the four-cylinder receiver type?

A. Uniform turning movement, excellent balance.

Q. What are the disadvantages?

A. Increased first cost and expenses of keeping up.

Q. What is the peculiarity of the Mallet "articulated" four-cylinder type?

A. The high-pressure cylinders are fastened to the rear part of the main frames, and drive one set of wheels, the low are on a front bogy 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.

Q. Describe the arrangement of cylinders and valves of the compound engine of the Rhode Island Locomotive Works?

A. As shown in figure 158, which gives a front section of the intercepting-valve at the ports *d* and *e*, and also a front view of a portion of the receiver with the exhaust-valve; in figure 159, which shows a side section of the same while running compound, and figure 160, which shows the same while running simple. The intercepting-valve being in any position as in figure 159, and the exhaust-valve closed as in the same figure, the throttle being opened, boiler steam will pass to the high-pressure cylinder in the usual manner, and also through the

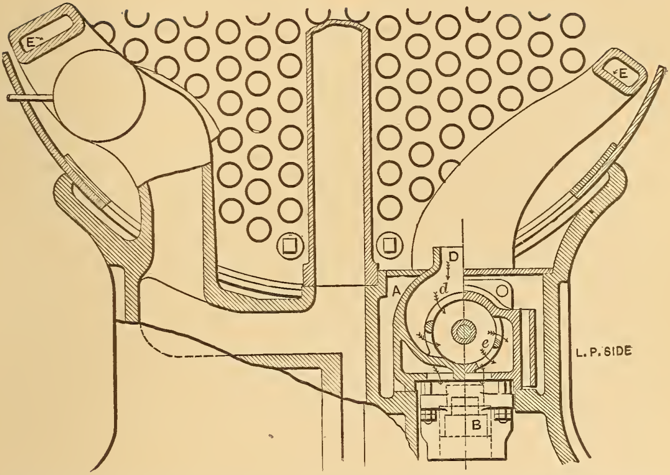


Fig. 158. Front Section of Rhode Island Locomotive Works' Intercepting Valve at Ports *d* and *e*; also Front View of Portion of Receiver with Exhaust Valve.

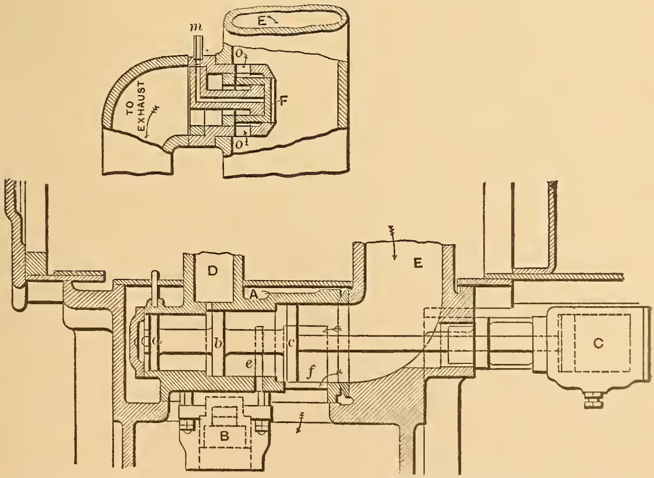


Fig. 159. Side Section of Rhode Island Locomotive Works' Intercepting Valve, Running Compound.

pipe *D* into the intercepting-valve *A*, causing the piston to move into the position shown in figure 160. In this position the receiver is closed to the low-pressure cylinder by the piston *C*, and steam from *D* passes through the ports *d* and *e*, and the reducing-valve *B*, into the low-pressure steam-chest; the pressure being reduced from boiler-pressure in

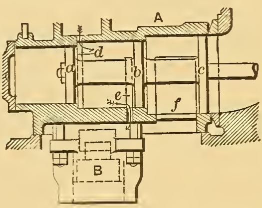


Fig. 160. Side Section Rhode Island Locomotive Works' Intercepting Valve, Running Non-Compound.

the ratio of the cylinder-areas. The piston *a-b-c* is so proportioned that it will automatically change to the compound position shown in figure 159, when a predetermined pressure in the receiver *E* has been reached by the exhausts from the high-pressure cylinder. The engine thus starts with steam in both cylinders and automatically changes to compound at a desired receiver-pressure.

Q. How may the engine be changed from compound to non-compound?

A. This may be done at any time at the desire of the engine-runner, by opening the valve *F* connecting the receiver to the exhaust-pipe, allowing the exhausts from the high-pressure cylinder to escape through the nozzle in the usual manner.

Q. How is the exhaust-valve F operated?

A. The small pipe *m* is from a hand-valve in the cab, connecting it to either steam or atmosphere. When desiring to run compound, *m* is put in connection with atmosphere; the receiver steam keeping the valve *F* in position as shown in figure 159. To run simple, *m* is connected to steam which will hold the valve *F* as in figure 160, the ports *o* opening *E* to the exhaust. The valve *F* takes either position at any time when desired by the engine-runner.

Q. How can the engine be used non-compound at starting, in case of bad conditions?

A. By opening the exhaust-valve before starting; on its closure the piston *a-b-c* will automatically take the "compound" position of figure 159, as already described.

Q. Describe the Schenectady compound locomotive?

A. Figure 161, page 274, shows a front elevation, partly in vertical cross section, showing the cylinders, their saddles, the smoke-box, the reservoir, intercepting-valve and steam-passages; figure 162 is a horizontal cross section through the intercepting-valve and other valves relating thereto on the line 2, 2 of figures 161 and 164, showing the relation of parts when the intercepting-valve is open. Figure 163 shows a similar view of some of the same parts in the position which they take when the intercepting-valve is closed. Figure 164 shows a vertical lengthwise section through the intercepting-valve on the line 4, 4 of figure 162, with the valve open; this figure being also a section on the line 3, 3 of figure 161. Figure 165 is a vertical cross section through the regulating and intercepting valve-working division

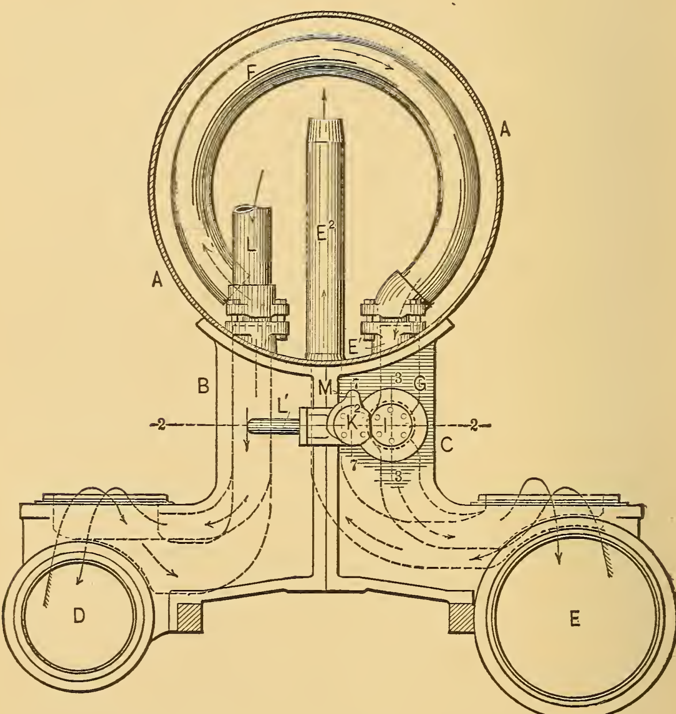


Fig. 161. Front Elevation (partly in Vertical Cross Section) Schenectady Compound.

on the line 5, 5 of figures 162 and 164. Figure 166 is a similar section on the line 6, 6 of the same figures. Figure 167 is a vertical lengthwise section through

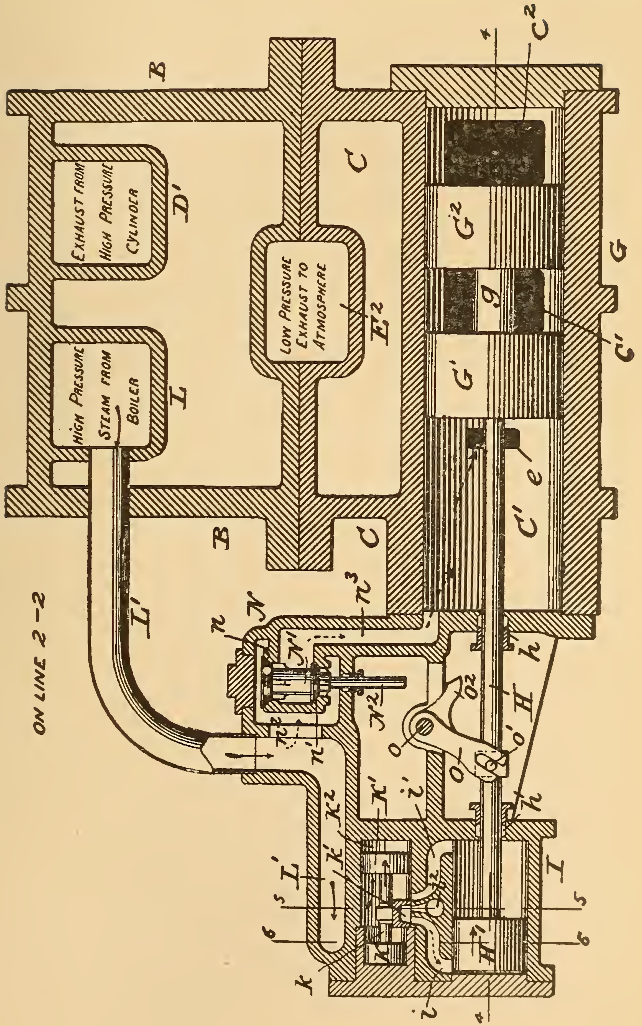


Fig. 162. Horizontal Cross Section of Intercepting Valve and other Valves on the line 2-2 of Figures 161 and 164.

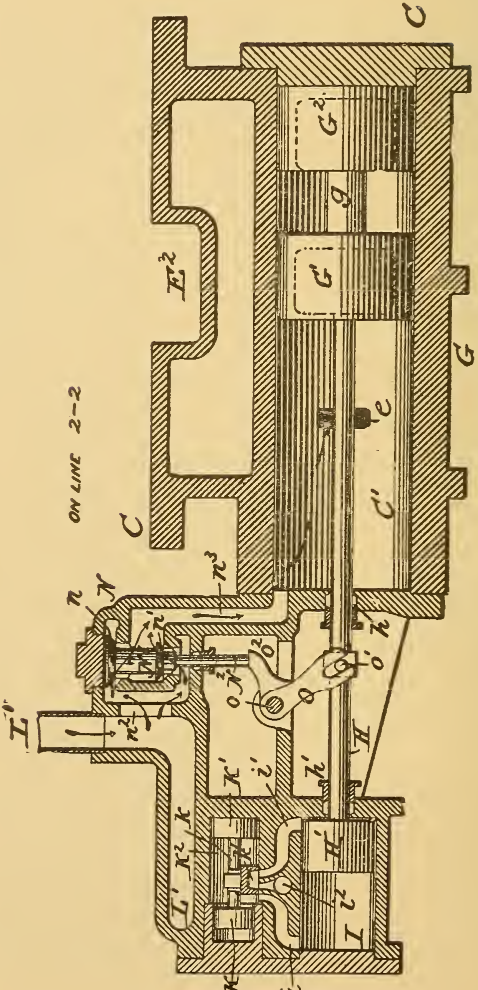


Fig. 163. Schenectady Compound, Working both Cylinders with Live Steam (see page 281).

PLATE VII.—Compound Express Passenger Engine, No. 694, Philadelphia & Reading Railroad. Built by Baldwin Locomotive Works.

Fuel, Anthracite Coal. Actual Total Weight in Working Order (including two men), 129,700 lbs.; on Drivers, 82,700 lbs. Total Wheel-base, 23 ft. 4 in.; Rigid Wheel-base, 6 ft. 10 in. Cylinders, 13 & 22 x 24 in. Driving-wheel Diameter, outside of Tires, 78 in. Wootten Fire-box. Grate-surface, 76 sq. ft. Heating-surface, Fire-box, and Combustion-chamber, 173 sq. ft.; Tubes, 1262 sq. ft.; Total, 1435 sq. ft.

the regulating division on the line 7, 7 of figures 161, 165 and 166; figure 168, a vertical cross section

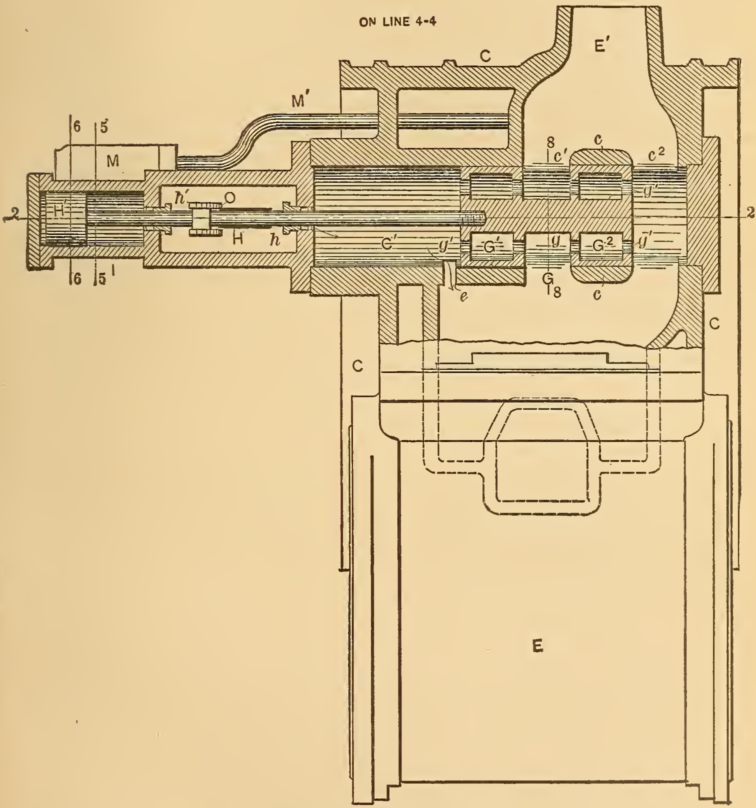


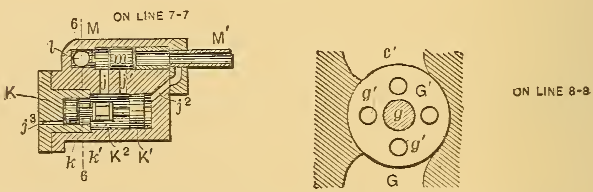
Fig. 164. Section of Schenectady Compound.

through the intercepting-valve on the line 8, 8, of figure 164. The feathered arrows show the course of the steam ; the short unfeathered darts in figure 162 show the movements of the regulating-valve and the actuating-piston of the intercepting-valve. Figure 161 shows a smoke-box *A* on saddles *B*, *C* connected respectively with a high-pressure cylinder *D* and a low-pressure cylinder *E*, on opposite sides of the engines and having suitable pistons and induction and eduction-ports (not shown). The exhaust-port of the high-pressure cylinder is connected by a pipe *D* (shown in dotted lines in figure 161, and in full lines in figure 164), with a reservoir *F*, the other end of which connects with the inlet-pipe *E* of the low-pressure cylinder, in which the intercepting-valve *G* is placed, and across which it reciprocates to open or close this passage. The intercepting-valve and the apparatus which belong to it are

Figs. 165 and 166. Sections of Schenectady Compounds.

shown as mounted on the saddle *C* of the low-pressure cylinder, while the live-steam connections and high-pressure exhaust divisions are on the other saddle *B*. The low-pressure exhaust-pipe E^2 lies centrally between them. The intercepting-valve *G* consists of two pistons G^1 G^2, mounted at suitable distances apart, and in fixed relation to each other, on a stem *g* and having lengthwise perforation g^1 for the passage of the live-steam through these valves or pistons. These valves traverse endwise a cylindrical chest C^1, which has ports c^1 c^2 opening into the low-pressure inlet-pipe E^1, and with bearings c therein, in which the piston-head G^2 traverses; these bearings forming, in fact, part of the valve-cylinder. A port or opening e in this valve-cylinder lets live steam into the low-pressure cylinder direct, beneath the intercepting-valve, while the pressure of the steam in the reservoir from the high-pressure cylinder acts in the opposite direction and on the upper side of the intercepting-valve when closed; so that the live steam, which gives the greater pressure, tends to compensate any looseness in the fitting of the valve by tending to press it upward against its seat when closed and thus to prevent leakage of live steam into the reservoir.

The piston-rod H, connected with the intercepting-valve, passes through suitable stuffing-boxes h h^1 in the heads of the valve-chest and of a separate cylinder I, provided with a piston H^1, which operates the intercepting-valve. This actuating-cylinder I has inlet-ports i i^1 and an exhaust-port i^2. The entrance of steam into this cylinder is controlled by the slide-valve K^1 on a stem K, carrying pistons K K sliding in a chamber K^2. Steam is let into this cylinder through ports j j^1 and j^2, the first two admitting steam between the two pistons, while the other admits it to act on the outer end of the larger piston K^1, which latter is made larger than the other in order to insure its movement in the proper direction at the proper time. Live steam from the boiler passes through a pipe L directly to the high-pressure cylinder. A branch pipe L^1 from this pipe connects with a port 1 of an auxiliary regulating-chamber M, provided with a piston-valve m called a "regulating-valve" and traversing the inlets $j\, j^1$ of the regulating-chamber K^2 to open or close them at the proper times. The pipe M^1 connects the reservoir F and its induction-pipe E^1 with this auxiliary pipe M and with the port j^2 figure 167, of the chamber K^2, which has at its piston end an outlet j^3 for the escape of steam or water which may leak into that end of the chamber.



Figs. 167 and 168. Sections of Schenectady Compounds.

The outlet i^2 of this chamber is contracted, as shown in figure 165, or provided with means for regulating the escape of the steam therefrom, so as to prevent the slamming of the piston H^1 and of the intercepting-valve actuated thereby. A valve chamber M contains a poppet-valve M^1, having two seats $n\; n^1$ and a stem N^2, projecting outside the valve-chamber. A port n^2 admits steam to this valve-chamber from the live-steam branch-pipe L^1, and a passage n^3 permits its escape into the intercepting-valve cylinder C^1 and thence through the port e, to the low-pressure cylinder E below the intercepting-valve.

An elbow-lever O, rocking on a fulcrum o, has its longer arm so formed as to embrace pins o^1 on the piston-rod *H* of the intercepting-valve. The other arm o^2 of this lever forms a tappet or wiper which acts at the proper time on the stem of the poppet-valve N^1 to open it. This valve has its outer member of larger area than its inner, the excess of pressure on its outer end tending to keep it closed when released from the wiper o^2. The relation of the wiper and valve-stem may be controlled either by adjusting the collar on its piston-rod or adjusting the wiper.

Q. What is the normal relation of the parts when working as a compound engine?

A. As shown in figures 162 and 164, in which the intercepting-valve is opened and the admission of steam to the low-pressure cylinder, except through the high-pressure cylinder reservoir and induction port E^1, is cut-off.

Q. How is it arranged to work both cylinders with live steam?

A. The throttle-valve is opened, permitting live steam to pass through the branch-pipe L^1 and port *l*, and the auxiliary or regulating-chamber *M*, the valve *m* of which it forces to the right (see figure 167), so as to open the port *j* and let steam pass into the valve-chamber K^2, between its pistons *K K*. The right-hand one K^1 of these pistons being larger than the other, the steam pressure forces them to the right from the position shown in figure 162, to that shown in figure 163. This causes the slide-valve K^1 to uncover the ports *i* of the cylinder *I*, which in turn forces the piston H^1 to the right, closing the ports c^1 c^2 of the intercepting-valve, as shown in figure 162. The relation of the ports is such that as the intercepting-valve closes, the wiper o^2 strikes the stem N^2 of the poppet-valve N^1 and opens it, thus letting live steam pass from the pipe L^1 through the passages n^2 n^3 into the intercepting-valve cylinder and through the port e therein to the low-pressure cylinder E below the intercepting-valve, thus operating it with the full pressure of the live steam. The intercepting-valve, as before remarked, is already closed, and the tendency of the live steam is to press it upward in its seat, so as to prevent any leakage into the receiver and consequent back pressure upon the high-pressure cylinder. The perforations g^1 in the intercepting-valve prevent the steam from exerting any endwise pressure upon it in either direction, and it is consequently entirely dependent upon the action of the live steam upon its piston H^1 in the actuating-cylinder I. The intercepting-valve should have sufficient lap to move slightly beyond its closing point, in order that the opening of the supply-valve N^1 may not take place until the intercepting-valve is fully closed, the tappet o^2 being correspondingly adjusted.

Q. When it is desired to change from direct to compound action, what is done?

A. The live steam is cut-off from the low-pressure cylinder. The pressure in the receiver and the induction-pipe E^1 then soon becomes sufficient to force steam through the return pipe M^1 into the auxiliary chamber M and force the regulating piston-valve m into its seat, thus closing the ports l and j

and simultaneously opening the port j^1. The steam then passes through this last-named port and the port j^2 to opposite sides of the larger piston K^1 the result of which is to force the slide-valve k^1 to the left in the position shown in figure 162, which opens the exhaust i^2 and the inlet i^1 of the cylinder I and forces the piston H^1 to the left, thereby opening the intercepting-valve. This movement of the piston H^1 detaches the wiper o^2 from the poppet-valve N^1 and allows it to close quickly before the intercepting-valve opens. The parts having thus resumed the position shown in figure 162, the engine resumes its compound working.

Q. Under what conditions will the intercepting-valve automatically be opened?

A. (1) Whenever the pressure in the receiver is sufficient to overcome that of the live steam in the auxiliary regulating-valve. (2) Even when the steam is cut-off, as in the case of a locomotive on a down grade, should there be sufficient exhaust from the high-pressure cylinder to cause the requisite pressure in the receiver.

Q. State briefly the general plan of working of the Schenectady compound engine, without going into details?

A. The opening of the throttle admits live steam simultaneously to both the high and the low-pressure cylinders, and by means of this same live steam acting through a mechanism separate and distinct from the intercepting-valve itself, the latter is automatically closed and the engine starts with its full power as a simple or non-compound engine. The steam-pressure thus caused in the receiver acts through the auxiliary regulating-valve *m* upon the slide-valve k^1 and opens the intercepting-valve, mechanism connected with which releases the valve controlling the admission of live steam to the low-

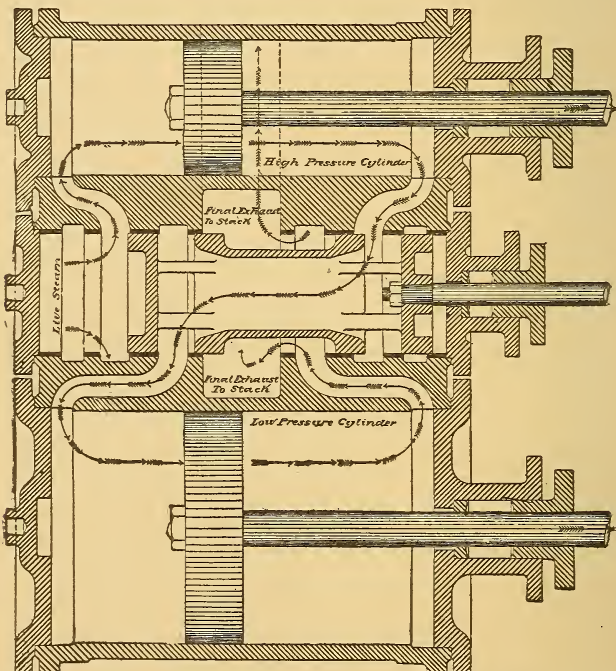


Fig. 169. Diagram of Vauclain Compound Cylinders and Piston Slide Valve.

pressure cylinder, which valve automatically closes itself, thus causing the parts to resume their compound working.

Q. Describe the Vauclain (Baldwin) compound type?

A. This type has four outside cylinders, the high-

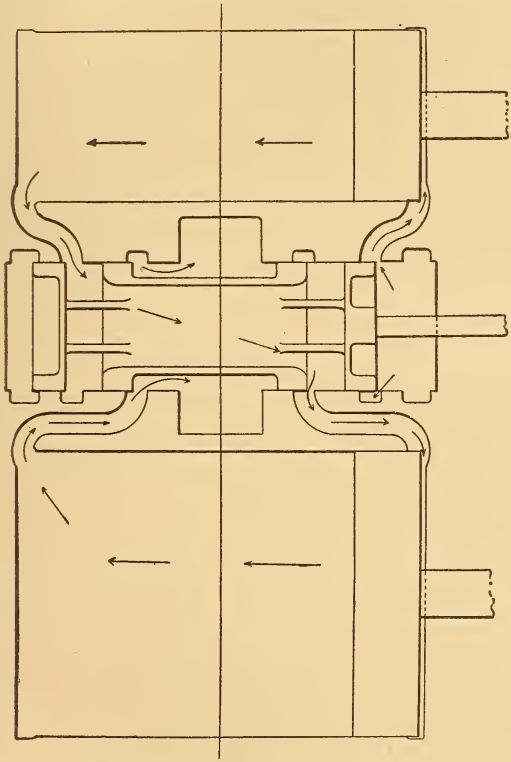


Fig. 170. Vauclain Compound.

pressure usually being above the low on each side, (see figure 169,) 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

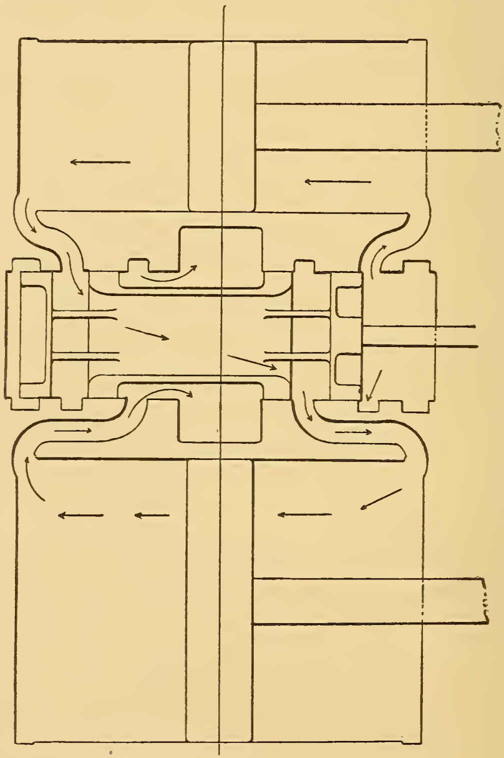


Fig. 171. Vauclain Compound.

rims of the plugs, leading to and from the ends of the cylinders from the steam pipe and the exhaust pipe. (See figure 169, page 284.) They are fitted with simple ring packings inserted by springing them into grooves in the plug. The steam enters the high-pressure cylinder and drives the piston

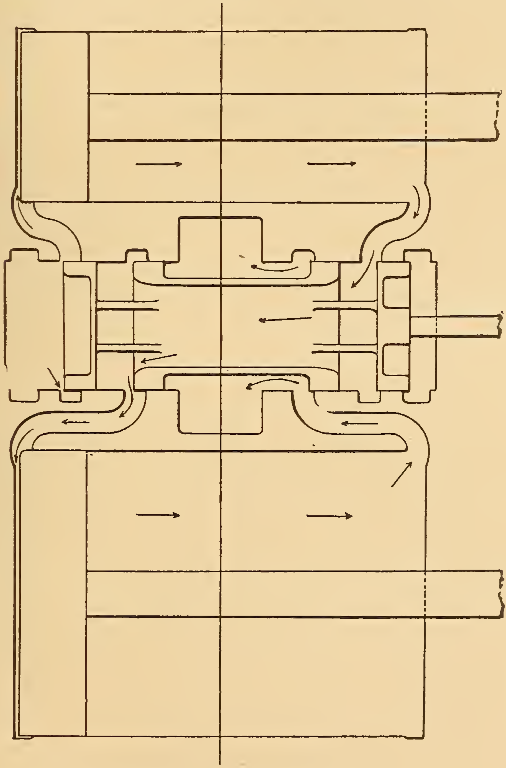


Fig. 172. Vauclain Compound.

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 figures 169 to 172, inclusive.) The same operation takes place in both ends of the cylinder. It takes steam at once from the high-pressure to the low-pressure cylinder, the two pistons being connected and moving together, no receiving-chamber being needed.

Q. What is the piston arrangement in the Vauclain compound?

A. Both pistons 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 figures 170, 171 and 172. In figure 170, both pistons are at the crosshead end or back end of the cylinder; in figure 171, both are at midstroke; in figure 172, 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.

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 the first cost and the repair-bill down, 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. Can a compound engine pull a heavier train than can be hauled at a given speed by a single expansion engine of the same weight and class?

A. No; the hauling power of every engine is limited by its adhesion; but at very slow speed on heavy grades, the compounds will often be found to be able to keep a train moving where a single expansion engine would slip and stall; because the compound, having more uniform and regular pressure on the crank-pins, takes a more regular bite on the rails.

Q. What is an objection to compound locomotives having the high-pressure cylinder on one side and the low on the other?

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.

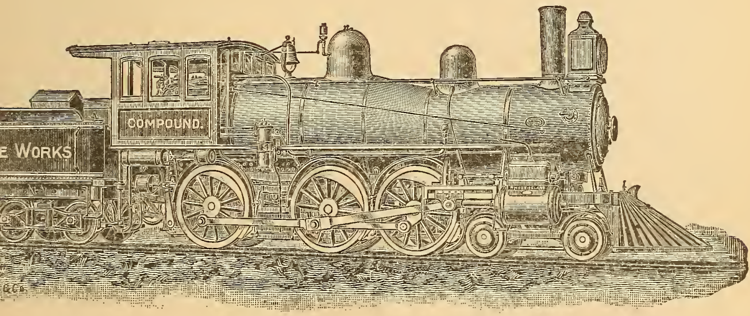


Fig. 173. Ten-Wheeler Compound, R. I. Locomotive Works.

Q. What diameter of low-pressure cylinder is it practicable to get with an outside cylinder compound engine?

A. Thirty-one inches, giving with a high-pressure diameter of twenty, a piston-area ratio of nearly 2 1-2 to 1.

Q. What should be the duty of an engineer before starting out of the yard or round-house?

A. To look at the crown-sheet and flues and be sure that the water-level is all right; to see that the fire is good; to examine all parts of the engine and tender to see that there is nothing amiss or broken; to test the rod keys by trying to drive them back with a copper hammer; to see that bolts and nuts are home; 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 unfrozen 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. Why is it that an engine is harder to start up after being still for awhile 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 traction 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. In starting a train should the reverse-lever be in full gear or not?

A. Yes, 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.

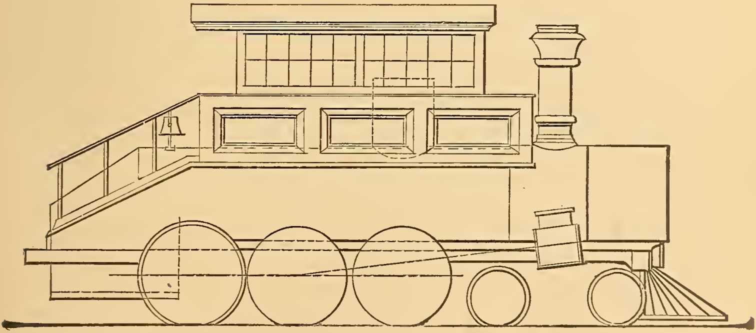


Fig. 174. Camel-back Locomotive.

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 centre.

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 had been started the engine should be opened out; then when all were going well the reverse-lever should be hooked back to near the centre in order to save steam.

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 as this be avoided?

A. By having a relief-valve in the dry-pipe to give the compressed air passage.

Q. How may the cylinder-cocks act in the case of a suddenly-reversed engine?

A. If they are opened when the motion is reversed, they will let the compressed air out at the end in which it is compressed, and at the same time that will 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 end the amount of cinders that are drawn in by suction.

Q. How does opening the cylinder-cocks in case of sudden reversal improve the lubrication?

A. By preventing the hot air from the smoke-box lapping the oil from the valve-seat.

Q. What is the advantage of having two engineers to run an engine 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 engineers to be sifted out.

Q. What should be done in case of the 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 hard-wood plug driven into the opening and braced, if the run is a short one.

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 centre of its travel by the reverse-lever; and if necessary to take water the engine must be kept still by chocking the wheels.

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. 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 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 in order that it might be towed to the shop in case of 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 to 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. Or, there should be scribe-marks or prick-punch marks which would show the mid-position of the valve.

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, then 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. What accident is much like an unshipped throttle?

A. The blowing out or unseating of the relief-valve, between the throttle and the boiler, which is 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 that it is found that the nuts on top of the throttle-valve stem have worked off, leaving the valve closed, what is then to be done?

A. The valve should be opened, in order to let steam to the chests, and after the dome-cover is replaced and steam is 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 nuts can be found.

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 in profusion; the engine can be controlled by the reverse-bar.

Q. What should be done in case of the throttle *getting disconnected inside the boiler, while open and the engine running?*

A. The fire-door should be opened and the engine cooled down to let the steam-pressure down to a point at which the engine could be controlled by working it by the reverse-lever. The train-men should be notified and the train worked to a siding by the reverse-lever.

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 telegraphic 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 should be done in case of a burst flue?

A. If it does not put out the fire, the engineer should dump it; he should lower the steam-pressure in order to save the water in the boiler; then he should plug the flue.

PLATE IX.—Compound Express Passenger Engine, "Special High Speed" Type, No. 13,350. Built by Baldwin Locomotive Works.

Fuel, Bituminous Coal. Actual Total Weight in Working Order, 126,640 lbs. ; on Drivers, 83,140 lbs. Total Wheel-base, 24 ft. 7 in. ; Rigid Wheel-base, 7 ft. 4 in Cylinders, 13 & 22 x 26 in. Driving-wheel Diameter, outside of Tires, 84¼ in. Grate-surface, 24.77 sq. ft. Heating-surface, Fire-box, 128.23 sq. ft. ; Tubes, 1349.90 sq. ft. ; Total, 1478.13 sq. ft.

Q. With what should it be closed?

A. It should be closed with an iron plug held in a special pair of tongs while being driven in; or if there is no iron one carried, it should be closed 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 should be done in case of a broken off blow-off cock, or of one that was stuck open?

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 the whistle blows out what should be done?

A. A wooden plug should be fitted in the hole and fastened by a lever held down by ropes or chains.

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 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 out or the apron should be 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 engine burns the fire 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 that is 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 out; and 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. What should be done in case of a broken smoke-box front?

A. It should be boarded up as nearly air-tight as possible, the boards being held by the front-end bolts.

Q. What should be done in case the pumps will not work?

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; then the heater-valve may be 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 then 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 does flow freely from the joints, the lower valves should be taken out and examined. If they are all right and the pump does not work, then the pump had better be taken down at the shop and overhauled.

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. 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.

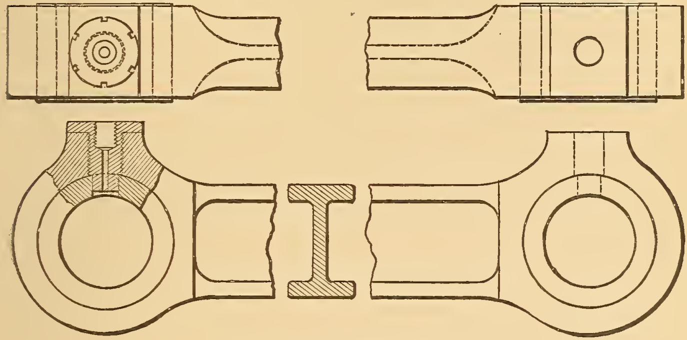


Fig. 175. Rod Ends.

Q. Suppose that the engine is crippled on one side, can the pump be worked on that side?

A. Yes, if the main rod, guides and crossheads are all right the pump, if worked from the crosshead, may be used by taking out the piston and leaving the main rod on.

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 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 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 earth or with coal-dirt.

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 can the train be held still in order to take water with the pump?

A. By chocking the wheels.

Q. Why should all pumps and injectors and their pipes be drained of water 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; and if there are none the joints should be slacked, to permit leakage out.

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. What may be said about the height at which it is desirable to carry water in the boiler when running?

A. It should be uniform as far as is possible.

Q. Why?

A. Because carrying first high and then low water, unless for a special reason, is wasteful of fuel and hard on flues.

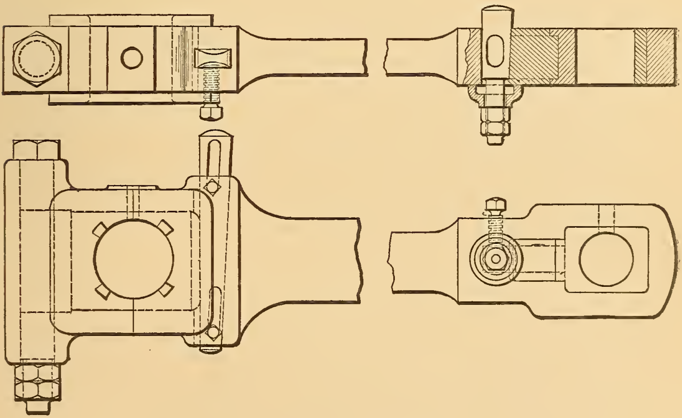


Fig. 176. Rod Ends.

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 levelled and covered to keep the steam-pressure down.

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 it was 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 right, 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 it should be opened. If there is insufficient supply of water 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 height of water being tried then with the throttle closed.

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 unslacked lime put in the tank will help matters; or a piece of blue-stone (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. In order 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 which 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.

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 the conditions of working.

Q. Suppose that would not raise it to a safe height, 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. 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 an 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 ash-pan being jammed), how may it be damped?

A. By covering it with earth or sods; or by drowning it out by snow or water.

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 piece 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 in order 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 on the disabled side should be disconnected.

Q. What should be done in case a bridge breaks out of a valve-seat?

A. The engine should be stripped on the disabled side and 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 causes a cut valve?

A. Tight fitting of a yoke, or its lack of alignment with the valve-stem.

Q. What will usually bring a cocked valve in place again?

A. Giving the reverse-lever quick jerks to move the valve shakingly; or taking out the steam-chest tallow-cup and with a metal rod driving down the valve.

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. Then the chest-cover should be taken up.

Q. In case of damage to steam-chest or valve 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. 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 should be done in case of a broken slide-valve?

A. It should be removed, and 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.

Q. What should be done in case of a valve-rod 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 and 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 rod 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 the side the rod 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. What must be done with the valve-stem in case it is broken off inside the chest?

A. It must be taken out and a plug put in the stuffing-box, else the stem would be blown out by the steam-pressure.

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 on that side and the crosshead blocked on that side. Instructions should then be asked for as to whether the train should be brought in as a whole, or only part of it brought in and the rest left.

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.

Q. What should be done in case of breaking or of blowing out a cylinder-head?

A. 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 means of 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. 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 ends of the cylinders. 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 stud that was left.

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. What is liable to spring and break piston-rods?

A. Loose guides; also pistons which are lined badly.

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 cross-head is injured the main rod should be taken down.

Q. What is liable to result from a loose piston-rod key?

A. Knocking out of a cylinder-head, or cracking of a piston-rod.

Q. What precaution should be taken in taking down a cylinder-head, as regards the nuts?

A. To lay them down in such a way that each will go back in the place from which it was taken.

Q. What precaution should be taken with the follower-bolts in dismounting the piston?

A. To lay them in such position that each one shall go back in the exact place from which it came.

Q. How can a piston be got in the centre 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 pressure of the springs?

A. To see by tapping the springs with a hammer that each one 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 to them?

A. Their joints should be cleaned.

Q. What is the danger in 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 it was too long and was held clamped by the follower.

Q. How can a follower-bound packing be remedied?

A. By putting between the follower and the spider a piece of stout paper.

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 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. 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 knocking out 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 is a common cause of broken cross-heads?

A. Pounding main-rod connections; or 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 is 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 was 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 of the stroke, 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. Then the piston 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 else 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; and the valve-stem should be well clamped.

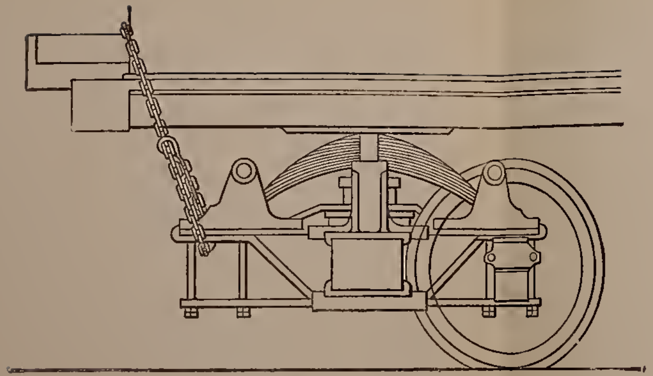


Fig. 205. Broken Tender-Wheel

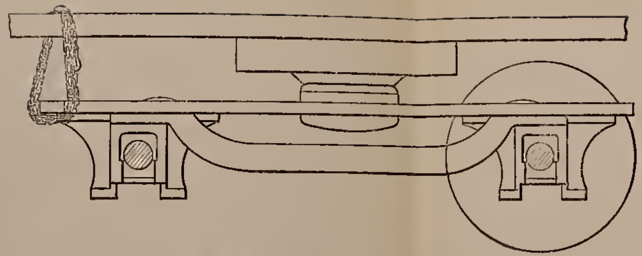


Fig. 204. Broken Truck-wheel.

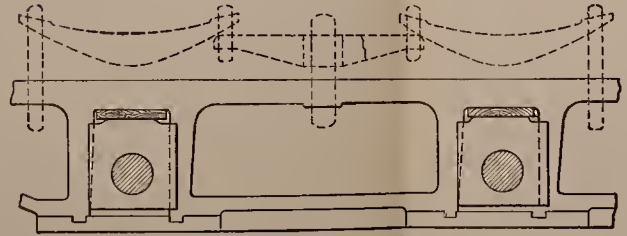


Fig. 202. Broken Springs.

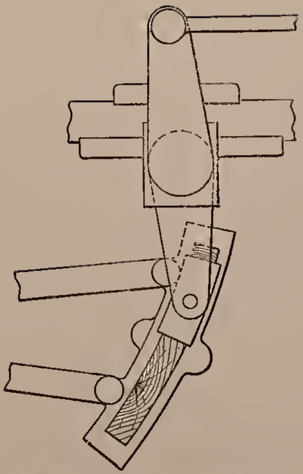


Fig. 200. Broken Reach-rod.

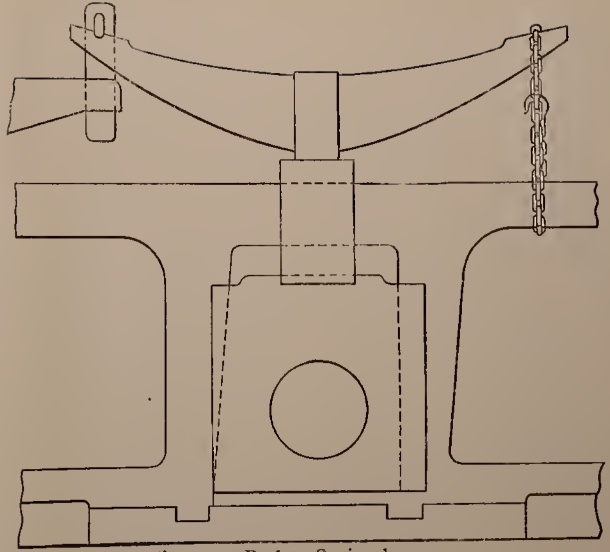


Fig. 203. Broken Spring-hanger.

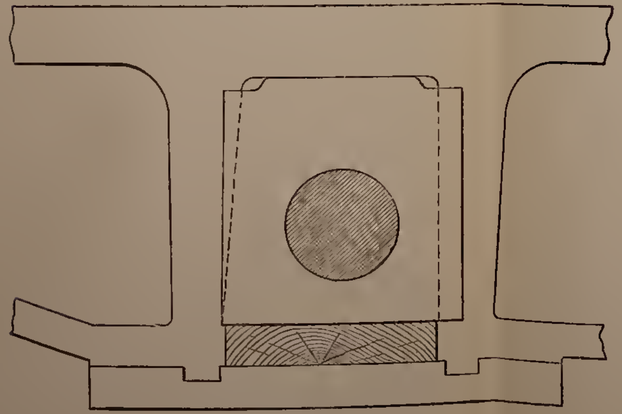


Fig. 207. Blocked-up Wheel.

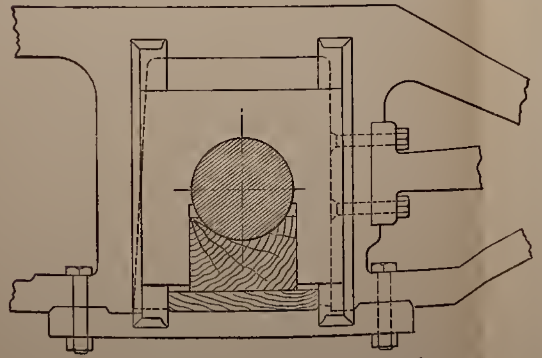


Fig. 206. Blocked Driving Axle.

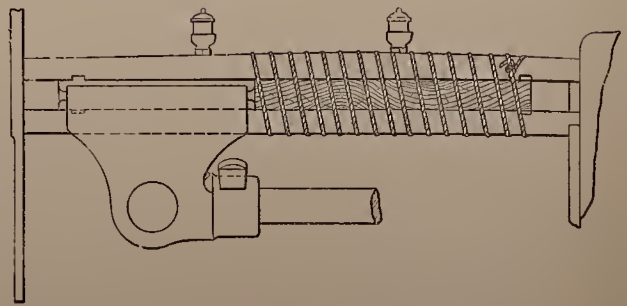


Fig. 201. Blocked Crosshead.

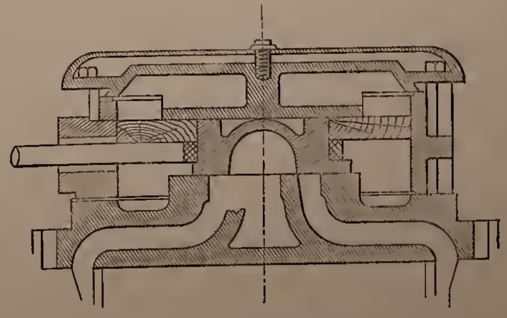


Fig. 208. Valve Blocked in Steam Chest.

Plate X. Emergency Repairs.

Q. Under what circumstance need not the crosshead be blocked?

A. If there is no pressure in the boiler.

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 driver, the exhaust that takes place just before it reaches the forward and the back centres 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 centre and the bottom quarter, or between the back centre and the top quarter, will be likely to be from trouble at the right-hand piston.

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 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. 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 centre, 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 centre should also be marked; then 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 mark 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.

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. In order 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 centres?

A. That the cylinder-packing is wrong.

Q. Of what is it a sign when an engine blows when passing over only one centre?

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 centres, 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 centre.

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 the 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 engineer 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. 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 centres.

Q. How may a loose spider be detected?

A. By the sharp knock made when passing the front centre.

Q. When will a thump caused by a driving-box wedge having the wrong taper, be made manifest?

A. When the engine is passing the back centre.

Q. Suppose that an engine pounds in full gear and the pounding cannot be stopped by either tightening or slacking the brasses, what should be done?

A. More lead should be given, or more cushion.

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. 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) a 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. Where are the riskiest pounds on a locomotive?

A. In the cylinder.

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 centre, 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 end, of what is that a sign?

A. That the eccentric-rod is too short.

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 one of the causes of slipping eccentrics?

A. Clogging up of the oil-passages in the eccentric-straps putting extra strain on the sheaves, thus causing them to slip.

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 do 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 centre, the reverse-lever put in the back notch of the sector (quadrant), and a line scratched with a knife 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 are then fastened, the engine will be adjusted well enough until more correct setting can be done (of course, care being taken that the bellies of the two eccentrics are not on the same side of the shaft).

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 centre, 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. Suppose that both eccentrics on one side slip, what should be done?

A. One way would be to put the engine on the forward centre, and set the go-ahead eccentric above the axle, and the back-up eccentric below the axle; to put the reverse-lever in the forward notch and advance the top eccentric until the front cylinder-cock shows 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 towards the crank-pin until steam shows at the front cylinder-cock; or else the back-up eccentric may be set by the forward one which has just been set, as though the forward one had not slipped.

Q. What should be done in case of breakage of a backing eccentric?

A. Both eccentric-rods should be taken down on

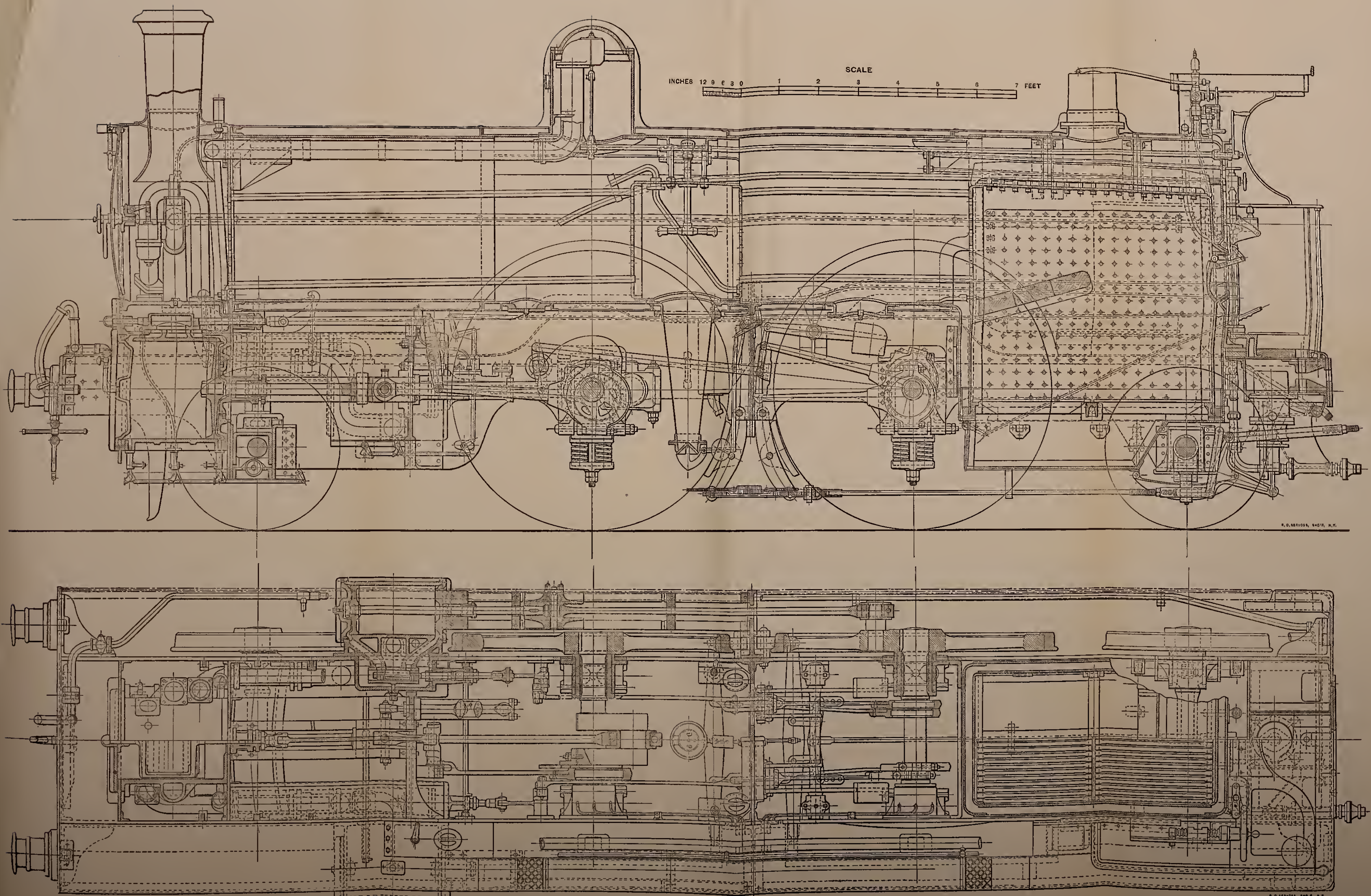


Plate XI. Seven-foot "Webb" Eight Wheeled Compound Passenger Locomotive, L. & N. W. Ry.

Firebox,	120.6 sq. ft.
Comb. Chamber,	39.1 "
Tubes: Front,	875.0 "
" Back,	506.2 "
Total,	1540.0 "

Number of Tubes—
156 Front (10 ft. 3 in. long, 2½ in. Outside Diameter.)
156 Back 6 " 0 " " 2½ in. " "

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.

Q. Why not run towards mid-gear; or in other words, hook up?

A. Because that would swing the link.

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. 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. 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 stroke.

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 a central position; the main rod disconnected and the crosshead blocked at one end of the guides.

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. What should be done in case of breakage of the lifter tumbling-shaft?

A. A piece of wood may be fitted and tied in between the block and the top of the link-slot, on which the link may rest, this piece being long enough to raise the link enough to produce the desired cut-off.

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 backward.

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 was 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.

Q. Why do you say in your answer to this last question, "if the engine was 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 position in which you desire it.

Q. What should be done in case of a broken reach-rod?

A. The links should be held as high as desired, by blocks of wood fitted in both slots; and the engine controlled with the brake.

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 should be blocked at mid-travel, and the crosshead and piston blocked at the back end of the stroke.

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. 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. In order 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 centre, the back axle could not be turned 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 should not an *engine 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 should be blocked, and the wheels pinched over until the screw is loosened.

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 wheels and causes them to slip, and the unbroken side is apt to be caught on one of the centres 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 centre; (2) thumping by reason of loose rods causing crystalizing of the metal 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 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 a 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 and does not work 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 or 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 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 new wheels and axle.

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 should be 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; the train should be left and the engine run 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 should be 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 should be taken off, the broken wheel taken off, the main rod taken down, the cross-head blocked at the front end of the stroke, 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; and 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 as a maximum.

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. 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, and wooden blocks placed between the axle and pedestal caps, and the front side-rod keys should be 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 on straight reaches, two and a half to three on curves.

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 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. What should be done in case of a broken front truck-wheel or axle?

A. It may usually be chained up until the engine can be side-tracked.

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.

Q. What should be done in case of a broken truck-wheel flange?

A. The engine should be run very slowly when necessary to run.

Q. What should be done in case of breakage of the centre-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 height.

Q. In case of this accident would you run in with full train or only part?

A. With full train.

Q. What should be done in case of breakage of the tender-wheel?

A. A tie or a piece of rail should be placed across the apron of the tender 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.

Q. What should be done in case of a broken equalizer?

A. It should be taken out, with the springs to which it is attached; the crippled side of the engine should be jacked up as high as the other, the spring-saddles removed, if possible, and nuts and washers put in on top of the driving boxes where the broken equalizer had been.

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 pairs of drivers 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. 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 placed 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 the weight off 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.

Q. Suppose that there is neither hanger nor chain available, what should be done?

A. The equalizer should be raised about level by a block of wood or of 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. What is the best device for removing gibs from spring equalizers, without jacking up the engine?

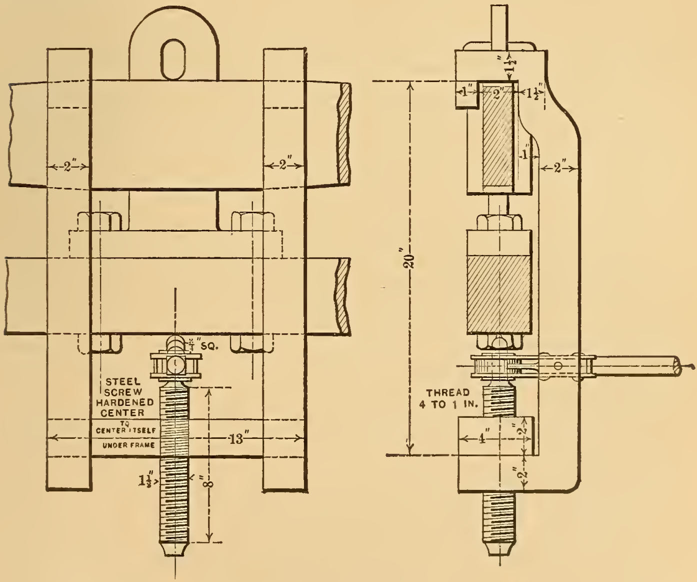


Fig. 177. Clamp for Removing Gib in Spring Equalizer.

A. As shown in figures 177 and 178, 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 as to allow room for the ratchet-handle to work. The nut-plate is

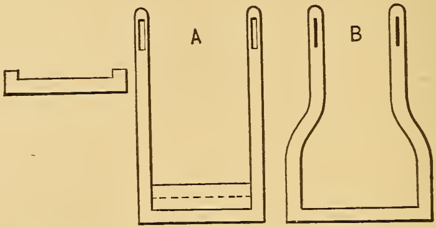


Fig. 178. Equalizer Gib Remover for Consolidation Engines.

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 on a stick of wood or a block of iron four to six inches thick, under the forward wheel, to ease the back one, or under the back wheel if it is the forward one that is crippled.

Q. What should be done in case of a broken spring?

A. The same as for a broken hanger.

Q. What size and kind of wedges would be necessary to run drivers on in case of a broken spring or hanger?

* Invention of Mr. Henry Tregelles, Erie Shops, Salamanca, N. Y.

A. Oak, about four inches square and a yard long, tapered down to nothing, and part of the top of the thick end left straight 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-centre 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 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 are 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 centred with the truck.

Q. If the engine is not in the centre of the truck, as shown by cut truck-flanges, which way should it be moved?

A. Towards the side of the truck that is cutting.

Q. What will be the effect if the engine is not in the centre 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. In case it is necessary to jack an engine up to get it on the track again, what precaution 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 same line along which it came.

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. What precaution should be taken when a locomotive is to be towed by another engine?

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. Why should the main rods be taken down when an engine is to be towed, or why should one rod be taken down if an engine is to be run with only the other side?

A. Because otherwise the piston would be running in the cylinder and would cut its packing and the cylinder-bore.

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 seems danger of freezing the water in the boiler itself 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. 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. 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, in order 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 wreck on the other; then the other may be cleared.

APPENDIX A.

Official Form for Examination of Firemen for Promotion, and of Engineers for Employment.

FORM OF EXAMINATION FOR FIREMEN FOR PROMOTION, AND OF ENGINEERS FOR EMPLOYMENT.

[At the meeting of the Traveling Engineers' Association, at Denver, in 1894, the Special Committee appointed for the purpose made a report bearing upon the examination of firemen for promotion and of engineers for employment, and suggested a certain concerted action on the part of Master Mechanics and others in authority, and certain lists of questions to be asked the candidates.

The report is here published entire, by reason of its many valuable suggestions; and the lists of questions are also given, with either the answers thereto, or references to the pages of the previously-published part of this book, where such answers may be found.

While this "Locomotive Catechism," as originally published, contained over 1300 questions and answers bearing on the modern locomotive (being more than double the number contained in any other work having the same object), it is, of course, not to be presumed that all the questions which it is possible to ask on the subject could be contained even in that number. Hence, it so happens that some of the questions recommended by the Traveling Engineers' Committee may not be found (at least not in the form put by that body) in the original 1300 questions prepared by me; and as many engineers and firemen wished the answers to those special questions, I have, with the risk of repetition, given the Committee's lists, with either the answers annexed or a reference to the pages where such answers may be found.—R. G.]

THE COMMITTEE'S REPORT.

Form for Examination of Firemen for Promotion, and Engineers for Employment.

So much has been written on this subject that your Committee feel they have considerably more on their shoulders than they can do justice to, but to our mind the most important thing that railroad companies can do for themselves is to procure the right kind of men for their firemen and future engineers. If care is not exercised in this particular, it is almost impossible to control the service later. The general reputation of the applicant for position, the kind of family he comes from and the company he keeps, so far as it can be ascertained, should all have an important bearing on this. Because he may be recommended by some prominent man in a town, or politician, should be given but little consideration. Those who are recommended by small politicians in towns or cities are generally of the poorest class that could possibly be had. Unless there is good reason, and one should know personally about the character of such people, it would be safe to reject them.

The day of railroading by brute force is about done away with, and intelligence and good "horse sense" are stepping in. It was but a few years ago when all the qualifications that were necessary for a man to have to secure a position of an engine was to be a "good fellow," and have lots of muscle; but in these days of sharp competition, brains must be the first element to be considered. Your Committee do not believe in going clear down in technicalities, as a man must learn a good deal of his business by experience; but we do believe that the only way to get fit men for our locomotives to-day is to have an examination that they know they will have to pass at stated intervals. This examination is gotten up conservative enough, so that you can reasonably demand of a man that if he desires to continue in the service he must be right up in his examination. Yet the examination is severe enough to leave no doubt that the candidate is taking an interest in his work.

We do not believe in publishing the answers to questions that are asked the candidates. There is always a way for a man to get information if he wants to very badly.

We would suggest that 19 years minimum and 22 years maximum be the standard of years at which men be placed as firemen. After a man is over 22 years of age he does not learn as readily as he does when younger. When the maximum age is placed between 25 and 30 years, the candidate on many roads is worn out before promotion comes.

The traveling engineer should be required to keep posted on the every-day habits of firemen and engineers, and in the matter of promotion, have that part govern the examiners to a certain extent. Firemen for promotion should be examined according to age or rank in the service, and should a younger man pass while an older man fails, the younger man should rank ahead. The man that failed should be given a reasonable length of time in which to get posted before he is called in for the final "test," failing in which he should be dropped from the service. About six months should elapse before the final examination is conducted.

Your Committee submit the blank next attached as the proper form to be filled out by all applicants for position as fireman:

....

RAILWAY COMPANY.

Application
for position as..................................

Present address..................................

Age..

Married or Single................................

Name and address of parents......................

....

....

If employed at present, state where and in what capacity:

....

....

What railroad experience have you had?

Give name of road; in what capacity employed; length of service on such road, and cause of leaving:

....

....

If ever discharged from any situation, state when and why:

....

....

Give names and address of two responsible persons for reference as to your character and ability:

....

....

....

I hereby certify that the above statement is correct, and if employed by the

. . . .

Railway, I will obey all their rules and regulations.

. . . .

Examined by. . . . .
Entered Company's service. . . . .

. . . .

Record

. . . .

This application blank should be filled out before a witness, and filed for future reference. When this has been done, the candidate should be examined on his ability to read some written matter; also a paragraph from newspaper or time-table should be submitted; then submit a few examples in arithmetic, to see if candidate is posted on this branch of education, which we think is very necessary. Candidate should then be examined on color sense and vision; and we think the Thompson color examination is the fairest and simplest color test that is now in use, and recommend its adoption. Blank on pages 32 and 33 covers that examination, and is very simple, a copy of which should be filed with the application blank for future reference.

The color examination should be gone through in all cases when an application for position has been made.

We would recommend that the examination on transportation rules and time card be conducted by the transportation department, and they be requested to file certificate of examination with the mechanical department of each individual examination that is under the Master Mechanic, and that certificate be attached to the application blank on file.

Your Committee would recommend that all men hired with the intention of making future engineers of them be

COLOR TEST.

.... R'y.

....189

EXAMINATION OF SIGHT AND HEARING OF

.... *Aged*...

Employed as ....

Applicant for ....

ACUTENESS OF VISION. The number of the series seen at 20 feet distance.		RANGE OF VISION.		
		Least number of inches at which type D—0, 5, in test type pamphlet can be read.	RIGHT EYE, ... inches	LEFT EYE, ... inches
Right Eye,	....	FIELD OF VISION.		
Left Eye,	....	Good or Defective,	....	

COLOR SENSE.

TEST SKEIN SUBMITTED	NAME GIVEN.	NUMBERS SELECTED TO MATCH.
A—Green.	....	....
B—Rose.	....	....
C—Red.	....	....

SECOND COLOR TEST.			THIRD COLOR TEST.		
No. Shown.	Name Given.	Numbers Selected.	Flag Shown.	Name and Use Given.	Numbers Selected.
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....

SELECTION PROMPT OR HESITATING.

....

HEARING.

RIGHT EAR.		LEFT EAR.	
Watch.	Conversation.	Watch.	Conversation.
.... Feet.	.... Feet.	.... Feet.	.... Feet.

REMARKS.

....

....

....

.... *Examiner.*

Acuteness,.......................... *Range*,.......................... *Field*,..........................

Color Sense.. *Hearing*..

....

....

.... *Superintendent.*

NOTE.—Those approved, mark "app'd."
Those not approved, mark "not app'd."

placed in round-house for a short time, as machinist helpers or wipers. All new men hired, with the intention of making future engineers of them, should be placed on six months' probation, to determine whether they are cut out of the right kind of cloth to make good engineers, this six months to include all men hired, regardless of their previous experience, unless the man hired is provided with a certificate setting forth his record. By this six months' probation, all roads hiring new men can very easily drop from their service any man that does not pass the examination required. To cover that head we submit the following notice, which can be changed to meet the service of any road, as desired:

OFFICE OF THE MASTER MECHANIC.

CIRCULAR.

To Locomotive Engineers and Firemen:

Commencing at an early date and continuing thereafter, all Engineers and Firemen who have served three years as road firemen on this line will be called to pass an examination on transportation rules and mechanical ability, in seniority order, for the purpose of establishing their ability as locomotive engineers. Mechanical examination to include air-brakes.

If any fail on first examination they will be given another chance six (6) months later, and if a second failure is made they will have the option of retiring from the service or going to the foot of the firemen's list.

If, when they come around again in regular order for examination, they do not pass, they will be dropped from the service. Applicants for a second examination will be permitted to bring one or two witnesses to attend the examination; said witnesses to be engineers who have successfully passed the same examination.

This system has been adopted for the purpose of giving all our firemen the chance of fitting themselves for locomotive engineers, as we do not wish to have in our employ as firemen any men who are not capable of making first-class engineers.

When engineers are needed, the Railroad Company will, if deemed advisable, promote to the position of switch engineer the fireman oldest in service who has passed the examination.

FIRST EXAMINATION.

At the end of six months would recommend the following list of questions be asked the candidate—that is, the candidate whose only experience has been for six months.

Q. 1. *What engines have you been firing?*

A.—

Q. 2. *What build and class of engines are they?*

A.—

Q. 3. *What kind of injectors on these engines?*

A.—

Q. 4. *Are you familiar with all the signals in use on this road?*

A. Yes.

Q. 5. *Explain them.*

A.—

Q. 6. *What is the use of the engine bell?*

A.—

Q. 7. *About how much coal does engine No.— burn each day, or trip?*

A.—

Q. 8. *Does engine No.— steam freely?*

A.—

Q. 9. *How much steam does she carry?*

A.—

Q. 10. *Do you allow the engine you have been firing to pop, or blow off, frequently?*

A. No.

Q. 11. *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. 12. *What are 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 round-house; 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 sand-box full of clean dry sand.

These questions are intended as a guide to the examiner, and to lead him to others of more importance, and in gauging the qualifications of candidate. If candidate has had three or more years' experience firing, give him full examination. In no case should the examiner confine himself to the questions set forth in this list, but should ask as many more, all leading up to the same point, *i. e.*, to find out just how much the candidate knows about the trade he has been learning.

SECOND EXAMINATION.

The second examination should be conducted when the candidate has fired about eighteen months, and we would recommend the following:

Q. 1. *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 lbs. per square inch. (Pressure including such atmospheric pressure is called "absolute pressure" or "pressure above vacuum.")

Q. 2. *What is the result of exhaust steam going through the stack?*

A. See page 51.

Q. 3. *In what way does the exhaust steam create draft on the fire?*

A. See page 51.

Q. 4. *What is your idea of the proper size of stack—inside diameter, length, and taper or straight inside?*

A. See page 57.

Q. 5. *Will air enough come through the grates and fire to form perfect combustion of the coal?*

A. Seldom, even with thin fires.

Q. 6. *Is it necessary to admit any air above the fire?*

A. Usually.

Q. 7. *What is the object 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. 8. *What is the object of holes in the firebox door?*

A. Partly to admit air above the grate, to facilitate complete combustion; partly to keep the fire-door from warping.

Q. 9. *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. 10. *What effect would a very small exhaust-nozzle have on the fire?*

A. See page 53.

Q. 11. *When the fire burns most in the front end of the firebox, what does it indicate?*

A. That the lower tubes have proportionately too much draft.

Q. 12. *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. 13. *What is the object of the brick arch?*

A. See page 44.

Q. 14. *Does it save any coal? How?*

A. See page 46.

Q. 15. *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 firebox 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. 16. *How do you keep smoke from trailing over train when running shut off?*

A. Avoid opening the fire-door; use the blower sparingly.

Q. 17. *What effect does it have upon the fire to open the firebox door when the engine is working?*

A. It causes excess of cold air to chill the combustion-gases, and makes black smoke; besides this, it tends to crack sheets and make fires leak.

Q. 18. *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. 19. *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 it is 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 I would see that it did not go out entirely.

Q. 20. *How does the blower operate?*

A. See page 29.

Q. 21. *Do you use it on a free-steaming engine to prevent dense black smoke when shut off?*

A. Sparingly.

Q. 22. *If blower is put on too strong when cleaning the fire, what is liable to happen?*

A. Tearing of the fire.

Q. 23. *How much coal does your engine burn each trip?*

A.—

Q. 24. *How does this compare with the other engines of the same class, in the same kind of service?*

A.—

Q. 25. *Do you consider it wasteful to have an engine blow off steam frequently?*

A. Decidedly; also in less degree to be always whistling.

Q. 26. *Are you on friendly terms with your engineer?*

A. It would be unfortunate if I were not; because it is in his power to help me gain a knowledge of the construction and operation of the engine, so that I can some day get a better run.

Examination for Firemen for Promotion and Engineers for Employment.

Your Committee recommend the following list of questions as necessary to be asked before promoting fireman to engineer, or employing new men as engineers, adding any question that is thought necessary and not down on the list. When answer is given to question asked, always ask the candidate *Why?* and be sure he gives the correct understanding to all questions asked. Your Committee would further recommend that the use of a stenographer be taken in this examination, and the answers to all questions recorded, so that the candidate cannot say that the examiner had it in for him and took the means of examination to "do him up." That is generally the ignorant man's excuse for failing.

Your Committee further suggest that the engineers for whom firemen have fired be consulted regarding candidate's ability, and said engineer's opinion to be considered in the best interest of the Company, and not allow any personalities to control the ability of engineers to pass judgment upon their firemen, should always be borne in mind.

Q. 1. *What is a locomotive?*

A. See pages 9 to 16 inclusive.

Q. 2. *What are your first duties when going out of the house with the engine?*

A. See page 290.

Q. 3. *What tools do you consider necessary?*

A. See page 290.

Q. 4. *What supplies?*

A. See page 290.

Q. 5. *How do you locate a pound in an engine?*

A. See page 324.

Q. 6. *If pound is in the rods, can you always locate it?*

A. Yes. (Same answer as to preceding question.)

Q. 7. *How would you commence to key up a Mogul or ten-wheel engine?*

A. Put the engine on the center on the side I was working on; slack all the keys on that side, then key up, commencing with the main key.

Q. 8. *If pound is in the wedges, can you set them up and get them right the first trial?*

A. Yes.

Q. 9. *How do you do this?*

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. 10. *Will an engine pound if pedestal-bolts are loose? Why?*

A. Yes, because the pedestal works loose and draws down the wedge.

Q. 11. *When wedge-bolts are broken, 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. 12. *If follower-bolts are loose, will it make a pound?*

A. See page 324.

Q. 13. *How do you detect this trouble?*

A. By listening as the crosshead passes the center when the engine is running shut off.

Q. 14. *How do you remedy it?*

A. By removing the cylinder-head and tightening the loose bolt.

Q. 15. *If cylinder-packing is blowing through, how do you tell which side it is on?*

A. See page 320.

Q. 16. *Will steam come out of both cylinder-cocks at the same time on the same side?*

A. Yes.

Q. 17. *If valve is cut and blowing, can you locate the trouble?*

A. Yes; see page 321.

Q. 18. *And which side it is on?*

A. Yes; see page 321.

Q. 19. *Will steam come into cylinder if valve is tight and stands in the middle of its travel—that is, covering both steam-ports?*

A. Yes; see page 321.

Q. 20. *Can you locate the trouble if steam-pipe is leaking? How?*

A. Yes. There will be a hard blow all the time in the firebox 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. 21. *If exhaust gets out of square on the trip, what does it indicate?*

A. Slipped eccentric, loose strap-bolts or strap-rods, broken valve-yoke, or bent rocker-arm.

Q. 22. *Can you locate the trouble, whether it is a slipped eccentric, loose bolts in the strap, eccentric-rod loose on the strap, or broken valve-yoke? How?*

A. Yes; see page 318.

Q. 23. *Is there anything else not mentioned that would affect the sound of exhaust?*

A. Loose exhaust-pipe, one exhaust-tip gone (where there are by rights two), bent lifter-arm, loose rocker-box.

Q. 24. *Can you set a slipped eccentric? How?*

A. See pages 141, 169, 325.

Q. 25. *How do you tell which one is slipped?*

A. See page 325.

Q. 26. *How are they kept in their places on the axle?*

A. See page 173.

Q. 27. *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, oy 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. 28. Which center is most convenient to set eccentric from?

A. The forward.

Q. 29. 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. (See pages 141, 169.)

Q. 30. 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. 31. What generally causes eccentrics to slip?

A. See page 325.

Q. 32. How do you move the eccentric back to its proper place on the axle?

A. See pages 169, 325.

Q. 33. Would you put water on a very hot eccentric or strap?

A. No.

Q. 34. *Are all eccentrics made in one piece?*

A. See page 173.

Q. 35. *What do you disconnect, take off and block up in case of a broken eccentric or strap?*

A. See page 326.

Q. 36. *Can an engine be worked ahead to a station with a full train, if back-motion strap is broken?*

A. See page 326.

Q. 37. *If link-hanger or pin is broken?*

A. See page 328.

Q. 38. *If arm is broken off tumbling-shaft?*

A. See page 328.

Q. 39. *With a broken reach-rod?*

A. See page 329; also figure 200.

Q. 40. *With a broken link-block pin?*

A. No.

Q. 41. *With broken piston-gland or stud?*

A. Yes.

Q. 42. *What would you do with an engine with broken piston?*

A. See page 315.

Q. 43. *With a broken cylinder-head?*

A. See pages 310, 315.

Q. 44. *With a broken valve-yoke?*

A. See page 310.

Q. 45. *With broken valve-seat?*

A. See page 308.

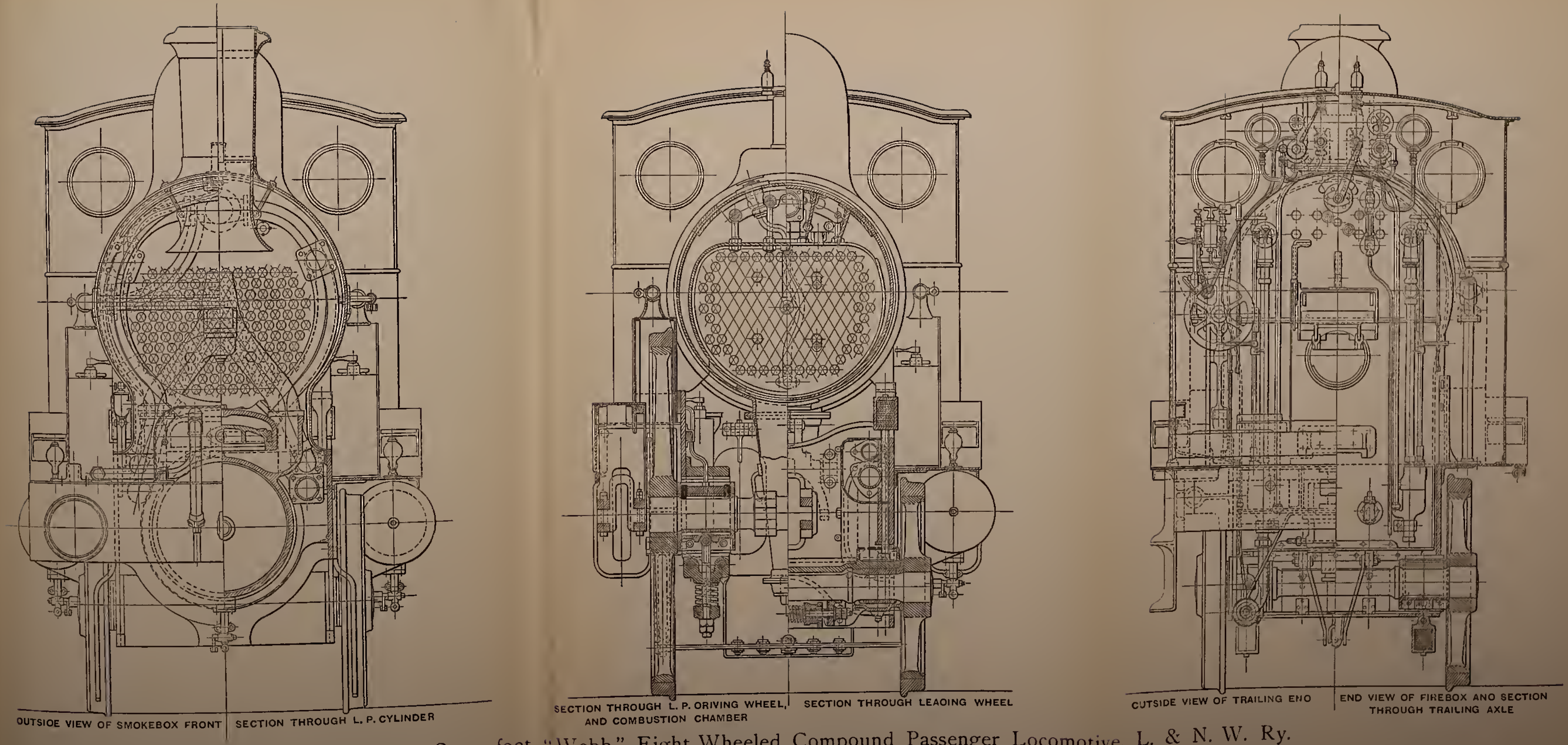


Plate XII. Seven-foot "Webb" Eight Wheeled Compound Passenger Locomotive, L. & N. W. Ry.

Q. 46. *With broken valve-stem gland?*

A. 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.

Q. 47. *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. 48. *What would you do with top rocker-arm broken?*

A. See pages 327, 328.

Q. 49. *How do you fix broken steam-chest if steam leaks out badly?*

A. See page 307.

Q. 50. *How do you keep steam from coming out of dry-pipe into broken steam-chest on the different builds of engines on this road?*

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 of the engine.

Q. 51. *How and when do you block the crosshead when disconnected?*

A. See pages 311, 314; also figure 201.

Q. 52. *How do you keep the packing-rings out of the counter-bore?*

A. By blocking the crosshead.

Q. 53. *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. 54. *What would you do if main-rod strap or crosshead should break?*

A. See pages 315, 316.

Q. 55. *What is done if side-rod or back pin breaks?*

A. See page 330.

Q. 56. *Can all four-wheel switch engines be run with the side-rods down?*

A. Not those which have the eccentrics on the front axle and the main pin on the back wheel.

Q. 57. *Why do you take rods down on the opposite side to that broken?*

A. To prevent straining.

Q. 58. *What is the effect of sanding the rail while engine is slipping, without first shutting off steam?*

A. To strain rods and pins up to the danger point.

Q. 59. *Is it good policy to allow sand to run from the pipe only?*

A. No. It wrenches the pins and connections.

Q. 60. *How do you block up an engine for a broken driving-spring or hanger?*

A. See page 342; also figures 202 and 203.

Q. 61. *With broken equalizer?*

A. See page 339.

Q. 62. With broken engine-truck spring or hanger?

A. See page 339.

Q. 63. With broken intermediate equalizer on Mogul?

A. Block between the cross equalizer and the boiler; remove the broken parts.

Q. 64. With broken engine-truck center-pin on 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. 65. What do you do when a tire breaks and comes off the wheel on standard engine?

A. See page 337.

Q. 66. With front tire on Mogul or ten-wheel engine?

A. Same as for preceding question.

Q. 67. Main tire on Mogul?

A. Same as for preceding question.

Q. 68. 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. 69. With both back tires on Mogul?

A. Same answer as for preceding question.

Q. 70. With the back tire or back driver broken off, how do you fix engine so you can back around curves, when necessary?

A. For a standard (eight-wheeled) engine take down coupling-rods and proceed as in case 68. For a Mogul, put a block between the engine and the tender on the side next the inside of the curve.

Q. 71. At what points is weight of engine carried when springs and equalizers are in good order?

A. See page 188.

Q. 72. 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. 73. When blocked up over the back driving-box?

A. Over that box.

Q. 74. What is the best material to use to block between driving-box and frame?

A. See page 343; also figure 202.

Q. 75. 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 figure 204.

Q. 76. Do you consider it an engineer's duty to have suitable hard-wood blocks on his engine to use in case of a break-down?

A. See page 290.

Q. 77. *How do you block up or get to a side track with broken engine-truck wheel or axle?*

A. See page 338; also figure 204.

Q. 78. *With Mogul; with broken engine-truck wheel or axle, what would you do?*

A. Remove the broken wheel and chain the engine-truck to the engine-frame; or else remove it and block on top of the engine-boxes.

Q. 79. *With broken tender-truck wheel or axle, what would you do?*

A. See page 339; also figure 205.

Q. 80. *Is it necessary to take down the main rod if 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. 81. *Would you take down either rod if frame is broken between forward and back driving-boxes?*

A. No.

Q. 82. *Where is the frame fastened solid to the other part of engine?*

A. See page 178.

Q. 83. *Would you disconnect an engine for a broken guide?*

A. Yes.

Q. 84. *How do you handle an engine if throttle sticks open, or dry-pipe joint leaks so steam cannot be shut off from engine?*

A. See page 295.

Q. 85. *What will you do if throttle is disconnected and remains shut?*

A. See page 296.

Q. 86. *If a crank-pin brass gets hot so the babbitt melts, would you cool it off with water before all the babbitt comes out?*

A. No.

Q. 87. *Can you take out a tender-truck brass and replace it with a new one? How?*

A. Yes. 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 of it; next taking out the jack and re-packing the box.

Q. 88. *An engine-truck brass?*

A. Yes. I should remove the cellar, jack up the box at the corner, slide out the old brass and slip in the new, then remove the jack and put in the cellar.

Q. 89. *When brass does not wear an even thickness at both ends, is it apt to run hot? Why?*

A. Yes. By reason of one end getting more weight than the other.

Q. 90. *How often do you examine the ash-pan, grates and dampers?*

A. At the end of each trip.

Q. 91. *What are your duties after cutting off from train at the end of trip?*

A. To inspect the engine all over, and report in the regular requisition-book all repairs or adjustments needed, that I cannot or should not make myself.

Q. 92. What are your duties in case of wreck when your 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 my command, to report in detail to the proper official.

Q. 93. If front end is broken, but flues and steam-pipes in good order, how could you make repairs on it to run in?

A. By boarding up the front end, using the studs if possible, and if these are not available, by bracing.

Q. 94. Do you understand the principle on which an injector works?

A. Its essential principle is to some extent the same as that which governs the blower, that of induced currents. The friction of one stream or material causes the flow of another, but in the boiler-feeding injector the momentum of the jet of steam at high pressure (which is considerably greater than that of a stream of water at the same temperature and pressure, through the same orifice) is utilized to force the warm water caused by the mixture of cold water and steam against the hot water in the boiler. In other words, the steam at a given pressure and temperature would have a certain velocity (about 2000 feet per second under ordinary locomotive-boiler pressures), while water at the same pressure would have much less (only about 150 feet). So we have a steam-jet tending to flow in one direction at 2000 feet and a stream of hot water tending to oppose it, with a velocity of only 150 feet. This being the case, the steam is able to force the water back into the boiler and to enter against its pressure, and also to carry with it a volume of water which it had first drawn along by induction and then heated; besides overcoming the friction in the pipes.

Q. 95. What are the different builds of injectors on this road?

A.—

Q. 96. 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. 97. If sand or dirt gets in the passages, will the injector work?

A. No.

Q. 98. 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. 99. 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. 100. 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. 101. When 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. 102. *Is there more than one check-valve between the injector and boiler?*

A. Sometimes; not usually.

Q. 103. *Will an injector work unless all the steam is condensed by the supply of water?*

A. No.

Q. 104. *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. 105. *Will an engine steam any better if this is done?*

A. Yes.

Q. 106. *How should an engine be pumped—continuously from beginning to end of trip, or would you shut the injector off when pulling out after each stop?*

A. See page 77.

Q. 107. *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. 108. *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. 109. *What makes a boiler foam?*

A. See pages 87, 88.

Q. 110. *How do you remedy it?*

A. See pages 304, 305.

Q. 111. *What is the danger when boiler foams badly?*

A. Burning the crown-sheet, cutting the valves, breaking the piston-packing rings, or knocking out cylinder-heads.

Q. 112. *Does water remain at the same level when the throttle is shut off?*

A. No.

Q. 113. *What do you do in case the water drops too low?*

A. See pages 305, 306.

Q. 114. *What is the least depth of water on the crown-sheet that is safe?*

A. One gage.

Q. 115. *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. 116. *Do you consider it safe to run an engine with one or more of the gage-cocks stopped up?*

A. No.

Q. 117. *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. 118. *Under what circumstances can it be used to show height 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. 119. *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. 120. *Is any more water used when an engine foams than when water carries well?*

A. Yes.

Q. 121. *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. 122. *Would you use valve-oil or lard oil for the same purpose?*

A. No; it would cause foaming.

Q. 123. *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. 124. *Is it a good plan to let an engine slip at such times?*

A. No.

Q. 125. *Is it liable to break the cylinder-packing rings or cylinder-heads?*

A. Yes.

Q. 126. *In case you get out of water on the road, 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. 127. *When an engine dies on the road in the winter, what will you do?*

A. Disconnect so as to be towed in, 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.

Q. 128. *How will 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. 129. *Can an engine be pumped by towing her with another engine? How?*

A. Yes. By closing all openings into the boiler except those from the tender, opening 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 remove the air from the boiler, and water will flow in from the tender to supply its place.

Q. 130. *Can she be filled up with hot water from a live engine, if you have a hose and suitable connections?*

A. Yes. Connecting the hose from the injector of the live engine to the check-valve of the dead one.

Q. 131. *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. 132. *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, will it help to keep them tight?*

A. Yes, and is to be recommended.

Q. 133. *Are you familiar with the working of the —— lubricator?*

A.—

Q. 134. *Explain how the oil gets from the 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. 135. *What about the small check-valves over sight-feed glasses—what are they for?*

A. They act by reason of the steam-pressure from the equalizing-valves, in case the sight-feed glass breaks.

Q. 136. *Are there any other valves between lubricator and steam-chest? Why not?*

A. No. They would prevent the oil-spray from reaching the steam-chest.

Q. 137. *After filling the oil-cup, what valve do you open first? Why?*

A. The water-valve, to let the oil expand.

Q. 138. *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. 139. *How often should lubricator 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. 140. *Should sight-feed glass or feed-valve on one side become broken or inoperative, can the sight-feed on the other side be used?*

A. That depends on the style of lubricator used; some will "cross-feed," some will not.

Q. 141. *Will any of the lubricators in service "cross-feed," that is, feed to the cylinder on the opposite side of engine?*

A. Same answer as to No. 140.

Q. 142. *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. 143. 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.

The foregoing questions are intended as a guide for Examiner, or Examining Board, to be governed by. Candidates should be asked questions all around the regular ones as laid down in this list, to find out what the candidate knows.

APPENDIX B.

FURTHER MATTER CONCERNING

COMPOUND ENGINES

INCLUDING DESCRIPTIONS OF ENGINES,

AND INSTRUCTIONS WHAT TO DO

IN CASE OF BREAK-DOWNS.

THE BALDWIN (VAUCLAIN) COMPOUND.*

Q. Describe the second combined starting-valve and cylinder-cock used on the Baldwin (Vauclain) compound, and replacing that first used, and shown on page 101.

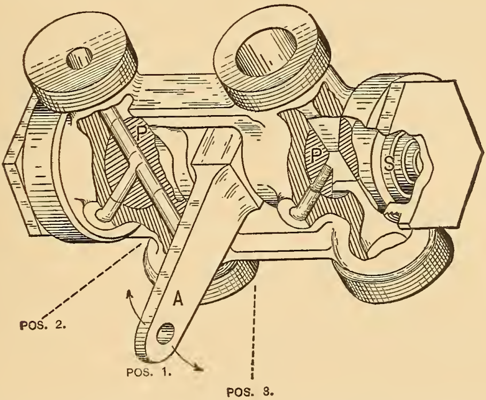


Fig. 212. Baldwin (Vauclain) Combined Starting-Valve and Cylinder-Cock.

A. As shown in figures 212 and 213, there is a casting in which are two taper plugs P, P, one controlling the high-pressure cylinder-cock and the steam for starting, and the other controlling the low-pressure cylinder-cock. These plugs are held in place by springs S and controlled by an arm A operated by a lever in the cab.

*Continued from pages 94, 266 and 285.

In position 1 of the lever, as in figure 212, the starting-valve is open to admit live steam to the low-pressure cylinder, and the cylinder-cocks are open to the atmosphere.

In lever position 2, indicated by a dotted line, all the passages would be closed; and in position 3, also

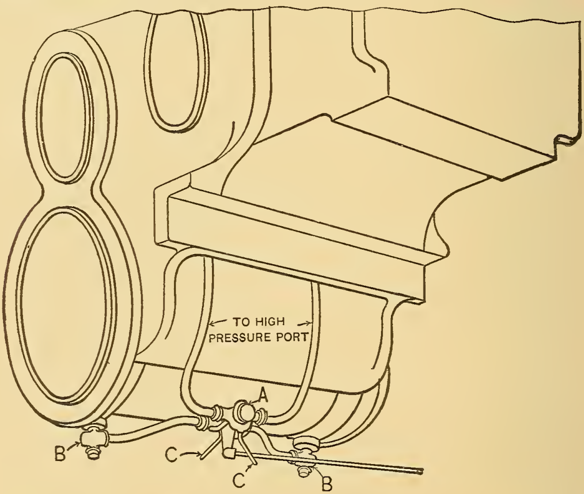


Fig. 213. Baldwin (Vauclain) Combined Starting-Valve and Cylinder-Cock.

indicated by a dotted line, the starting-valve only would be open to admit live steam to the low-pressure cylinder.

Q. Describe in detail the operation of the combined cylinder-cock and starting valve?

A. As shown in figure 212, when the valve is in starting position, live steam passes across from that end of the high-pressure cylinder which is receiving steam from the boiler, to the other end of the same cylinder, and thence through the main valve to the low-pressure cylinder; putting the high-pressure piston head very nearly in equilibrium but giving the low-pressure cylinder nearly full boiler pressure. The valve has two taper plugs, one controlling the high-pressure cylinder-cock and 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 low-pressure cylinder direct, in starting, the cylinder-cocks are open. In a second position all passages are closed; in a third, the only opening is to let live steam to the low-pressure cylinder.

Q. In a Vauclain (or Baldwin) compound, what is the proportion between the areas of the high and the low-pressure cylinders?

A. Very nearly one to three.

Q. In the Vauclain compound, how is the vacuum in the low-pressure cylinders, when the engine is running with steam shut off, relieved?

A. By air-valves in the cylinder ends.

ACCIDENTS WITH THE BALDWIN COMPOUND.

Q. In case of a broken or disconnected main valve-rod on a Baldwin 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 cylinder into the air without going into the stack.

Q. If the engine were run without disconnecting 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 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 through both ends of the high-pressure cylinder through the open ends of the low-pressure cylinder.

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 on each side of the small crosshead.

Q. What would be the effect of breakage of the small equalizing-valve in the end of the main steam-valve oj some of the earlier Vauclain compounds?

A. To convert that side into a high-pressure engine having a piston the diameter of the low-pressure cylinder.

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.

THE BROOKS (PLAYER) TANDEM COMPOUND.

Q. In the Brooks (Player) four-cylinder tandem compound, what is the arrangement of the cylinders?

A. There is a structure (see figure 215) containing the low-pressure cylinder and saddle and the final exhaust-passage and the live-steam passage connecting with the boiler, to this is also attached the low-pressure steam-chest; this cylinder structure being right and left and interchangeable with that on a single-expansion locomotive. On the front end of this low-pressure cylinder-structure is attached another structure containing the high-pressure cylinder and its steam-chest, having connection with the live-steam passage of the low-pressure cylinder-saddle by a connecting-pipe attached thereto. The rear end of the high-pressure steam-chest is enlarged to form a receiver, and is connected to the front end of the low-pressure steam-chest.

Q. Describe the valves and the means of operating them?

A. The low-pressure steam-chest (figure 214) contains an ordinary balanced slide-valve with external admission-edges and internal exhaust-edges, this valve being operated as in a simple engine, by a yoke.

This yoke is connected to the top arm of a rocker, pivoted in the receiver, the opposite end of the rocker being connected to the high-pressure valve (which latter is of the annular piston type, with internal

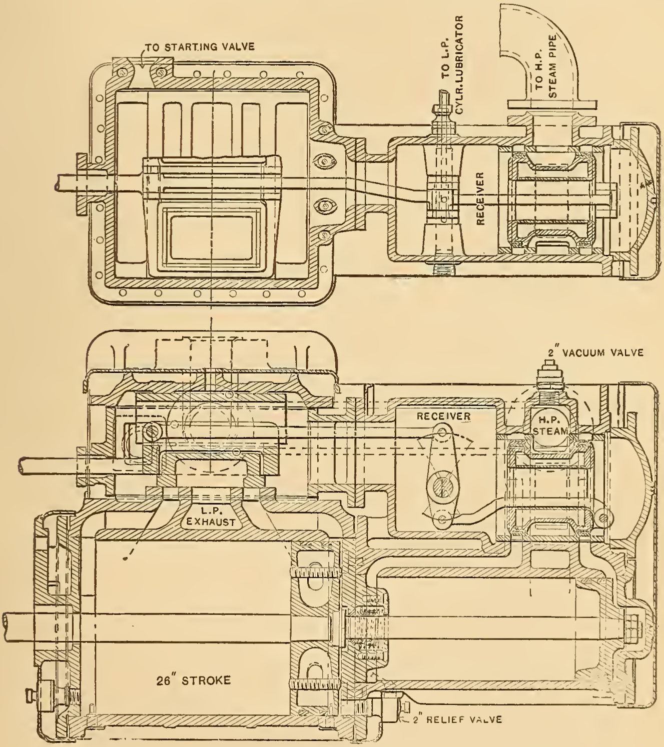


Fig. 214. Brooks (Player) Tandem Compound.

admission-edges and external exhaust-edges, and has a reverse motion from that of the low-pressure flat slide.

Q. What provision is there for starting, or for grade-climbing?

A. There is an automatic reducing starting-valve (figure 215) which admits reduced-pressure live steam to the low-pressure cylinders when starting, or at other times when it is desired to increase the engine-power. This starting-valve is operated by the reverse-lever in the cab so as to admit steam only when the latter is in full forward or full backward gear.

Q. Describe the course of the steam?

A. Steam is admitted through the high-pressure steam-chest and connecting-pipes and passages to the cavity of the annular piston valve for the high-pressure cylinder, thence through the ports into the high-pressure cylinder, and operates on the high-pressure piston. The exhaust steam from the high-pressure passes through the port into the end of the high-pressure steam-chest, thence through the annular high-pressure valve into the receiver and low-pressure steam-chest, where it is admitted to and exhausted from the low-pressure cylinder in the ordinary manner.

Q. What special arrangement of the rocker-arm is there?

A. It is so proportioned that the travel of the two valves on each side is different; giving the two valves different travels and different points of cut-off, and permitting the use of internal exhaust-edges for the high-pressure valve, thus lessening the cooling of the entering steam.

Q. What is the usual cylinder-ratio?

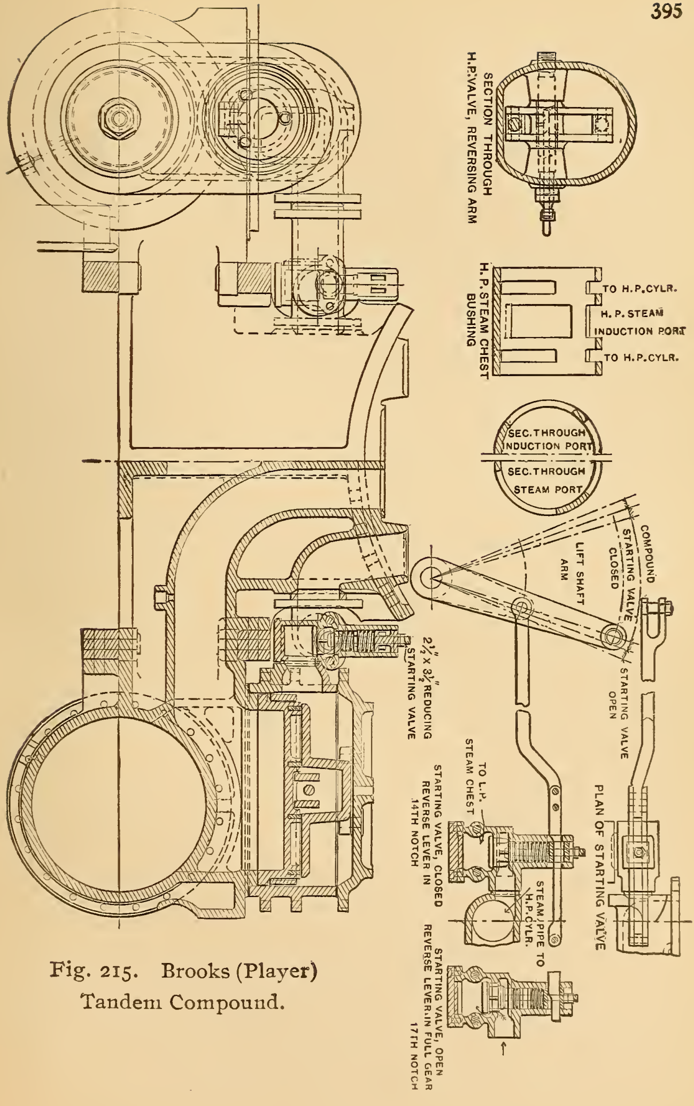


Fig. 215. Brooks (Player) Tandem Compound.

A. 1 to 2.37.

Q. What are the usual valve-elements?

A. The high-pressure or piston valve with 4 inches travel has ½ inch steam lap, 1-16 inch exhaust clearance and no lead; the low-pressure or plain balanced flat slide-valve has 7 inches travel, ¾ inch steam lap, ¼ inch exhaust clearance and 1-10 inch lead.

Q. Why say "steam lap" and "exhaust clearance?"

A. Because in the case of the high-pressure valve the steam edges are inside.

Q. In what position are the valves in the illustrations (Figures 214 and 215)?

A. Intentionally misplaced in central position or mid-travel, for the purpose of showing their laps; not in the position corresponding to stroke-end.

Q. What would be the real position of the high-pressure valve with the pistons in the front end of the cylinders, at stroke-end, as shown in the illustrations?

A. It would have its forward steam edge "line and line" with the inner edge of the front end port, and be ready to move further ahead; the back end port would be open by an amount equal to the steam lap, plus the clearance, or 9-16 inch.

Q. Where would the low-pressure valve be?

A. ⅞ inch to the rear of mid-position, which would bring its forward steam edge 1-10 inch back of the front edge of the front end port; and it would be ready to move further back.

Q. If a forward movement of $\frac{1}{2}$ inch (equal to the steam lap) brings the high-pressure valve "line and line," and the low-pressure valve has 7-4 as much valve-travel, why does not this give the low-pressure valve 7-4 times $\frac{1}{2}=\frac{7}{8}$ inch movement back of mid-position, and cause $\frac{7}{8}-\frac{3}{4}=\frac{1}{8}$ inch valve-lead?

A. Because of the angular movement of the links connecting the valve-yokes with the rocker, while the entire travel of the low-pressure valve is (barring lost motion) exactly $\frac{7}{4}$ as great as that of the high-pressure valve, it does not follow that while the latter makes the first $\frac{1}{4}$ inch of its travel the former makes $\frac{7}{16}$-inch.

Q. In full gear, in which cylinder is cut-off the later?

A. In the high-pressure cylinder.

Q. When hooked up, in which cylinder is cut-off the later?

A. In the low-pressure cylinder.

THE PITTSBURG COMPOUND.

Q. Describe the two-cylinder compound of the Pittsburg Locomotive Works (Colvin-Wightman system)?

A. Referring to figures 216 and 217, the essential features are

(1). An intercepting controlling-valve of the piston or spool type, operated either through a rod and lever by the engineman or by a steam-actuated device also in the cab. This puts the high-pressure exhaust in communication with either the receiver or an independent exhaust-nozzle, according as the engineman wishes to run compound or non-compound; in the latter case opening a passage to the receiver from

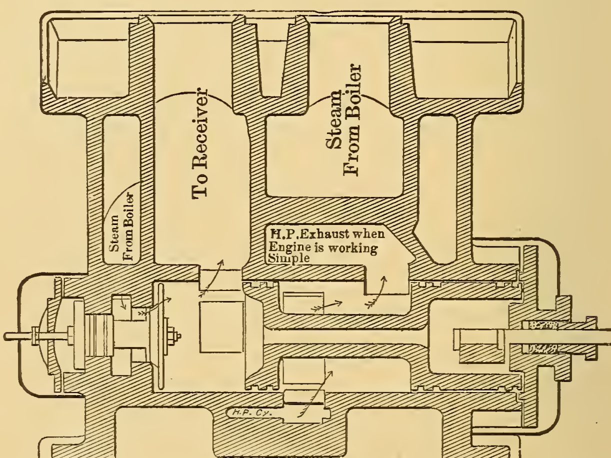


Fig. 216. Pittsburg (Colvin-Wightman) Compound, Working Single-Expansion.

(2). An automatic reducing-valve having a poppet at one end of a stem and a piston at the other, in communication with the live-steam passage and with disk-areas proportionate to those of the two cylinders—the larger one towards the receiver. This reducing-valve automatically prevents the low-pressure and the high-pressure cylinders, when running non-compound, exerting unequal pressures on their respective crosshead-pins and connections. By its action in automatically opening between the live-steam passage and the receiver and reducing the pressure, the low-pressure and the high-pressure cylinders have pressures practically inversely proportionate to their areas.

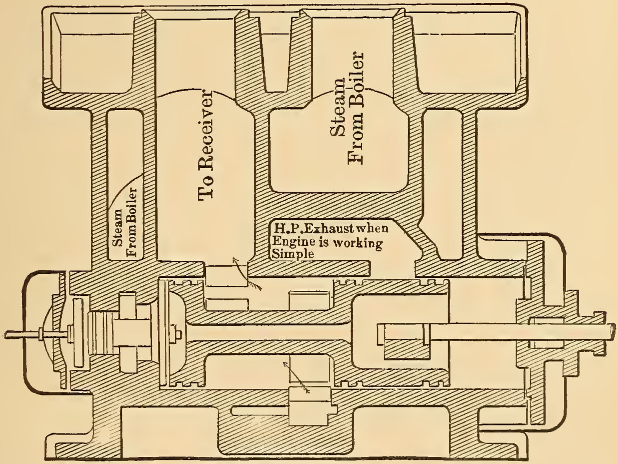


Fig. 217. Pittsburg (Colvin-Wightman) Compound, Working Compound.

Q. When working compound, what is the position of the reducing-valve?

A. In the forward position, as shown in figure 217, so as to cut off live steam from the receiver and the exhaust-pipe from the high-pressure cylinder to the independent exhaust-nozzle, and send the high-pressure exhaust into the receiver.

Q. When working "simple" (or non-compound) where does the exhaust from the high-pressure cylinder go?

A. Through an independent exhaust-passage and nozzle, as in figure 216.

Q. Can the engine be run either compound or non-compound at will of engineman?

A. Yes. The position of the intercepting-valve regulates that; and the change from either to the other can be made either when the engine is standing or when it is running at speed.

Q. What are the relative horse-powers of the two sides, working compound at five miles per hour, when the cylinder-ratio is 1 to 2.3?

A. Under certain conditions 52 per cent. of the horse-power is in the low-pressure cylinder.

Q. What are the relative horse-powers of the two sides, working compound at 20 miles per hour, when the cylinder-ratio is 1 to 2.3?

A. Under the same conditions of pressure etc., as in the last answer, 52½ per cent. of the horse-power is in the low-pressure cylinder.

Q. What are the relative horse-powers of one of these engines with a cylinder-ratio of 1 to 2.3. when working simple and when working compound at a speed of five miles per hour?

A. Under certain conditions, 24 per cent. more horse-power when working simple than when working compound.

Q. What are the relative horse-powers with cylinder-ratio 1 to 2.3 when working simple and when working compound, at 20 miles per hour?

A. It is not practicable to run this compound at 20 miles per hour as a simple engine.

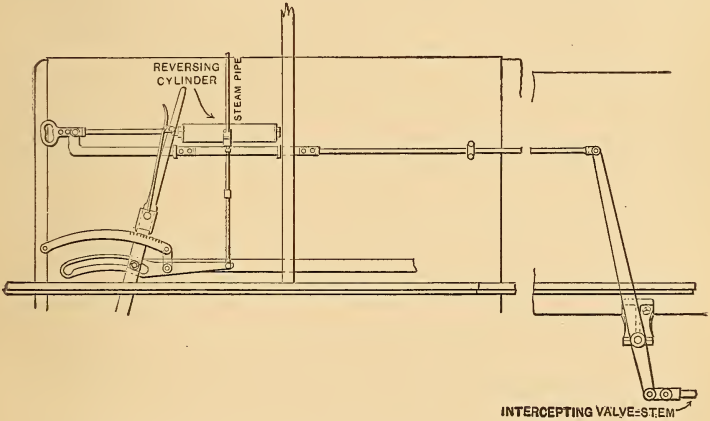


Fig. 218. Reversing-device, Pittsburg (Colvin-Wightman) Compound.

Q. Describe the reversing device in the cab?

A. As shown in figure 218 there is an air or steam reversing-cylinder actuated by the reversing lever as follows: when the lever is down, or at full stroke, at either end, the intercepting-valve is in the position indicated by figure 216, permitting admission of live steam to the receiver; but the moving of the reverse-lever one or more notches opens a valve which admits pressure to the reversing-appliance, and the intercepting valve is moved to the position shown by figure 217. The dropping back of the lever to full stroke again changes the valve, and the engine is thrown into simple as before.

Q. With this attachment can the engine be worked simple at early cut-offs, or compound at late cut-offs?

A. No.

ACCIDENTS WITH THE R. I. LOCOMOTIVE WORKS COMPOUND.

Q. What should be done in case of a broken low-pressure valve-rod?

A. Block the valve on that side, in the center; open the receiver exhaust-valve to the exhaust-nozzle; run with the high-pressure side after disconnecting the low-pressure main-rod, as in a simple engine.

Q. In this case, why would not the live steam from the reducing-valve escape into the receiver and thence into the air?

A. Because there would be no pressure in the receiver, as the live steam would be held in the low-pressure steam-chest.

Q. What should be done in case of a broken or disconnected low-pressure main-valve?

A. As for a broken valve-rod.

Q. With a broken high-pressure valve-rod or main-rod, what should be done?

A. The high-pressure steam-valve should be blocked in the center of the seat to cover all ports; and the engine run with the low-pressure side only.

Q. How does the live steam get to the low-pressure chest in this case?

A. Through the reducing-valve and intercepting-valve, the latter of which will hold the steam in the low-pressure chest.

Q. In case of broken or cracked piston-head of the intercepting-valve which closes the receiver to the low-pressure chest, how could the engine be run?

A. By removing the back head of the intercepting-valve oil-cylinder, blocking the intercepting-valve in the compound position, and replacing the head.

Q. Why could not the receiver exhaust-valve be opened in this case and the engine run high-pressure?

A. Because the hole in the intercepting-valve would permit live steam to escape to the air through the low-pressure chest.

Q. What would happen if the middle piston-head of the intercepting-valve was broken out or cracked?

A. The live steam would put the intercepting-valve into the compounding position, closing the receiver, letting live steam to the low-pressure cylinder, and putting a heavy back-pressure against the high-pressure piston-head.

Q. How could this back-pressure be overcome?

A. By opening the receiver exhaust-valve, closing the intercepting-valve, and running high-pressure.

Q. Why should the intercepting-valve be closed in this case?

A. To keep live steam from passing through the receiver into the exhaust-pipe.

Q. In case of a broken or cracked receiver, what should be done?

A. The receiver-exhaust should be opened and the engine run high-pressure.

THE RICHMOND (MELLIN) COMPOUND.

Q. Describe the intercepting arrangements of the Richmond Locomotive & Machine Works (Mellin) two-cylinder compound engine?

A. As shown in figures 219 to 222 inclusive, there is an intercepting-valve, I V, a reducing-valve, R V, and an emergency-valve, E V; all in the same axial line.

The intercepting-valve I V, which is of the unbalanced double-poppet type, controls the passage of steam to the low-pressure cylinder from the receiver R. It bears on its stem a piston P which plays in a dash-pot to prevent slamming; also a sleeve R V, serving as a reducing-valve.

This latter has lengthwise motion on the stem of the intercepting-valve, while playing steam-tight in a bored cavity T as well as on the stem of the intercepting-valve I V. It has on the end next the intercepting-valve an enlarged portion which plays steam-tight in an enlarged bore Q. The function of this reducing-valve R V is to admit live steam at reduced pressure from the passage C (which is in connection with the dry-pipe) to the low-pressure cylinder through the passage G.

The emergency-valve E V is a plain, bevel-seated wing-valve, controlling an opening to the main exhaust from a chamber J, which is in communication with the receiver through small holes J in the small

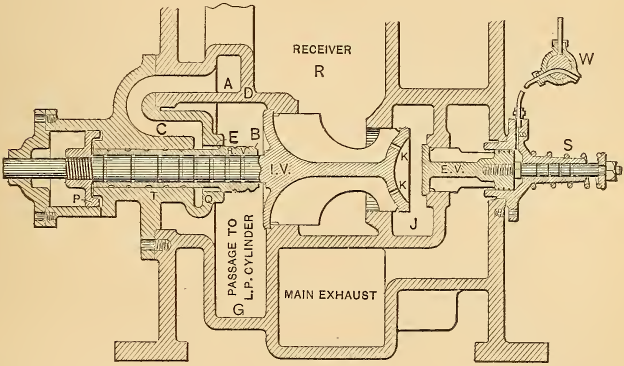


Fig. 219. Richmond (Mellin) Compound. Position in Starting at Maximum Pressure in Steam-Chest.

disk of the intercepting-valve I V. The emergency-valve is normally closed to the main exhaust by a spring, aided by the receiver-pressure in J. It may be opened by the engineman by admitting steam at full boiler pressure through the three-way cock W, in the cab.

Q. Where is the receiver?

A. In the smoke-box.

Q. What is the action in starting automatically?

A. Steam from the boiler goes to the high-pressure cylinder in the ordinary way; also to the port C through a $2\frac{1}{2}$-inch steam-pipe connected with the dry-pipe. When the throttle is opened, there is no pressure in the receiver R, and the pressure on the

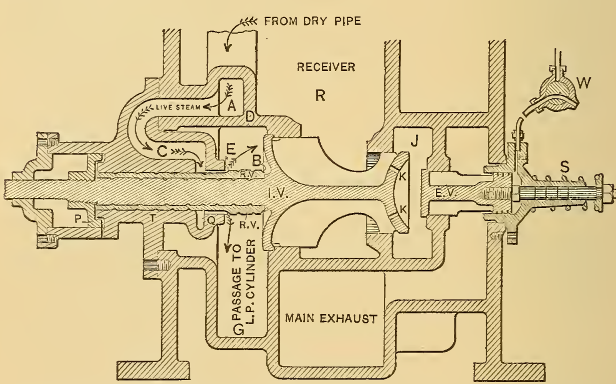


Fig. 220. Richmond (Mellin) Compound. Position in Starting Automatically.

shoulder E of the reducing-valve RV moves the reducing-valve, and with it the intercepting-valve, to the right (as shown in figure 219), closing the receiver R, and letting reduced-pressure steam into the low-pressure steam-chest G.

The end B of the sleeve RV being about twice that of the shoulder E, half of the boiler-pressure then moves this sleeve to the left, cutting off the access of steam from port C and equalizing the total pressure on the two pistons, by giving the low-pressure piston a proportionately lower pressure per square inch. At say $1\frac{1}{2}$ revolutions pressure which has accumulated in the receiver R, by reason of the exhaust from the high-pressure cylinder, acts on the large face of the intercepting-valve IV, and moves it to the left, as shown in figure 221, carrying with it the sleeve or reducing-valve RV, and thus opening a straight connection between the high-pressure exhaust-passage and the low-pressure steam-chest, while permanently cutting off live steam from the port C.

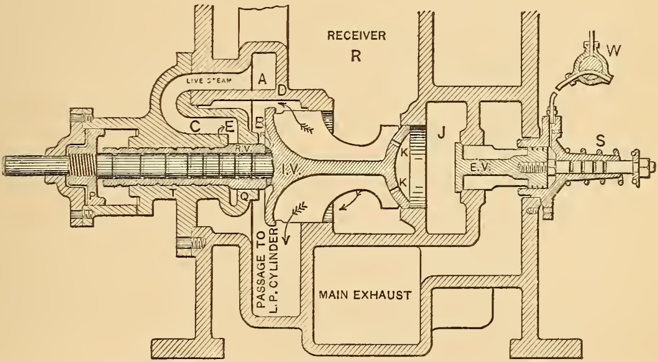


Fig. 221. Richmond (Mellin) Compound. Position in Working Compound.

Q. What is the action in starting on grades, or elsewhere running with maximum power?

A. The engineman opens the three-way cock W, admitting steam behind the piston on the emergency-valve EV, and holding it open against its spring S. This permits exhaust of the cavity J; and the intercepting-valve IV, being then unbalanced, moves (taking with it the sleeve reducing-valve RV) to the right; being aided in this by the steam-pressure on the shoulder E of the sleeve. This gives the high-pressure cylinder a separate exhaust around the end of the intercepting-valve IV, through the emergency-valve EV, into the main exhaust-passage ; the intercepting-valve IV remaining closed, as there is no accumulation of pressure in the receiver R.

Q. In this case, whence does the low-pressure cylinder receive steam, and at what pressure?

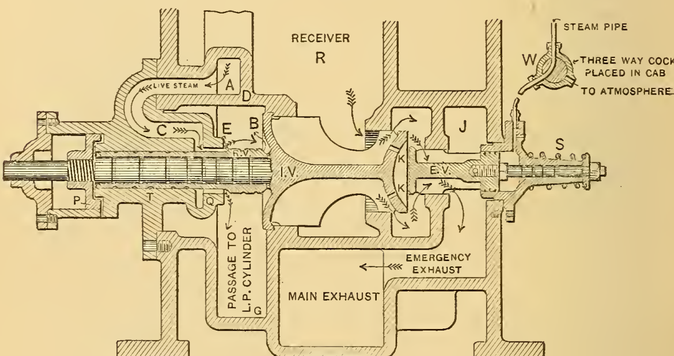


Fig. 222. Richmond (Mellin) Compound, Working Single-Expansion.

A. It gets reduced-pressure steam direct from the boiler through the port C and reducing-valve RV, as shown in figure 222.

Q. What are the relative horse-powers of the two sides or cylinders, when working compound, at say five miles per hour?

A. With cylinder areas in the ratio of 1 to $2\frac{1}{2}$ about the same in both cylinders.

Q. What are the relative horse-powers of the two sides at twenty miles an hour, working compound with cylinder-ratio of 1 to 2½?

A. About the same in both cylinders.

Q. What are the relative horse-powers of one of these engines with a cylinder-ratio of 1 to 2½, when working simple and compound, at a speed of five miles an hour?

A. At that speed the horse-power should be about 30 per cent. more simple than compound.

Q. What are the relative horse-powers with cylinder-ratio of 1 to 2½, when working simple and compound, at twenty miles per hour?

A. The builders state that with present proportion of emergency exhaust running compound should give about double the horse-power developed than that when running simple, at that speed.

"The percentage of work done in the high-pressure cylinder in running compound varies slightly with the variations of speed and other circumstances as to load and condition of track. For instance, at 20½″ cut-off there was a variation of work in the H.-P. cylinder from 48.5 to 50.1 per cent. at a varying speed of from 38 to 90 turns, averaging 49.12 per cent.; and at 18¾″ cut-off there were cases of 52.3 per cent. at 78 turns; 51.3 per cent. at 198 turns; 51.8 per cent. at 90 turns; 49.4 per cent. at 108 turns, and 49.93 per cent. at 156 turns, which practically makes an average of 50 per cent. The tendency seems to be that the percentage of work done in the H.-P. cylinder falls slightly with the earlier cut-offs."*

*Letter from C. J. Mellin, M. E., Sept. 5, 1895.

ACCIDENTS TO THE RICHMOND (MELLIN) COMPOUND.

Q. What should be done where it would be required to run a Mellin compound with one cylinder?

A. Block the slide-valve on the disabled side in its central position and open the emergency-valve, and the engine will run one-sided as a simple engine under similar circumstances.

Q. If the accident should occur on the low-pressure side (the high-pressure side being disabled), would it be necessary to open the emergency-valve?

A. No, but it simplifies the rule, and the emergency-valve is in that case perfectly ineffective, either open or closed, except that, when open, it prevents unnecessary accumulation of pressure in the receiver in case of leaking balance strips, etc., of the high-pressure valve.

ACCIDENTS WITH THE SCHENECTADY COMPOUND.

Q. In case of breakage or disconnection of the high-pressure main-rod, what should be done?

A. The valve on that side should (if the steam-chest is large enough, which it is not in some older engines of this type) be put ahead to clear the exhaust-port, and the piston blocked in the forward cylinder-end. Where the steam-chest is small, and the Allen valve is used, high-pressure steam may pass into the exhaust through the Allen port if the valve is moved to extreme position. Where neither of these plans can be used, the high-pressure valve can be placed to cover all ports. The engine should also be run with the throttle partly closed.

Q. Where will the intercepting-valve then remain?

A. In starting position; supplying steam to the low-pressure cylinder through the poppet valve.

Q. What would be the course of the steam in this case?

A. Through the high-pressure exhaust-port into the receiver, and thence to the low-pressure chest; causing the low-pressure cylinder to act high-pressure.

Q. When the low-pressure cylinder of a Schenectady compound is running high-pressure, what care should be taken?

A. Not to open the throttle suddenly.

Q. What should be done in case of breakage or disconnection of the low-pressure main rod of a Schenectady compound?

A. The piston-head should be blocked in the back end of the cylinder, the low-pressure valve should, if the chest is long enough, be moved back to clear the exhaust-port and cover the back port.

In some cases the valve will not move back enough on all engines to open the exhaust-port. When Allen valves are used the exhaust may pass through the Allen port, but in other cases it may be necessary to take off the forward cylinder-head and exhaust through the front steam-port, or to unscrew the relief-valve in front of the cylinder-saddle and exhaust through the hole thus made.

Q. If either of these methods must be used, how could steam be maintained?

A. With the blower; and the engine could take only a small load.

Q. How could a free exhaust be obtained in all cases?

A. By taking out the low-pressure valve; but this would involve too much work under ordinary circumstances.

Q. Why should the exhaust-port be left open?

A. To give the high-pressure exhaust an outlet.

Q. When a valve-rod breaks on a Schenectady compound, what should be done?

A. The same as for a broken main-rod on that side; and the main-rod should be disconnected and the crosshead blocked.

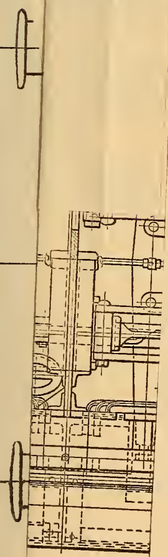
Q. In case the intercepting-valve of a Schenectady compound had its back head broken out, could the engine be run compound?

A. Yes, because the steam in the intercepting-valve cylinder could not move the valve to the starting position, and the high-pressure exhaust would hold it in compound position.

Q. In this case would steam escape from the intercepting-valve cylinder?

A. No, unless the lever in the cab was in starting position.

Q. Could high-pressure steam be used in both



N. W. R

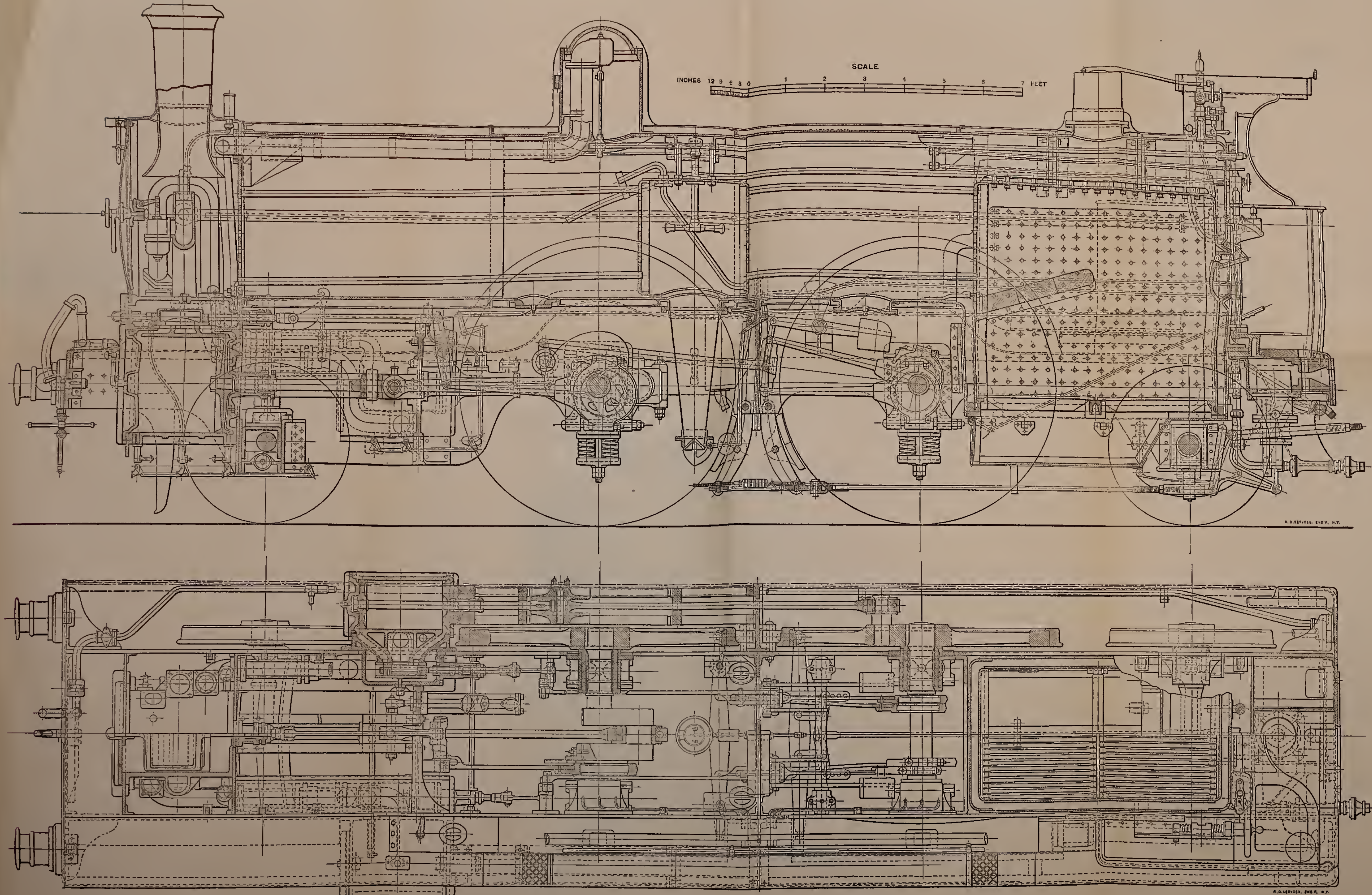
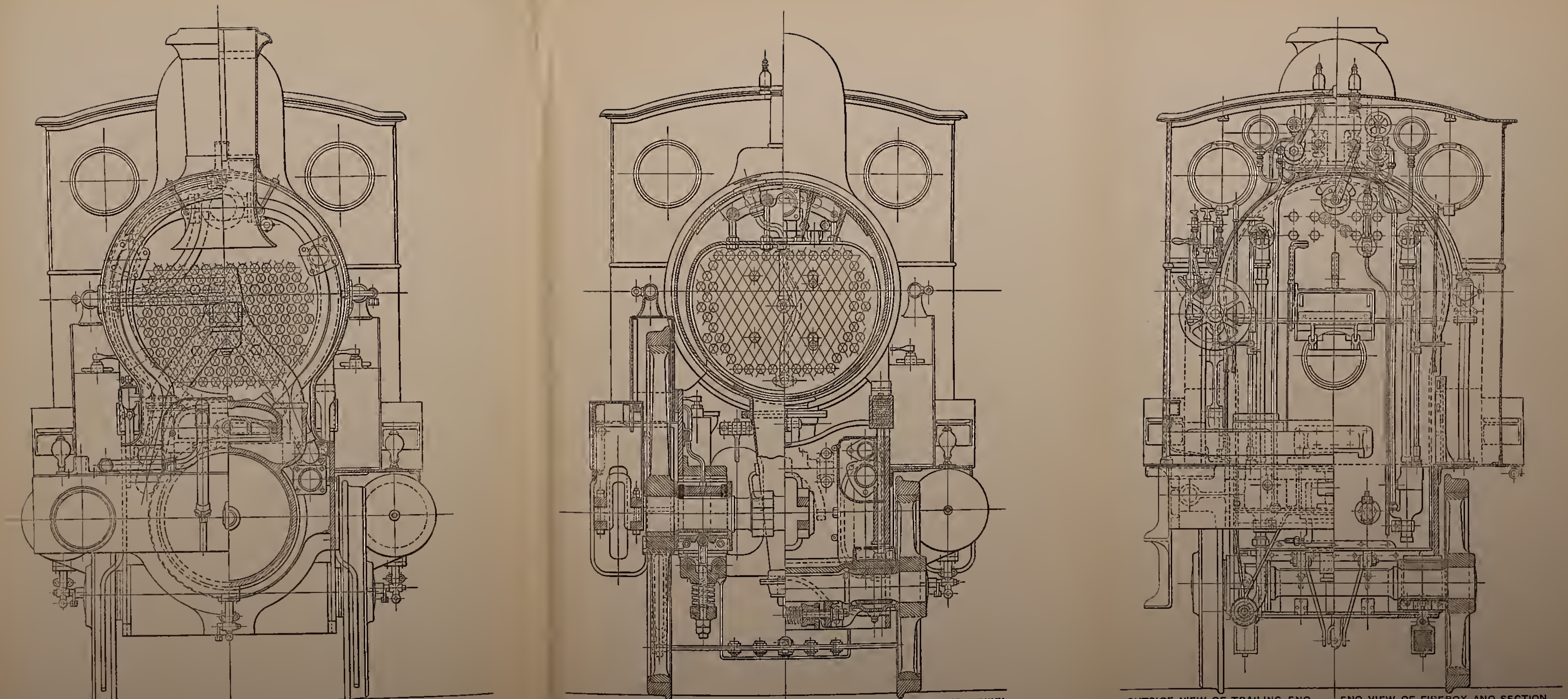


Plate XI. Seven-foot "Webb" Eight Wheeled Compound Passenger Locomotive, L. & N. W. Ry.

Firebox, ...	120.6	sq. ft.
Comb. Chamber, ...	39.1	"
Tubes: Front, ...	875.0	"
" Back, ...	506.2	"
Total. . . .	1540.0	"

Number of Tubes—

156 Front (10 ft. 3 in. long, 2½ in. Outside Diameter.)
156 Back 6 " 0 " " 2½ in. " "



OUTSIOE VIEW OF SMOKEBOX FRONT | SECTION THROUGH L. P. CYLINOER

SECTION THROUGH L. P. ORIVING WHEEL, ANO COMBUSTION CHAMBER | SECTION THROUGH LEAOING WHEEL

CUTSIOE VIEW OF TRAILING ENO | ENO VIEW OF FIREBOX ANO SECTION THROUGH TRAILING AXLE

Plate XII. Seven-foot "Webb" Eight Wheeled Compound Passenger Locomotive, L. & N. W. Ry.

cylinders for starting, if the intercepting-valve cylinder had its back head broken out?

A. Yes, by blocking the poppet valve from its seat (before opening the throttle, of course), to let live steam into the low-pressure chest.

Q. Could a Schenectady compound be run with the low-pressure cylinder only, if the high-pressure valve covered all its ports?

A. Yes, live steam could pass through the intercepting poppet-valves into the low-pressure chest, if the lever in the cab was put in starting position, to let steam into the back end of the intercepting-valve cylinder; thus closing the receiver and holding the poppet open.

Q. Why in this case will not the intercepting-valve open and close the poppet?

A. Because there would be no steam in the receiver.

Q. How else than by blocking could the poppet be held open so as to let live steam into the low-pressure chest?

A. By removing the intercepting-valve cylinder back head, blocking the piston-head in the forward cylinder-end, and replacing the head; or by doing the same thing with the small piston which moves the valve, admitting steam to the intercepting-valve cylinder.

Q. What should be done in case of breakage of both high-pressure cylinder-heads of a Schenectady compound?

A. Put the high-pressure valve in the position to cover all its ports; disconnect on that side.

Q. What should be done when a front head is broken out, taking with it a piece of the seat between the steam-port and the front?

A. The same as when both cylinder-heads are broken out.

Q. What should be done with the valves when running with low-pressure cylinder alone?

A. The same as noted under the first question relating to accidents with this type of engine (breakage or disconnection of the high-pressure main-rod).

Q. Is there any steam in the intercepting-valve cylinder when the throttle is closed and the dry-pipe empty?

A. No.

Q. Suppose it is desired to run a Schenectady compound high-pressure for some time after starting, as on an up-grade?

A. Schenectady compounds cannot be run high pressure, except for a revolution or so at starting. Shifting the lever in and out of starting position, although it would admit some live steam to the low-pressure cylinder, would also close the intercepting-valve and block the high-pressure cylinder, unless a separate exhaust-valve were used; and there would probably be no gain in power over compound working.

MISCELLANEOUS.

Q. In a tandem compound engine, where the exhaust from a high-pressure cylinder passes into a low-pressure cylinder, what is the effective pressure on the piston?

A. In pounds per square inch it is that due to the degree of expansion of the steam; but it is counteracted in some measure by the pressure on what is at that moment the exhaust side of the high-pressure piston; that is, if it is the forward stroke and there is a pressure on the back of the low-pressure piston, there will be one on the front of the high-pressure piston; so that the total pressure on that side of the engine will be found by adding the pressures on the backs of the two pistons and taking from the sum the sums of the back pressures on the front sides of the two pistons.

Q. How may these pressures be calculated for a high and a low-pressure cylinder, when the pressure per square inch on each side of each piston is known?

A. By multiplying the area of each piston in square inches by the pressures on its front and back respectively (thus getting four products); then adding the two products on the front faces and the two on the back faces, and taking the difference between the sums.

Q. What is the difference between the four-cylinder and the two-cylinder engine, as regards the method of handling the exhaust?

A. In the two-cylinder engine the steam goes into a receiver in the front end and is there heated, thus utilizing some of the otherwise waste heat of the combustion-gases.

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 high-pressure cylinder; the walls of the low-pressure cylinder not having a much lower temperature at the moment of expansion of steam than those of the high-pressure.

Consult also Index to Appendix A and B, beginning on page 435.

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TO

APPENDIX A and B

CONSULT ALSO INDEX BEGINNING ON PAGE 417.

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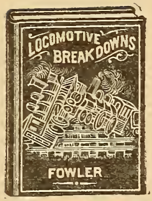

LOCOMOTIVE BREAKDOWNS
FOWLER