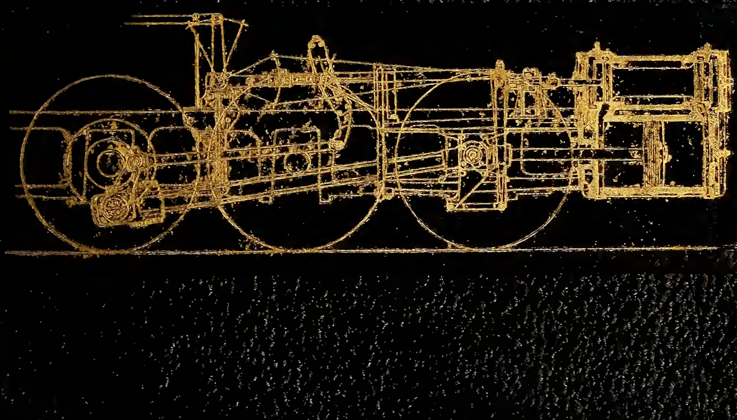
WALSCHAERT VALVE GEAR BREAKDOWNS AND HOW TO ADJUST THEM

SWINGLE



Walschaert Valve Gear

BREAKDOWNS

AND

HOW TO ADJUST THEM

BY

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THE WALSCHAERT VALVE GEAR.

INTRODUCTION.

Egide Walschaert, the designer of the valve gear that bears his name, worked like Watt, Stephenson, and other great inventors to solve the problem for future generations. He produced his invention in the year 1844 when the locomotive was yet in its infancy as compared with modern practice. He wrought much better than he knew, for his work now fulfills a need that did not really exist at the time, but his gear today appears to be almost indispensable to meet the conditions which have arisen in consequence of the development of the locomotive.

It is altogether fitting, therefore, that a short historical sketch of the man, and his work, be inserted in this connection, as it will prove to be not only interesting, but helpful to the student. The author desires also to acknowledge his indebtedness to Mr. Carl J. Mellin, Consulting Engineer from the American Locomotive Company, for valuable information, diagrams, etc., pertaining to the Walschaert valve gear. The author is also under obligations to the Baldwin Locomotive Works, and the American Locomotive Company for descriptive details, cuts, etc., relative to the design, construction and operation of this valve gear.

HISTORICAL.

The following is a history of Walschaert and his valve motion by Prof. M. J. Boulvin of the University of Ghent, which was published in the *Railroad Gazette* of November 24, 1905, and is here reproduced by permission of that journal.

Egide Walschaert died on the 18th of February, 1901, at Saint-Gilles, near Brussels, at the age of eighty-one years. His mechanism, which is so original, has been adopted for many years in most of the countries of Europe and has been wrongly attributed to Heusinger von Waldegg. He was born January 21, 1820, at Malines, which place became, fifteen years later, the central point of the System of Belgian Railways. The line from Brussels to Malines was opened in 1835, and this event decided the career of young Walschaert. Three years later, at the exhibition of products of Malines, there appeared some remarkable models executed by him, and described as follows in the catalogue:

No. 19. M. E. Walschaert, Jr., student of the Municipal College.

a. A stationary steam engine of iron (the main piston having the diameter of 4.5 c. m. or 1.77 in.).

b. A working model of a locomotive in copper to the scale of 1/20 of the railway locomotives.

c. Section of a stationary steam engine.

d. Model of a suction pump and a duplex pump.

e. Glass model of an inclined plane.

Minister Rogier was so much struck by it that he had Walschaert enter the University of Liege, but his studies were interrupted by a serious illness, and were never completed. We find traces of him at the National Exhibition in Brussels in 1841. The report of the jury mentions with praise a small locomotive constructed entirely by Walschaert, and a steamboat 6.50 meters long and 1.75 meters wide, which was capable of carrying sixteen men and traveling (so the report says) at four leagues an hour on the canal.

The boiler of this little boat was of a new system invented by the constructor. The jury does not give further details. Walschaert received the silver medal.

In 1842 Walschaert was taken into the shops of the State Railway at Malines as a mechanic. Machine tools existed only in the most rudimentary forms, and the storerooms were badly provisioned. The lack of organization in the shops rendered a man of Walschaert's abilities particularly valuable, and at the end of two years he was made shop foreman at Brussels. Although he was only twenty-four years of age he had already shown the qualities which make an engineer, which should have carried him in a few years to be the technical head of the motive power department. It is humiliating to be compelled to say that he remained shop foreman throughout his life.

The first locomotives came from England and had not been in service for more than ten years when Walschaert was made foreman. The railroad was growing rapidly and it was necessary to increase the forces and to acquire experience. Walschaert was not content with the duties incurred in these difficult circumstances, but began his career by the invention of his system of valve motion.

On October 5, 1844, Mr. Fischer, Engineer of the Belgian State Railways, filed for Egide Walschaert an application for a patent relating to a new system of steam distribution applicable to stationary steam engines and to locomotives. The Belgian patent was issued on November 30, 1844, for a term of fifteen years. The rules of the department did not allow a foreman to exploit a Belgian patent for his own profit and this explains probably the intervention of Mr. Fischer, who has never claimed the slightest part, material or moral of the invention.

On October 25th, of the same year, Walschaert took out a patent in France for the same invention. There also exists among the documents left by the inventor, a contract signed at Brussels in 1845 by Demeuldre, from which it appears that he undertook to obtain a patent of importation into Prussia for the new valve motion, subject to an assignment by Walschaert of half of the profits to be deducted from the introduction of the new valve motion in this country. It is probable, however, that this contract was never carried out.

The design attached to the Belgian patent is reproduced in Figure 1. In this primitive arrangement the link oscillated on a fixed shaft, in regard to which it was symmetrical, but it had an enlarged opening at the center so that only at the ends was it operated without play by the link block, which was made in the form of a simple pin. There was one eccentric, the rod of which terminated in a short T carrying two pins. The reverse shaft operated the eccentric rod and maintained it at the desired height. For one direction the lower pin of the T engaged in the lower end of the link, and to reverse the engine the rod was raised so that the upper pin engaged in the upper end of the link. The angle of oscillation of the link varied with the position of the pin in the link, and this oscillation was trans-

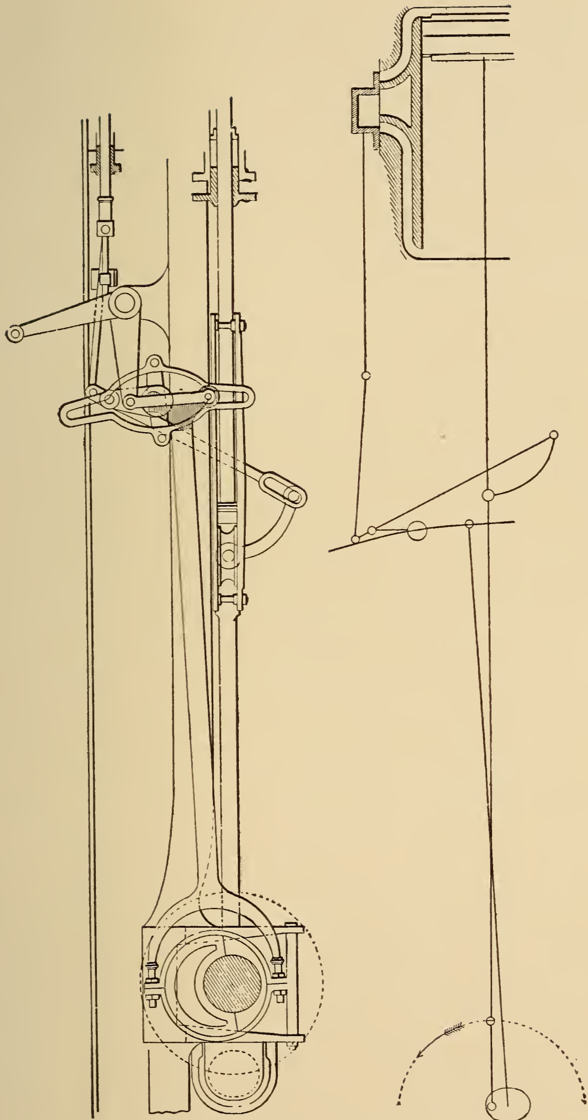


FIGURE 1. ORIGINAL DESIGN OF THE WALSCHAERT VALVE GEAR.
Patented 1844.

mitted by an arm to the combining lever, which was also operated by the crosshead.

The central part of the link could not be used for the steam distribution, as it was necessary to enlarge it to allow for the plan of the pin which was not in operation. It may be asked why the inventor used two separate pins mounted on a crosspiece on the end of the eccentric rod instead of a single pin on the center of the rod which would have served for both forward and backward motion without requiring the center enlargement of the link. It must be borne in mind that the raising or lowering of the eccentric rod by the reverse shaft was equivalent to a slight change in the angular advance of the eccentric. Consequently with a link of a sufficient length to keep down the effect of the angularity it was necessary to reduce as much as possible the movement of the eccentric rod. Notwithstanding its differences the mechanism described in the patent of 1844 is in principle similar to the valve motion with which every one is today familiar and which the inventor constructed as early as 1848, as is shown by a drawing taken from the records of the Brussels shops, on which appears the inscription: "Variable Expansion; E. Walschaert's system applied to Locomotive No. 98, Brussels, September 2, 1848."

Figure 2, taken from this drawing, shows the valve motion as we know it today. For although it is true that the link and the combining lever are usually placed in a different position so as to shorten the eccentric rod and the valve stem, yet the design of the locomotive often requires an arrangement similar to that shown in Fig. 2. The system which Hensinger von Waldegg invented in 1849, and which he applied in 1850 to 1851, differs only in a few insignificant particulars from

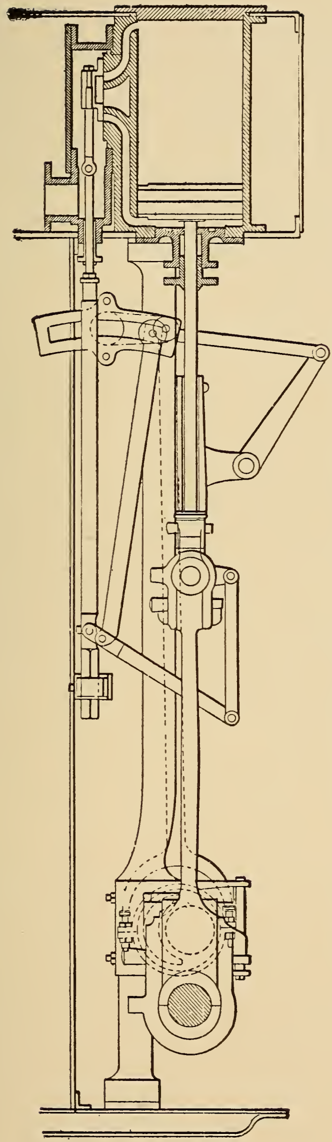


FIGURE 2. THE WALSCHAERT VALVE GEAR—IMPROVED DESIGN.
Patented 1848.

that shown in Fig. 1. Walschaert had therefore preceded him. There are at the present time many systems of steam distribution, and the progress made in kinematics has greatly facilitated their development.

At the time, however, of Walschaert's work there was but one system of valve motion that was at all extensively used, viz., that of Sharp, with two eccentrics having forked rods. The link credited to Stephenson was invented by Howe in 1843, and it is doubtful whether Walschaert had ever seen it.

A problem which nowadays appears very simple was, for the investigators of that time, extremely complicated, and the man who discovered the most correct solution, which has yet been put forward, certainly merits honorable mention and unreserved admiration. Notwithstanding his arduous work at the Brussels shops, where he built, with limited facilities, several new locomotives, Walschaert did not lose sight of the problem of steam navigation.

The records show that he appeared at the National Exposition at Brussels in 1847 with a screw yacht that proved to be a success. The propeller had several blades, each one with only a small part of the thread similar to those of the modern screws. Walschaert had invented this arrangement himself, without knowing of the results obtained by Normand with the Corse in 1841 or 1842. Locomotive practice had taught him the intimate correlation which should exist between the engine and the boiler and in this machine he made use of a boiler of high power which attracted much attention. A similar machine was built a little later by the Couillet Co., as is shown by the plan drawn up in 1853. This machine is compact and light. The documents which remain do not mention the pressure or the speed. It was non-condensing, and in all probability the exhaust steam assisted the draft.

During the years which followed, Walschaert's activity was given entirely to his duties as foreman and it is difficult to determine his part, which was valuable though anonymous, in the design of the railroad equipment. He is credited with the differential throttle in which the opening of an auxiliary slide on the back of the main slide assisted the opening of the valve. He also designed a brake with shoes acting on the rails which was used for a long time in switching locomotives and in which the principle of a lever acting near its dead point was applied in an ingenious manner.

It was very remarkable that his initiative spirit did not suffer from his long services under an administration with so much complicated routine. It is possible that he found a stimulant in the adoption of a large number of his ideas by the Great Central Belgian Railway and in encouragement which, without making him rich, kept his intelligence on the alert. He took an important part for many years in the design of the motive power of this railroad, which was rendered the more difficult by reason of the difficult profile of the lines terminating in Charleroi and by the heavy traffic to be handled. The design of the freight locomotives for heavy grades, built in 1862 for the Great Central, belongs entirely to Walschaert. The company built more than one hundred locomotives from the original plans without making any important alterations. These locomotives have not been without their influence on the Belgian shops in which they were built. They have left behind them traditions of which traces are found in a large number of engines exported to various countries of Europe.

GENERAL DESCRIPTION.

The Walschaert valve gear differs from the Stephenson link motion in that it requires for each cylinder but one eccentric or its equivalent, to insure the movement of the valve, and the proper distribution of the steam for both forward and backward motion. The elimination of the heavy eccentrics and their connections relieves the axle of an appreciable portion of its dead weight. It also makes it possible to place the gear outside the driving wheels in a more accessible position, where the parts can readily be oiled, inspected and repaired.

While it may not be possible to adjust the valve as readily with the Walschaert gear as with the Stephenson motion, for the reason that the parts and connections are not as susceptible to change, it is not as liable to become disarranged, and if correctly designed and fitted up will give accurate results with less difficulty in application and greater economy in construction.

Equal cut-offs in both ends of the cylinder are more easily secured than with the Stephenson motion, and the play of the engine on its springs has practically no influence on the steam distribution.

In the Walschaert valve gear the operating eccentric is secured to the driving axle either directly or by a return crank from one of the crank pins.

The position of this eccentric or crank is such as to give the proper valve travel, the throw corresponding with the movement of the valve irrespective of its lap and lead; the angular advance of the eccentric being 0°.

The link is of any convenient form and is usually pivoted to a support on the engine frame or suspended from the guide bearer. The trunnion is rigid and there is no chance for twisting strains. The link is actuated by the eccentric rod which is commonly attached to its lower extremity. The sliding block in the link is secured to one end of the radius rod. The raising or lowering of this rod by means of the reversing shaft, shifts the block from one end of the link to the other above or below the pivotal connection; this reverses the movement of the valve with relation to that of the eccentric.

In many cases the gear can be so designed that the motion is transmitted from the eccentric to the valve stem in one vertical plane so that practically all of the pins can be put in double shear, and all tendency to twist the valve motion is avoided. In some cases (see Fig. 11) it is necessary to have the eccentric and the valve stem in different vertical planes. In such cases some form of rock shaft is necessarily employed to transfer the motion from one plain to the other and give the required solidity to the gear. It is sometimes urged against the Walschaert motion that it requires more moving parts than the Stephenson. This is, however, offset by the better opportunities for solid construction and ready inspection and adjustment.

The end of the radius rod opposite the link is attached to a combining lever, the function of which is to give the required lap and lead to the valve. The lower end of this lever is connected to and travels with the crosshead, while to the upper end is secured to both the valve rod and the radius rod, one being placed above the other. The point at which the radius rod is attached to the combining lever becomes a fulcrum. The relative movement of the two ends of the lever must be such that the full movement of the crosshead imparted to the lower end of the lever will give a movement of the upper end equivalent to twice the required lap plus the lead.

Under ordinary conditions with steam chest valves having outside admission, the connection or fulcrum between the radius rod and the combining lever is placed below the valve rod connection. With valves having inside admission, this fulcrum is usually placed above the valve rod connection as shown in Fig. 3.

The link should have a radius equal to the length of the radius rod. If this is so it will be seen that when the engine is on the dead center the link block can be moved from end to end of the link without altering the position of the valve with relation to the ports and the lead will be constant.

As any variation in the length or relative position of the link, the radius rod, and the combining lever or its connections, will necessarily change the resulting movement of the valve; it is absolutely essential, first, that the motion shall be correctly designed and plotted, and second, that the detail parts shall be accurately constructed according to the diagram. With these two points assured the adjustment of the gear on the locomotive is quite simple. The dead center marks on the rim of the driving wheel and the port tram marks on the valve stem are found in the usual manner. After connecting the gear any slight variation which may occur between the forward and backward position of the valve can be adjusted by lengthening or shortening the eccentric rod.

The size and arrangement of parts in a modern locomotive make it difficult for an engineer to properly examine the eccentrics and link motion when the engine is on the road, and breakdowns are more frequent on this account. The conditions of service also tend to

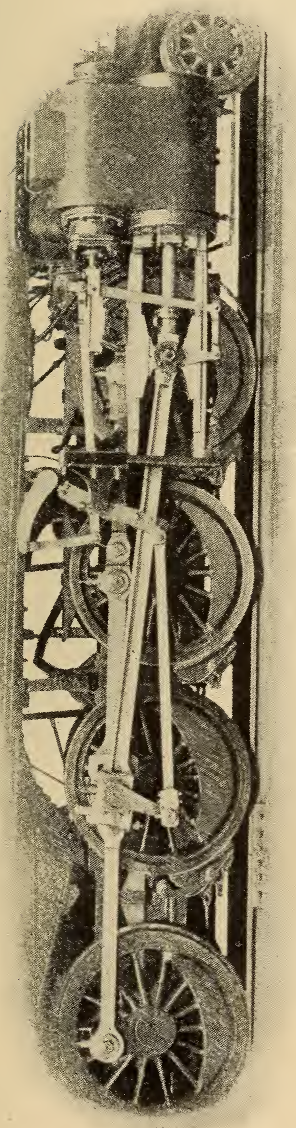


FIGURE 3. WALSCHAERT'S VALVE GEAR AS APPLIED TO CONSOLIDATION LOCOMOTIVE FOR THE PENNSYLVANIA RAILROAD.
Baldwin Locomotive Works.

make it more and more difficult for the engine man to give the close inspection and care which is demanded in other branches of engineering service with high speed machines. Stationary engine practice may serve as a guide to those responsible for the successful operation of locomotives, which are even to a greater extent than stationary engines, high speed machines. With the Walschaert valve motion only a single eccentric or its equivalent is necessary for each valve. As usually constructed it is found more convenient to substitute a return crank, thus reducing the pin bearings to the smallest possible diameter, so that they may be readily lubricated, and, owing to the small amount of work they have to do, give satisfactory service and absolute freedom from heating.

So far as the distribution of steam in the cylinders is concerned, the constant lead, which is a feature of this motion is not considered objectionable, and it has some distinct advantages. Under such conditions it is possible to determine the amount of lead the engine should have at the most economical point of cut-off. This point determined, and so designed, it cannot be altered by anyone in the shops or roundhouses. Another advantage is that it prevents valve setters from attempting to produce results by moving the eccentrics into improper relations one to another.

The constant lead of the Walschaert motion prevents the sealing of the cylinders by the piston valve when the piston is at the end of its travel or approaching it. Whereas with the link motion, either by derangement or excessive wear, the valve laps the ports at the end of the stroke, thus causing excessive compression and many other troubles.

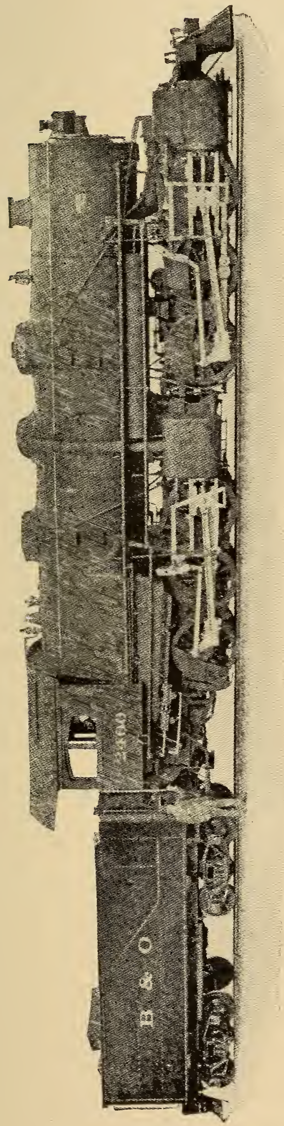


FIGURE 4. MALLET ARTICULATED COMPOUND FREIGHT LOCOMOTIVE WITH WALSCHAERT VALVE GEAR.

Built for Baltimore & Ohio Railroad. (American Locomotive Co.)

Another feature of the motion which appeals to the engineer is the ease of handling the reverse lever when the locomotive is running at a high rate of speed.

Table I.—General Dimensions.

Freight Locomotive—Mallet Compound, with Walschaert Valve Gear Built for Baltimore & Ohio Railroad by the American Locomotive Company.

Gauge of track, 4 feet 8½ inches

Loaded Weights

On driving wheels	334,500 pounds
Total engine	334,500 pounds
Tender	143,000 pounds

Wheel Base

Driving	10 feet and 10 feet
Total of engine	30 feet 8 inches
Total of engine and tender	64 feet 7 inches

Cylinders

Diameter	20 inches and 32 inches
Stroke of piston	32 inches
Valves	H. P. piston, L. P. slide

Wheels

Diameter of driving wheels, outside	56 inches
Diameter of tender wheels	33 inches

Journals—Diameter and Length.

Driving	9x13 inches
Tender	5½x10 inches

Type, 0660 C 334, Mallet Articulated

Boiler.

Type	Straight Top, Radial Stay
Outside diameter at front end	84 inches
Length of fire-box, inside	108 inches
Width of fire-box, inside	96 inches
Number of tubes	436
Diameter of tubes	2¼ inches
Length of tubes	21 feet
Working pressure per square inch	235 pounds
Heating surface in tubes	5,366.3 sq. feet
Heating surface in fire-box	219.4 sq. feet
Total heating surface	5,585.7 sq. feet
Grate area	72.2 sq. feet

Tender Capacity

Water	7,000 gallons
Fuel	15 tons

Clearance Limitations

Height of stack above rail	15 feet
Width	10 feet 5 inches
Length over all	79 feet 6½ inches

Maximum tractive power, 71,500 pounds working compound.

DETAILS OF CONSTRUCTION.

Having presented a general description of the Walschaert gear, together with a few of the advantages to be derived from its use, it is now in order to consider it more in detail. Valve gear has not improved proportionately to the improvement of other factors in connection with locomotive development during the past twenty-five years, and it is certainly to the interest of engine men, machinists, engineers, and all others connected with the construction, maintenance, and operation of locomotives, to familiarize themselves with a valve gear that offers so many mechanical and structural advantages over the Stephenson motion as does the Walschaert gear. The facts are that this valve gear has become almost a necessity in modern locomotive practice, owing to conditions created by the demands of transportation.

The Walschaert valve gear has long been in use on the main line locomotives in Europe, about 90 per cent of the engines there being equipped with it, and American designers now turn to this gear to enable them to meet present and future conditions. The principal reasons given by the builders of American locomotives for applying the Walschaert gear to their engines, especially those of the larger types, may be summed up as follows:

(1) *Accessibility.* There is not room enough for the Stephenson gear under a very large passenger or freight locomotive. The eccentrics are crowded, and proper inspection, not to speak of proper care, is difficult, except over a pit. Valve gear to be properly maintained must be accessible for inspection and lubrication. The accessibility of Walschaert gear should reduce engine failures.

(2) *Weight.* A saving of 1,745 pounds is possible by using the Walschaert gear, in the case of a very heavy passenger locomotive (see table 2). Stephenson gear, weighing as much as two tons, is far too heavy to be satisfactorily reversed twice in every revolution on fast running locomotives.

(3) *Directness.* Walschaert gear transmits the moving force to the valve in very nearly straight lines, avoiding the springing and yielding of the rocker arms, rocker shafts and transmission bars, which cannot be avoided in these parts of the Stephenson motion, even if they are made very heavy.

(4) *Permanence of Adjustment.* The advantage of permanence of adjustment lies with the valve gear which has no large eccentrics. All connections in the Walschaert gears are made with pins and bushings, which are designed specially to resist wear.

(5) *Wear.* Large eccentrics, besides occupying too large space, wear unevenly, and lubrication is difficult with the high surface velocities of the largest sizes. With hardened pins and hardened bushings the Walschaert gear has an important advantage in maintenance.

(6) *Smooth Operation.* Stephenson links, under the influence of two eccentrics, move through wide angles, resulting in a wedging action of the link block, which strains the gear when working hard, and produces lost motion. Walschaert links oscillate through smaller angles, producing less lost motion. The effect of this angularity of the links is plainly discernible on the testing plant.

(7) *Frame Bracing.* The removal of the valve gear from between the driving wheels facilitates bracing the frames of the locomotive laterally.

The great saving in weight of the various parts of the Walschaert valve gear, as compared with the Stephenson link motion is shown in table 2.

It may be assumed that the student is familiar with the meaning of the terms lap, lead, and cut off, when used in connection with the operation of the valve, also that the principles governing the action of outside admission valves, as compared with those of inside admission, are thoroughly well understood, therefore it will not be necessary to occupy space by an explanation of these matters.

In the construction of the Walschaert gear the desired travel of the valve, the lead and the maximum cut-off which determines the lap of the valve, are selected. The stroke of the piston being given, the combination lever is proportioned so that a motion equal to the lap and lead is given to the valve when the crosshead is moved from one end of the stroke to the other. The link may be made of any approved design, and is so located that the radius bar will have a length of at least eight times (ten or twelve times is better) the travel of the link block, and the radius of the link should be equal to the length of the radius bar.

For outside admission valves the radius bar is attached to the combination lever between the valve stem and the crosshead connections, and for inside admission (piston valves) it is attached above the valve stem. The fulcrum of the link should lie as nearly as practicable upon a line drawn through the union of the radius bar and combination lever, parallel with the center line of the valve stem. The suspension point of the lifter should have a locus which causes the link block to travel as nearly as practicable on a chord of the arc described by any point of the link wherever the block happens to be when the link is swung into one of its extreme positions. This is most

TABLE 2—(AMERICAN LOCOMOTIVE CO.)

Saving in Weight with Walschaert Valve Gear—Comparative Weights, Stephenson and Walschaert Valve Gear—Lake Shore & Michigan Southern Locomotive.

Crank pins, main	520	490	390	365	440	415
Crank pin arms	...	100	...	80	...	90
Crosshead arms	...	60	...	50	...	50
Eccentric	600	...	740	...	740	...
Eccentric strap	800	...	880	...	1,120	...
Eccentric rods	200	220	200	175	280	200
Link	280	260	260	240	300	275
Link support	...	280	...	250	...	260
Link lifter	45	...	120	...	120	...
Reverse shaft and arms	260	400	350	375	385	390
Rockers	260	...	280	325	280	350
Rocker boxes	240	...	300	300	300	325
Transmission bar	300	140	270	160	300	170
Transmission bar hanger	80	72	120	65	120	75
Transmission bar bracket	...	...	...	...	200	...
Valve rod	80	70	130	100	100	100
Vibrating rod	...	220	...	180	...	180
Vibrating link	...	70	...	60	...	60
Total, lbs.	3,666	2,382	4,040	2,725	4,685	2,940
Saving in weight, lbs.		1,283		1,315		1,745

closely approached by a lifter through which the radius bar slides, and does not swing with the link. A properly suspended hanger will accomplish practically the same result, though the slip of the link bar will be somewhat more in the back than in the forward motion, but as the suspension point cannot be made to follow the theoretical locus, it should be made to do so as nearly as possible by favoring the position of the most commonly used cut-offs. In locating the longitudinal position of the link fulcrum, consideration should also be given to the length of the eccentric rod, which should have a minimum length of three and one-half times the eccentric throw, and should be made as long as circumstances will permit, with an approximately equal length of the radius and eccentric rods. The point of connection between the eccentric rod and the link should be as near the center line of motion of the main rod as this correction for rod angularities will permit, but this is often accompanied with the requirement of excessive eccentric throw. In such cases a compromise must be made to raise this point. The fore and aft position of this point relative to the tangent of the link arc must also be determined with reference to the angularity of the eccentric and main rods, so that the link is exactly in its central position when the piston is at either end of the stroke. The angles through which the link swings on both sides of its central position should be as nearly as practicable equal, but this is subordinate to other conditions. Attention should be paid to the effect of the angularity of the main connecting rod upon the cut-off, to reduce this to a minimum, this having an effect upon determining the locus of the suspension point of the lifting link as well as that of the eccentric rod connection to the link.

Walschaert gears should be correctly laid out and constructed from a diagram, as the proportions cannot be tampered with by experimental changes without seriously affecting the correct working of the device.

The only part capable of variation in length is the eccentric rod, which connects the eccentric with the link. This rod may be slightly lengthened or shortened, to correct errors in location of the link center, from center of driving axle which carries the eccentric.

The eccentric usually assumes the form of a return crank on one of the crank pins, and its center is at right angles to the plane of motion, viz.:—at ninety degrees to a line drawn from the point on the link at which the eccentric rod is attached, through the center of the driving axle. This eliminates the angular advance of the eccentric, and allows the use of a single eccentric for both forward and backward motion. The throw as specified must be correctly obtained, and great care taken that the position shown in the design be adhered to. The crank representing the eccentric is permanently fixed to the pin, and the slightest variation will be detrimental.

METHOD OF LAYING OUT WALSCHAERT GEAR.

Having presented a general outline of the gear, we may proceed in determining the more important points necessary to obtain a successful motion of the valve, and, as previously stated, the stroke of the engine is given, and the travel and lap and lead of the valve are selected to suit a desired cut-off. We have first to find the proportions of the combination lever. By designating the lap and lead with a letter C, the crank Radius with R, the crosshead end of the combination lever with *L*, and the valve end of the same with V, we have $R:C = L:V$, or $V = \frac{CL}{R}$, with the connection F of the radius bar as a fulcrum. The length of the combination lever must be determined from a height of the valve stem over the piston rod and a convenient angle of oscillation of 45° to 50°, which should not exceed 60°.

We have next to find the required travel of point F, Fig. 5, to obtain the desired valve travel, which for convenience sake is taken on one side of the center position, or half its total travel in full gear, and which we will designate b, when we have:

$$b = \frac{R\sqrt{a^2 - c^2}}{R + c} \text{ for outside admission, and}$$

$$b = \frac{R\sqrt{a^2 - c^2}}{R - c} \text{ for inside admission valves.}$$

This may be laid out graphically as in Figs. 6 and 7, when *a* is equal to one-half the travel of the valve and R and *c* the same as in the above formulæ.

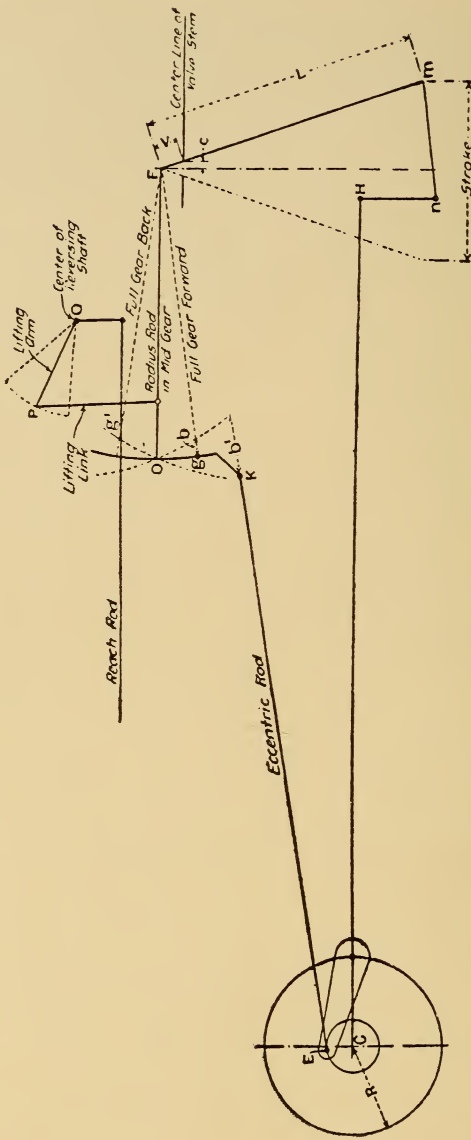
With the limited amount it is advisable to allow in raising or lowering the link block in reversing the motion, we can without practical error consider the half movement of the link block g to be the same as that of point F, and by limiting the angle of the swing of the link to a maximum of 45°, we get the raise or depression of the radius bar and link block $Og = \frac{b}{\tan. d}$, where O is the link fulcrum and $d =$ half the angle of the swing of the link.

The location of the link and eccentric rod connecting point K, Fig. 5, cannot be determined with any practicable formula, but must, as already stated, be found by plotting to meet the requirements of the different cut-offs and corresponding crank positions. The same is also the case with determining the locus for the suspension point P of the lifting link, and in these two locations lies the principal success of the gear.

Note.—The cuts, Figures 5, 6 and 7, are reproduced from an article by Messrs. C. J. Mellin and G. L. Fowler in *Railway Machinery*, September, 1905.

Figure 8 illustrates the Walschaert valve gear as applied to a heavy freight locomotive, in fact one of the largest type belonging to the Lake Shore and Michigan Southern Railway.

This cut will serve to show in a graphic manner the location of the various connections of the valve gear, and piston valve. The combination lever is shown in its central position and it will be noticed that in this position the lower connection, m (see Fig. 5), is in line horizontally with point n, the crosshead connection. The vertical height of these two points relative to each other slightly influences the port opening. The cross section through



$R\sqrt{a^2 - c^2}$

FIGURE 5. DIAGRAM ILLUSTRATING METHOD OF LAYING OUT THE WALSCHAERT VALVE GEAR.

cylinder and valve shown in Fig. 8 will give a clear idea of the action of the valve and gear.

Figure 9 is an outline diagram of the Walschaert valve gear as applied to a compound locomotive, and serves to show the adaptability of the gear to any type of locomotive and all conditions of service.

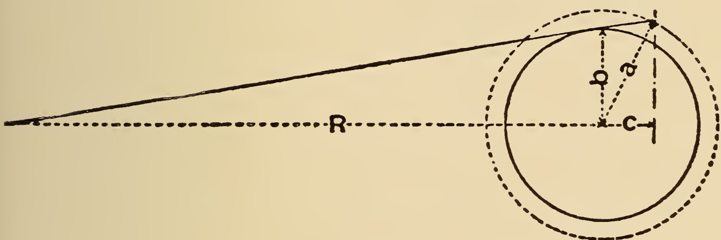


FIGURE 6.

But, it is evident that a correct design of the Walschaert valve gear can only be laid out by a skilled draughtsman, and in the adjustment and maintenance of the gear the greatest care is required, that all parts should preserve

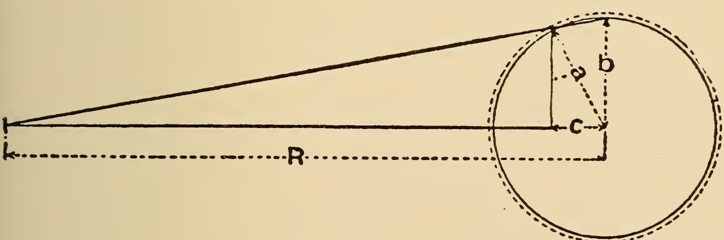


FIGURE 7.

their original forms and locations, and this should be checked by verifying the valve events through turning the main driving wheels before the locomotive goes into active service.

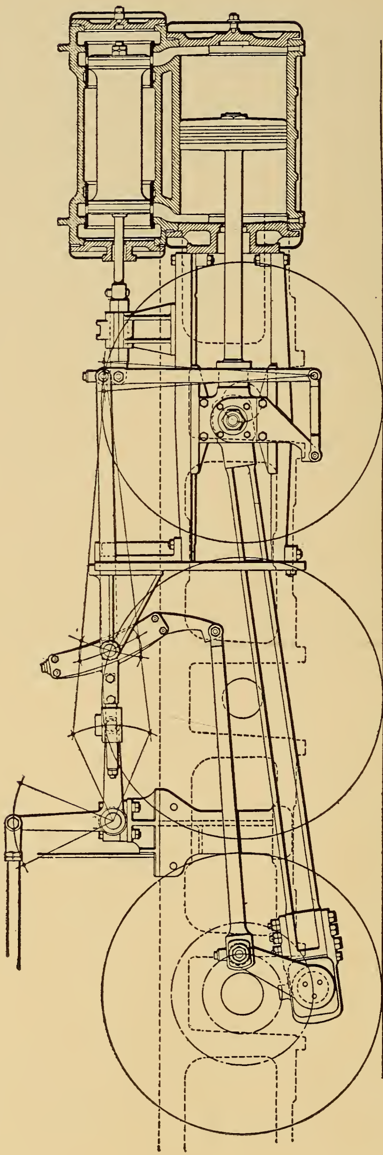


FIGURE 8. WALSCHAERT VALVE GEAR.

As applied to Consolidation Freight Locomotive, Lake Shore & Michigan Southern Railway, illustrating a cross section through cylinder and valve—American Locomotive Company.

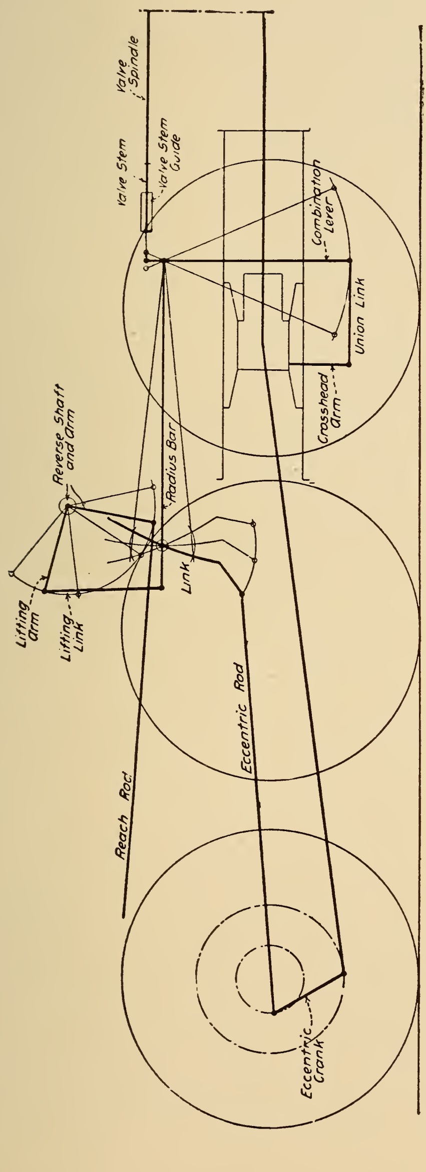


FIGURE 9. OUTLINE DIAGRAM OF WALSCHAERT VALVE GEAR.
As applied to Mallet Articulated Compound. Baltimore & Ohio Railroad.

The Walschaert motion, as usually constructed, does not lend itself as freely to adjustment as does the Stephenson motion with independent eccentrics, and for this reason it is not as liable to get out of adjustment. It must be correctly laid out in the design and correctly fitted up. The importance of this cannot be overestimated. The various points must be carefully plotted in order to give the best results in the combination movement of the parts of the motion. The movements of the motion involve such complications in plotting as to render the complete plotting of all, too laborious for every new design, and for this reason the use of an adjustable model is very desirable in designing this gear. However, with complete knowledge of the nature of the gear, simple methods and formulæ may be used to determine the locations of the various points covering the motion. One object of this description is to avoid the necessity of a model except to verify the results.

To entirely overcome the irregularities inherent in all motions transformed from circular into lineal, cannot for practical reasons be expected, but the errors may be reduced to such an extent that they do not affect either the power or economy of the locomotive. This remark is made to forestall the inference that the accuracy of the Walschaert motion as to the cut-off points is not superior to the Stephenson motion when the latter is turned out of the shop.

The chief point of difference between the Walschaert and Stephenson motions is that the former gives to the valve a constant lead at all cut-offs, whereas the latter produces an increase of lead which becomes excessive at short cut-offs.

DETAILS OF ADJUSTMENT.

In setting the Walschaert valve gear it must be borne in mind that two distinct motions are in combination, viz.: the motion due to the crosshead travel, and the motion due to the eccentric throw.

The crosshead motion controls the lead, by moving the valve sufficiently to overcome its lap, by the amount of lead in both front and back positions. The eccentric throw controls the travel and reversing operations. It will be seen that the movement due to the eccentric, without the crosshead motion, would place the valve centrally over the ports when the piston is at the extreme end of the stroke. The combined effect of these two motions, when the parts are properly designed, gives the required movement of the valve, similar to that obtained by the use of a stationary link. To reverse the engine, the link block is moved from end to end of the link, instead of moving the link on the block. This operation is accomplished by means of a reversing shaft connected with a reversing lever in the cab.

Walschaert gears should be correctly laid out and constructed from a diagram, as the proportions cannot be tampered with by experimental changes without seriously affecting the correct working of the device.

The only part capable of variation in length is the eccentric rod, which connects the eccentric with the link. This rod may be slightly lengthened or shortened, to correct errors in location of the link center, from center of driving axle which carries the eccentric.

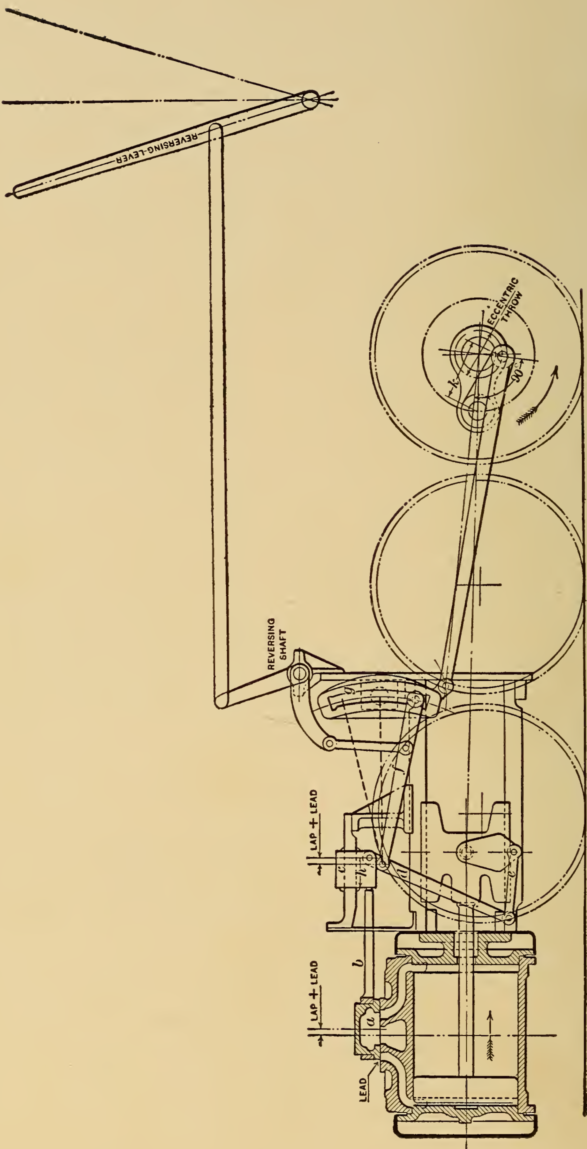


FIGURE 10. WALSCHAERT VALVE GEAR DIAGRAM.

When the engine is assembled, the throw of the eccentric should be checked up by the specifications, and any error should be reported at once, in order that the mistake may be rectified by either correcting the position of the eccentric, or by a change in the design of the other parts to compensate for the error.

The lap and lead being determined by the proportion of the arms of combination lever, and the stroke of the piston, the amount is found by turning the engine from one dead center to the other in any cut-off position.

Mr. Carl J. Mellin of the American Locomotive Company furnishes six very useful hints relating to the adjustment of the Walschaert valve gear as follows:

1. The motion must be adjusted with the cranks on the dead-centers by lengthening or shortening the eccentric rods until the link takes such a position as to impart no motion to the valve when the link block is moved from its extreme forward to its extreme backward position. Before this change in the eccentric rod is resorted to, the length of the valve stem should be examined, as it may be of advantage to plane off, or line under, the foot of the link support which might correct the lengths of both rods or at least only one of these should need to be changed.

2. The difference between the two positions of the valve on the forward and back centers is the lap and lead doubled, and cannot be changed except by changing the leverage relations of the combination lever.

3. A given lead determines the lap, or a given lap determines the lead, and it must be divided for both ends as desired by lengthening or shortening the valve spindle.

4. Within certain limits this adjustment may be made by shortening or lengthening the radius bar, but it is desirable to keep the length of this bar equal to the radius

of the links, in order to meet the requirements of the first condition.

5. The lead may be increased by reducing the lap, and the cut-off point will then be slightly advanced. Increasing the lap introduces the opposite effect on the cut-off. With good judgment these quantities may be varied to offset their irregularities inherent in transforming rotary into lineal motions.

6. Slight variations may be made in the cut-off points as covered by the previous paragraph, but an independent adjustment cannot be made except by shifting the location of the suspension point, which is preferably determined by a model.

The Baldwin Locomotive Company supplies the following "Special Instructions" for guidance in the erection of the Walschaert valve gear and setting the valves:

1. Check carefully the dimensions of the following parts, rejecting any that are not exactly to drawing:

a—Valve.
b—Valve stem.
c—Valve crosshead or slide.
d—Combining lever.
e—Crosshead link.
f—Link radius rod.
g—Reverse link.
h—Location of combining lever on crosshead.
k—Length of eccentric crank.

2. Check eccentric throw to see that it is exactly as specified.

3. Be sure that guide bearer is correctly located from center of cylinder, as the reverse link is usually attached to it, and variations in the location of the link cannot

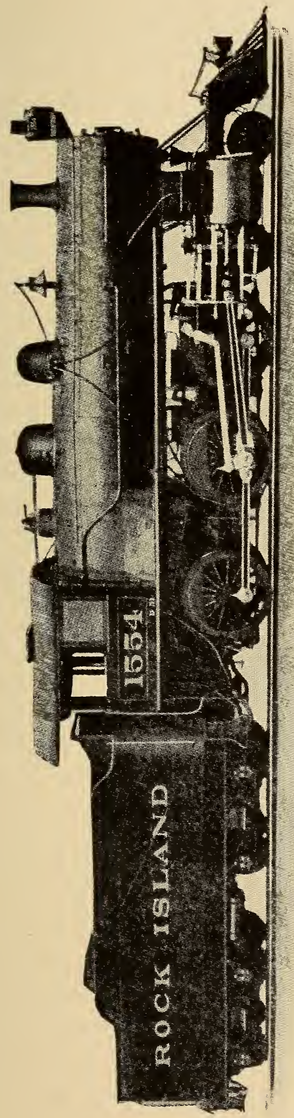


FIGURE 11. TEN WHEEL LOCOMOTIVE FOR THE CHICAGO, ROCK ISLAND & PACIFIC RAILWAY, 1905.
Equipped with Walschaert Valve Gear. (Baldwin Locomotive Works.)

be allowed. If the link is attached to separate crosstie, similar precautions must be taken to insure its correct location.

4. Exercise great care in the location of the link so that the trunnion center is exactly to dimensions from the center of cylinder.

5. See that the reverse shaft center is correctly located to dimensions given, and that the lifting arm and link are of the exact lengths as specified.

6. Connect crosshead gear to valve, and radius rod to link, without connecting eccentric rod to link.

7. Hook up radius rod to exact center of link, and then revolve driving wheels, seeing that crosshead gear gives correct lead as specified for both front and back admission ports.

8. Connect link to return crank by eccentric rod, and obtain full travel front and back, and in both forward and backward motions, correcting any errors by lengthening or shortening eccentric rod, as previously noted.

The valves may now be considered as definitely set, and may be tested to any cut-off points in the usual manner. A simple additional check should be made as follows: set one side of the engine so that the piston is at its extreme forward position in the cylinder, and check the lead on the admission port.

In this position it should be possible to move the link block through its entire travel in the link, without in any way disturbing the movement of the valve.

This operation should then be reversed, and the other side of the engine similarly tried with the piston located at its extreme backward position in the cylinder.

TYPES OF LOCOMOTIVE VALVES.

The adaptability of the Walschaert valve gear to the many and varied conditions in locomotive practice has already been commented upon, and will be referred to again later on.

A short space will now be devoted to the leading types of locomotive valves and their operation. The plain old time D slide valve still retains a large place in the steam distribution of locomotives, notwithstanding the disadvantages attending its use.

The principal objection to the use of the D slide valve is the large amount of friction caused by the action of the steam pressing the valve against its seat, and inventors have racked their brains for many years in efforts to produce a valve that would work without friction, and at the same time give a correct distribution of the steam to and from the cylinders.

The piston valve, while practically balanced, owing to the pressure of the steam acting upon each end, is, nevertheless, not a perfectly balanced valve unless the valve rod extends through both ends of the valve chamber, and this necessitates an extra gland and set of rod packing. In order to more clearly illustrate this idea, reference is made to Figs. 12 and 13. Fig. 12 shows a plain D slide valve, and it will be noticed that the full pressure of steam in the valve chest acts upon the back of the valve. Of course there is a certain amount of back pressure from the steam port and exhaust port that tends to overcome the direct pressure; still there is an enormous strain on the valve gear that is required to move a valve under such conditions. Fig. 13 shows a solid piston valve with outside admission, being thus identical in action with the D valve.

No valve rod is shown in either cut, but it will easily be seen that with the valve rod attached to but one end of the piston valve the area of that end will be decreased

FIGURE 12.

just so much, and the valve will be unbalanced by an amount equal to the sectional area of the valve rod, but this amount is so insignificant that builders very seldom add the extended valve rod, and so the piston valve may

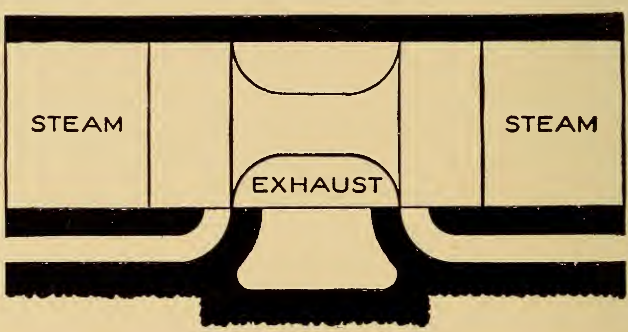


FIGURE 13.

be considered as balanced, the only friction being that due to the weight of the valve and the friction of the packing rings when the valve is fitted with them. In some types of piston valves the live steam is admitted inside, between the heads, as shown in Fig. 14, and the exhaust passes out around the ends, but the same principle of balancing is retained as with the outside admission type, for the reason that the pressure is applied between the ends of the valve instead of on the outside as with the other type. The sketches here given do not show the valves in their true proportions, being merely used to illustrate the principle upon which the piston valve works. In practice the valve is made as long as possible, in order that the ports leading to the cylinder may be shortened to the minimum.

Another type of piston valve is shown in Fig. 15. This valve is made hollow for lightness and has packing rings at each end to prevent the steam from passing into the ports until at the proper moment. The edges of these packing rings control the admission of steam to the ports in the same manner as do the edges of the D valve, and when the valve is one of outside admission it is set in the same manner as the D valve is. But if admission is from the inside, as shown in Fig. 16, the movement of the valve is reversed, as is the method of setting also. As it is very essential that the packing rings at each end of a piston valve be steam-tight, a certain element of friction is introduced in this manner. In the larger number of cases where piston valves are used, central or inside admission is the rule, a great advantage of this type over outside admission valves being that the larger portion of the cooling surface of the valve chamber is reserved for the exhaust steam. Another advantage is that of having only exhaust pressure against which to pack the valve rods, and make the joints for the heads of the valve chamber.

In taking charge of an engine having piston valves, an engineer should always first "look her over" and note the positions of the eccentric with relation to the crank pin. He should also take a look at the rocker shaft if

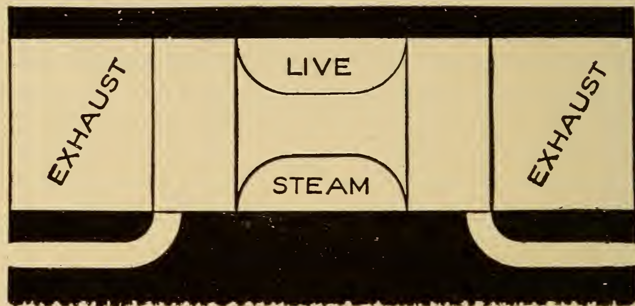


FIGURE 14.

there is one. He will then be able to satisfy himself as to whether the valves have outside or inside admission, a very important thing to know in case anything should happen out on the road that necessitated resetting of one

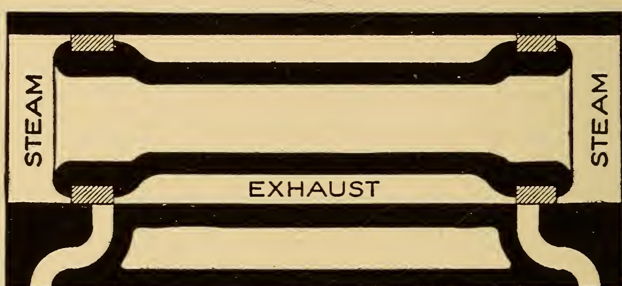


FIGURE 15.

or both of the valves to enable him to bring his engine home. As before stated, the movement of a piston valve having outside admission is precisely the same as that of a D slide valve, but it is well to note the fact that while the great majority of engines fitted with D slide valves have indirect valve gear, still there are some in which the motion is direct. For the guidance of the engineer in such cases, the following four simple rules are here given:

Rule 1. If the eccentric and crank pin are together, that is, on the same side of the driving shaft, and there is a rocker arm that reverses the motion, the valve has outside admission, indirect.

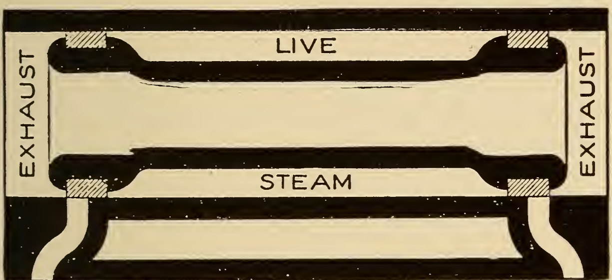


FIGURE 16.

Rule 2. If the eccentric and crank pin are together and there is no rocker arm, but direct motion, the valve has inside admission, direct.

Rule 3. If the eccentric and crank pin are on opposite sides of the driving shaft, and there is a rocker arm to reverse the motion, the valve has inside admission, indirect.

Rule 4. If the eccentric and crank pin are on opposite sides of the shaft, and there is no rocker arm to reverse the motion, the valve has outside admission, direct.

The American Balanced Valve Company of Jersey

Shore, Pa., are the makers of a new type of piston valve, which they term "The American Semi-Plug Piston Valve." This valve, a description of which is here given, has performed very efficient service since its introduction, and it appears destined to occupy a prominent position in locomotive work in the future.

Referring to Fig. 17, an internal admission valve is shown. The inner sides of the two snap rings, 1-1, are beveled. The outer sides of the snap rings are straight and

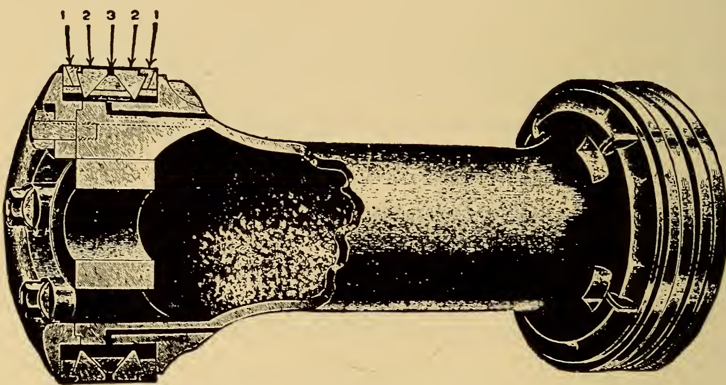


FIGURE 17.

fit against the straight walls of the valve spool. Against the beveled sides of the snap rings, solid, uncut, non-expansible wall rings, 2-2, fit. Their inner sides are beveled at a greater degree of angle than their outer sides, which fit the snap ring.

In between the two wall rings is placed a central double tapered snap ring, 3. This ring is properly lapped, and is put in under tension, thus holding the wall rings apart, putting a slight grip on the snap rings laterally. Thus applied, the action is as follows: When steam is admitted to the steam chest, or central portion of the valve, it passes through openings in the spool to the space beneath all of the rings, and acts upon the central wedge ring direct, giving it a lead of the snap rings in action, and forcing the wall rings against the sides of the snap rings, so that prevention of their excessive expansion is positive. The snap rings are thus expanded against the casing just enough to make steam-tight contact, and the central ring grips them there, and they are prevented from further expansion. This is demonstrated by withdrawing the valve from the valve chamber while under steam until the first ring in the spool is entirely out of the cylinder, when no increase in the diameter of the snap ring can be observed. It can then be pushed back into the cylinder again. It will readily be understood how easy it is to prevent further expansion of the snap ring by the pressure underneath it, when the degree of angle of the bevel on the inside of the snap ring is considered. By making this degree greater, the power of the central wedge ring would be sufficient to decrease the diameter of the snap ring, closing it away from the valve chamber. Therefore it appears that this valve has all the advantages of the plug valve, without the drawbacks of the plug valve, and it has all the advantages of the snap ring valve, without the drawbacks of the snap ring valve, because it is practically a plug that does expand and take care of itself, not only for the difference in contraction and expansion, but also for wear; yet the plug is not so rigid as to knock a cylinder head out before relieving the water from the cylinder, and yet it is absolutely adjusted to the diameter of the casing at all times, and is held there and allowed to get no larger during its work under pressure. The rings are so lapped that they are steam-tight from all directions, and the bevel lap joint

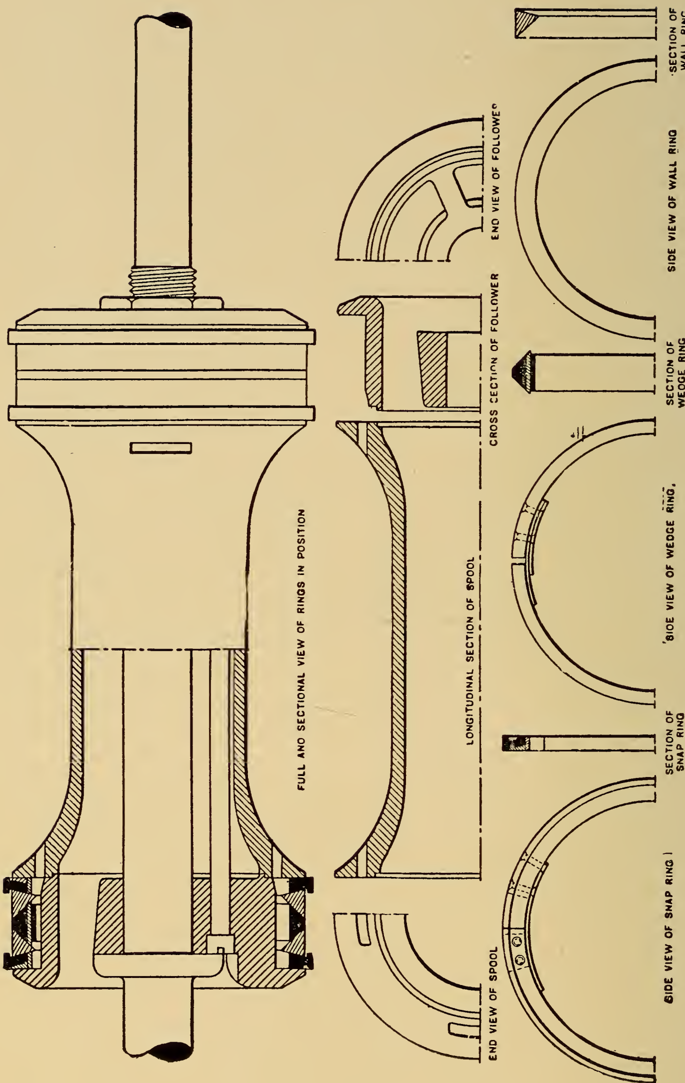

FULL AND SECTIONAL VIEW OF RINGS IN POSITION
END VIEW OF SPOOL
LONGITUDINAL SECTION OF SPOOL
CROSS SECTION OF FOLLOWER
END VIEW OF FOLLOWER
SIDE VIEW OF SNAP RING
SECTION OF SNAP RING
SIDE VIEW OF WEDGE RING
SECTION OF WEDGE RING
SIDE VIEW OF WALL RING
SECTION OF WALL RING

FIGURE 13.

maintains unbroken steam and exhaust lines at the edge of the ring.

Fig. 18 further illustrates the construction of this valve, giving end and sectional views of the different parts. A common defect of snap ring piston valves is that the steam pressure gets under the rings, and expands them against the casing with the full force of the chest pressure, thus causing excessive friction, while at the same time the cage is worn unevenly by the valve working at short cut-off and over the ports. Under such conditions, steam-tight joints soon become leaky, and the leakage rapidly increases as the wearing goes on.

A piston valve, in order to give efficient steam-tight and durable service, should automatically regulate the frictional contact of the rings against the cage, and keep the cage perfectly true.

Many locomotives are equipped with piston valves of different types, but the internal admission valve appears to be the favorite.

One of the advantages the piston valve possesses over other forms of slide valves is that it may be made long enough to bring the two faces or working edges near the ends of the cylinder, thus greatly reducing the clearance between the valve face and the piston.

The term balanced valve, as used in this connection with reference to locomotive practice, is meant to include all balanced valves except those of the piston type. As stated at the beginning of this section, there have been many different kinds of balanced valves applied experimentally to the locomotive, by inventors in their efforts to reduce the friction between the face of the valve and its seat.

A few of the more meritorious of these will be described and illustrated. Fig. 19 shows the Jack Wilson High Pressure Valve.

This valve has two faces. One face moves on the valve seat proper, and the other face moves in contact with the face of the balance plate. Both faces are the same, and it has no crown, but is open throughout. The face of the balance plate is an exact duplicate of the cylinder valve seat, and set in alignment therewith, therefore whatever conditions exist on one face of the valve must necessarily exist on the other face.

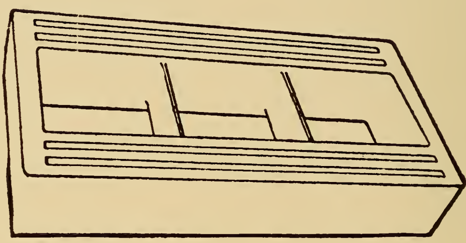


FIGURE 19.

The walls of the valve are provided with ports which pass from face to face of the valve. The balance plate, Fig. 20, contains balancing cones M C and P C (main cone and port cone), and two centering ring grooves, that register with similar grooves in pressure plate.

The face of the balance plate, Fig. 21, is an exact duplicate of the cylinder valve seat and forms a second valve seat against which the valve operates in unison with its operation on the cylinder valve seat, the second seat being held by means of the centering rings CR, Fig. 22, in exact alignment with the valve seat proper. The back or opposite side of the balance plate, Fig. 25, contains the following cones: one large or main cone (MC) and two small or port cones (PC) on the interior of the

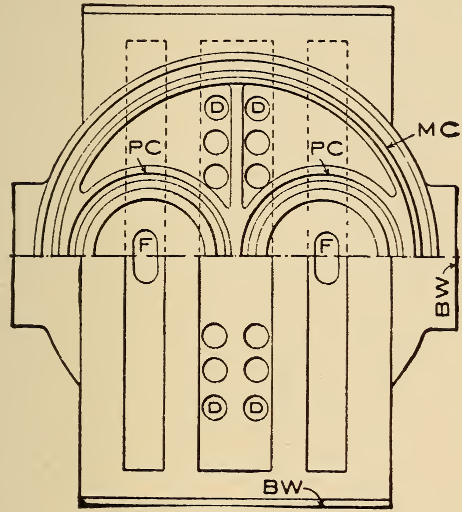


FIGURE 20.

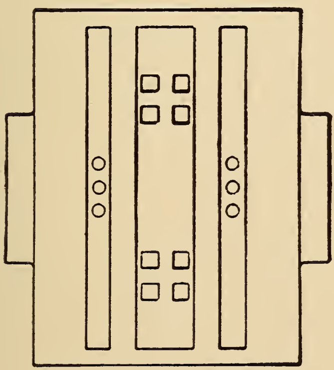


FIGURE 21.

main cone, and on which the packing rings are placed, which forms the balancing feature to the valve, and the

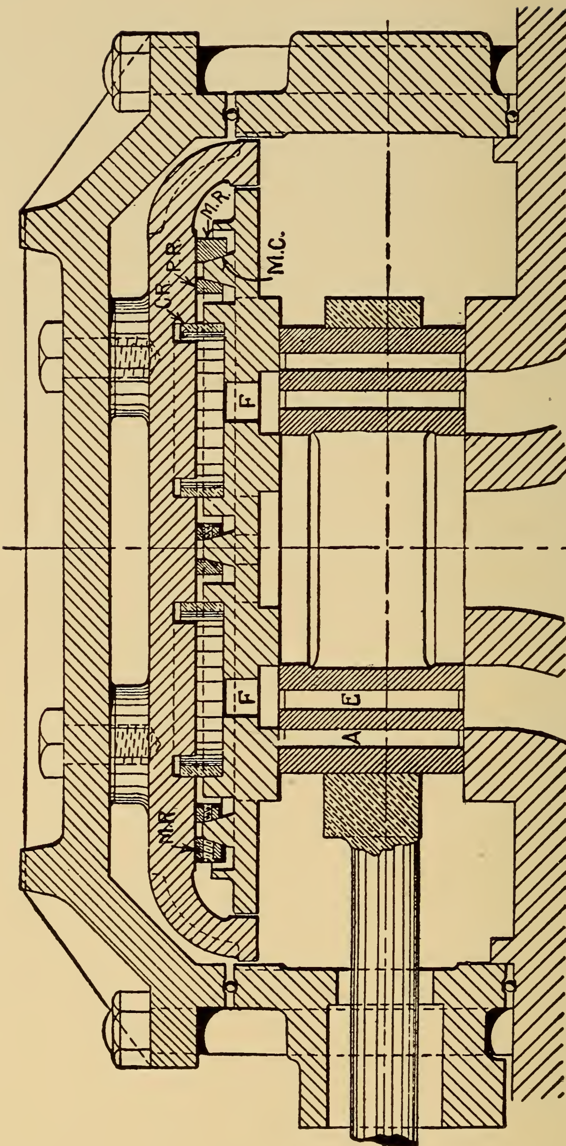


FIGURE 22.

centering ring cones. The balance plate is provided with wings (BW) which fit 1-16 inch loose into the wings of the pressure plate (or into the steam chest itself), preventing excessive movement of plate. Taper or beveled packing rings set on the cones form joints against the pressure plate.

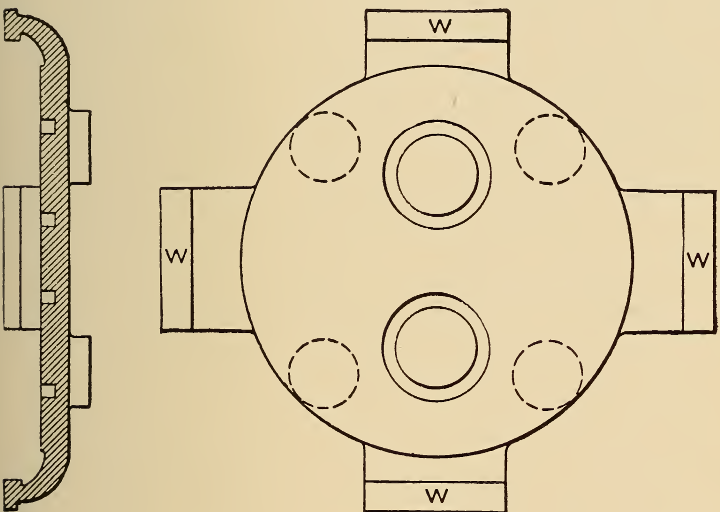


FIGURE 23.

Pressure Plate. The pressure plate is made either as a part of, or separate from the chest cover. In the type of valve here referred to, the pressure plate is made separate (see Figs. 23, 24 and 25) and is provided with wings (W) which are machined to fit snugly into the steam chest; the chest being first centered with the valve seat by fitting over lugs on the cylinder, or by dowel pin, and machined at the top to receive wings (W) of the pressure plate. Into the face of the pressure plate two grooves are cut with either straight or taper walls and which register correctly with the corresponding grooves in the balance plate; these are called centering ring

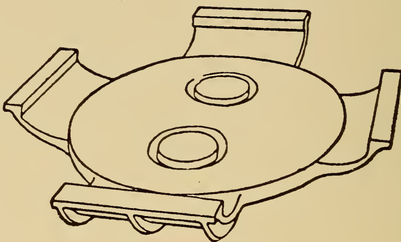


FIGURE 24.

grooves and into them two centering rings (CR) are placed, slightly under tension. Under normal conditions these steel rings hold the balance plate in alignment with the valve seat, but under abnormal conditions, such as

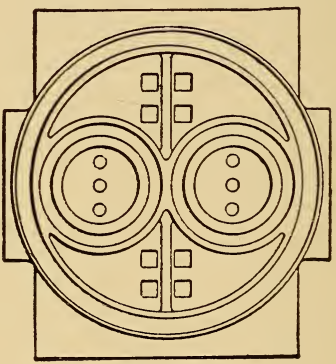


FIGURE 25.

dry valves, the strain will be taken by the wing of the balance plate against the wing of the pressure plate, preventing excessive contraction of the centering rings. Against the face of the pressure plate the balancing rings form steam joints. The balanced area of this valve is changeable, the change taking place automatically, so as to correspond with the changed condition of the valve on its seat at different points of its travel.

Referring to assembled cross sectional view, Fig. 22, the valve is seen in central position on the seat and the upper seat or face of balance plate in position corresponding with the valve seat. The steam chest is centered by machined faces fitting over machined lugs on the cylinder; on old power, dowel pins are used. The chest has finished strips at top into which the finished ends of the wings of the pressure plate (W) fit snugly, thus insuring the central position of the pressure plate over the valve seat. The finished wings of the balance plate (BW) fit 1-16 inch loose between inside faces of the wings of the pressure plate, but the balance plate is held perfectly central by two steel centering rings (CR). The tops of the cones on the balance plate are ⅛ inch from the face of the pressure plate, allowing the balance plate to lift ⅛ inch off from the valve, which affords perfect relief to the cylinder while the engine is drifting and for the relief of water from the cylinder. This ⅛-inch clearance in height adjustment must be maintained. The main balancing ring (MR) is made the proper diameter to balance the valve as great as possible while in its central (or heaviest) position, there being just sufficient area left on to insure the balance plate being held steam-tight on the valve. The interior of the main ring is open to the atmosphere through the holes D, which lead to the exhaust cavity of the valve.

The valve is thus balanced so that it will move perfectly easy in its heaviest position, but conditions are changed by the opening of a steam port (and at instant of cut-off. See Fig. 26), at which time the ordinary

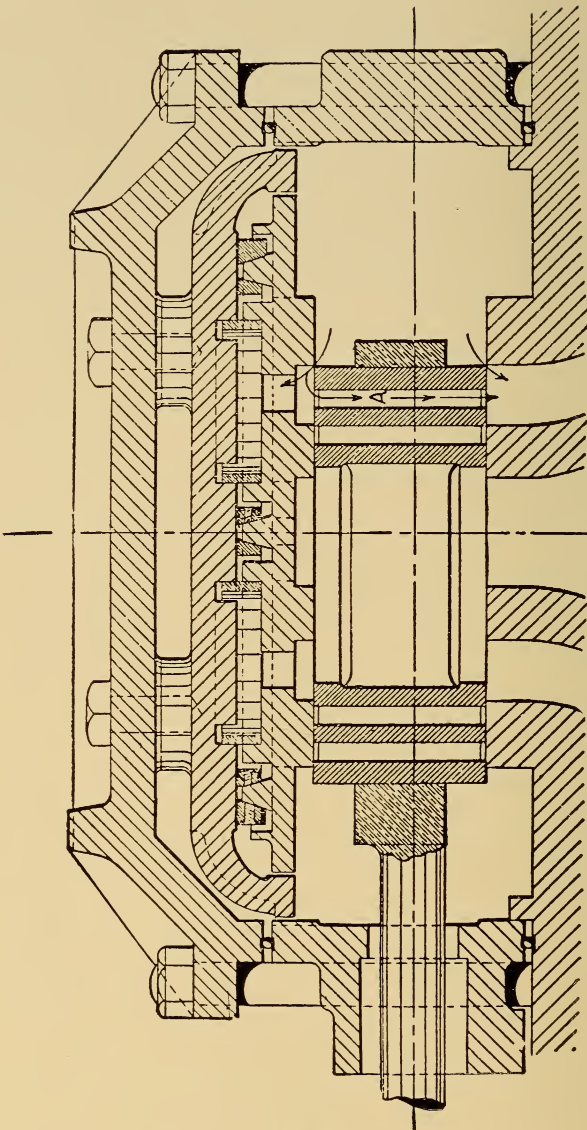


FIGURE 26.

slide valve is subjected to the upward pressure of the steam in the cylinder port, and if properly balanced in central position would, at this position, be thrown off its seat, but in this valve the port pressure (whatever it may be) has free access to both sides of the valve by reason of the passages through the valve to the port in the face of the balance plate which corresponds with the cylinder port; therefore the pressure in the port has no effect whatever upon the valve, it being on both sides of the valve face of equal area, and pressure is, therefore, equalized so far as the valve is concerned, but the pressure in the port of the balance plate would lift the plate off from its seat on the valve if it was not also equalized, or annulled; therefore a port ring, PR, of proper area to balance this pressure, is placed over each port in the inside of the main ring on the top of the balance plate and is open to the port through passage F, Fig. 22, so that a pressure equal to that in the steam port is always on both sides of the balance plate, as well as on both sides of the valve, and the port pressure is rendered inoperative on the valve or on the balance plate. Communication from the cylinder port, through the valve and through the balance plate to the interior of the port ring, PR, cannot be shut off at any time, but is maintained throughout the travel of the valve. Therefore the same pressure that is in the port at any given time is also on both sides of valve and pressure plate in the same area, and the port pressure is, therefore, not considered in figuring the main balance for the valve.

There is another position of the valve during its stroke where the slide valve is subjected to an upward pressure, or pressure against its face, which tends to lift it from its seat; that position is at over-travel of the valve face over the valve seat; this position is shown in Fig. 27, but in

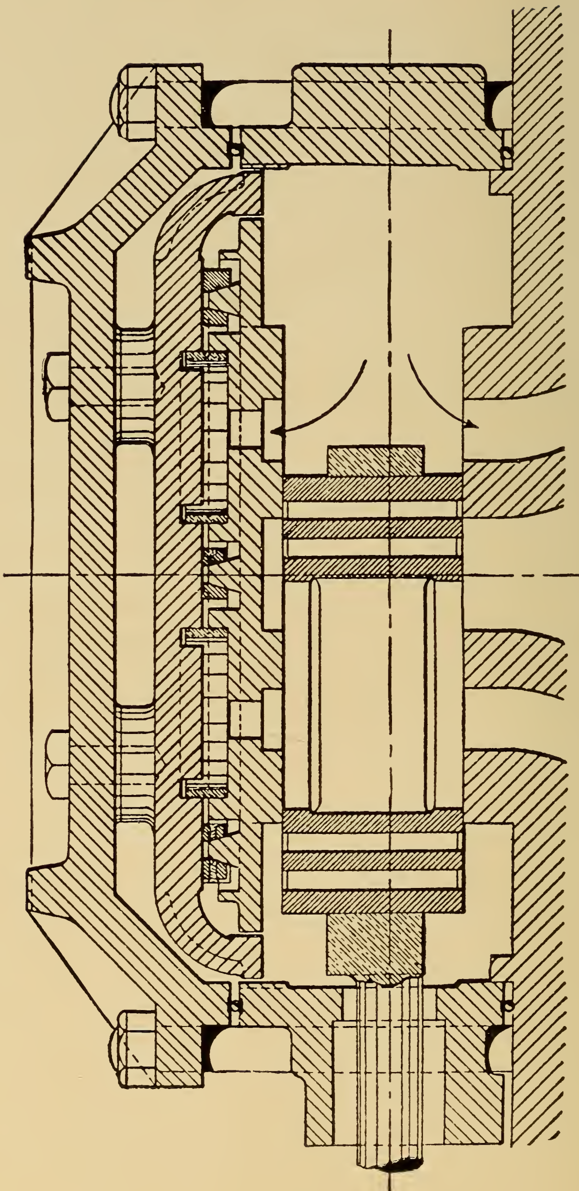


FIGURE 27.

this valve it will be observed that the top face or back of the valve travels out from under the seat of the balance plate exactly to the same extent that it over-travels the cylinder seat, and pressure is, therefore, equal on both sides of that portion of the valve that is over the seat at any point of travel. With the main ring balancing the valve fully in its central or heaviest position, the port ring balancing the port pressure, and over-travel of the

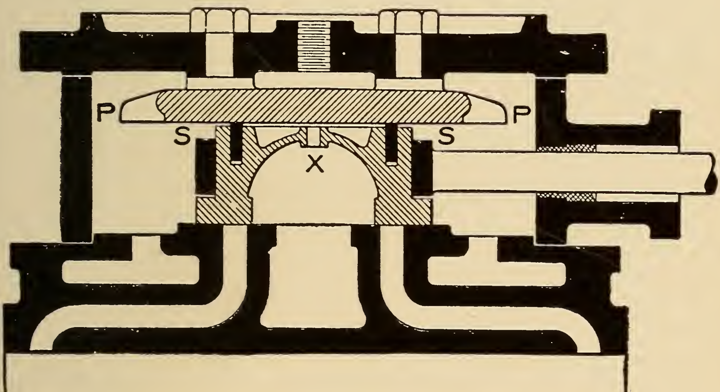


FIGURE 28.

valve on its seat being equalized by equal exposure at top and bottom, it will be clear that the valve is fully balanced in all positions of stroke, and is, therefore, available for high pressures.

The Richardson Balanced Valve. This form of balanced slide valve, together with the Allen-Richardson balanced slide valve, is manufactured by H. G. Hammett of Troy, New York, and is largely used on locomotives. Figs. 28 and 29 represent transverse and longitudinal sections through the center of an ordinary locomotive steam chest fitted with the Richardson valve. Fig. 30 shows a plan of the valve, and Fig. 31 is an elevation of one end of the packing strips and spring, the only alter-

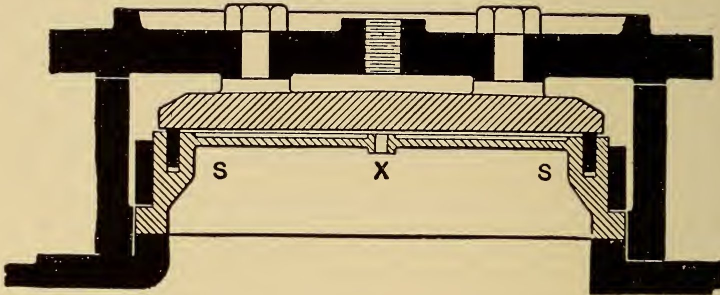


FIGURE 29.

ation being the addition of the balance plate, PP, Fig. 28, and the substitution of a valve adapted to receive the packing strips S, S, S, S.

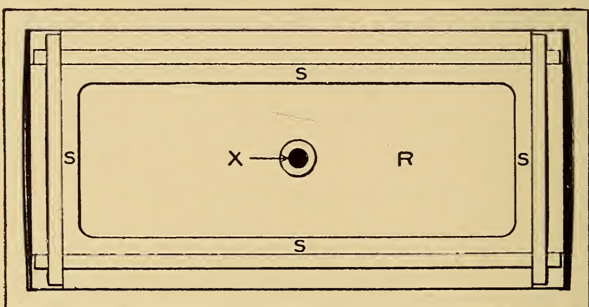


FIGURE 30.

It will be noticed in this instance that the balance plate is bolted to the cover of the steam chest, but these may be cast in a single piece. The four sections of packing enclose a rectangular space, R, Fig. 30, which equals in its area the total amount of valve surface which is to be relieved of excess pressure, the packing strips preventing the steam from entering this space, and the small hole, X, communicating with the exhaust cavity in the valve, relieves space, R, from any possible accumulation of pressure.

The four packing strips consist of two longer ones, which are simply rectangular pieces of cast iron, while the two shorter ones, Fig. 31, have gib-shaped ends to retain them in their proper position. Beneath each packing strip a light elliptic spring, shown in Fig. 31, is placed, which holds these strips in position against the balance plate when steam is shut off.

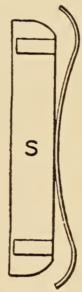


FIG. 31.

In operation these different sections maintain a steam-tight contact, by a direct steam pressure, with the balance plate and with the inner surfaces of the grooves provided to receive them, the joint being secured by the abutting of the ends of the two longer sections against the inner surfaces of the gibbed sections at the four corners.

THE ALLEN-RICHARDSON BALANCED SLIDE VALVE. The Allen valve is designed to at least partly prevent the wire-drawing of the steam, when high speeds are maintained with the valve cutting off early in the stroke.

In the Allen valve, an additional passage for the inlet of steam is furnished, as will be clearly seen by referring to Figs. 32 and 33. These are transverse and longitudinal sections through the valve and steam chest, and it will be noticed that, when the steam port is open one-half inch in the ordinary manner, the port of the cored passage is also open to a like extent on the other side of the valve; consequently the effective area of the steam port is doubled, and is thus the actual equivalent of a single port with a one-inch opening.

The wire-drawing incident to running at high speeds with the valve cutting off early in the stroke is thus greatly diminished, with a resultant economy of steam and fuel. A reduction of wire-drawing carries with it a

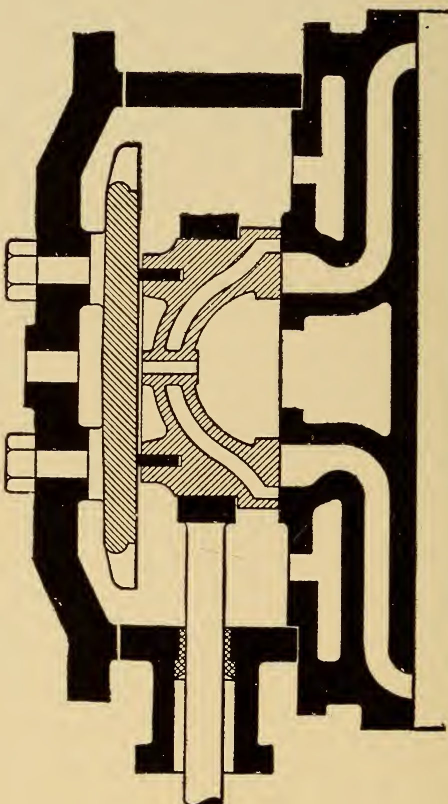


FIGURE 32.

higher average pressure on the piston when working at a similar cut-off; consequently the usual average pressure can be maintained with a shorter cut-off, resulting in an appreciable economy. While the unbalanced Allen valve, therefore, secures a better and more economical distribution of steam, its use entails certain disadvantages.

On the face of a slide valve, the area of bearing surface is never sufficient to secure its wearing well under a heavy steam pressure; and this wearing surface is yet further reduced in the Allen valve, owing to its internal steam ports. This internal passage actually divides the valve into two parts, and the steam pressure, acting on the outer part, springs and bends its working face below that of the internal or exhaust port of the valve. The available wearing face is consequently reduced to a space

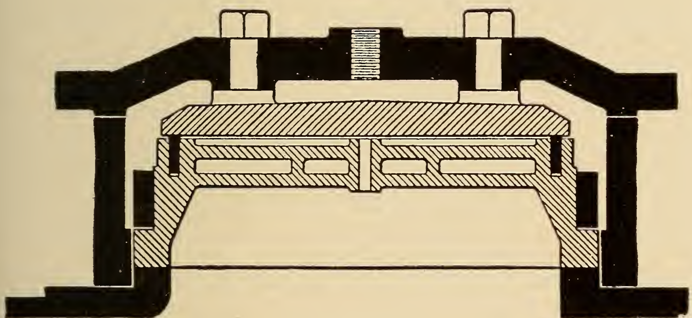


FIGURE 33.

about one-half as wide as the outside lap of the valve, and this fully accounts for the rapid wearing of the unbalanced Allen valve, and for the trouble and expense of constantly refacing valves and seats, and the loss of the steam blown through leaky valves quite offsets the advantages gained by a reduction of wire-drawing.

These manifest disadvantages are entirely overcome by a proper balancing of the valve, which secures all of the advantages of the Richardson device, plus an increased steam economy resulting from using the Allen ports.

In order to secure the best possible results from the employment of the Allen unbalanced valve, its ports and bridges should exceed the full travel of the valve, by at least one-eighth of an inch, and the radius of the link should always be as long as permissible to escape an excessive increase of lead when cutting off early in the stroke. This latter, however, is prevented with the Walschaert valve gear, which gives a constant lead at all points of cut-off.

The Allen valve has made fair progress in American locomotive practice, but there is still considerable prejudice against it. This prejudice, we believe, is founded in want of experience, or in a mistaken view of what the capabilities of the valve are. While this conflict of opinion continues to exist, we think that some remarks made by Mr. E. M. Herr, superintendent of motive power of the Northern Pacific Railway, at a meeting of the Western Railway Club, might be studied to advantage. The discussion was on lead in the setting of locomotive valves, and in this connection he said:

"With a very long port you can give an engine less lead than with a short port, and the kind of valve used has also an effect. With an Allen ported valve you can still further reduce the lead and get the same work out of the engine. The Allen valve, in my opinion, is a very valuable device if rightly used, and I believe that many railroad men condemn it because they have not used it in just the right manner. You do not get the full advantages of an Allen valve if you give it anything like as much lead as you would a plain valve. One of the principal advantages of an Allen valve is that you can reduce the lead and still retain the mean effective pressure in the cylinder. Of course, there is another advantage with the Allen valve, and that is the more rapid admission of steam into the cylinder, and this enables a locomotive at high speeds, with an Allen valve, to very much exceed in power the same engine with a plain valve.

In making some tests on the North-Western testing plant not very long ago, we showed very conclusively that at high speeds a 16x24-inch engine would develop more power with an Allen valve than a 17x24-inch engine, with practically the same size of driver, would develop with a plain valve. In fact, a 16x24-inch engine on a certain division, where the ruling grade could be approached on a good run, was put in freight service with 17-inch engines, and it did satisfactory work with the 17-inch engines, pulling over rugged parts of our division, until one day the train happened to stop at the foot of this ruling grade. That day the engine stalled, and it stalled simply because it was not as strong as a 17x24-inch engine when pulling at slow speeds. At very high speeds it was stronger."

A cut-off valve for locomotives has been invented by Mr. Wm. Goodspeed of Bloomfield, Iowa. This device consists of a plain slide valve having no outside lap, a loose cut-off plate encircling the valve and moved by the action of the valve.

The following description of the device is given in the words of the inventor. We quote as follows:

"This invention is in the nature of an attachment that may be applied to the slide valve of any ordinary engine with only slight modifications of the valve, and it is especially designed for use in connection with a link motion for controlling the speed and direction of rotation of the engine.

"My object in this invention is to provide a valve of this class, of simple, strong, durable and inexpensive construction, that may be adjusted, or set to automatically cut-off at any desirable point, without employing any valve stem, or the like in addition to the ordinary ones used.

"A further object is to provide a valve in which a comparatively large and free induction-port is provided when the valve is set to cut-off at a relatively small portion of the piston's stroke to thereby tend to produce a high initial pressure and the consequent increase in the efficiency of the engine.

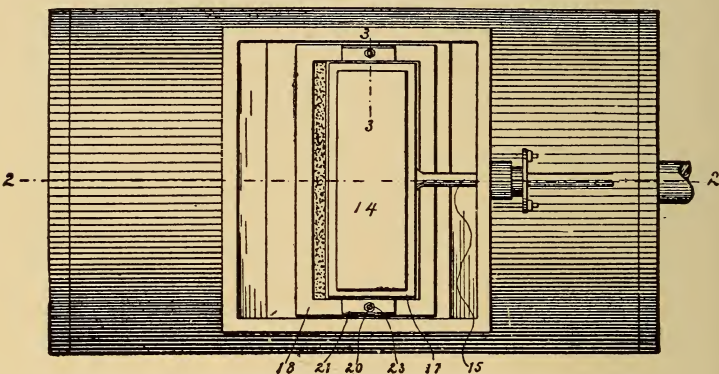


FIGURE 34.

"A further object is to provide a valve which may be operated so as to admit steam during the entire stroke of the piston, so that the entire boiler pressure may be used throughout the entire stroke of the piston, when it is desired to generate an unusual amount of power, and further to provide an engine of this class in which the wear upon the valve seat will be extended over a large area, and hence the durability of the engine will be increased.

"Fig. 34 shows a top or plan view of the valve mounted on its seat within the steam chest.

"Fig. 35 is a central longitudinal vertical section on line 2, 2 of Fig. 34.

"Fig. 36 shows a transverse sectional view through the line 3, 3 of Fig. 34, and Figs. 37 and 38 show detailed perspective views of parts of the engine and valve to illustrate certain details of construction."

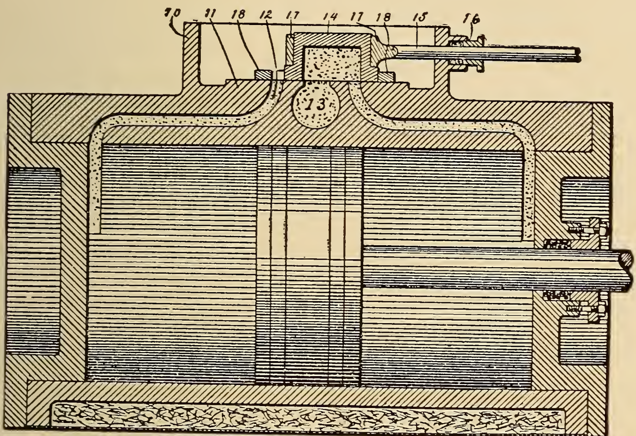


FIGURE 35.

In describing the cuts, numbers, instead of letters will be used to designate the different parts.

Referring to Fig. 35, 14 is a slide valve which differs from the valve of ordinary construction, in that it has a diminished inside or outside lap, and 15 indicates the valve stem passing through the packing box, 16, and having a yoke, 17 (Fig. 37), attached to it, which encircles the upper portion of the valve.

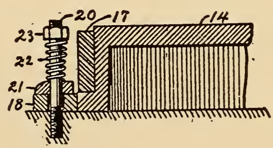


FIGURE 36

All of the above mentioned parts are of the ordinary construction with the single exception noted.

The essential novelty in the valve consists of a rectangular auxiliary cut-off, 18, Fig. 38, having a flat lower surface, and having a rectangular opening in its central portion.

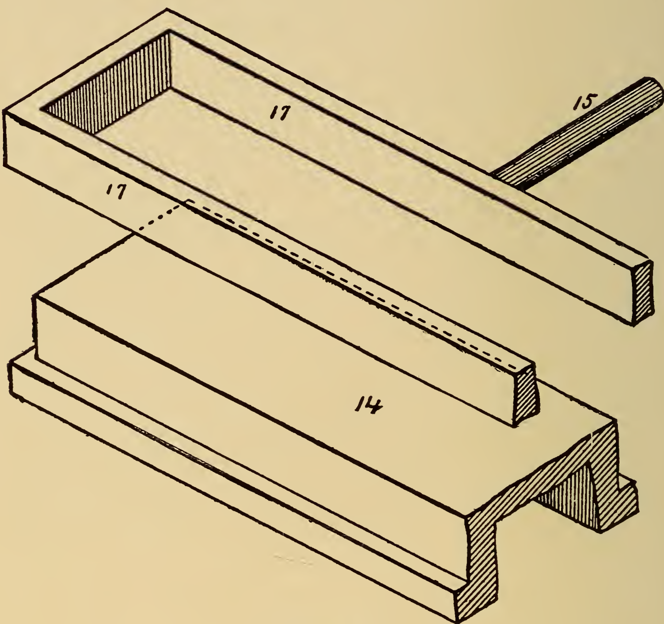


FIGURE 37.

The dimensions of this central opening are in one direction, the exterior length of the valve plus the width of one of the ports, 12, and in the opposite direction exactly the width of the valve.

In the side pieces of the auxiliary cut-off are the longitudinal slots, 19, through which standards or guides project, being screwed into the valve seat.

21 indicates elongated washers having openings through which the standards, 20, are passed, so that the

under surfaces of the washers may engage the top surface of the auxiliary cut-off.

22 indicates spiral springs which are mounted upon the standards and compressed by nuts, 23, thus holding the washers, 21, in frictional contact with the auxiliary cut-off, 18.

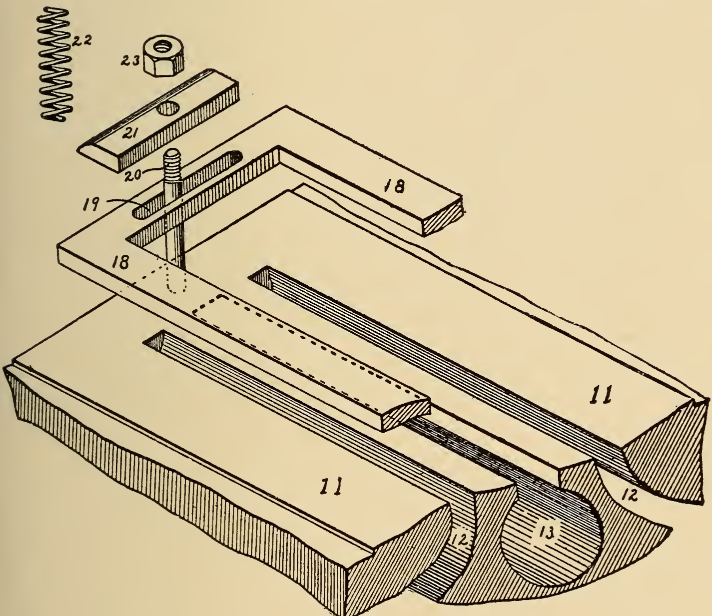


FIGURE 38.

This arrangement is for use only when there is no steam pressure in the valve chest.

In practical operation it is obvious that the valve proper will be moved a slight distance upon its seat before engaging the auxiliary cut-off and when it does engage, the cut-off will be moved slightly, that is, when the stroke of the valve is of greater length than the width of the ports leading to the cylinder.

This valve is designed for use only in connection with a link motion or other means of regulating the length of its travel.

Assuming that the link motion is set so that the valve will cut off at one-quarter stroke, and assuming the valve to be in its position for starting, that is, with a small lead opening, it is obvious that the first movement of the valve will be to open the induction port wide.

Then the auxiliary cut-off is moved by the valve so that the side of the cut-off adjacent to the induction port will be moved to partially cover the said induction port.

Then as the valve starts on its return movement it will meet the auxiliary cut-off or that portion thereof that is partially covering the induction port at a point midway between the sides of the induction port, thus cutting off the steam while the valve has only partially covered the induction port, that is, before the full stroke of the valve has been made.

It is obvious that the further movement of the valve, that is, to the limit of its travel, and part of the way back, will not open the induction port.

Hence, as Mr. Goodspeed expresses it, "We have a one-quarter cut-off with a full opening of the induction port, and also a full opening of the exhaust port."

It is to be understood in this connection that the earlier the cut-off the greater is the required length of the valve travel.

When it is desired to work the engine to its fullest capacity the valve may be assumed to be in the same position as in the former instance, that is, with a small lead open.

Assume, further, that the link motion is set or adjusted so that the stroke imparted to the valve will be only the same as the width of the induction port.

It is obvious that in this instance the induction port will be opened gradually until at the end of the valve's stroke it will be wide open.

In this instance it will be noticed that the auxiliary cut-off is not moved, hence the friction of the valve upon its seat will be lessened, inasmuch as the area of the valve subject to the steam pressure is less than with the ordinary sized valve having considerable outside lap.

HALEY'S SLIDE VALVE.

The objects sought to be attained by the use of this valve are an increased expansion of the steam after cut-off, and the relief of excessive compression.

It is the invention of Mr. J. A. Haley of Fort Wayne, Ind.

It consists in the construction and combination of, first, a main valve constructed with shortened face, but adapted to actuate an independent valve face, the object of which is to supplement the shortened valve face.

Second, an independent valve face, and, third, devices and means whereby during a portion of the travel of the main valve, the independent valve face is not operated by the main valve, but remains stationary, and thus serves to give an increased inside lap at one part of the valve, together with increased clearance at the other part alternately with each stroke of the main valve.

By the term "independent valve face," is meant a valve face which during a given portion of the travel of the valve remains stationary and is not moved by the valve either directly or indirectly.

The form of construction of the Haley valve is shown in Figs. 39 and 40, where A is the main valve, which has portions of its faces cut out in the form of a rabbet, thus leaving the faces, a, shortened.

These rabbets are cut out sufficiently deep to permit an independent valve face, B, to be placed underneath them and afford room for its independent motion.

This independent valve face consists of two bars, B, B, connected by cross bars, H, which are also placed under rabbets on either side of the main valve, A, and

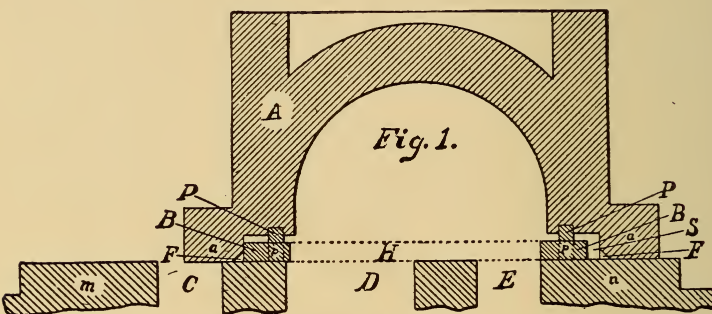


FIGURE 39.

its dimensions are such that there will be a space, S, between it and the extreme length of the rabbets on the inside of the face of the valve, A.

This frame composing the independent valve face is placed on the valve seat within the rabbeted parts of the face of the valve, A, and packing, P, is placed above the independent valve face, and other packing, p, is placed upon the side, in the side rabbets, as shown in Fig. 40, for the purpose of preventing steam from passing between the valve faces, B and a.

The space S, is for the purpose of, and designed to allow a movement of the main valve, A, through that distance or space, without moving the independent valve face, B.

Its length is determined by the requirements for inside lap, and inside clearance.

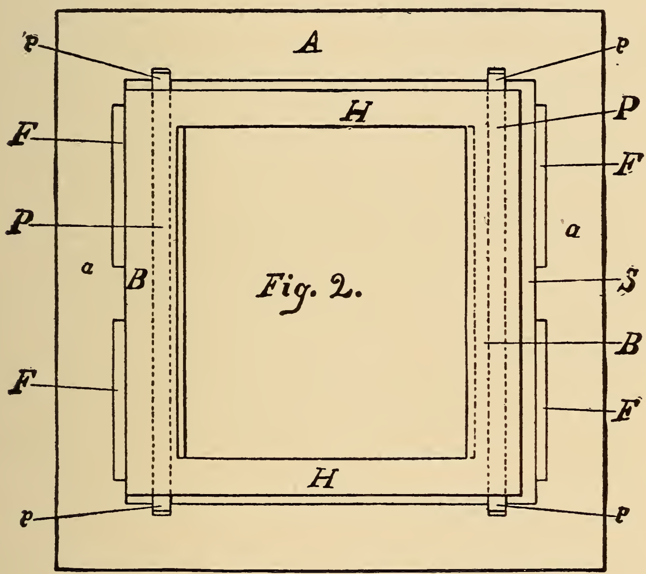


FIGURE 40.

When the space S has been traversed by the valve A moving from n to m, the end of the rabbet impinges against the independent valve face B at the port E and moves it to the end of travel of main valve A.

On the return stroke the positions and movements are reversed. The faces, A, have chamfers, F, on their inside corners for the purpose of permitting the steam to operate against the ends of the independent valve face, B, to aid in keeping it alternately pressed against the ends of the rabbets for the purpose of preventing any movement of B except when actuated by the main valve, A.

The operation of the device is as follows: When the engine is first started the ports are used to their full capacity, steam being admitted to the cylinder throughout the stroke of the piston, in which case this valve has no special operation, but when the stroke of the valve is reduced or shortened in order to use steam expansively then the following results take place:

Referring to Fig. 39, let it be assumed that the opening of the port, C, as shown, is the extreme opening for a given point of cut-off.

At this point the cylinder is therefore taking the full amount of steam at such point of cut-off, while the port, E, is exhausting at the other end and is open to its full extent.

The width of the exhaust cavity measured on the valve seat is determined by the fixed distance apart of the inner edges of the two plates, B, B, which form the independent valve face.

The packings, P, p, prevent the passing of steam between the faces, B and a, into and from the exhaust cavity.

The area of space on the valve seat covered by the combined valve faces, B and a, varies during the travel of the valve.

When the valve travels, say, on the return stroke (see Fig. 39), the faces, B, B, remain stationary until the distance, S, has been traveled by the face, a, at the end, n, of the valve seat.

The inner end of the face, a, then impinges against and actuates B.

At this point of travel, and continuing to the end of the return stroke, the combined faces, B and a, on the end, n, of the valve seat, cover a diminished distance, while the faces, B and a, on the other end, m, cover an increased distance over the ports and valve seat, the difference being represented by the space S.

Such movement increases the inside lap of the combined valve faces, B and a, on the end, m, of the valve seat, because of the lengthening of the combined valve faces, and thereby delays the release of the steam at the port, C, thus allowing a greater expansion before exhaust takes place.

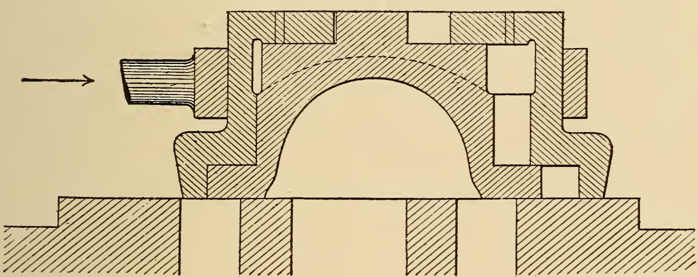


FIGURE 41. METZGER'S SLIDE VALVE.

At the same time while so traveling the distance covered by the combined faces, B and a, at the end, n, has been reduced correspondingly, and the face, B, has remained stationary during a portion of the travel, so that the closing of port, E, has been delayed, thereby giving a free release and reducing the compression in that end of the cylinder.

This increase of the inside lap at the end, m, of the valve seat and increased clearance at the opposite end, n, is reversed with the reverse travel of the valve.

METZGER'S SLIDE VALVE.

The principle involved in the design of this valve is practically the same as that in the Haley valve which has just been explained. Fig. 41 is a vertical section through the valve and shows the construction plainly, the object being the same as with the Haley valve, viz; an increased inside lap and free release.

This form of valve is the design of Mr. Jules P. Metzger of Paterson, N. J.

A NEW LOCOMOTIVE VALVE AND VALVE SEAT.—C. I. & L. RY.

There is shown in Fig. 42 a valve and valve seat which, while tending in a direction the limit of which has probably been tested in another design, is, we believe, quite new. It should be understood at first that the drawing shows the valve as applied to the ordinary

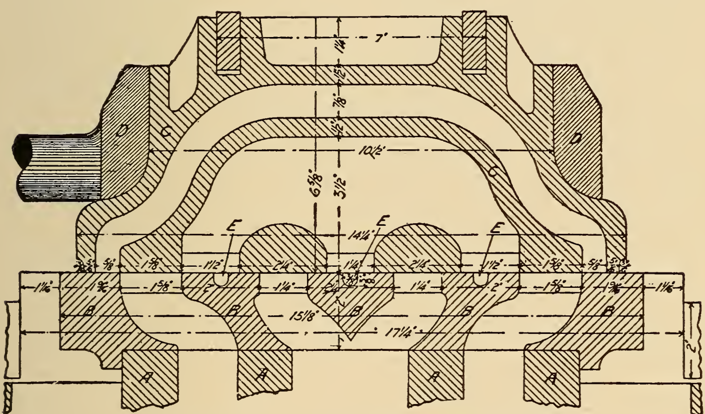


FIGURE 42. THE WATKEYS VALVE.

cylinder casting A A, cored with a steam port on either side of the single exhaust port, so that it is necessary to put in a false seat, B B, 2 in. thick, and having ports suitably arranged for the openings in the valve. This makes it necessary also that the steam chest be raised 2 in., and accordingly a filling piece 2 in. thick is placed under the steam chest. For new work the ports can, of course, be cored in the cylinder casting and then the valve seat and steam chest would be of the same height as in the ordinary design.

The valve is shown as central on the seat, and the exhaust edges of the steam ports are line and line with the inside edges of the valve, so that if it is considered that the valve is moving from right to left, the left steam port is about to open for exhaust. The double exhaust port, however, is covered ½ in. so that after the point where the interior of the valve is opened to the exhaust steam, the valve must travel ½ in. before the exhaust port begins to open. The exhaust port being double, the area of the port which is uncovered by a certain movement of the valve is twice the area that would be uncovered were the port single, and a freer exhaust must therefore result. The double exhaust port and single steam port would be no better than if both ports were single were it not for the arrangement which makes it possible to open the exhaust side of the steam port ½ in. by the time the valve begins to uncover the exhaust port. The claim made for the valve is that the steam can be held in the cylinder during a longer portion of the stroke (except for the steam which expands into the inside of the valve) because when the valve begins to uncover the exhaust port the required opening is given by one-half the travel of the valve required for the single exhaust port. The grooves E E E are cut in the seat to assist lubrication; it is reasoned that they are soon filled with water or oil, or a mixture of both, and that the face of the valve is coated each time the valve passes over them. The valve is the design of Mr. H. Watkeys, Master Mechanic of the C. I. & L. Ry.

One of the greatest drawbacks to the efficiency of high speed locomotives is excessive compression.

This is a fact that cannot be questioned, and the device which will distribute the steam to the pistons, and from thence to the atmosphere with the least loss of heat, while at the same time smooth running is effected, will always meet with favor.

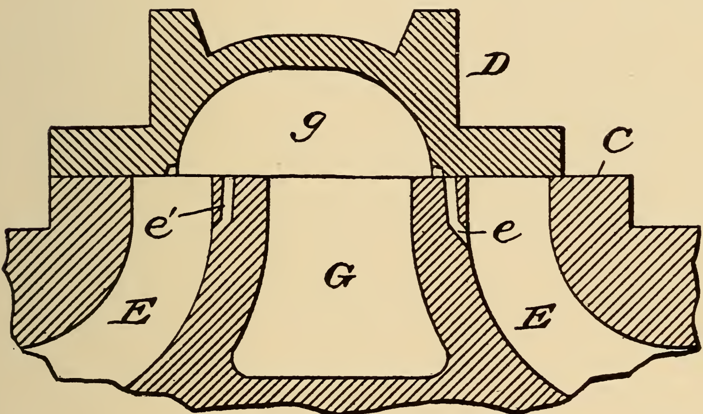


FIGURE 43. FARRER'S VALVE.

Not only does great loss of heat occur through compression, but another source of loss is excessive clearance, whereby a needlessly large volume of steam is required to fill the space between piston and cylinder head at each end of stroke.

Fig. 43 illustrates the improvement of Mr. Chas. S. Farrer of Dunmore, Pa., as applied to the ordinary slide valve and the principle of the device is as follows:

Two small holes e, are drilled through each bridge in the manner shown.

These serve as relief ports, and coincide with the grooves cut on the exhaust edges of the valve D thereby permitting a portion of the air that is being compressed in the cylinder to escape to the exhaust cavity G and thence to the stack, thereby reducing compression.

The advantages obtained by this arrangement are as follows: First, a smaller clearance space can be made. Second, higher speed can be obtained owing to the fact that excessive resistance in the front of the piston, in other words back pressure, is obviated, when cutting off at short points of cut-off, and third, a saving in the general wear of the engine, and especially in the wear of the valve and seat, by reason of the valve keeping down on its seat at all times and not being forced off its seat by back pressure caused by excessive compression.

There is therefore a saving effected in the coal consumption of the engine, as steam cannot blow under the valve to the exhaust port and the engine will do the same work at shorter points of cut-off.

BALANCED SLIDE VALVES.

For a great many years the plain slide valve answered all the requirements for locomotive service, but with the enlargement of the locomotive and the increased steam pressures it was found almost impossible for one man to reverse an engine with such an enormous pressure on top of the large slide valve which modern locomotives require. The object of designers was, therefore, to produce a valve that would require as little power as possible to move it. To lessen this friction, what is known as the "Roller Valve" was first invented. It was a plain slide valve with rollers attached to each side of the valve. While this valve required less power to handle it, yet it failed to remove the cause of the great amount of friction between the valve and its seat, and therefore did not come into general use, although it is still in use upon some roads. But, when the balanced valve, sometimes called the equilibrium slide valve, was invented, the correct principle seems to have been followed, viz: The removal of the steam pressure from the back of the valve. These valves have been universally adopted. The various forms of these valves that have been invented are too numerous to mention, but they are all constructed upon the same principle, that of removing the pressure off the valve.

We have illustrated a few forms of these valves, varying all the way from very good to very bad. The best form of balance valve will be found to be the one which overcomes the greatest friction (within practical limits), the most simple in construction and positive in its operation and has the fewest parts which are liable to break or get out of working order.

THE GOULD BALANCED SLIDE VALVES.

Figures 44 to 49 serve to illustrate the construction and operation of the Gould balanced slide valves, of which there are two styles.

These valves are the invention of Mr. W. F. Gould of Des Moines, Ia.

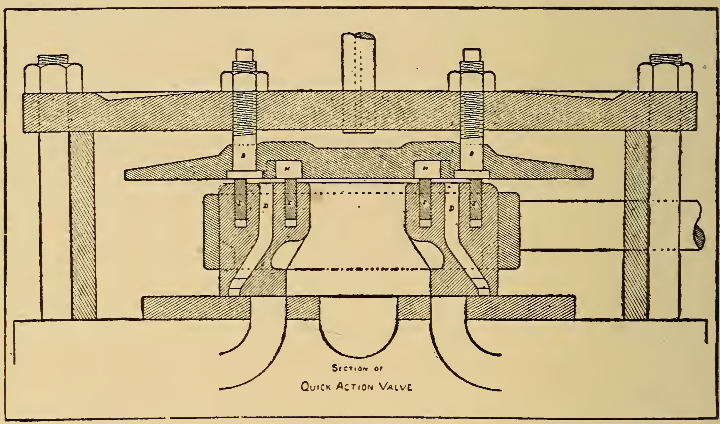


FIGURE 44. GOULD QUICK ACTION VALVE.

The form known as the "Quick action valve", Fig. 44, deserves special attention.

Heretofore it has been the generally accepted belief among practical men that it would be impossible to prevent the valve from lifting off its seat if all the pressure were removed from the top of the valve, but the action of the "quick action valve" appears to refute this theory.

The principles of the Gould balanced valve are similar to those of the piston valve.

Either form of the Gould valve may be applied to the ordinary flat valve seat.

Two methods of balancing are employed, one form of which, the "quick action valve" may be used with either a flat pressure plate, or a semi-circle balance plate, and promises to be an important rival to our best forms of balance valves.

For the other form of valve the balance is obtained by means of a semi-circular balance plate fitted into the steam chest lengthwise.

It is not bolted to the cover like most pressure plates, but rests on the valve seat. It has lugs that are closely fitted on the ends to prevent it from moving lengthwise, while the pressure on its back serves to hold it to its seat.

The top of the valve is also a semi-circle in form, slightly smaller than the plate and has balance strips set into it which bear against the plate in the usual manner.

A small port at each end permits live steam to enter between the valve and the pressure plate, which is permitted to cover sufficient area to overcome the back pressure from the cylinder, thereby obtaining almost a perfect balance.

In construction the two balance plates, (one for each valve) are first planed off on the edges, then the two are clamped together and bored out to their required size.

The valves are finished in a similar way, first the two faces are planed off, then clamped together and turned off in a lathe, and made a little smaller than the pressure plate.

When the valve requires facing, the same amount is taken off the bottom edges of the pressure plate also, thereby retaining their original positions, and the plates automatically adjust themselves to any inequality due to the wear of the valve.

Fig. 44 is a sectional view of the quick action valve, and shows the relative positions of the small ports D, D at either end of the valve, to the ports leading to the cylinder. (Not lettered.)

The valve cover A is supported by four bolts to the steam chest cover, in such a manner as will permit of the cover A to be raised or lowered at will. H, H are ports in the base of the cover running longitudinally parallel to the steam ports.

The ports D, D already referred to are longitudinal cavities in each end of the valve, and should be of the same length as ports H, H and nearly as long as the steam port that leads to the cylinder.

E, E are packing bars placed on each side of the cavity D in the top of the valve in such a manner that the distance between them is of very little more area than the width of the steam port, for the purpose of holding the valve down when the steam port at the end of the valve is filled with steam.

In the operation of the valve as shown herein, when the valve is pulled back so as to open the steam port, it will be observed that the packing bar nearest that side will have also been pulled back so that the steam at the top of the valve will pass over that top of the packing bar E into cavity H, thence through cavity D, into the steam port, thereby forming a double opening into the cylinder.

Another feature shown in Fig. 44 is that, the valve on its return shows the port D in communication with the steam port after cut-off has occurred, thereby showing the area between the packing bars E, E to be in communication with the steam in the steam port. This is done in order to balance the valve.

It should be noted that the outside packing bar can be placed as near the outside end of the valve as desired, so as to take all, or nearly all of the pressure off of the valve.

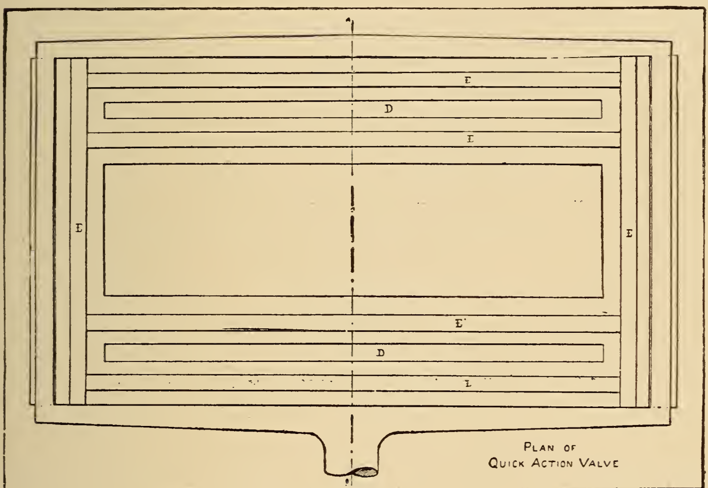


FIGURE 45.

Another noteworthy feature connected with this valve is, the relative position of the ports to each other when the engine is running at a high rate of speed, and a comparatively short cut-off, or in other words, using the full amount of lead.

In such cases there is more or less cushion, or back pressure in the cylinder but owing to the fact that port D will be in communication with the steam port, the bad effects of this back pressure are entirely obviated.

When it becomes necessary to reverse the engine while running at a high rate of speed it will be observed, (by studying Fig. 44) that the valve will lift, and relieve the pressure in the cylinder, for the reason that the movement of the valve will be exactly opposite to the movement it had before the engine was reversed.

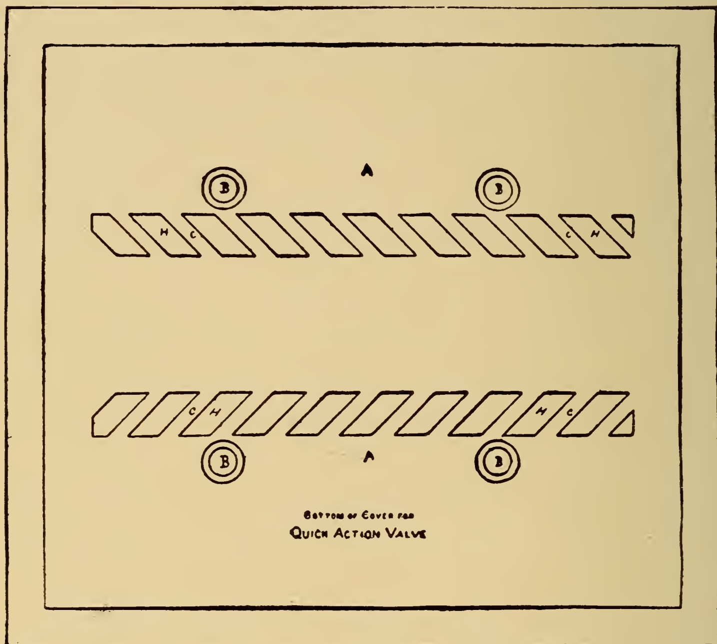


FIGURE 46.

In the plan view (Fig. 45) the relative position of the side bars and the end bars E to each other is clearly shown.

The valve is also shown to have an open back, which prevents the exhaust steam from having any effect upon the valve, but allows it to keep the bottom of the cover well lubricated.

Fig. 46 shows a view of the bottom of the cover A. The ports H, are shown placed diagonally with the small bars C, in them.

The reason that ports H are placed diagonally is to prevent ridges from becoming worn on the packing bars E as they move across ports H.

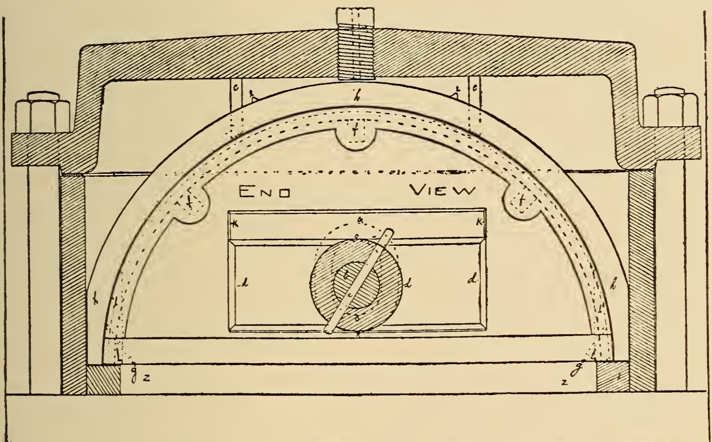


FIGURE 47. GOULD BALANCE VALVE.

GOULD BALANCED VALVE.

Figs. 47 and 48 are sectional views of the Gould balance slide valve, Fig. 47 being an end sectional view of the valve, valve cover and steam chest, and Fig. 48 is a vertical side sectional view of the same.

Referring to Fig. 47 H, is a loose cover that fits over the top of the valve, and is prevented from having too much longitudinal movement by stops c, c. This movement should never exceed 1-16 of an inch over all.

The space occupied by the packing is designated by the dotted lines in the semi-circle, and this packing is enclosed in the pockets f, f, f.

The letters k, k, represent a chipping strip upon the rear end of the valve, which may be faced off so that the back end of the yoke d, may fit it.

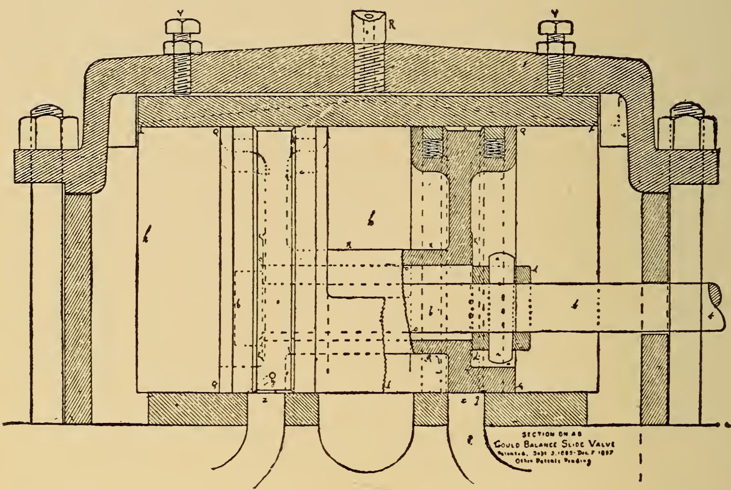


FIGURE 48.

The letters n, n, represent the sleeve, which is cast solid to each wing of the valve, and extends across the cavity o, in order to contain the valve stem b.

The cavity o, is oblong in shape in order that the vertical movement of the valve may not bind upon the valve stem.

The letters g, g, Fig. 47 designate two small holes drilled in the face of the valve for the purpose of establishing communication between the port z, and the cavity x, shown in Fig. 48.

Small ribs e, e, are cast upon the top of the valve cover h, in order to prevent the valve oil from running down the sides of the cover.

These ribs e, e, also cause the oil to be distributed to the end of the cover, thereby effecting a more perfect lubrication of the valve and seat.

Fig. 48 is a side sectional view of the valve, in which the packing rings are shown, held up by the spiral springs on one end of the valve, while the dotted lines on the opposite end of the valve designate the spring pockets.

Two cavities x, x, Fig. 48 extend around the outside faces of each end of the valve, while the packing as shown is placed upon each side of these cavities x, x.

The area of cavity x should always slightly exceed the area of the steam port z, in order that when port z, is filled with steam, and communication established with cavity x through hole g, (shown also in Fig. 47) the pressure in cavity x will at least equal the port pressure, and the valve will be held down on its seat.

It will be observed that a practically perfect balance may thus be obtained, the degree of perfection depending upon the location of the packing rings, relative to the outside edge of the valve, and the giving of the proper area to cavity x.

The check stubs y, y, Fig. 48, in the top of the steam chest cover are for the purpose of regulating the vertical movement of the valve cover h and preventing it from lifting too high from the valve.

It will be observed that these stubs do not quite touch the valve cover, being adjusted to allow a slight movement in a vertical direction.

Letters l, l, see Figs. 47 and 49, designate a web that holds the bottom of the wings of the valve firmly together in one piece and prevents any leakage of steam into the exhaust, which might occur if the valve cover was raised from the seat.

This valve is semi-circular in form and is constructed in the following manner.

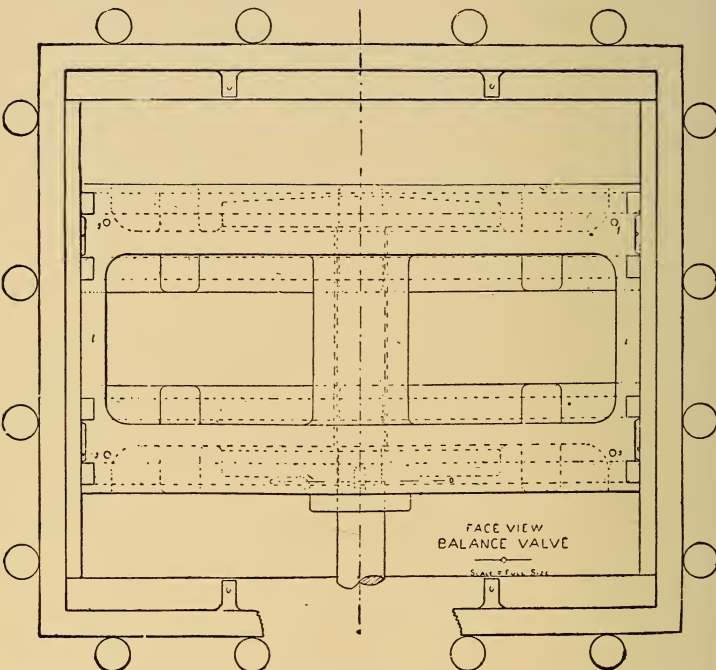


FIGURE 49.

As soon as the castings come from the sand their faces are planed and fastened together, and they are then placed in a lathe and turned to the proper size.

Grooves for the packing, also cavities x are cut into their faces. The valve covers have their edges planed, and they are then fastened together and bored out to fit the valves, thereby making one for each side of the engine.

The valves and their covers should fit iron to iron when they are cold, for the reason that when the cover becomes hot it expands a little more than the valve does, which leaves the valve free to move perfectly easy under it.

When it becomes necessary to face the valve the same amount of iron should also be planed off of the bottom edge of the valve cover, thus causing each to assume their normal position relative to each other, and as cavity o in the valve through which the valve stem passes is made oblong vertically, it will readily be seen that facing the valve will not affect the valve stem in the least.

When the exhaust is being planed out the tool should not be allowed to cut through line l shown in Fig. 49, which is a face view of the valve, and shows the form of the exhaust.

The sizes of the ports will of course have to be governed by the sized engine upon which the valve is to be used.

The packing rings should have at least five-eighths of an inch face with a depth of one-half inch.

The valve stem should be at least 1½ inches in diameter, and the stops c, c, Fig. 47, should not be less than ⅝ of an inch in width.

The valve cover should finish 1¼ inches in thickness, in order that there will be no danger of its ever becoming distorted, or out of shape. This thickness would also permit of it being bored out the second time to fit the valve.

The depth of the cavities x should not be less than ⅛ of an inch and the diameter of the hole g, should be not less than 3-16 of an inch.

The diameter of the bolts y should be not less than ¾ of an inch.

The springs that are designed to hold the packing should be made of about No. 70 steel wire so that the pressure on them would be very light for the reason that if these springs are too stiff they will cause the packing to wear too fast or might hold the cover up from the valve when steam was not being used.

VACUUM RELIEF VALVE.

This valve, R, Fig. 50, is designed to be placed in the steam chest to automatically supply clean air to the cylinders through the air valve when engine is running shut off, and thus furnishes a free supply of air from the outside instead of its being sucked in from the smoke box laden with hot gases and cinders which lap all oil from the valves and seats.

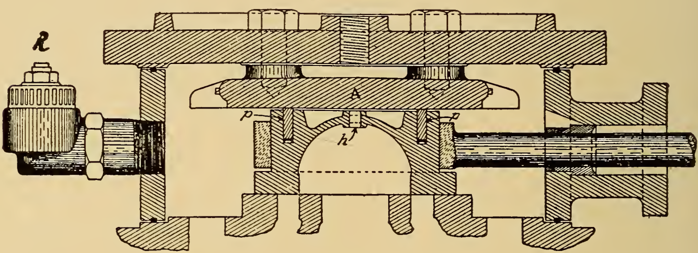


FIGURE 50. VACUUM RELIEF VALVE.

The pressure relief valve performs a very valuable function in preventing the dangerous accumulation of pressure in the steam chest and dry pipe and ofttimes breaking of same when engine is suddenly reversed. The valve is set to open at a pressure slightly above the maximum boiler pressure, and will allow any excess of pressure to escape to the atmosphere, yet will maintain in the cylinders a uniform pressure of air within the limits of safety, when running forward after reversing, and thus supply resistance to the pistons and overcome the momentum of the train, and perform the functions of an automatic air brake in assisting to stop the train. By using this valve an engine may be suddenly reversed while running at high speed without strain or damage to any portion of the machinery or boiler.

This valve should be well designed and made from the best steam metal. Combined pressure and vacuum relief valves on low-pressure steam chest and single-pressure relief valves on low-pressure cylinder heads should be set at 45 per cent of the boiler pressure, and the high-pressure cylinder head relief valves set at 20 lbs. above boiler pressure.

THE PISTON VALVE.

Reference has already been made to the piston valve for locomotives and as there are many different varieties, of this type of valve, the discussion will be continued for a short space.

The piston valve is an old affair in locomotive practice, having lain dormant for years. One of the early designs of these valves was that of Mr. Thomas S. Davis of Jersey City, in 1866. A difficulty which developed with his design and others at that time was the rapid wearing away of the valve cage at the port openings, due in part to the absence of bridge strips in the port openings, as ring-bearers for the piston. It was supposed also that the valve piston rings needed adjustment the same as those of the steam cylinder piston. Occasionally this adjustment was faulty and, cramping the free motion of the valve, over-balanced all the advantage of the piston for the time being. The tallow then used for lubrication troubled the piston valve, as it did also the plain D valve. The cause which more than any other, however, led to the disuse of the piston valve after these early experiences was the introduction of the balance on the slide valve. This balance rendered the slide valve form acceptable at the then low pressure standard on engines.

In the meantime the piston valve has gained a position at the head in steam vessels, small and large, naval and commercial, at all pressures the world over. It is used in fast steamers crossing the ocean, the entire distance being passed, in some instances, without lubrication. It is also used in the best and fastest electric engines running almost continuously. The piston valve has of late years been improved in form, eliminating the features which caused objections to the old form, and with the advent of high pressures it is fast coming into favor again.

Owing to the fact that the piston valve is practically encased within the walls of the cylinder it permits of a greater port area, and occupies less space than the D slide valve does.

It has been commonly supposed to be a perfectly balanced valve, but recent tests have proved that it is not as perfectly balanced as was generally supposed.

It has been found that its perfection of balance depends largely upon the width of its rings, and the steam pressure, for the simple reason that so long as the steam exerts a pressure under the rings, thus holding them against the walls of the cylinder, there is thereby created an unbalanced friction the amount of which depends upon the area of the rings, and the pressure of the steam under them.

Of course a great deal depends upon the workmanship in the construction of the valve. The closer the rings are made to fit the grooves without binding, the better, but it is practically impossible to fit the packing rings perfectly steam tight without their sticking in the grooves, and the more the sides of the rings wear from service, the greater will be the steam pressure under the rings, and as a consequence the greater the friction.

Owing to the usual forms of piston valves, they being generally made either of one long casting, or in two parts connected with a rod or tube, it is possible to locate the two faces near the ends of the cylinder, thus reducing the clearance considerable, as compared with the D valve.

This lessening of the space to be filled with live steam between the piston and the valve face, for each stroke of piston, most certainly tends toward an increase in the efficiency of the engine, as the expansive force of the steam is in no way decreased, while the weight of steam to be exhausted at the completion of the stroke is considerably less. While the correct principle for reducing the clearance seems to be followed in placing these valve faces near the ends of the cylinder it should be remembered that while the distance between the valve and piston is lessened the clearance space extends clear around the valve and the claim of reduced clearance for these valves has frequently been overthrown by the Indicator.

In the Vauclain Compound locomotive built by the Baldwin Co. the valve employed to distribute the steam to the cylinders is of the piston type, working in a cylindrical steam-chest located in the saddle of the cylinder casting between the cylinders and the smoke-box, and as close to the cylinders as convenience will permit.

As the steam-chest must have the necessary steam passages cast in it and dressed accurately to the required sizes, the main passages in the cylinder casting leading thereto are cast wider than the finished ports.

Fig. 51 shows the arrangement of the high and low pressure cylinders in relation to the valve. The steam-chest is bored out enough larger than the diameter of the valve to permit the use of a hard cast iron bushing

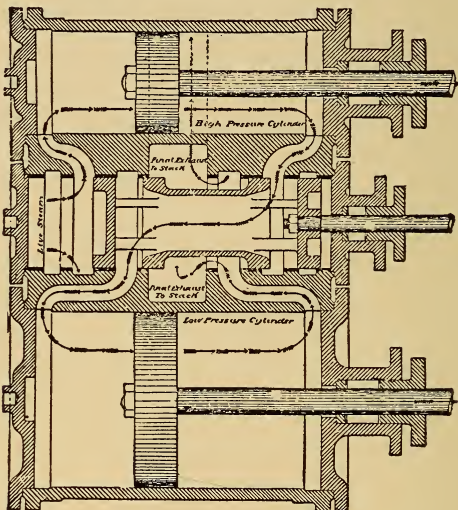


FIGURE 51. SECTION OF CYLINDERS AND VALVE CHEST—VAUCLAIN COMPOUND ENGINE.

(Fig. 52). This bushing is forced into the steam-chest under such pressure as to prevent the escape of steam from one steam passage to another except by the action of the valve. Thus an opportunity is given to machine accurately all the various ports, so that the admission of steam is uniform under all conditions of service.

The valve, which is of the piston type, double and hollow, as shown in Fig. 53, controls the steam admission and exhaust of both cylinders. The exhaust steam from the high-pressure cylinder becomes the supply steam for the low-pressure cylinder. As the supply steam for the high-pressure cylinder enters the steam-chest at both ends,

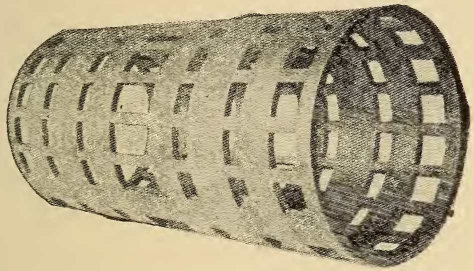


FIGURE 52. BUSHING FOR VAUCLAIN PISTON VALVE.

the valve is in perfect balance, except the slight variation caused by the area of the valve-stem at the back end. This variation is an advantage in case the valve or its connection to the valve-rod should be broken, as it holds them

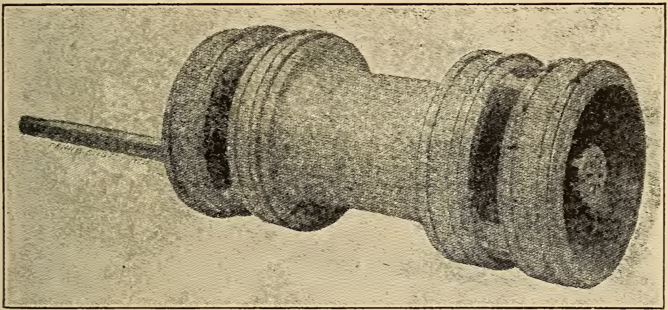


FIGURE 53. PISTON VALVE USED ON VAUCLAIN COMPOUND LOCOMOTIVE.

together. Cases are reported where compound locomotives of this system have hauled passenger trains long distances with broken valve-stems and broken valves, the parts being kept in their proper relation while running by the compression due to the variation mentioned To avoid the possibility of breaking, it is the present practice to pass the valve-stem through the valve and secure it by a nut on the front end.

Cast iron packing rings are fitted to the valve and constitute the edges of the valve. They are prevented from entering the steam-ports when the valve is in motion by the narrow bridge across the steam-ports of the bushing, as shown in Fig. 52. The operation of the valve is clearly shown in Fig. 51, the direction of the steam being indicated by arrows.

In setting these piston valves, only the high-pressure ports are to be considered. Both heads of the steam chest are removed, and with a tram, from some point on the body of the cylinder to the valve stem, the line and line positions of the valve in both front and back motion, are laid off and indicated by a prick punch mark on the valve stem. Using the same tram, the position of the valve at different parts of the stroke can be ascertained, and the opening of the ports noted by the distance from the point of the tram to the prick punch mark. The relation of the low pressure ports to the valve must be ascertained by measurement, the same as the exhaust ports in ordinary slide valves.

THE AMERICAN BALANCE VALVE.

This form of balance can be applied to almost every form of slide valve.

The American balance valve Fig. 54, has been adopted by a great many of the principal railroads in this country, consequently we give details of its construction, believing it will be interesting to a large number of our readers.

It has also attracted the attention of foreign builders and is now in use upon many locomotives in other countries. It is claimed many thousands of these valves are in use, being used by 110 different railroads in this country and

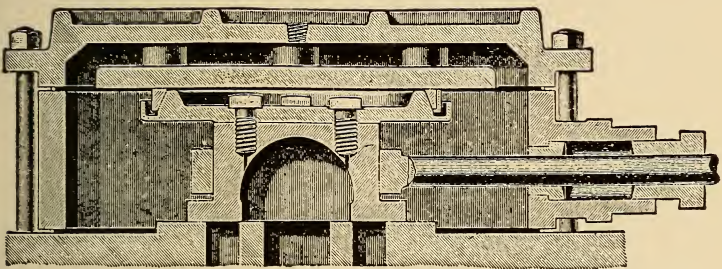


FIGURE 54.

many foreign roads; also on marine and stationary engines. One of our illustrations shows its application to an Allen ported valve. The claims made for this form of balance are:

1. *Self supporting*—when not under steam.
2. *Supported by steam*—when under steam.
3. *Automatic adjustment*—with or without steam.
4. *Absolute steam joints*—no waste from leakage at any time.
5. *Positive action*—impossible for ring to stick.
6. *No lateral wear*—ring moves as part of the cone itself.
7. *Permanency of cone*—cones retain original dia. and taper.
8. *Standard sizes*—rings interchangeable, old or new.
9. *Stock*—carried in stock for new work or repairs.
10. *Lathe work*—stock from the lathe is economy.

11. *Greater area of balance*—equaled by no other design.

12. *Simplicity*—always most desirable in machinery.

It is claimed by the makers of this valve, (The American Balance Valve Co. of Jersey Shore, Pa.) that, first of all it furnishes an absolutely steam tight joint, not only when newly fitted, but all the time.

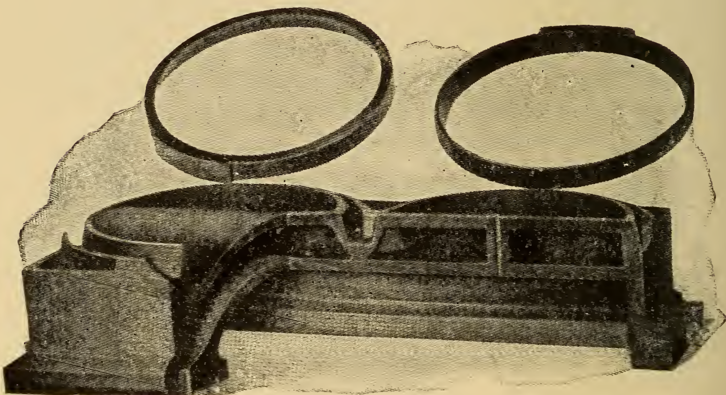


FIGURE 55. RINGS AND CONES—AMERICAN BALANCE VALVE.

Second, greater area of balance, the valve being balanced in what is presumably its heaviest position, and with the steam pressure acting upon the conference of the taper rings, (See Fig. 55) it will be observed that for the valve to lift off its seat, it is necessary to force the cone up into this taper ring, and since the ring is held by the steam pressure from opening, the valve cannot lift without first overcoming the entire friction of the beveled face, besides opening the ring against the pressure in the steam chest.

It will therefore be seen that, whether the chest pressure be heavy or light the valve is always retained upon its seat.

It might at first glance appear to be a natural conclusion that this taper of rings and cones would crowd the valve down on its seat unnecessarily hard, and no doubt it would have that tendency if the degree of taper was made great enough, say 45 degrees for instance, in which case the action of the steam chest pressure upon the circumference of the ring would of course wedge it in between the cone and the chest cover and thus exert an enormous pressure upon the valve.

Experience has however demonstrated that there is a correct degree of taper, which varies all the way from 9 to 24 degrees, to be given to the rings and cones, depending upon the style of valve, whether it be single "disc," double "disc," single cone, etc., and the claim is made that rings have run 190,000 miles with but 1/32 inch wear off their faces.

It is also claimed in favor of this system of balance, that it is positively automatic, in adjustment, also self supporting, with no delicate parts, and therefore not easily broken having, no springs.

The only repairs necessary on the American balance is to put in a new ring when the old one has worn out from the top downward.

The new rings are one inch in depth, and they can easily wear ⅜ inch, and still adjust themselves.

Assuming that the rings are made of the proper quality of metal, and that they receive the proper care in service, the time required to wear ⅜ inch from the face, would be from four to eight years of continuous service.

It will thus be seen that the cost of repairs is very light, and another great advantage is, that when an old ring is replaced by a new one there is absolutely no change in the balance.

This is explained by the fact that since the steam pressure on the circumference of the ring holds it firmly against the beveled face of the disc or cone, while in operation, under steam (its own tension holding it when not under steam), there is absolutely no lateral wear on either the ring, or the disc, consequently a new ring fits an old disc.

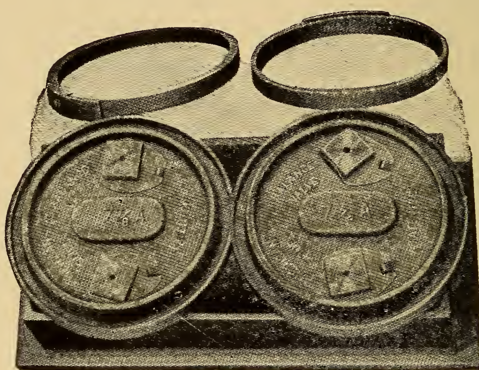


FIGURE 56. T RING—AMERICAN BALANCE VALVE.

The rings are made from standard gauges which are used on the lathe in place of a caliper, or rule, and as the rings are all lathe work the time required for fastening on the L-shaped piece for covering the cut of the ring is very short, not more than twenty minutes hand work.

In turning up the rings, they are made ¼ inch smaller in diameter than their working diameters. They are then cut, and expanded over the cone which gives them a tension that makes them self supporting when not under steam.

The pressure of the steam on the circumference of the ring supports it when in operation.

The latest improvement in this form of balance is the T ring (Fig. 56); the flanges on the top of the ring give an extra width for wearing surface, which prolongs the life of the ring. The top face of the ring is provided with a small groove for oil. The L-shaped joint plate forms joints both on the beveled face and at the top of the ring. The "outside rim" or flange extending outside the taper ring is to prevent pieces of the ring from falling in the path of the valve in the event of accident to the ring.

SINGLE "DISC" BALANCED VALVE.

Always use the single balance where chest room will permit it, as one ring and disc is simpler than two.

For length of steam chest for single balance add the extreme travel of the valve to the outside diameter of disc, and to this sum add not less than ½ inch for clearance—¼ inch at each end of chest. If a little more clearance is desired the rims of disc may be cut ⅛ inch—just flattened on two sides in line of valve travel. But in no case are they to be cut beyond their inside diameter.

If sufficient clearance cannot be obtained by cutting the rims ⅛ inch each side in line of valve travel, then double balance must be used.

DOUBLE "DISC" BALANCED VALVE.

When the steam chest is too short to leave clearance for the outside diameter of the disc, or cone of single balance at extreme travel of valve, it then becomes necessary to use double balance.

If the yoke fit (or box) of the valve is large enough two cones are cast on the valve, but in case the yoke fit is not large enough to cast cones on, then two discs are used.

If the distance across the two discs when they are side by side on top of the valve is greater than the width of the steam chest, the rims on each disc may be cut 1/8 inch at the center of the valve, thus drawing the discs 1/4 inch closer together, and if more clearance is still required the rims may also be cut 1/8 inch and the ends of the valve, thus giving 1/4 inch more, making a total of 1/2 inch.

But in no case should the rims be cut more than 1/8 inch or to their inside diameter.

If discs thus cut will not clear the sides of the steam chest, it will be necessary to use a smaller balance.

"DISC" BEARING ON CONE.

In all cases where possible the height adjustment should be made by lowering the cover of the steam chest, or bearing plate, but when this cannot be done, the discs may be raised.

When it becomes necessary to raise the disc on the valve, longer bolts should be used, and the liners placed between the disc and the valve must be true, and large enough to give a solid bearing for the disc on the valve.

If it is found necessary to raise the disc to clear the top of the valve, the same rules must be observed.

The bolts that hold the disc to the valve should be steam tight on threads, also steam tight under the heads, a copper washer being used under the heads, thus forming a bolt lock.

The interior of each disc or cone is relieved to the exhaust cavity of the valve.

In "cone" balance, relief holes are drilled through the top of the valve, but in "disc" balance these relief holes (¼ inch in diameter) pass through the bolts, one hole through each bolt

SINGLE "CONE" BALANCED VALVE

This style of valve must be cast flangeless if a valve yoke extending all around the valve (as in locomotives) is used, but need not be flangeless when made for center rod to drive the valve (as in stationary engines). In case of the locomotive yoke we recommend the yoke to be carried on the steam chest at the ends of the valve. Where old chests have rubbing strips wide enough they can be planed on top and the yoke allowed to ride on them, and in new work this can be done cheaper than to put on a front carrying horn and is more efficient than to support the yoke on the valve stem packing the valve itself. A valve need not be flangeless to thus support the yoke, it can be carried with any valve, and it insures the free upward movement of the valve at all times, which is very essential in obtaining the best results.

OUTSIDE RIMS.

The outside rim on disc or cone is merely a safeguard to the ring in case of accident—it performs no other duty. The required inside diameter of this rim must allow the ring to be expanded on the cone until the top face of the ring is flush with top of cone and still clear the ⅛ inch joint plate on the outside of ring. In single balance the rims may be cut ⅛ inch front and back, giving ¼ inch more clearance, when the disc runs too close to steam chest at full travel of valve.

In double balance the rim of each disc may be cut 1/8 inch so as to draw the discs 1/4 inch closer together at center of valve, and if more clearance at sides of chest is required the rims of each disc may be cut at ends of valve also. The distance across the two discs can thus be shortened 1/2 inch.

In no case shall the rim be cut more than 1/8 inch. The two cones where they come together at center of valve in double balance must not be less than 3/4 inch apart at the bottom.

If discs thus cut will not clear the steam chest, then smaller balance must be used.

HEIGHT ADJUSTMENT.

When the valve is in position and the chest cover has been screwed down there must be 1/8 inch between the face of the bearing plate (sometimes called balance plate) and the top of disc or cone.

The rings are bored for this position and in this position have their proper tension. This allows the valve to lift off its seat 1/8 inch, which it will do as soon as steam is shut off while the engine is in motion, provided it is not held down by the valve yoke.

The valve yoke must not interfere with this upward movement of the valve.

Rings are all bored smaller than the diameter at which they are to work; therefore when a ring is set on its proper cone it will stand higher than its working position.

The face of bearing plate must not be closer than 1/8 inch to top of cone after chest cover has been screwed down. In placing the cover in this position the ring is expanded over the cone until its inside diameter at bottom is the proper balancing diameter.

Owing to the natural elasticity of the ring and its expansion over the cone, a tension is placed on the ring, the action of which is (the same as the steam pressure) to close the ring on the cone, which necessarily moves upwards.

The ring is therefore self-supporting and self-adjusting. All rings are interchangeable on discs and cones of respective sizes whether standard or special.

BALANCES.

American balances are known under the following heads, one valve being balanced in each case:

Single "disc" balance, i. e., one ring and one disc.

Double "disc" balance, i. e., two rings and two discs.

Single "cone" balance, i. e., one ring with cone cast on valve.

Double "cone" balance, i. e., two rings with two cones cast on valve.

CYLINDER RELIEF.

The valve shall always be free to lift ⅛ inch off its seat, to allow the free passage of air from one end of the cylinder to the other, between valve and valve seat, when engine is running without steam. The tops of all American balance discs, or cones, show a polish, giving positive evidence of their contact with the bearing plate or cover, and that they therefore do float.

The explanation is: At the first stroke of the piston, after engine has been shut off, air is compressed in one end of the cylinder while the valve is traveling a distance equal to its outside lap; at an early stage of this compression the valve is thrown off its seat and the escaping air rushes under the valve into the opposite end of the cylinder to relieve the suction which is taking place in that end; this operation is repeated so rapidly that the valve is kept floating until a slow speed has been reached.

Sufficient air is always drawn in, through the (lift valve) cylinder cocks, and exhausted through the exhaust port, to keep the current of air in the direction of the stack, but not enough to "fan the fire." This affords the most perfect cylinder relief and vacuum valves in steam chest are not a necessity.

FORMULAE OF BALANCE USED (AMERICAN BALANCE VALVE).

Area of balance for plain valves.

Area of one steam port, two bridges, and the exhaust port, plus 8% if for single balance, and plus 15% if double balance.

Example for single balance.

Steam port, 1¼" plus bridge 1" plus exhaust port 2½" plus bridge 1" equals 5¾" × 16" equals 92 sq. in.

8% of 92 equals 7.36.

92 plus 7.36 equals 99.36 sq. in. equals area.

Example for double balance.

Steam port 1¼" plus bridge 1" plus exhaust port 2½" plus bridge 1" equals 5¾" × 16" equals 92 sq. in.

15% of 92 equals 13.80.

92 plus 13.80 equals 105.8 sq. in. equals area.

105.8 divided by 2 equals 52.9 equals area of each ring.

The nearest diameter for 52.9 equals 8¼ in., which is the diameter for each ring.

For Allen ported valves, use the same formulæ as above, then from the area derived subtract the area of one side of the Allen port.

Example.

1½ plus 1⅜ plus 3 equals 7¼ in. × 17 equals 123.25 sq. in. plus 15% equals 141.73 sq. in. equals area.

Allen port equals ½ × 17 equals 8½ sq. in., then,

141.73 minus 8.5 equals 133.23 sq. in., which divided by 2 equals 66.61 sq. in. equals area of each ring.

THE BARNES BALANCED VALVE.

The following description and illustration of the Barnes balanced valve is taken from *"Locomotive Engineering"*: A balanced valve having some points with a strong flavor of originality is that designed and patented by Superintendent of Motive Power Barnes, of the Wabash Railroad, and illustrated in Fig. 57.

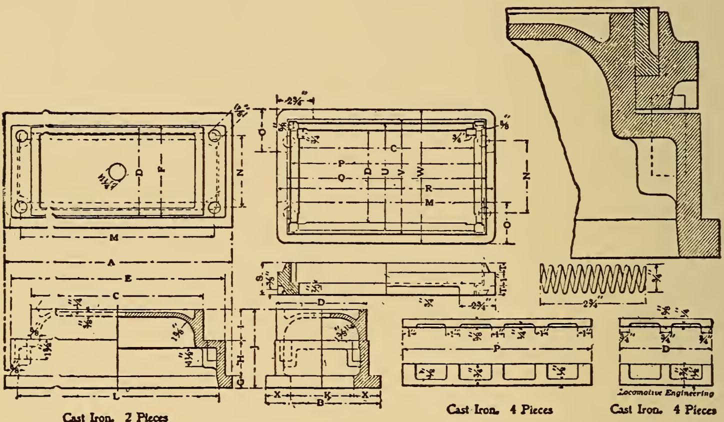


FIGURE 57. BARNES BALANCED VALVE—LONGITUDINAL SECTION.

The full size part of a longitudinal section will perhaps give a clearer idea of the balance part of the device than will a first reference to details.

This view shows a cast iron frame surrounding the valve, with a recess equal to the width and depth of the balance strips on its inner face.

There are four balance strips $\frac{5}{8}$x$1\frac{3}{4}$ in. carried in position by the frame, which latter is $1\frac{5}{8}$x$2\frac{1}{2}$ in. in the overall dimensions of its cross section.

Both the frame and the strips are cored for lightness.

The combination is held up to the balance plate by four helical springs made of German silver wire 0.125 in. in diameter. It is seen that the balance strips have a very deep bearing between that valve and frame, and since the strips are carried by the frame, there must be a constant depth of support to them on the outside face, no matter how much wear takes place, nor what the lift of the springs. This condition of things tends to reduce the liability of cocked or broken strips as has been found in service. The springs placed at the ends of the frame would seem to exert a more equable pressure on all the strips than is possible with a long spring under each individual strip, for the reason that it is a delicate undertaking to attempt to make four flat springs of the same degree of elasticity.

On these grounds it is not unreasonable to expect a continuance of the good results so far shown by this style of balance. The dimensions shown are for a ten wheeler.

THE McDONALD VALVE.

The points of advantage claimed for this valve are as follows: First, that the pet cock on top of the steam chest cover is always open to the atmosphere, so that should the joint leak, the engineer will be able to see the steam escaping through the pet cock, which is sure evidence that the valve requires attention.

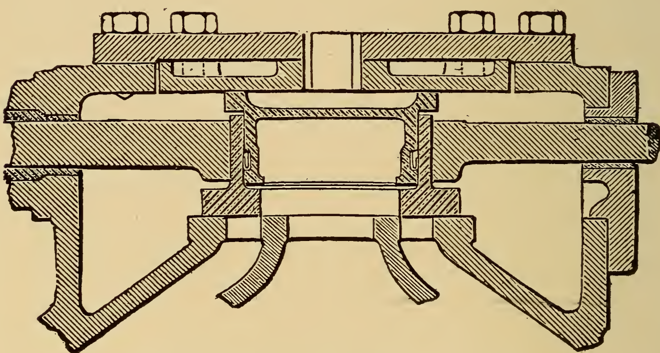


FIGURE 58. McDONALD VALVE.

Second, he can then close the pet cock and the valve will operate on the same principle as a simple D valve.

Third, the U shaped packing strips maintain a satisfactory and tight joint and the flat steel spring beneath the valve is of the simplest form. This valve has recently been introduced into this country. Mr. McDonald, the inventor, is a mechanical engineer at Yokohama, Japan, and has had these valves in service some two or three years, and it is claimed they are giving excellent results.

The McDonald valve in shown in vertical section in Fig. 58.

THE BRIGGS BALANCED VALVE.

The following illustrations (Figures 59 to 63) and description of this valve is taken from *Locomotive Engineering:*

The inventor, Mr. R. H. Briggs, Jr., of Amory, Miss., describes this valve as follows:

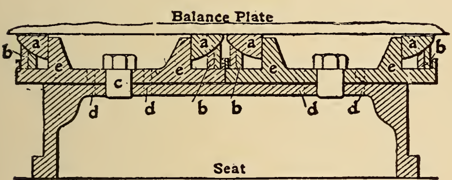
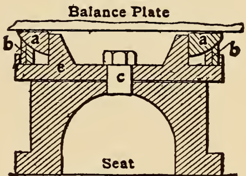


FIGURE 59.

FIGURE 60.



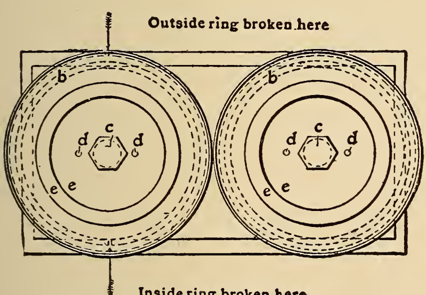


FIGURE 61.

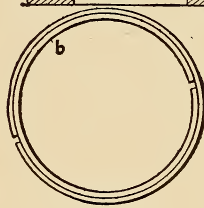


FIGURE 62.

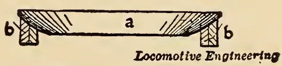


FIGURE 63.

"You can readily see that it will require very little explanation as to the operation of this improved balance. This balance consists of four parts—cone E, two packing rings B and joint ring A. The packing rings are cut as shown in Fig. 62. To break the joints these rings are pinned together. To prevent the cuts working around, they are also ground on cone E, to prevent any leak at bottom of packing ring. They have a ball joint on top with joint ring A perfectly ground to them. Joint ring A is a nice, neat fit on cone E. Now you can very readily see that it is impossible for this valve to blow, as the greater the steam pressure on the outside of packing rings B the tighter ring A will be on the balance plate. I give these rings only 1-32″ compression. Another advantage that I claim for this valve is that it balances to outside diameter of outside packing rings B."

THE MARGO VALVE.

The Margo balanced valve was one of the first forms of balanced valves. It had two small discs and small packing rings (similar to air pump packing rings); the steam pressure holding the disc up against the pressure plate. Much trouble was experienced with this form of valve, owing to a gumming up of its parts which would cause the disc to stick. Very few of these valves are now in use.

POWER REQUIRED TO MOVE A VALVE.

To determine the power required to move a valve multiply the area of the valve face by the steam pressure upon it less ⅓ allowed for back pressure from the steam port and exhaust port. The friction between two smooth surfaces well lubricated varies from 1-10 to 1-14 of the pressure (the weight of the valve being so slight it is seldom considered. Friction is the resistance which two contracting surfaces have to being moved one over the other and is of three kinds: Sliding, rotation, and liquid). For example: If a valve face measures 10x20 with 120 pounds' pressure proceed as follows:

10×20=200×120=............24,000
8,000 less one third,

Divided by the friction, 10......16,000 1,600 lbs. power required.

THE ALFREE VALVE.

In the Alfree system of steam distribution as applied to locomotives by the Locomotive Appliance Co. of Chicago, a somewhat new departure from standard practice is made.

This consists in what is termed a compression controlling valve, in addition to the main valve which controls admission, cut-off, and release. According to the claims of the manufacturers "this system not only embodies principles that are entirely new but utilizes old and well known principles in the use of steam not heretofore suitable for locomotive uses because of the complication of the mechanical means necessary for their use, together with the peculiar and severe conditions under which they must operate.

"The mechanical means for producing these results are extremely simple; the few special features being contained within the valve chambers of the cylinders. All that is necessary for an application of the system to a locomotive is to apply our cylinders in precisely the same manner as standard cylinders connecting the valve stems to the standard rockers and making the usual adjustments. It involves substantially a change of cylinders only. Any of the standard valve gears, Stephenson, Walschaert or any other may be used.

"The following is a brief analysis of the means through which these results are attained:

"1. *Reduced Heat Losses.* Our cylinders are designed with short ports and the exhaust passages carrying cold steam are separated and insulated from the live

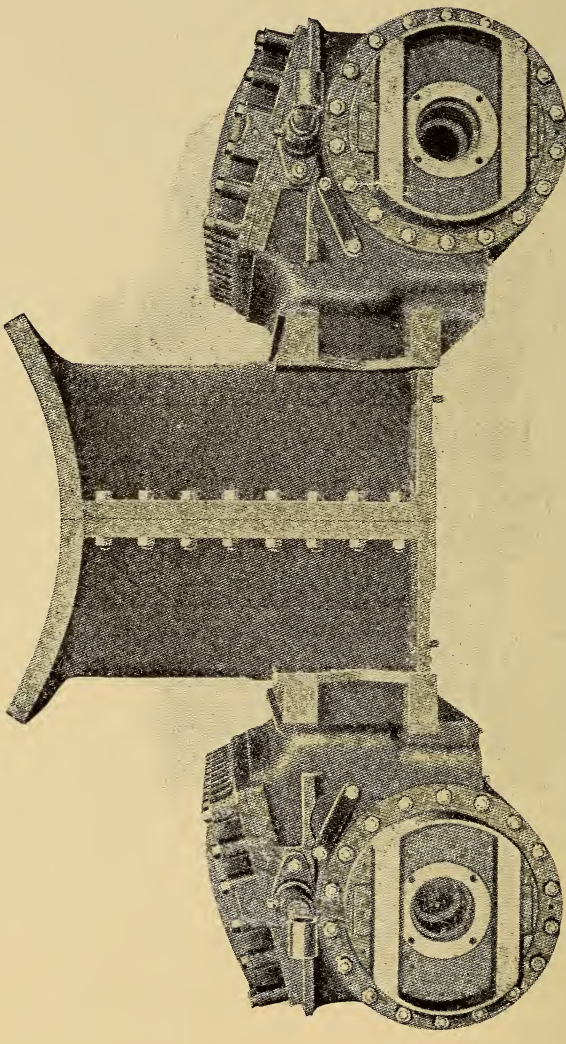


FIGURE 64. END ELEVATION OF ALFREE VALVES AND CYLINDERS.

steam passages; consequently heat losses from radiation and condensation are greatly reduced.

"2. *Less Steam Used for a Given Cut-off.* The waste spaces in the cylinders are reduced to the minimum. In common practice this amounts to at least 10% of the piston displacement, while our cylinders have not more than 2.5%. To illustrate, for a 7-inch cut-off in a 30-inch stroke engine we, in effect, draw upon the boiler for 7¾ inches of steam, while for a like cut-off in a standard engine it will require an average draft on the boiler of 10 inches of steam.

"3. *Higher Ratio of Expansion.* Because of the minimum waste spaces in the cylinders and of the ability to hold the steam in the cylinders longer before exhausting it, we get a higher ratio of expansion—that is, more work—out of the steam admitted to the cylinders.

"4. *Perfect Exhaust.* Having an increased exhaust area of about 50%, this system produces a quick, extraordinarily free, and large opening of exhaust, discharging the exhaust steam perfectly and quickly. This greatly reduces back pressure, or negative work, in the cylinders, and, due to the sudden release, a better fire is maintained even with an enlarged exhaust nozzle.

"5. *Reduced Negative Work.* In the return or exhaust stroke of the piston the exhaust is not closed until very late in the stroke; but when the proper point is reached, just enough exhaust steam is entrapped in the cylinders and small clearance spaces to produce sufficient compression to answer the mechanical needs of cushioning. In the standard locomotive the exhaust is closed comparatively early in the stroke and negative work commences correspondingly early. As the compression begins early in the standard engine, a large amount of clearance space must necessarily be provided to prevent compression running too high, and a correspondingly large amount of negative work must be done to compress the larger volume. Therefore, the negative work of compression in our engines is reduced enormously and a corresponding amount of available positive work is added.

"6. *Increased Turning Effort.* It is found in locomotives where the power is applied to the drivers through rotative rather than reciprocating motion that such locomotives pull, without slipping of the drivers, considerably greater tonnage than the standard locomotive of the same weight. The reason for this is that the power is applied steadily in one case and intermittingly in the other. In the reciprocating engine, if the release is early and an unnecessary resistance set up on the opposite side of the piston, more steam must be applied in the center of the stroke to make up for losses at each end. Consequently, the power is applied to the drivers intermittingly, producing a jerky effect, and the limit of adhesion of the drivers is reached long before the real power of the engine can be used. But in our system by holding onto the steam longer at one end and by removing the resistance at the other end of the stroke, higher average pressure will result and the power distributed more evenly through the stroke; thus imparting to the drivers a steadier or more even rotative effect, increasing the available power of the engine and greatly decreasing tendency of slipping."

"It is a well established fact in standard locomotive practice, that a single valve either of the piston or flat type, will perform three out of its four functions perfectly, viz.: admission cut-off, and release, but the fourth, known as closure, or the compression event, is wrong. If the valve is provided with a sufficient amount of exhaust lap, to obtain an economic expansion through delaying the release, the exhaust closure becomes excessively early, and an enormous clearance space must be provided equal to fully 15% of the piston displacement. This entails such a loss that a compromise is generally effected by reducing the exhaust lap, making the release earlier but delaying the closure to a point where not to exceed 10% of clearance space need be provided This requires a valve having its exhaust edges about equal to the exhaust edges of the ports, generally designated as line and line, or if the valve is cut a little shorter, giving say about one-eighth exhaust clearance, the clearance or waste spaces may be reduced to about 8% of the piston displacement Any further reduction of exhaust lap would result in a greater loss through an early release than would be gained through a reduction of clearance.

"In the Alfree System a single valve correctly controls admission, cut-off and release the same as in the standard engine, except that a sufficient amount of exhaust lap is used to carry the steam to a point that will give a greater expansion. Then to avoid an early closure, a small piston valve, called the Compression Controlling Valve, is introduced through a section of the ports beneath and to one side of the main valve, and has only the function of controlling the compression and providing greater freedom for the escape of exhaust steam. While the two valves release at the same instant, the compression valve in closing falls about one and one-fourth inches behind the main valve. This allows the exhaust steam that would otherwise be in compression, to escape until the piston reaches about 90% of its stroke (at ¼ cut-off) or within 2½ or 3 inches of the end of its stroke. The clearance having been reduced to 2½% of the piston displacement, a sufficient amount of compression takes place to perfectly cushion the reciprocating parts.

"It will be seen that through these simple means we are enabled to greatly reduce the inherent losses, increase

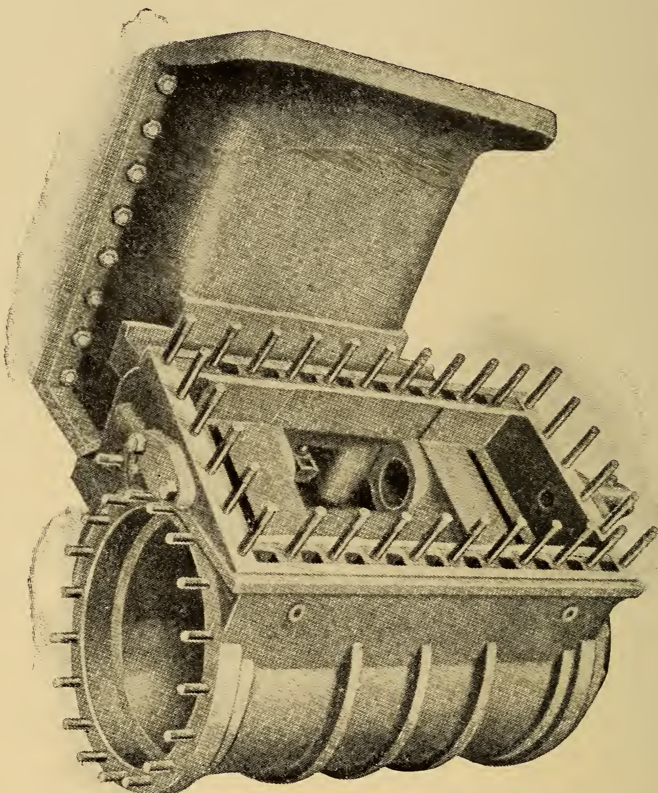


FIGURE 65. ALFREE CYLINDER, WITH STEAM CHEST COVER, AND VALVES REMOVED.

the mean effective pressure, increase the effective exhaust area, and increase the turning effort on the drivers. The results as found by actual test are 5% to 8% more tonnage, with 8% to 10% less fuel and water, higher speeds, fewer engine failures, and reduced running repairs. These are positive and practical facts which will not only be found true by critical examination of the system, but will be better proven by actual use."

Fig 65 shows the Cylinder with Steam Chest Cover and Valves removed. As will be seen, the Cylinder and Valve Chamber or Steam Chest are one casting; the ports are short and practically straight with the Compression Valves passing through their longest section. The admission is from the inside, which brings the live

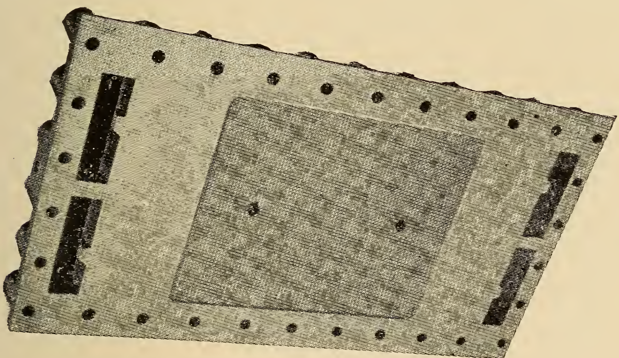


FIGURE 66. STEAM CHEST COVER.

steam in contact with a considerable portion of the Cylinder walls, while the exhaust is at the ends and is most effectually insulated from the live steam, thus eliminating one of the greatest sources of heat loss. Double walls are used around all live steam passages wherever practicable with the object of making the insulation as perfect as possible. This design produces an exceptionally strong cylinder well adapted to resisting shocks which would often destroy Cylinders of the ordinary design.

The Combined Steam Chest Cover and Pressure Plate, as shown by Fig. 66, has a by-pass chamber connecting with each end, thus permitting a portion of the exhaust from one end to flow through the exhaust passage at the opposite end, which greatly aids in preventing the induction of cinders into the cylinder when drifting. Between this by-pass chamber and the face of the cover a dead air space is provided, insulating the live steam from the exhaust steam, while the exhaust steam, passing through the by-pass, insulates the dead air chamber from the atmosphere, which is somewhat further shut off by the usual cylinder casing. The cover also serves as a Pressure Plate for the Main Valve.

GENERAL ARRANGEMENT OF PARTS.

The general arrangement of Valves, Valve Chambers, Steam Chest Covers, etc., is shown in Figs. 67 and 68.

The Steam Chest or Main Valve Chamber is on an angle of 15° with the horizontal and placed close to the cylinder bore. The ports are short and practically

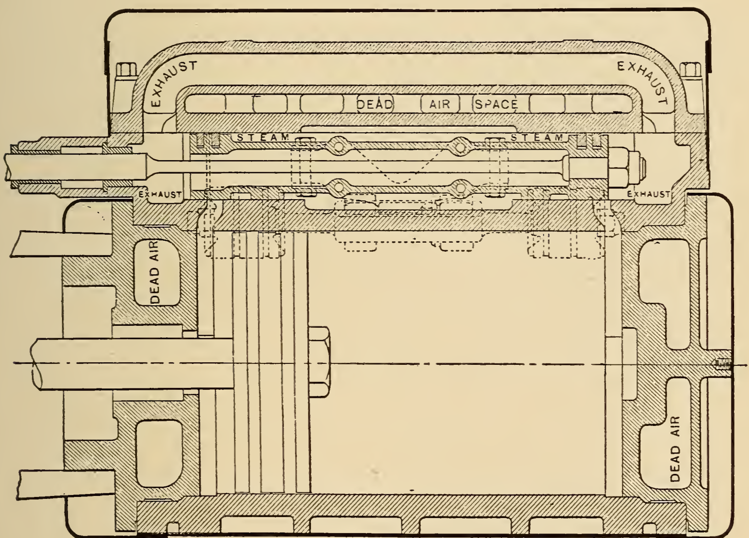


FIGURE 67. THE ALFREE SYSTEM.

straight so that their surfaces may be scraped clean and smooth. The Compression Controlling Valve Chamber passes through the longest section of the ports, and is bushed in the usual way to provide for repairs. The Steam Chest Cover forms the top side of the Main Valve Chamber and provides a by-pass connection between the exhaust passages which equalizes exhaust pressures.

The Main Steam Valve is of rectilinear form rigidly constructed and designed so that the wear is uniform regardless of the travel. It is balanced for all speeds and under all pressures, running or drifting, and with its wearing surfaces nearly doubled by special riding shoes, the wear on the Valve and Valve Seat is very slight.

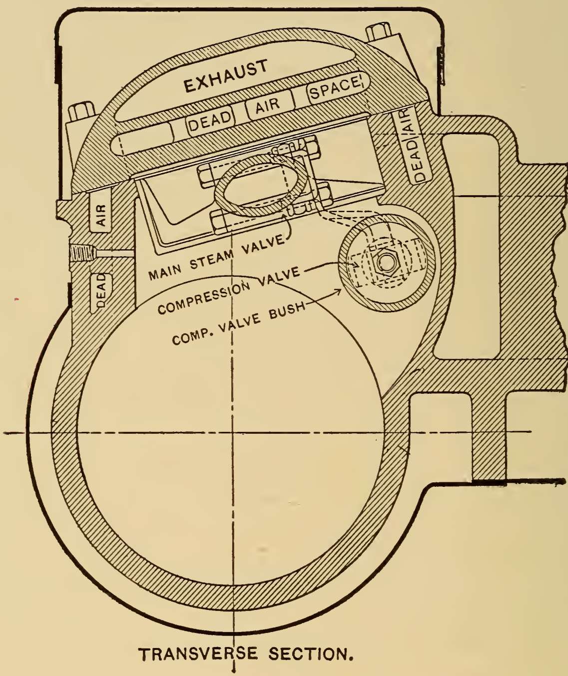


FIGURE 68. THE ALFREE SYSTEM.

The Compression Controlling Valve is a piston valve of the usual design except that it is very light and provided with wide snap rings to overlap the ports and for protection against wear. It takes its motion from the Main Valve by means of an arm connection of rigid construction.

The admission of steam to the cylinders and the cut-off is controlled by the Main Steam Valve. Steam is admitted along the entire lower edge and up one side, providing an unusually large port area for admission. Ex-

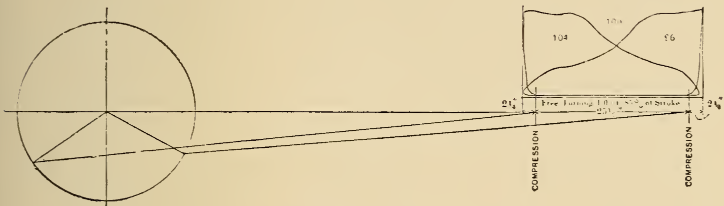


FIGURE 69.

haust also is controlled by the Main Steam Valve, but to this is added the exhaust of the Compression Controlling Valve which releases simultaneously with the Main Valve.

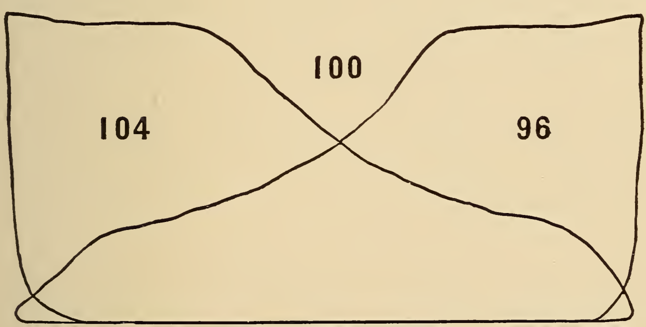


FIGURE 70.

Closure or Compression is controlled entirely by the Compression Controlling Valve, which delays the final closure of the exhaust until the piston has completed 90% of its stroke at the short cut-offs, thereby reducing the volume of the exhaust steam in Compression from about 10 inches in the usual practice to 2¾ inches in this system

Fig. 69 is a diagram furnished by the Locomotive Appliance Co. of Chicago, which that company claims shows the effective turning effort of the piston to be applied throughout the greater part of a revolution of the drivers.

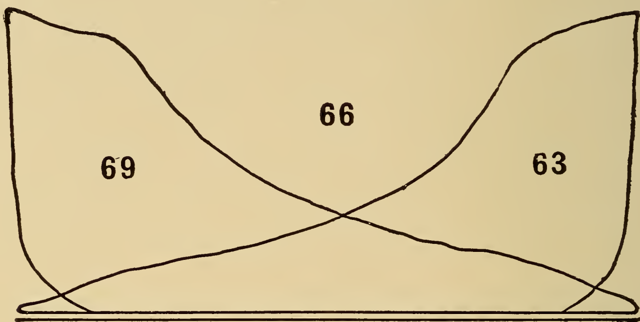


FIGURE 71.

Fig. 70 is an enlarged sample of the same card. Fig. 71 is another sample of an indicator diagram taken from a locomotive equipped with the Alfree cylinders and valves.

These diagrams certainly show great efficiency in the use of the steam.

The action of the valve, and the relative positions of the crank pin, and eccentric during the stroke, may be graphically illustrated by means of valve diagrams.

There are several different kinds of diagrams employed for this purpose.

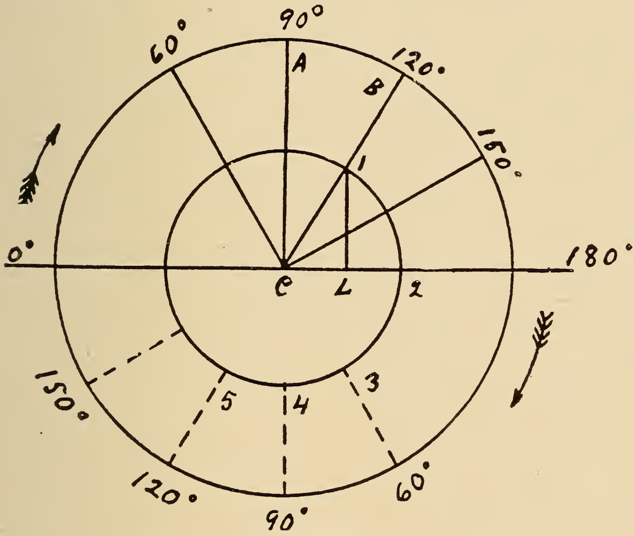


FIGURE 72.

In this connection the Reuleax and Zeuner diagrams will be used, and first we will make use of a simple diagram in order to bring the subject clearly before the mind of the student.

Referring to Fig. 72, the inner circle represents the path described by the high point of the eccentric, and the large circle that of the crank pin. The radius C2 of the small circle represents the throw of the eccentric, and the distance CL is the lap of the valve plus the lead. The point of intersection of the vertical line, L1, with the eccentric circle locates the position of the highest point of the eccentric, and the line CB, drawn from the center of

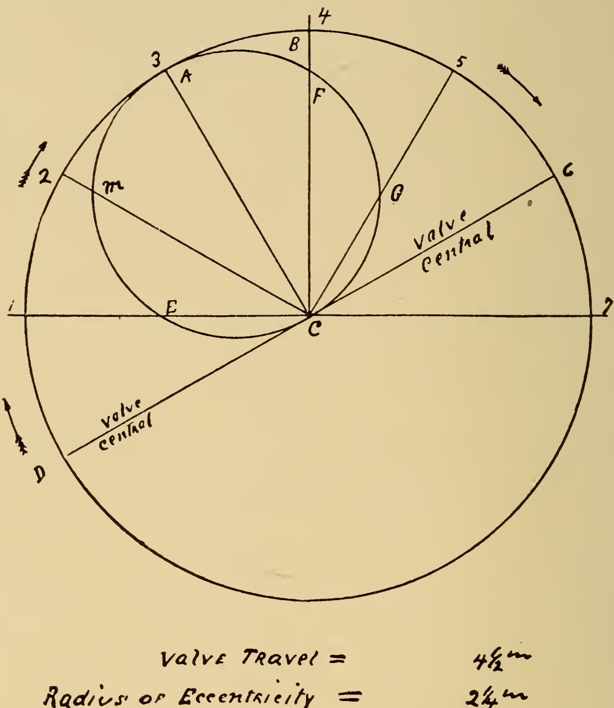


FIGURE 73.

the crank shaft through this point, indicates the angular advance, which in this case is 30° represented by the angle ABC. The figures 1, 2, 3, 4, 5 indicate the position of the high point of the eccentric at the moment of each function of the valve.

Fig. 73 shows the total movement of the valve, regardless of lap and lead. First draw line C1 to represent the center line of the engine. Next draw line C4 perpendicular to the line of centers, with C as the center of the crank shaft. The radius of the semi-circle D, 1, 2, 3, 4, 5, 6 equals the radius of eccentricity. Line CD represents the position of the crank when the valve is at mid-travel or in its central position, D being the location of the crank pin.

Again referring to Fig. 73, draw line CA in such a position that the angle ABC will equal the angular advance of the eccentric, which we will assume in this case to be 30°.

This will bring the high point of the eccentric at B, while the crank pin, as before stated, is at D. Next, using line CA as the diameter, draw a circle about it, called the valve circle. Now, suppose the crank to be turning in the direction of the arrows. At position D the crank line is just about to cut into the valve circle, the valve being central. When the crank gets to position 1 the valve has moved the distance CE. When the crank is at 2 the valve has moved the distance CM, and when the crank arrives at 3 the valve has moved to the limit of its travel from its central position and it now begins the return movement. The motion of the valve is comparatively slow at this point for the reason that the high point of the eccentric is now passing the center at 7. The distance the valve has moved backward while the crank has moved from 3 to 4 is the distance BF, while FC represents its distance from the central position, and GC the same when the crank is at 5. When the crank arrives at 6 and its line has left the valve circle, the valve is again central. Fig. 73 merely shows the movement of the valve through one-half of its travel without giving any details regarding port openings, cut-off, etc.

In Fig. 74 the influence of outside lap is delineated. According to the dimensions of the valve under consideration the outside lap is one inch. The diagram is drawn precisely as in Fig. 73, and in addition strike an arc representing the outside lap, using C as the center with

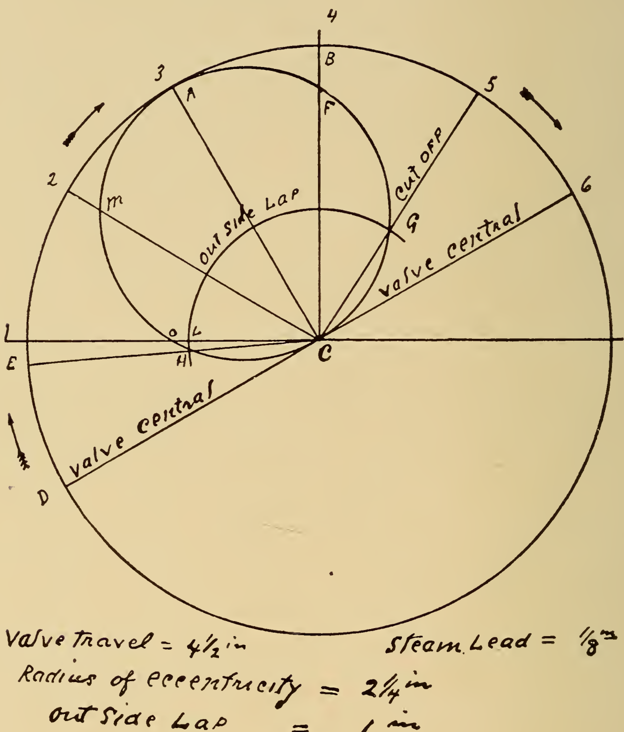


FIGURE 74.

a radius equal to the outside lap. As before, the crank is at D and the valve central. When the crank has moved to E and its line cuts the intersection of the outside lap and valve circles, the valve has moved the distance CH, just equal to the outside lap, and the port begins to uncover at this point. Then by the time the crank gets to the center, 1, the port is open the distance LO, which is the lead, in this case ⅛ inch.

The position of the crank when cut-off takes place is ascertained by drawing a line, CG5, through the intersection of the outside lap and valve circles, where the

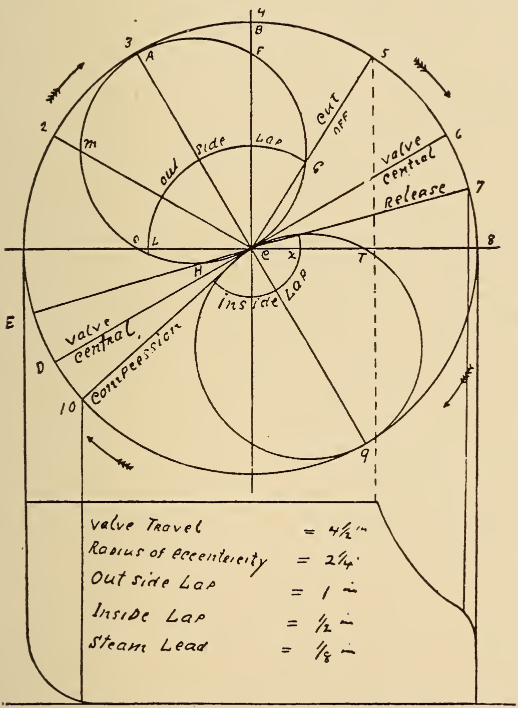


FIGURE 75.

valve is on its return movement. Thus far no account has been taken of release and compression, and in order to determine the position of the crank when these events occur it will be necessary to draw the valve circle for the opposite movement of the valve, for, be it remembered, that the movement of the valve so far considered has been only one-half of its travel, that is, it has moved from its central position towards the head end of the cylinder, and back again. We have seen how it has performed the functions of admission, full port opening, and cut-off for the crank end of the cylinder, and now by reference to Fig. 75 it will be seen at what points of the stroke the remaining events, viz., release and compression, occur.

Draw a second valve circle, Fig. 75, diametrally opposite the first. Also draw an arc with a radius equal to the inside lap, which in this case is assumed to be one-half inch. When the crank gets to the position 7 its center line, cuts the intersection of the inside lap and valve circles and release begins. When the crank arrives on the center 8, the valve has moved the distance CT from central position; but CX of this distance has been occupied by the inside lap, therefore the lead on the exhaust is represented by the distance XT. When the crank on its return stroke arrives at the position marked 10, its line again cuts the intersection of the inside lap and valve circles and compression takes place. By dropping perpendiculars from the positions of the crank at 1, 5, 7, 8 and 10 an indicator diagram may be drawn showing the performance of an engine with this style of valve.

Fig. 76 shows the effect of decreasing the angular advance, that is, setting the eccentric back towards the crank.

In this instance the eccentric is set back 10 degrees, thus making the angle of advance 20 degrees instead of 30 degrees as before. The full lines represent the new angle, while the dotted circles and lines indicate the valve, and its movements as drawn at first.

A shows the original point of admission, and A′ the position of the crank when admission takes place with the lesser angle of advance. Similarly R and R′ show the old and new points of release, and C and C′ the compression. The two different points of cut-off are also indicated.

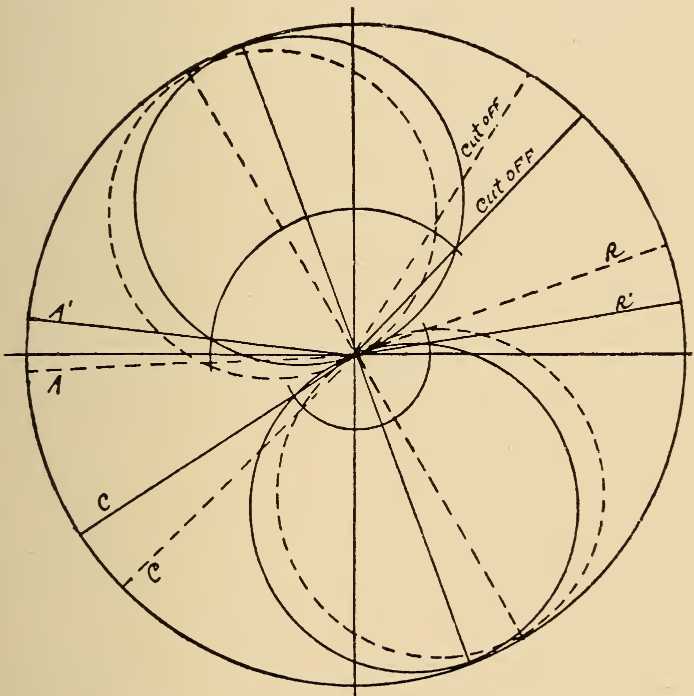


FIGURE 76.

The effect of decreasing the valve's travel is illustrated by Fig. 77, the full lines showing the decreased travel and its influence, and the dotted lines showing the original. Admission and release occur later, while cut-off and compression take place earlier.

The travel of the valve as indicated in Fig. 77 has been decreased one inch, thus making it 3½ in place of 4½ inches as before. Fig. 78 shows the result of increasing the outside lap. The lap has been increased in this in-

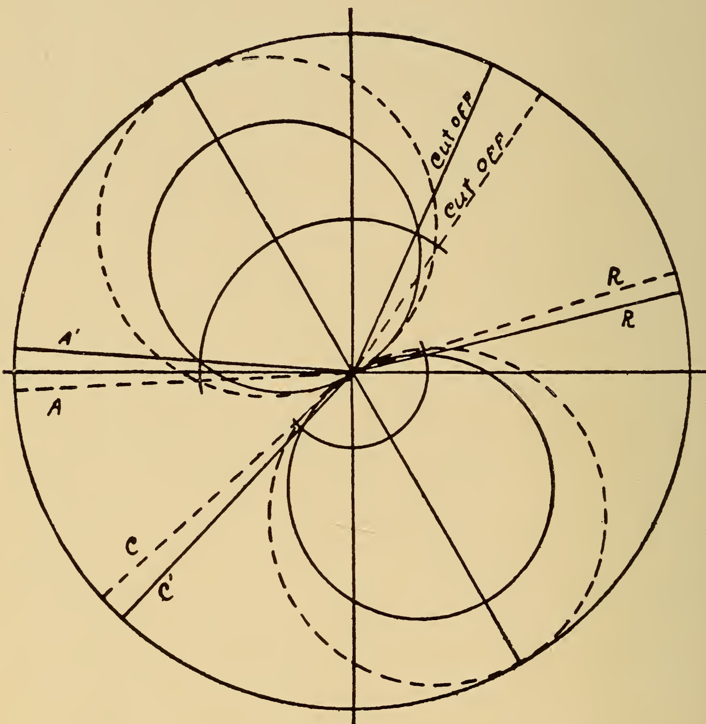


FIGURE 77.

stance from 1 inch, as originally drawn, to 1¼ as indicated by the full lines, while the dotted lines show the lap as it was before being changed. The effect of this change is to cause less lead, a later admission and an earlier cut-off, but compression and release are not affected, for the reason that these latter events are controlled by the inside lap, which has not been changed.

In Fig. 75 the valve is shown as cutting off the steam when the crank has completed 120 degrees or two-thirds of the half revolution, but the point of cut-off on the indicator diagram shows that the piston has traveled 7-9 of the stroke.

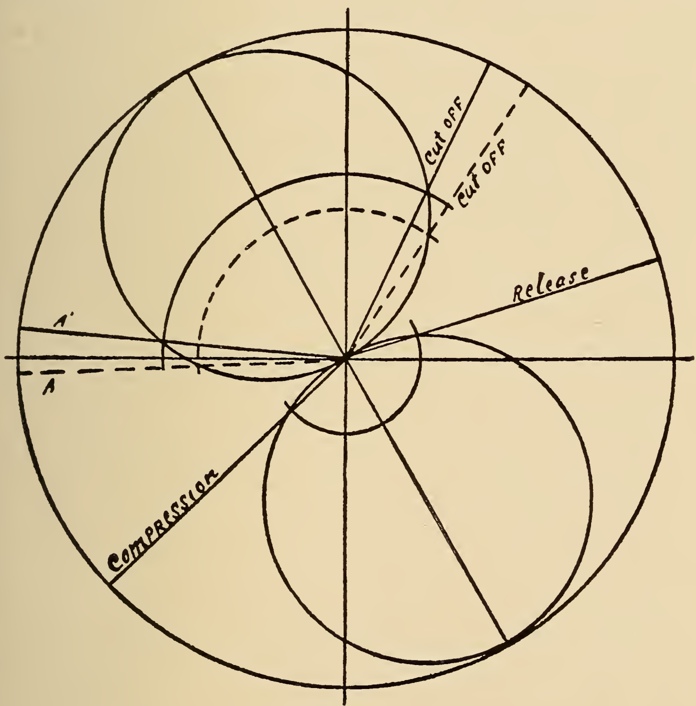


FIGURE 78.

This discrepancy is due to the obliquity of the connecting rod, as it will be seen by looking at the valve diagram (Fig. 75), that the crank must travel farther to complete the stroke from this point than the piston does.

In order to cause the valve to cut off earlier, say, at one-half stroke, it will be necessary to do one of two things, either to increase the outside lap, which would have a tendency to cause admission to occur too late, or

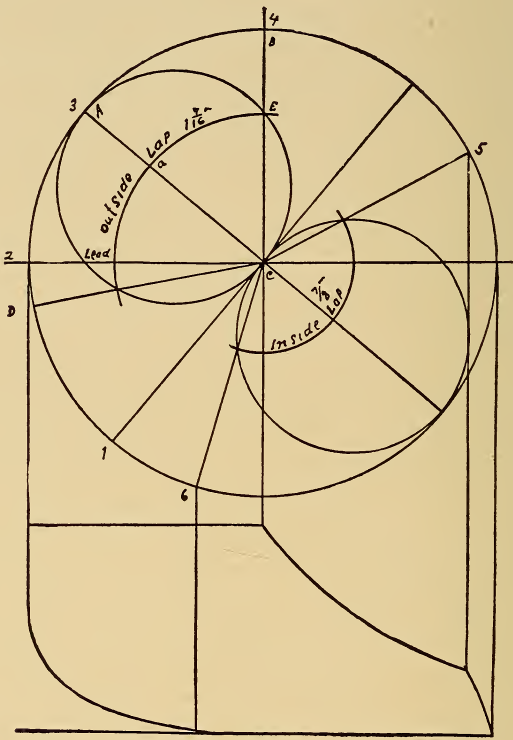


FIGURE 79.

the angle of advance may be increased sufficient to cause cut-off to take place at half stroke, but to do this alone would cause admission to occur too early. Therefore the proper thing to do is to increase both the angle of advance and the outside lap. Fig. 79 shows how this can be done without decreasing the travel of the valve. The angle of advance, ABC, is now 50°, where before it was 30°, as in Fig. 75.

The valve is central when the crank is at position 1; the high point of the eccentric being at point 4. The outside lap which before was 1 inch had 7-16 inch added to it, making it 1 7-16 inches. When the crank gets to D the port is just commencing to open, and with the crank on the center at 2, the lead is ¼ inch.

It will readily be seen at this point that by increasing the outside lap still more the lead can be diminished, and the point of cut-off made still earlier, but this would result in a still further reduction of the power of the engine, which has already been considerably reduced, as shown by the diminished area of the indicator diagram as compared with the one in Fig. 67. When the crank gets to position 3 the valve has reached the limit of its travel, and the port is open the distance Aa, which is as far as the outside lap will permit. With the crank at point 4 cut-off occurs. But with the increased angular advance and the inside lap remaining as it was before, viz., ½ inch, release would occur too early. Therefore it will be necessary to increase the inside lap sufficient to cause release and compression to take place at as near the proper points as possible. In this instance ⅜ inch has been added, making the inside lap ⅞ inch, and release takes place with the crank at position 5, while compression begins at 6.

These points, viz., release and compression, may also be changed by simply adding to, or decreasing the inside lap. It should be noted that in the foregoing discussion of valve gear it is understood that the valve stem moves in the same direction as the eccentric rod does, that is the direction of motion is not reversed by a rocker arm interposed between the eccentric and the valve. In other words, the motion is direct. In case the motion is reversed by a rocker arm (indirect motion) it will be necessary to set the eccentric behind the crank.

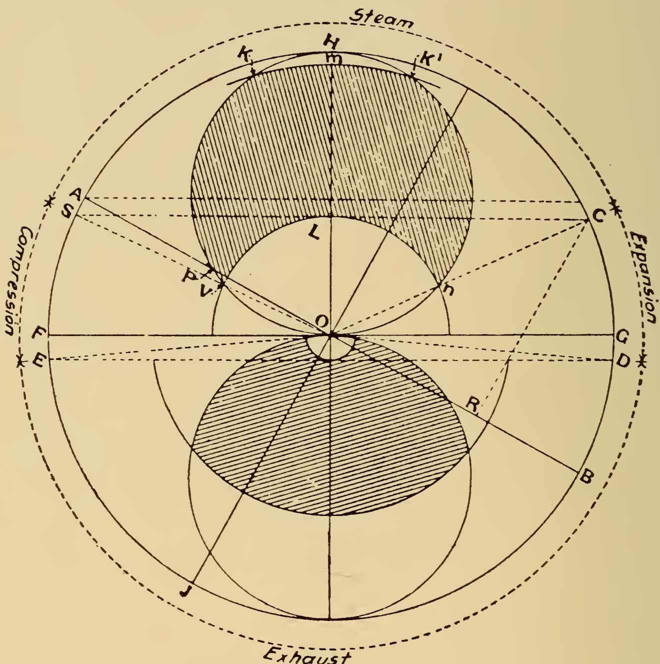


FIGURE 80.

Fig. 80 is a combination of the Releaux and Zeuner diagrams used to represent the different valve events.

This cut, together with Fig. 81 and the explanation following is presented by Mr. Carl J. Mellin, Consulting Engineer for the American Locomotive Company, and if closely followed will serve to still more clearly fix in the mind of the student an understanding of the action of the valve in the performance of its various functions.

Referring to Fig. 80, the distance AB represents the travel of the valve as well as the stroke of the engine, though in different scales, which makes no difference when the cut-off is always expressed in fractions or per cent of AB. The maximum cut-off is determined upon to be AR. Draw a perpendicular line RC from AB until

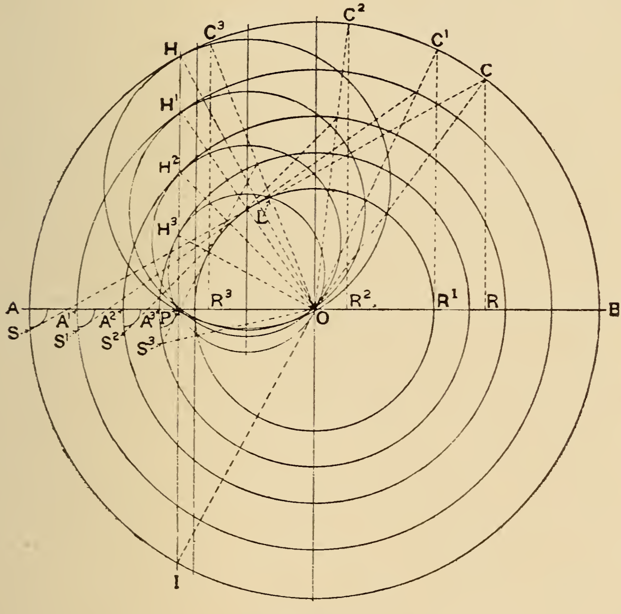


FIGURE 81.

it cuts the arc ACB. Next decide on a desired lead and with that as a radius, draw an arc with A as a center. Draw a line from C tangent to the lead circle around A, when the lap of the valve is found to be equal to the perpendicular distance from the line CS to the center O of the diagram. The crank will then be in position OS when the valve commences to open, or the angle AOS in advance of the dead center, and on OC at cut-off. Continuing, we find the valve in its middle position when the crank is on OG which is drawn parallel to SC through the center O. Extend this line to F, and with the exhaust lap as a radius draw the exhaust lap circle on the opposite side of the line GF and draw DE tangent to this circle, when OD is the position of the crank at the release point. From this point the exhaust remains open until the crank reaches the position OE, when it closes and compression takes place until it again reaches OS for admission and one revolution is completed.

By placing the Zeuner diagram upon this, draw HJ perpendicular to FG, and with the radius OH of the eccentric circle as a diameter, draw the admission valve circle OVHnO and the lap circle with the steam lap as a radius and find the intersection occurs at V, both with the circles and the previously laid down admission line OS and the cut-off point at the intersections at n. On the line OH set off the width of the steam port from L toward H equal to Lm and with Om as radius draw the arc KmK^1. The shaded figure enclosed by the letters VKK^1nL represents the steam port opening during the admission period and the width of the port opening at any desired position of the crank is found by measuring the distance radially from O between the lap and valve circles on the port line, as the case may be, on the desired crank position.

The exhaust openings are determined in the same manner and are shown on opposite side of FG, where the crank passes through the arc DJE during the exhaust period with a positive exhaust lap of the size EF. When the exhaust edge of the valve is line and line this arc becomes GJF or 180 degrees, and when a negative lap (clearance) occurs, the duration of the exhaust period exceeds the half revolution of the crank. The various events are indicated around the eccentric circle on the figure as they take place during a complete turn of the crank.

In Fig. 81 the eccentric and admission valve circles are shown at different cut-offs where each set of lines and circles is governed by the same explanation as those of Fig. 80, where the admission points S, S^1, S^2, S^3 correspond to the closing positions C, C^1, C^2, C^3, cut-off points R, R^1, R^2, R^3, etc. On OH we have the full travel valve circle and OL the lap or radius of the lap circle, the latter being the same for all cut-offs as well as the lead, the radii H^1, H^2, H^3, etc., of the eccentric circles or diameters of the corresponding valve circles terminate on a line HI drawn perpendicular to AB and at a distance from O equal to that of lap and lead.

When the reverse lever is in its center position the diameter of the valve circle falls on the line AB and is equal to lap and lead. Continuing in back position we have the same method repeated and OI would be the full travel valve circle diameter, or the same as the eccentric radius for the valve travel. Any desired cut-off position may be laid out in same manner as that in Fig. 77, which shows all the valve events for a complete revolution of the axle.

The movements are in actual practice not so regular as the circles indicate, as it is impracticable to obtain the various loci in their theoretical positions; besides we have the angularities both of the main rods and the eccentric rods to contend with and whereby irregularities are entering in the problem that must be compensated for, as referred to in the general description. It is not to be considered that a uniform circular motion is the best, but an approximation to it works with less shocks or jerks, and is therefore more desirable for so high speed an engine as a locomotive. A few advantages can be taken, however, in selecting the suspensions and various connections, so that better results can be ob-

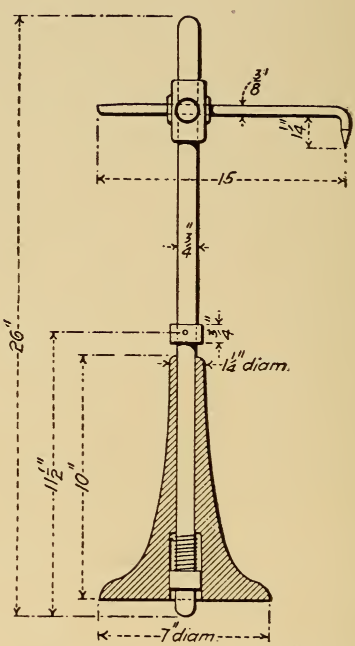


FIGURE 82. A CONVENIENT GAUGE FOR SETTING THE ECCENTRIC CRANK.

tained than from a true circular motion, which are principally affected by three union points and are, first, the connecting point of eccentric rod and link; second, the locus of the lifting link suspension point; and third, the relative height of the crosshead connection point of the union bar to the corresponding point of the combination lever.

It is not necessary to lay out the valve diagrams except where a given cut-off per cent. is wanted. This is the most convenient way to find the required lap.

Reason for Increase of Lead as Reverse Lever is Locked Back with Stevenson Valve Gear.

The explanation of this problem, although simple enough, is generally presented to the student by technical writers in such a form as to be incomprehensible to the man with limited education, therefore the author considers it his duty to explain in as clear a manner as possible the causes of this very annoying, but inevitable occurence.

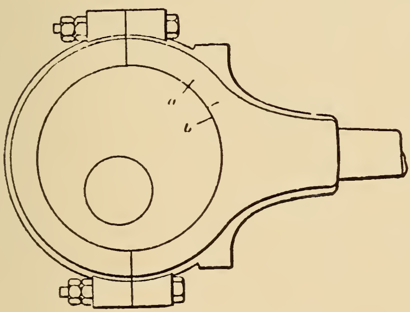


FIGURE 83.

Lead is the amount of opening that the valve gives to the steam port when the engine is on the dead center, that is with the piston at the extreme end of the stroke, and this lead is obtained by advancing the eccentric the required number of degrees ahead of the crank in the direction it is to run.

Referring to Fig. 83, let a, represent the locus of the eccentric and eccentric strap with the reverse lever in the position of full valve travel. Now as the lever is hooked back to shorten valve travel the eccentric rod is raised, and the eccentric strap is moved back on the eccentric, which would increase the lead to the same amount as moving the eccentric ahead on the driving axle would. Mark a, would now be broken, as at b.

The amount that the lead is increased depends to some extent upon the length of the eccentric rods, as with long rods the lead will not be affected so much, as with short rods. But with Walschaert Valve Gear the lead is constant at all points of cut-off, for the reason that it is derived through the crosshead connection, of the combination lever actuated by the reciprocating motion of the piston, instead of by the circular motion of the driving axle transformed into a reciprocating motion through the instrumentality of rods accompanied with all of the errors incidental to their angularity. When an outside admission valve is used the upper end of the combination lever is connected directly to the valve stem, while the radius rod connection is between the valve stem, and crosshead connections, and acts as the fulcrum for the combination lever. When the valve is of the inside admission type, these connections are reversed, the upper end of the combination lever being connected to the radius bar, while the valve stem connection lies between the crosshead connection below, and the radius bar connection above. The motion thus imparted to the valve stem by the combination lever when the position is at the extremities of the stroke, and the eccentric crank in its middle position is uniform, and so modifies the motion received from the eccentric crank through the medium of the link and radius bar, as to give the valve a constant lead at all times, for either the go-ahead, or back-up motion.

The connection of the radius bar with the combination lever, always forms the fulcrum of the lever. If this fulcrum is below the connection of the lever with the valve stem, it is plainly evident that the motion of the crosshead when nearing the end of the stroke, will through the medium of the long arm of the combination lever which is attached to it, push the valve stem in the direction that the piston is to move on the return stroke, thus giving the correct lead for an outside admission valve.

On the other hand if this fulcrum is above the connection of the valve stem with the combination lever, the valve stem will be drawn by the lever in the direction opposite to that in which the piston is to move on the return stroke, and this movement will impart the proper lead for an inside admission valve.

The proportions of the combination lever are such that, given the stroke of the piston, a motion equal to the lap, and lead, is imparted by the combination lever to the valve as the crosshead is moved from one end of the stroke to the other. As before stated the length of the radius bar should be equal to the radius of the link.

DETAILS OF OPERATION.

The requirements of modern railway service in all its branches, but especially in the department of motive power have reached that condition wherein the best of everything is needed.

In this the Walschaert Valve Gear is demonstrating day by day that it is fully capable of holding its own indefinitely, not only as regards economy but also in the matter of reliability, and freedom from annoying breakdowns, or disarrangement of parts. The first requisite is that it be correctly designed and constructed to meet the requirements of each particular type of engine, and class of service.

The second requisite is that it be accurately adjusted before the engine leaves the shop, as it is not possible to make any changes in adjustment while out on the road, with the exception of a slight change in the length of the eccentric rod.

The third requisite is that it be well cared for on the route. This regulation applies to any valve gear, and implies that it be properly lubricated, and that it, and all other working parts of the engine in general, and the driving boxes in particular be kept free from lost motion.

Owing to the small amount of friction, in the Walschaert valve gear it is not nearly so liable to heat as is the Stevenson link motion, and besides this it has the advantage of being outside the frame in full view of the enginemen, which cannot be said of the Stevenson gear.

It has been demonstrated beyond all doubt that the

Walschaert gear will withstand a much longer term of service between shop repairs than the Stevenson valve gear will, and this fact is easily accounted for when we consider the difference in weight between the two types of valve gear.

In this connection it might be well to quote from a paper read before the International Railway Congress by Mr. F. C. Muhlfeld.

With reference to the weight, friction, liability to heat, wear, breakage, etc., Mr. Muhlfeld says:

"When comparison is made between the weight of the moving parts and the size of the bearings of the Walschaert outside gear with similar parts of the Stephenson inside gear, it will be found that a simple design of the latter weighs more than double the amount of the former, and is becoming a very cumbersome and heavy suspended reciprocating and revolving arrangement. The increased complication and weight of the Stephenson gear has resulted in a distorted steam distribution, to say nothing of the destructive effect of the heavy parts and the increased cost for maintenance on account of excessive wear and breakage. The eccentrics and straps have not only to carry the increased friction of the larger sizes of valves, but the reversing twice for every revolution and the inertia of the reciprocating parts of the gear has contained the principal load, and they have become one of the troublesome details of locomotive machinery, requiring constant inspection and maintenance attention to prevent liability of heating or failure. Furthermore, the inaccessibility of the entire arrangement, due to its location within the frames, makes proper attention almost impracticable in connection with the modern locomotive dispatchment conditions.

"A motion placed outside of the frames certainly has the advantage of accessibility and convenience for inspection, lubrication, repairs and cleaning, and the Walschaert type provides for this and gives an opportunity for better diagonal and cross bracing which is so necessary between the main frames and the frames and boilers, to maintain alignment and stability and reduce frame failures.

"The Walschaert gear has long been popular in France, Germany, Belgium, and other foreign countries, and it is used extensively on compound and simple types of locomotives for high and low speeds. It can be made of comparatively light parts, and having no angular advance and no lead that can be given other than by the crank arm, a valve movement can be produced that is equivalent to that given by an eccentric having angular advance.

"Unless improvement can be effected in the design and application of the Stephenson motion, it will be necessary to inaugurate the use of the Walschaert or some similar type of gear for the modern locomotive construction in this country to insure the best results from high pressure with a single valve having large port openings and rapid movement for admission and exhaust, delayed opening of exhaust port for longer expansion and initial expansion, and effective action on crank when the angularity of the main rod and piston pressure is most favorable to produce the greatest degree of efficiency as well as economy at high and low speeds."

The operation of the Walschaert valve gear is not disturbed by the vibration, up and down, of the engine upon its springs, to the extent that the Stevenson valve gear is, provided of course that the point of connection of the eccentric rod, and the link is as near the center line of motion of the main rod as it is possible to locate it. Great care should be exercised in adjusting a valve gear to see that the valve is in the center of its travel, when the piston is at mid-stroke and the reverse lever is in the middle or central notch of the quadrant. The position of mid-stroke for the piston does not necessarily imply that the center of the crank pin is perpendicular above or below the center of the driving axle.

On the contrary, owing to the angularity of the main rod, the position of the crank pin, with the piston at mid-stroke, will be a slight distance to one side of a perpendicular line cast through the center of the driving axle, the distance depending upon the length of the rod. The longer the rod the less this distance will be.

The main pin will in this position be on what is termed the working quarter, the center of the crosshead pin will be at the center of its travel or mid-stroke, and the combination lever of the Walschaert valve gear will be in a perpendicular position, which can be ascertained by dropping a plumb line from the center of the connection of valve stem and combination lever, to the center of the connection of crosshead and combination lever.

With the reverse lever in the central notch, the centers of the link fulcrum pin, and link-block pin, should exactly coincide. If they do not it is an indication that the center notch of the quadrant is not properly located, and this defect should be remedied at once before proceeding to test the correctness of the valve's position.

Having finally succeeded in getting all of the other parts correctly located, an off hand test of the valve may be made as follows: If with the cylinder cocks open, the piston at mid-stroke as just described, and reverse lever in center notch, a slight opening of the throttle causes the steam to blow from one of the cylinder cocks on that side of the engine, it is an indication that the valve is not at mid-travel, and that it does not cover the admission ports. Which port is uncovered will be shown by the cylinder cock from which the steam is blowing.

The cause of an error like this in the position of the valve, and the proper remedy for it can only be determined by careful experiment. First it might be corrected by a slight change in the length of the valve stem, but this should be proceeded with very carefully. Secondly, the link bearer, which is usually attached to the guides, may possibly not be in its true position and may require to be moved either back or forward a slight distance.

This latter move is liable to cause another error, however, due to the fact that it changes the distance between the link fulcrum and the eccentric.

But this fault can be easily corrected by adjusting the length of the eccentric rod. Any changes in the Walschaert valve gear, after the engine has been turned out of the back shop, should be proceeded with carefully, always bearing in mind that this gear from the link forward is permanently located, all motion bearers as a rule being attached to the guides. Back of the link, however, slight changes in distances may be made when necessary to take up lost motion due to wear.

The necessity of correcting the length of the eccentric rods may be ascertained by the following method:

Place the engine with one side on the forward dead center, and the reverse lever down in the go-ahead corner notch. Then have a helper slowly move the reverse lever back towards the center notch of the quadrant. Watch the valve stem closely while the link block is rising, and if the stem is pushed forward slightly, it is an indication that the eccentric rod needs to be lengthened.

On the other hand if the valve stem is drawn backwards by the rising link-block, the eccentric rod should be made slightly shorter. Very slight changes in either case should be made in the length of the rod. It is better to make several tests of hooking up the reverse lever to the center notch, and slightly changing the length of the rod as required at each test. Finally when, by moving the reverse lever from the corner notch back to the center notch, with the engine in the position as indicated above, neither valve stem nor radius rod is affected, the adjustment for that side of the engine may be considered correct. The same method of testing should be followed on the other side, with the exception that the engine be placed on the back dead center. The facilities for making changes in the length of the eccentric rods on modern locomotives, equipped with the Walschaert gear appear to indicate plainly that it is a "back shop" job in most cases.

One very important feature connected with the successful operation of the Walschaert valve gear, is that the bracket supporting the link trunnion should be permanently fixed at an unchangeable distance from the cylinder, and valve chest, and in order to accomplish this it is necessary that this bracket be firmly attached to the guide yoke or bearer.

The valve stem slide which supports the combination lever, and forward end of the radius bar, represents another point which permits of no variation in distances, and for this reason it also is securely attached to the guides.

A discussion of the operation of the Walschaert valve gear would not be complete without a reference to the subject of breakdowns and their remedies, and in treating this subject we will start with the eccentric crank, that being the prime mover, and main source of motion for the other parts of the gear. In this connection it may be well to note, particularly, an advantage possessed by this gear over the Stephenson link, viz., that the eccentric is invariably attached to, and derives its motion from the main driving axle, through the medium of the main crank pin. This cannot be said of the Stevenson gear, as on some types of engines the eccentrics are not located on the main axle, but on one of the other axles. Especially is this the case with engines having three or more pairs of driving wheels.

The breaking of a side rod on an engine of this type equipped with the Stephenson link would totally disable the engine, for the reason that the driving axle carrying the eccentrics would not remain in accord with the main driving axle, and crank pin still being driven by the main rod. With the Walschaert valve gear the breaking or removal of a side rod does not totally disable the engine, for the reason as before stated, that the eccentric is actuated by the main crank pin, and the engine on the uninjured side of the locomotive could still be operated.

In case an eccentric crank, or eccentric rod of a Walschaert valve gear should break or become disabled in any way, the broken parts should be removed, then lower the link block and radius bar to the bottom of the link, after doing which disconnect the suspension bar from the radius bar, also disconnect the radius bar from the combination lever, and raise the front end of the radius bar clear of interference, and firmly secure it by wiring through the pin hole, and to any convenient and solid part of the engine. This should be done in order to prevent the link from vibrating with the motion of the engine. Having thus secured the link and radius bar, the next move is to block the valve, the methods of doing which will be described later on. Very often a breakdown occurs with some part of the engine that will prevent the working of steam on that side, despite the fact that the valve gear is intact. In such cases it will be necessary to block the valve to prevent admission of steam to the cylinder, while at the same time the other parts of the valve gear need not be wholly taken down or disconnected, excepting of course the radius bar, which should always be disconnected at least, at the front end when it becomes necessary to block the valve.

In case a breakdown of this character should occur, with the engine having but a short distance to travel to reach its terminal station, a quick method of solving the problem would be to block the valve, disconnect the radius rod at the front end, and suspend the rod by a pendulum of strong wire or rope passed through the pin hole, and attached to some point above in such a manner as to allow the rod to swing freely back and forth with the motion of the link. Care should be exercised to see that the suspended end of the radius bar does not strike anything in its vibrations. However this method should not be pursued, except as before stated, when the engine has but a short distance to run. A much safer method, and one which will permit the engine to be speeded up, and run for a long distance with one side disabled, would be as follows:

Locate the link block and back end of the radius bar in the exact center of the link by placing the reverse lever in the center notch of the quadrant. Then cut two blocks of wood of the proper dimensions to fit and place them between the lower part of the link and the link block for the purpose of supporting the link block in the center.

These blocks should be secured by lashing with wire or rope. Next disconnect the hanger between the lifting arm, and radius bar, also disconnect the front end of the latter, from the combination lever, and wire the radius bar up as previously directed, or suspend it in any way that will support it securely, there being no motion imparted to it so long as the link block, with the back end of the radius bar, remains at the center of the link.

It is not necessary in all cases to disconnect the combination lever as the motion imparted to its lower end by the crosshead is not likely to disturb the valve, but the precaution should be taken to watch the first movement of the crosshead and see that the combination lever does not strike the crosshead pin, since the motion of the lever may be slightly changed by the disconnection of its upper end.

A good plan is to carry wood blocks on the engine of the proper shape and dimensions, to hold the link block, and radius bar at the center of the link. They will then be available at any time that it is desirable to carry the link block and radius bar without motion.

It should be remembered that in this discussion of rules for guidance in case of breakdowns, there is always one feature that must not be neglected, viz., the placing of the valve in the center of its travel in order to prevent admission of steam to the cylinder of the disabled side. This applies always in case of breakdowns when it is desired to proceed with one side disabled. In the case of a broken radius bar, the pieces of the broken bar should all be taken down, except possibly in case there should be enough left of the bar forward of the link to make it safe to block it up in the center of the link as heretofore described, and suspend or secure the front end of the bar. The location of the lifting arm, or suspension bar of the Walschaert valve gear is governed by the type of engine to which it is applied. On some engines it is connected to an extension of the radius bar back of the link, and on others it is connected to the bar forward of the link. In case the lifting arm should break, or the extension of the radius bar back of the link should become bent or broken from any cause, while the connection of the radius bar to the link block still remained intact, the following method may be pursued:

Assuming that the engine is to run forward, first place the reverse lever in the notch that it will be expected to work in. Then note the height of the link block from the bottom of the link on the side of the engine that is not disabled. Next place a short block in the link under the radius rod, or the link block on the disabled side, this block being of a length sufficient to raise the radius bar and link block to about the same height in the link as the one on the other side is. All broken parts should be removed and another block placed in the link above the link block or radius bar to prevent them from slipping up in the link. Having thus secured all parts, the engine may be operated, always bearing in mind however that the reverse lever must not be moved from the notch at first chosen, neither hooked up, nor dropped lower, so long as the engine is working with one of the lifters disabled.

When a valve stem breaks disconnect the radius bar and secure it in the manner already described. Then place the valve in its central position and block or clamp it there. The combination lever may be left in place, provided that its lower portion does not strike the crosshead pin in its travels. As has been stated, the motion of the combination lever is liable to be changed slightly, due to its having been disconnected at the top from the radius bar, but in case of a broken valve stem, the slide from which the valve stem has been disconnected by the breakage, and to which the combination lever is still connected, may now be placed, and secured in any position on the slide bar, that offers the safest motion to the combination lever, and it should then be blocked in that position in order to preclude any possible chance of its being moved by the combination lever to such an extent as to affect the valve in the least, or push it off center.

In case the combination lever, or the short bar connecting it to the crosshead should get broken or bent, the pieces should be removed, and the radius bar disconnected, and dealt with in the manner already explained, after which the valve should be placed at mid travel and blocked. When an engine that is equipped with the Walschaert valve gear, is disabled on account of a broken main rod, and no other parts of the engine have been disabled or broken, one of the first things to do is to disconnect the radius rod and secure it in the manner heretofore outlined. Then if the valve is of the inside admission type, it should be pushed to the forward end of the valve chest and secured by a clamp on the stem, or it may be blocked at the slide, to hold it in that position.

If the valve is an outside admission valve it should be secured at the back end of the valve chest in such a manner as to prevent it from moving. The object aimed at in securing the valve, in either case, is to keep open the admission port for the front end of the cylinder, in order to permit the steam to enter the cylinder through that port, while the back port is kept open to the exhaust.

The next move is to draw the crosshead towards the back end of the guides as far as it will go, or until the piston is up snugly against the back cylinder head, and there block the crosshead. This will hold the piston firmly in that position, whether the throttle is open or closed, and there will be no danger of its moving.

Of course, when the trottle is open, the piston will be blocked by the steam admitted through the front port, but in drifting down hill, or if the engine should receive a sudden jerk caused by an application of the air brakes, or from any other cause, there is danger of the piston slamming up against the front cylinder head, unless the crosshead is securely blocked.

The combination lever need not be disturbed. If the eccentric crank and rod have not been damaged in any way they may also be left in position, as the motion imparted to the link by the eccentric rod will do no harm, so long as the radius bar is properly suspended.

Having removed the parts of the broken main rod, and attended to the above described details, the engine is ready to proceed, with one side in working condition.

If a piston gets broken, or disconnected from the piston rod, the usual result is that the front cylinder head also gets broken. Whether the front head is broken or not it should always be removed, and the broken piston taken out of the cylinder. If the piston rod is not broken the main rod may be left up, but the radius bar must be disconnected, and secured, and the valve centered and blocked. The engine is now ready to go, provided the piston rod has not been bent, but if the rod is bent in the least, the main rod should be taken down also, and the crosshead be blocked in the manner already recommended. In case a front cylinder head is broken, or blown out, the radius bar should be disconnected, as usual, and the valve centered. The back cylinder cock should be removed, also, in order to prevent the formation of a vacuum behind the piston in its travels, and also to allow any water of condensation to escape. The lubrication of the piston with the front cylinder head removed becomes an easy problem.

If the back cylinder head should get broken or blown out, an accident which fortunately does not occur very often, the main rod should be taken down, as it would not be safe to take any chances on the piston rod having been bent when the cylinder head was broken.

If the breakdown is not serious as for instance a piece broken out but still leaving the head strong enough to withstand the pressure of the piston against it, while under steam, the same method may be pursued as in the case of a broken main rod, viz., blocking the piston with steam admitted through the front port, also blocking the crosshead.

In case the back cylinder head is broken very badly, in fact rendered entirely useless except for scrap, the main rod should be taken down, the radius bar disconnected, and secured as already explained, and the valve placed at mid travel, and blocked.

If at any time it should happen that the short connecting bar between the crosshead and the lower end of the combination lever, should get broken, and lost, from both sides of the engine, and it is desired to obtain the lengths of the lost bars, the following method may be resorted to, and it will give at least a close approximation:

Place the crosshead at mid travel, in that position which would indicate that the piston is at mid stroke.

Then place the reverse lever in the center notch of the quadrant, which should bring the link blockpin and the link fulcrum pin or trunnion center to center.

When the above mentioned parts are in the positions designated, viz., the piston at mid stroke, and the link block, and link trunnion centers together, the long arm of the combination lever should hang perpendicular, and it may be placed in this position by the use of a plumb line, after which the length of the lost bar may be obtained by taking the distance from the center of the pin in combination lever to the center of the pin in the arm on the crosshead, to which the short bar is connected.

EXAMINATION QUESTIONS.

1. What is the chief difference between the Walschaert, and the Stephenson valve gears?

2. How is the Walschaert gear operated?

3. How is the link secured?

4. Describe in general terms the construction, and operation of the radius rod and link.

5. Is a rock shaft always necessary with the Walschaert valve gear?

6. What is the function of the combining levers?

7. Describe the connection, and operation of this lever.

8. Where is the fulcrum of the combination lever with outside admission valves?

9. With inside admission valves where is the fulcrum located?

10. What should the radius of the link be equal to?

11. How can this be ascertained?

12. What are the two essential points to be kept in view in the design and construction of the Walschaert valve gear?

13. If, after connecting the gear there should be a slight variation between the forward and backward position of the valve how may it be corrected?

14. What disadvantage attends the investigation of the Stephenson valve gear on a modern locomotive when out on the road?

15. How many eccentrics, or eccentric cranks are required to drive the Walschaert valve gear?

16. How does this gear compare with the Stephenson gear, in the items of size of bearings, and friction?

17. Does the lead of the valve vary at different points of cut-off with the Walschaert gear?

18. Mention some of the advantages to be gained by a constant lead.

19. Is the Walschaert valve gear as easy to handle from the cab as is the Stephenson?

20. Has the valve gear of locomotives kept pace with other parts in general development and improvement?

21. Owing to the demands of modern transportation, what can be said of the Walschaert valve gear?

22. What are its advantages over the Stephenson gear as regards accessibility?

23. What is the saving in weight effected by the use of the Walschaert gear?

24. What can be said of this gear as regards directness of transmission?

25. As to permanence of adjustment?

26. How does it compare with the Stephenson gear in the matter of wear?

27. In regard to smooth operation what can be said of the Walschaert gear?

28. How is the frame bracing affected by the use of this valve gear?

29. In the construction of the Walschaert valve gear how are the proportions of the combination lever determined?

30. What factors govern the location of the link?

31. What rules are to be observed in the location of the suspension point of the lifter?

32. In the location of the longitudinal position of the link fulcrum, what points are to be considered?

33. Where should the point of connection between the eccentric rod and the link be located?

34. If this location should cause too much eccentric throw, how may a compromise be affected?

35. What important rule should govern the laying out, and construction of the Walschaert valve gear?

36. Why should this rule be strictly observed?

37. Is there any part of this gear in which changes may be made, once it is erected?

38. What form does the eccentric usually assume in the Walschaert valve gear?

39. What is the position of the center of the eccentric crank relative to the plane of motion?

40. Has the eccentric an angular advance?

41. Does the Walschaert valve gear lend itself as freely to adjustment as does the Stephenson link?

42. What great advantage has the Walschaert gear over the Stephenson gear as regards the lead given the valve?

43. What motion controls the lead?

44. What motion controls the valve travel and reversing operations?

45. Where would the motion of the eccentric alone place the valve when the piston is at the end of the stroke?

46. Wherein does the reversing operation of the Walschaert valve gear differ from that of the Stephenson link?

47. What precaution should be observed regarding the position and throw of the eccentric when the engine is assembled?

48. How is the amount of lap and lead ascertained?

49. In the adjustment of this valve gear, how is the length of the eccentric rod determined?

50. What should be done with the valve stem before changing the eccentric rod?

51. What does the difference between the two positions of the valve on the forward and back centers represent?

52. Can this be changed?

53. How is the lead equalized for both ends?

54. How may the lead be increased?

55. Referring to Special Instructions by the Baldwin Locomotive Co. regarding the erection of the Walschaert valve gear, what precautions are to be taken as to the dimensions of the various parts?

56. What should be done with the eccentric?

57. What suggestion is made concerning the guide bearer?

58. What should be done regarding the location of the link?

59. What is said concerning the reverse shaft, lifting arm and link?

60. Concerning connections of crosshead gear or combination lever, and the radius rod to the valve, what method should be pursued?

61. If any errors exist after the eccentric has been connected, how may they be corrected?

62. After the valves have been adjusted, in common parlance, "set," how may they be tested?

63. Referring to types of valves, what is the principal objection to the use of the D slide valve?

64. Is the piston valve a perfectly balanced valve?

65. What is a necessary factor in order that a valve may be perfectly balanced?

66. Can an inside admission valve be balanced similar to an outside admission?

67. Why should a piston valve be made as long as possible?

68. Is there any particular advantage in the use of inside admission valves over those of outside admission?

69. Name four simple rules by which an engineer may ascertain whether the valves of his engine are inside or outside admission.

70. Mention a very common defect of snap-ring piston valves.

71. Describe in general terms the Wilson high pressure valve.

72. Is the balanced area of this valve the same at all points of its travel?

73. Does the port pressure influence the balancing of the Wilson valve?

74. Mention the names of five types of balanced valves for locomotives that are being used extensively.

75. How may the actions of the valve and the relative positions of the crank pin and eccentric be illustrated?

76. What diagrams are generally used for this purpose?

77. Explain the reason for the increase of lead as the reverse lever is hooked back with the Stephenson valve gear.

78. Upon what does the amount of this increase of lead depend?

79. Why is there no change in the lead with the Walschaert valve gear?

80. What part of this gear is it which forms the fulcrum for the combination lever?

81. What is the first requisite to be considered in connection with this gear?

82. What is the second requisite in connection with the operation of the Walschaert valve gear?

83. What is implied in the third requisite?

84. Does the vibration of the engine upon its springs disturb the Walschaert valve gear in its operation?

85. What precautions are to be observed in order to attain this object?

86. When the piston is at mid stroke, is the crank pin center exactly perpendicular above, or below the center of the driving axle?

87. What then is the position of the crank with the piston at mid stroke, and what causes it to assume that position?

88. Where will the center of the crosshead be with the piston at mid stroke?

89. What should be the position of the combination lever of the Walschaert gear, with the piston at mid stroke?

90. How can this be ascertained?

91. What should be the position of the link fulcrum pin, and the link block pin when the reverse lever is in the central notch of the quadrant?

92. If these pins are not in their correct position, what is the probable cause of the error?

93. How may an off hand test of the valve adjustment be made? Describe the process.

94. If by this test the position of the valve is found to be wrong, how may it be righted?

95. What precaution should be observed in regard to making changes in this gear after it has been turned out of the back shop?

96. Describe the method of correcting the length of the eccentric rods.

97. Mention a very important feature in connection with the link support.

98. What other portion of this gear permits of no variation of distances?

99. What can be said of the Walschaert valve gear regarding its source of motion, and the location of its eccentric crank?

100. Does this apply to the Stephenson gear in all cases?

101. What especial type of engine would be totally disabled by the breaking of a side rod if equipped with the Stevenson link?

102. Why should the engine be disabled?

103. If such an engine was equipped with the Walschaert gear would such an accident disable it from proceeding further?

104. Give the reason for this.

105. In case of an accident to the eccentric crank, or eccentric rod of a Walschaert gear, what is the proper method to pursue?

106. If a breakdown of this kind should occur with the engine having but a short distance to cover to reach the terminal station, what would be a quick method of solving the problem?

107. Is this method to be recommended at all times?

108. Describe a much safer method which will permit the engine to be speeded up with one side after the job is completed.

109. Is it necessary in all cases to disconnect the combination lever?

110. What precaution must be observed in this particular?

111. What is a good plan to pursue in the way of preparation for breakdowns?

112. What particular feature must not be neglected with any kind of a breakdown when it is desired to proceed with one side?

113. What should be done in case of a broken radius bar?

114. Is the lifting arm, or suspension bar of the Walschaert valve gear always located in the same position relative to the link?

115. In case the lifting arm should break, or the extension of the radius bar back of the link should become bent or broken while the connection of the radius bar to the link remained intact, what method should be pursued?

116. When temporary repairs of this kind are made what precaution regarding the reverse lever must be observed?

117. When a valve stem breaks what may be done to fit the engine for running with one side?

118. If the combination lever or its connection to the crosshead gets bent or broken what should be done?

119. What must always be done with the valve, on the disabled side?

120. In case of a broken main rod what is the proper course of procedure?

121. If the valve is an inside admission valve, what must be done with it?

122. If the engine has outside admission valves what must be done with the valve?

123. What is the object aimed at in thus securing the valve?

124. What must be done with the crosshead in case of a broken main rod?

125. Why is this precaution necessary with the crosshead?

126. What must be done with a broken or disconnected piston?

127. Is it necessary to take down the main rod in all cases of a broken piston?

128. When is it absolutely necessary to take down the main rod for a broken piston?

129. If a front cylinder head should get broken or blown out what should be done?

130. Why should the back cylinder cock be removed in this case?

131. In case a back cylinder head should get broken or blown out what should be done?

132. If the break in the back cylinder head is not serious what may be done?

133. What is the proper method of procedure when the back cylinder head is badly broken?

134. If the connecting bar or link between the cross-head and the lower end of the combination lever should happen to get broken and lost from both sides of the engine, how may the lengths of the lost bars be obtained?

SERVICE RESULTS WITH WALSCHAERT GEAR.

That the advantages herein outlined for this valve are not merely theoretical, is indicated in the following quotations from communications from Mr. H. F. Ball, Superintendent of Motive Power of the Lake Shore & Michigan Southern Railway:

"Our enginemen are very enthusiastic over the Walschaert valve gear, and we are about to arrange with the American Locomotive Company to equip twenty-five consolidation engines with it. My feeling in the matter is that the Walschaert gear has come to stay, particularly for all heavy power."

"In reference to the Walschaert valve gear, engine No. 912 has now a total of 1/16 in. lost motion in the valves. This is the total lost motion in the whole motion work. This engine has made approximately 39,000 miles, and engine No. 5924 (with link motion), examined the same date, had 5/16 in. lost motion in the valve stem, and has made approximately 32,000 miles. This seems to be very much in favor of the Walschaert motion."

OPINION OF DR. GOSS.

"This design (the Walschaert) makes a strong appeal to engineers who are forced to go outside of the frames with their valve motion, and for this reason its use is likely to increase in American practice. If, as many engineers believe, some form of balanced compound is to gain ascendancy in this country there will be a greater difficulty in retaining the valve gear between the frames." —*Southern and Southwestern Railway Club.*

EXAMPLES OF UNIVERSAL ADAPTABILITY.

Mention has already been made of the ease with which the Walschaert valve gear can be applied to any type of locomotive.

It is therefore fitting that a space be devoted to illustrations and short descriptions of several of the more interesting examples of the adaptability of this valve gear to the varied and at the same time changing demands and conditions of modern locomotive practice.

The following concerning the DeGlehn four cylinder compound locomotive is copied from the *Railway Master Mechanic* of August, 1907:

The Baldwin Locomotive Works has recently built twenty ten-wheel locomotives for the Paris-Orleans Railway of France. These engines are compounded on the DeGlehn system, and were built to drawings furnished by the railway company. All measurements in their construction were made on the metric system, necessitating the introduction by the builders, of many new standards and gauges.

The DeGlehn type of locomotive is characterized by an arrangement of cylinders which divides the application of the power between two driving axles, and provides a separate valve gear for each cylinder, so that the high and low pressure cut-offs can be independently varied. The high pressure cylinders are placed outside, while the low pressure are inside between the frames. The Walschaert valve motion is used throughout. The gears for the inside cylinders are driven from eccentrics placed on

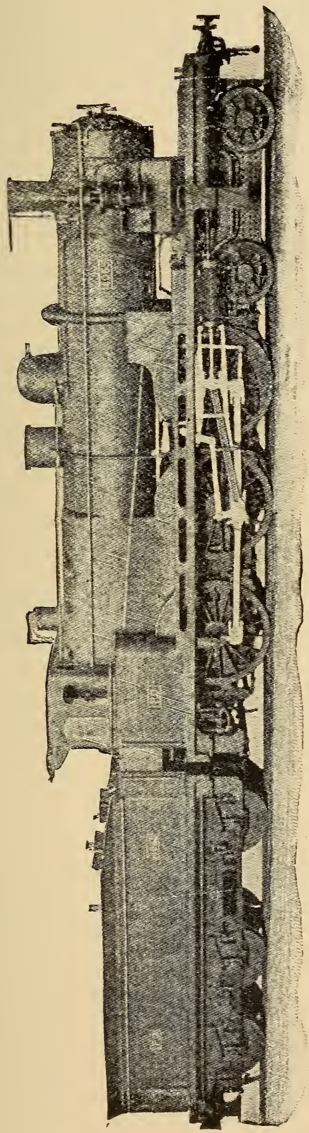


FIGURE 84. DE GLEHN FOUR CYLINDER COMPOUND LOCOMOTIVE—PARIS-ORLEANS RY.

the first driving axles, while those for the outside cylinders are driven from the second pair of driving wheels by return cranks placed on the crank pins.

The outside, or high pressure cylinders, are connected to the second pair of driving wheels, while the inside, or low pressure, are connected to the first pair, which has a cranked axle. In order to keep the main rods of as nearly the same length and weight as possible, the high pressure cylinders are set some distance in the rear of the low pressure cylinders. This arrangement of cylinders is facilitated by the use of plate frames to which the cylinder castings are conveniently bolted. In the locomotive mentioned, the high pressure cylinders are located immediately in front of the leading pair of driving wheels. The slide valves are balanced, and are of bronze. The low pressure valves are also of bronze, but unbalanced; they have inclined seats, and their steam chests are formed within the cylinder casting. All the cylinders are set on an inclination of 3½ per cent to provide clearance for the engine truck under the low pressure cylinders. Steam is conveyed to the high pressure cylinders through external pipes, and is passed on to the low pressure cylinders through special valves which are operated by air pressure controlled from the cab.

The center lines of the high pressure steam chests are placed outside the cylinder center lines, all parts of the valve motion are located in the same plane. With the low pressure cylinders, such an arrangement is impossible, as the valves are driven by eccentrics which are placed on the first axle between the inside crank cheeks. The links are mounted on rock shafts, which serve to transfer the motion from one plane to the other. Independent reverse shafts are provided for the high and low pressure valve gears, which may be operated together or

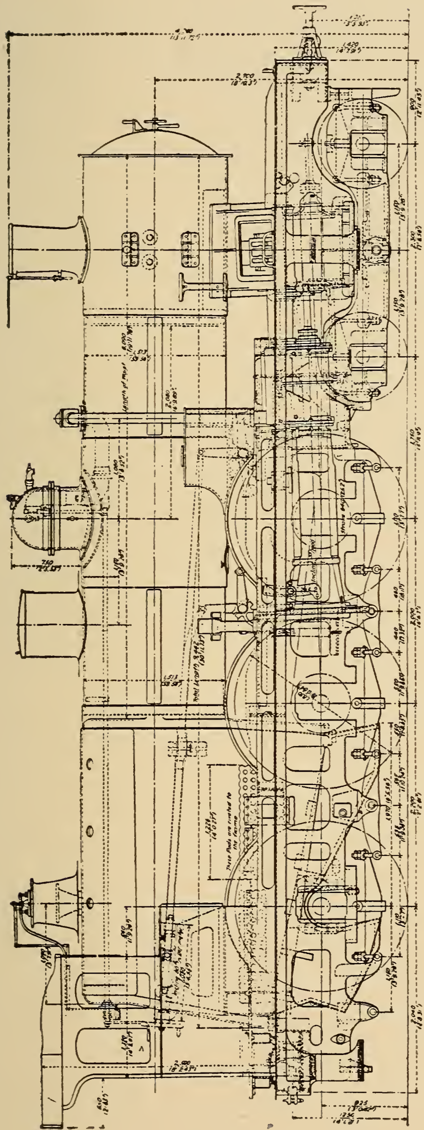


FIGURE 85. SIDE ELEVATION OF DE GLEHN FOUR CYLINDER LOCOMOTIVE—PARIS-ORLEANS RY.

separately by means of an ingeniously arranged screw reverse mechanism placed in the cab.

The boiler is of the Belpaire type, built of steel with the exception of the inside fire box, which is of copper. The grate is placed between the frames and is inclined toward the front at a sharp angle, thus giving an exceptionally deep throat. The stay bolts in the water legs are of maganese bronze. Each bolt is drilled throughout its entire length with a hole ¼ of an inch in diameter. These holes are closed up at their inner ends by riveting the bolts over after they have been screwed into the sheets. The firebox is provided with a brick arch which is supported on copper strips, secured to the side sheets by copper studs. The grate is of the rocking type. The tubes are soft steel, of the "Serve" pattern, with internal ribs.

The boiler shell is built with longitudinal butt joints having double covering strips, while the circumferential seams are double riveted with lap joints. The throat sheet completely encircles the barrel. The cab is built of steel plate, and has narrow side windows. Access to the running boards may be had by climbing around outside of the cab, and for this purpose suitable hand rails are provided. An interesting part of the equipment is the Haesler Chronotachymetre, which keeps a complete record of the speed throughout the run, and also shows the engine men the rates of speed at any instant. The motion for this device is derived from a stud which is screwed into the rear right hand crank pin, and works in a slotted arm on a gear shaft located under the running board.

The tender is carried on six wheels, the two rear pairs of which are equalized. The frames are of the plate form, placed outside the wheels.

The principal dimensions and specifications are as follows:

Type of engine .... 10-wheel DeGlehn Compound
Service .... Passenger
Fuel .... Bit. Coal
Tractive force .... 21,466 lbs.
Gauge .... 4 ft. 9 in.
Cylinders H. P. 14 3-16 in. x 25 3-16 L. P. 23⅝
.... in. x 25 3-16 in.
Valve gear, type .... Walschaert

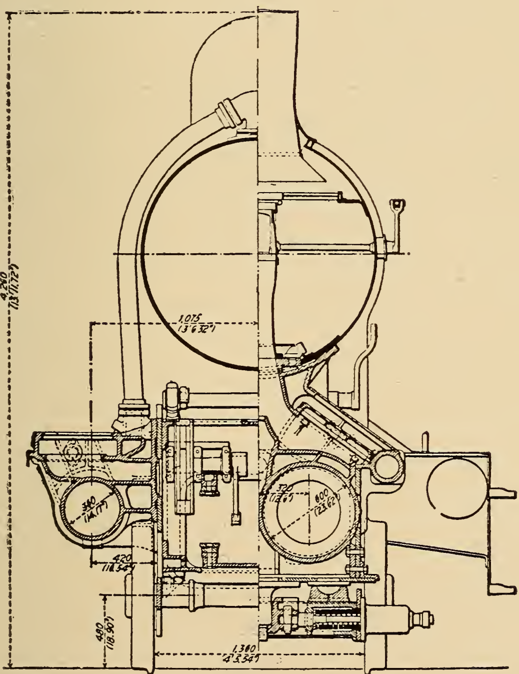


FIGURE 86. CROSS SECTION THROUGH BOILER HIGH AND LOW PRESSURE CYLINDERS, DE GLEHN FOUR CYLINDER COMPOUND—PARIS-ORLEANS RY.

In this connection it will be interesting to note the comments of Mr. William Forsyth read before the International Engineering Congress. Speaking with reference to the DeGlehn four-cylinder compound locomotive, and the Walschaert valve gear, Mr. Forsyth says:

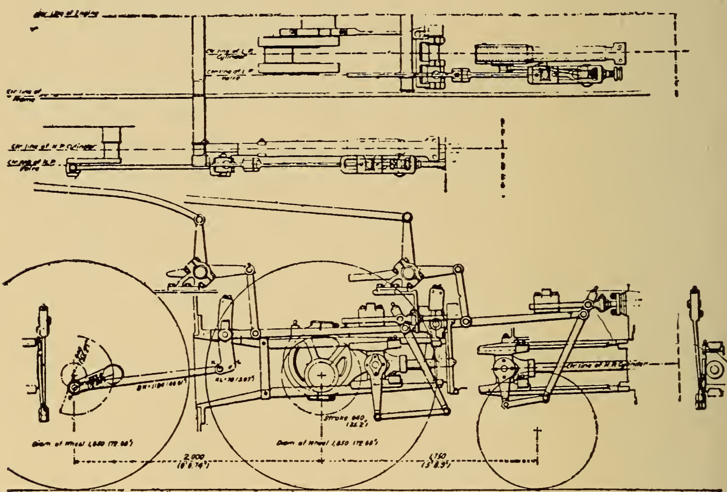


FIGURE 87. SIDE ELEVATION AND PLAN OF WALSCHAERT VALVE GEAR, DE GLEHN FOUR CYLINDER COMPOUND—PARIS-ORLEANS RY.

"The use of the Walschaert valve motion on the Baltimore & Ohio Mallet articulated locomotive, and on the Pennsylvania Railroad's DeGlehn four-cylinder compound, which are now on exhibition at Saint Louis, has again brought the merits of this gear to the attention of American designers. These two locomotives represent extreme conditions as to the speeds for which they are intended. The one is for slow speed on heavy grades, the other for high-speed passenger work. This would indicate that the Walschaert gear is well adapted to any kind of service, freight or passenger. It is fortunate that a well-designed gear of this type will soon be seen in operation in this country, and its performance on these locomotives will be watched with interest. * * *

"A valve gear outside of the frames is conveniently inspected and repaired, while one inside of the frames is certainly in an awkward position for either operation. With inside cylinders and crank axles there is little room for eccentrics and links, and if all this be removed it allows ample length for main pin bearings, and it is then possible to have an inside bearing for the crank axle. The Walschaert gear, as ordinarily designed, is not symmetrical in a vertical plane, and there is a tendency to lateral bending and unequal wear when so constructed. In the illustrations above referred to Mr. DeGlehn has taken special care to avoid these objections, and his design shows well-balanced wearing surfaces of ample proportions, which should be quite durable.

"The point to which we wish to call particular attention is the great contrast in the weight of the moving parts and the size of the bearings when this Walschaert outside gear is compared with similar parts of a Stephenson link motion driven by eccentrics. A prominent superintendent of motive power, who has made a special study of indicator cards and who has given much attention to valve gears, in a recent discussion on 'Modern Tendencies in Locomotive Design in America,' made this statement: 'I consider that the increased complication and weight of the valve motion is an exceedingly serious matter in giving distorted steam distribution, due to the destructive effect of the valve motion in causing wear and tear.' The reports on 'Weights of Detail Parts of Locomotives,' in the proceedings of the Master Mechanics' Association, 1903, page 187, gives the weights of parts of the Stephenson valve gear for large locomotives, as follows, in pounds: Eccentric, 212; eccentric strap, 225; eccentric rod, 125; link, 148; rocker arm, 248; transmission bar, 128; valve rod, 66; valve yoke, 90; valve, 211. These figures indicated that the Stephenson valve gear, including the eccentrics and straps, as found on our modern locomotives, has become a very ponderous affair. Some attention has been given to the valve pattern in the effort to make it as light as possible, but the same care has not been taken with the moving details connected with it, and which easily becomes a disturbing factor at high speeds if made too heavy.

"The principal load which comes on the eccentrics and straps, causing them to heat, is not the friction of the valve, but it is that due to the inertia of the reciprocating parts of the valve gear whose motion is reversed twice for every revolution. If we include the rocker arm, the weight, as found above, of the moving parts from valve to eccentric strap for one cylinder is 1,052 pounds, and at high speeds the energy of this moving mass must impose a heavy load on the eccentrics. The eccentrics and straps are the most difficult details in the locomotive machinery to keep properly lubricated, and it requires constant vigilance to prevent them from heating. When they do heat and cut and the straps are taken down, their location inside the frames is the most inconvenient one possible, and with the increasing weight of the machinery this part of the locomotive repairs has become very laborious and expensive. More attention should be given to the reduction of the weight of the moving parts of the Stephenson valve gear, or some other type should be used. The Walschaert gear, located outside the frames is easily accessible and very convenient for inspection, lubrication and repairs. The main driving bearings are two small

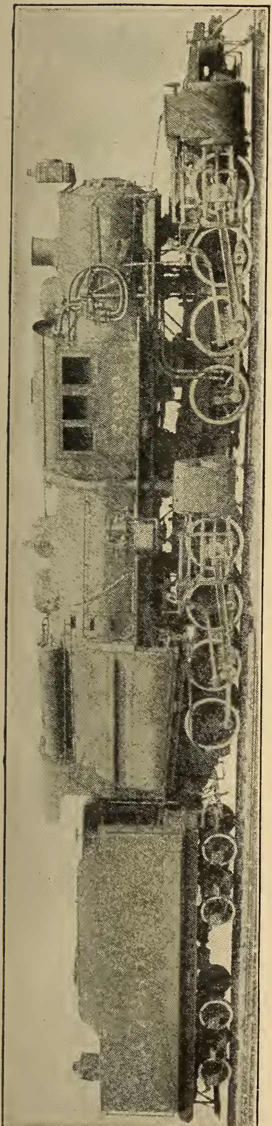


FIGURE 88. MALLET COMPOUND LOCOMOTIVE FOR PUSHER SERVICE ON ERIE RAILROAD—WEIGHT 410,000 POUNDS, TRACTIVE FORCE 94,800 POUNDS.

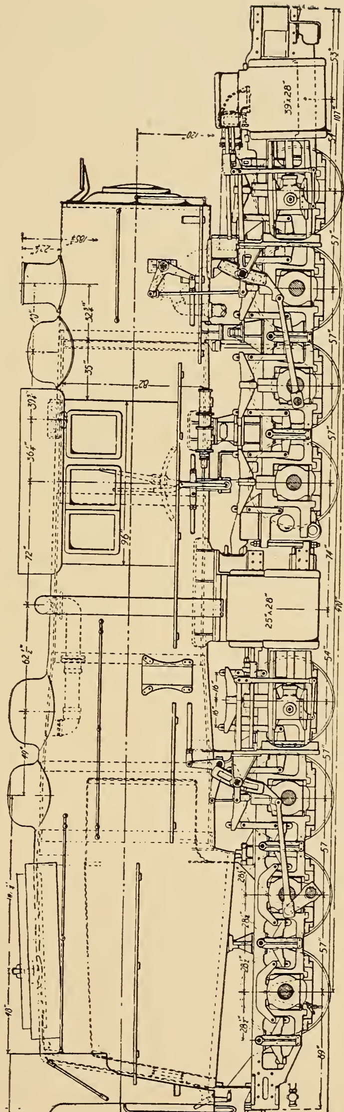


FIGURE 89. SIDE ELEVATION OF MALLET COMPOUND LOCOMOTIVE—ERIE RAILROAD.

pins with bushed bearings, and the contrast with the heavy and cumbersome eccentrics and straps which are their equivalent in a valve gear system is very striking. This gear is simple and light throughout, and it has much to recommend it which would overcome the objectionable features of the shifting link motion driven by eccentrics."

Another example of the adaptability of this valve gear to any and all kinds of railway service is seen in the Mallet compound locomotive which has within the past four years been successfully introduced into the United States. Figures 88 and 89 will serve to illustrate in general the design of this type of locomotive.

Although a radical departure from the usual design in use in this country, the performance of the locomotive has been entirely satisfactory from the standpoints of operation and maintenance. The success of this type led to its adoption by the Northern Pacific Railway, first for helper service and later for regular road work. The latest development in this type is the locomotive lately completed at the Schenectady Works of the American Locomotive Company for the Erie Railroad, which is the heaviest and most powerful locomotive in the world.

The enormous size and capacity of this locomotive is shown by the total weight of 410,000 pounds, all of which is on the drivers and the available tractive force of 94,800 pounds. The locomotive was designed for pusher service between Susquehanna and Gulf Summit where the grade is 1.3 per cent. If the tractive force is maintained the locomotive should handle over 3,000 tons in a train of 60 cars up the grade in fair weather, which demonstrates the capacity of the locomotive and its adaptability to helper service on heavy grades.

The engines are compounded on the Mellin System, the intercepting valve being located in the upper part of the left cylinder casing. Exhaust steam from the right high pressure cylinder passes through a cored passage to the back of the cylinder casing, from whence it passes through a U-shaped pipe connecting to a passage in the left cylinder casting leading up into the intercepting valve chamber, into which the exhaust steam from the left high pressure cylinder also passes.

The emergency exhaust valve is located in the side of the left cylinder casting, and has a four and one-half-inch jointed pipe connection within an opening in the back of the nozzle in the smoke box.

Steam from the high pressure cylinders passes into a nine-inch receiver pipe extending forward from the center of the cylinder saddle, to which it is connected by a ball joint.

In order to facilitate putting in place or removing, this pipe is made up of three sections, and is connected at the front end by means of a slip joint to cover variations in length, due to curving to a Y pipe through which steam reaches each of the low pressure steam chests.

The receiver pipe is laid out for 16 degree curves. Steam from the low pressure cylinders, which are located considerably ahead of the front end of the boiler, exhausts back through a flexible pipe connection to the exhaust pipe in the smoke box.

The high pressure cylinders are equipped with piston valves, and the low pressure cylinders with the Richardson slide valves, described in another part of this book.

The valve gear is of the Walschaert type, and by an ingenious arrangement of the reversing gear, the weights of the valve motions of the front and rear engines counter-balance each other.

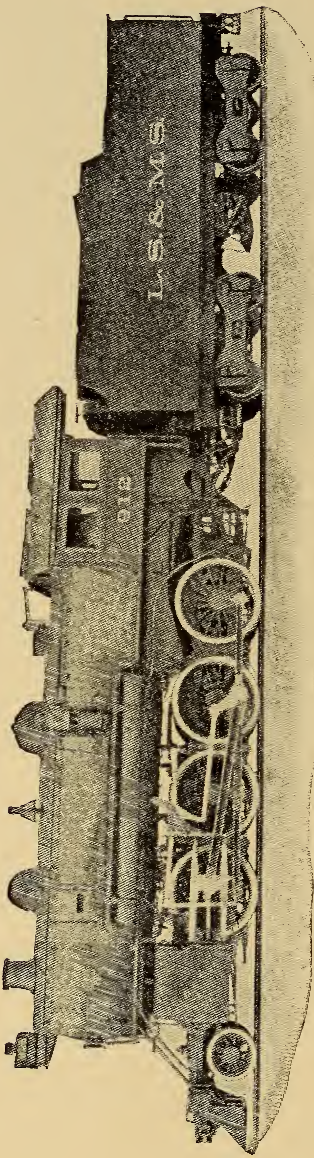


FIGURE 90. CONSOLIDATION FREIGHT LOCOMOTIVE, WITH WALSCHAERT VALVE GEAR.
Built for Lake Shore & Michigan Southern Railway by the American Locomotive Company.

The valve motion is reversed by means of a pneumatic operating device.

Fig. 90 shows a consolidation freight locomotive of the Lake Shore and Michigan Southern Railway equipped with the Walschaert gear and the following interesting comparison of the weights of this gear and the Stephenson link motion is made by the *American Engineer and Railroad Journal,* using the locomotive shown in Fig. 90 as an example:

"In the matter of weight of parts, the details, in pairs, of the Walschaert gear of this engine (Lake Shore & Michigan Southern 2-8-0 type No. 912) are as follows: Cross-head arms, 60 pounds; vibrating rods, 220 pounds; eccentric rods, 220 pounds; links, 260 pounds; transmission bars, 140 pounds; valve rods, 70 pounds; eccentric cranks, 100 pounds; vibrating links, 70 pounds; valve stems, 72 pounds; and transmission bar hangers, 72 pounds. This means a total weight of 1,252 pounds for the entire valve gear of the Lake Shore engine, not including the valves. The weight of the corresponding valve gear parts of a recently constructed 20x28-inch, 4-6-0 engine, with Stephenson link motion, is 2,734 pounds. Such a weight, which must be moved and reversed for every revolution, imposes severe duty upon the eccentrics, and it is not surprising that they heat."

Figs. 91 and 92 illustrate examples of recent construction of locomotives equipped with the Walschaert valve gear by the Baldwin Locomotive Co.

Referring to Fig. 91 the general dimensions are as follows:

Gauge ....4 feet 8½ inches
Cylinders ....28x32 inches
  Valve ....Balanced
Boiler—type ....Wagon top

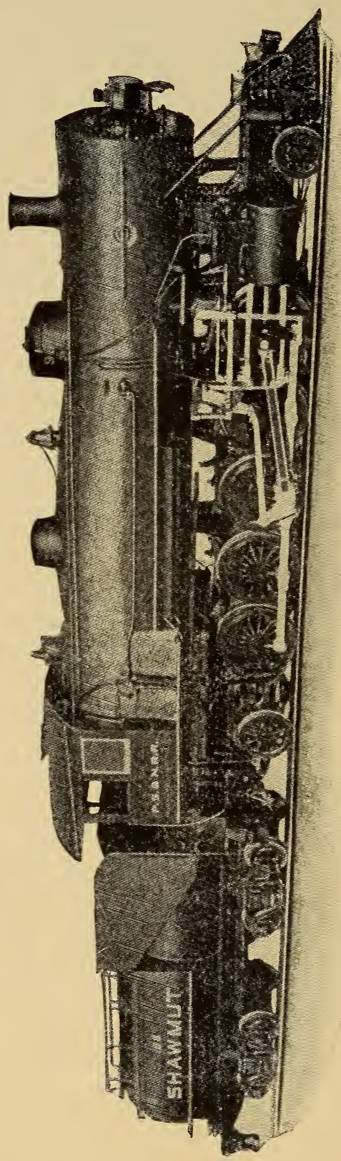


FIGURE 91. SANTA FE TYPE LOCOMOTIVE FOR THE PITTSBURGH, SHAWMUT & NORTHERN RAILROAD, 1907.
Baldwin Locomotive **Works.**

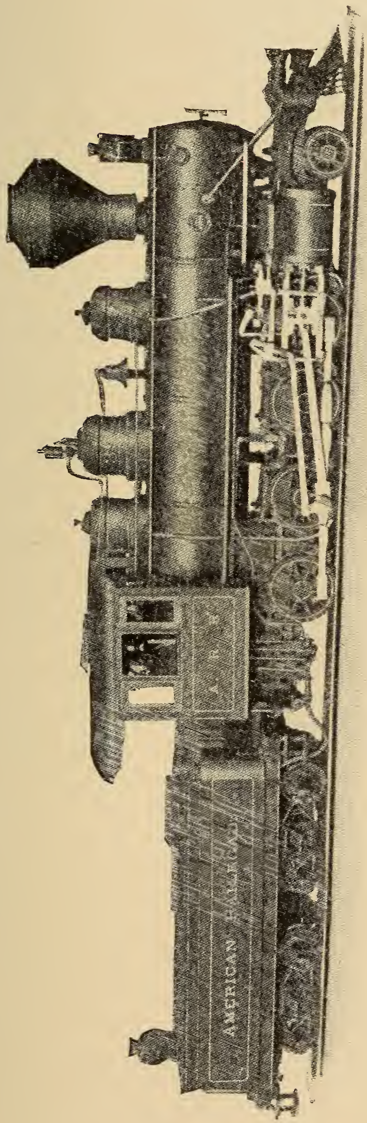


FIGURE 92. COMPOUND CONSOLIDATION LOCOMOTIVE FOR THE AMERICAN RAILROAD OF PORTO RICO, 1907.

By the Baldwin Locomotive Works.

Material ....Steel
Diameter ....78¾ inches
Thickness of Sheets............⅞ and 15/16 inches
Working Pressure ....160 lbs.
Fuel ....Soft Coal
Staying ....Radial

Firebox—Material ....Steel
Length ....108 inches
Width ....78 inches
Depth ....front, 80¼ inches; back, 78¼ inches
Thickness of Sheets..sides, ⅜ inches; back, ⅜ inches;
..................crown, ⅜ inches; tube, 9/16 inches
Water Space ....front, 4½ inches;
...................sides, 5 inches; back, 4 inches

Tubes—Material ....Steel
Wire Gauge ....No. 11
Number 391
Diameter ....2¼ inches
Length ....20 feet

Heating Surface—Firebox..................210.0 sq. ft.
Tubes ....4586.0 sq. ft.
Total ....4796.0 sq. ft.
Grate Area ....58.5 sq. ft.

Driving Wheels—Diam. Outside..............57 inches
Diameter of Center.......................50 inches
Journals ....main, 11x12 inches
others, 10x12 inches

Engine Truck Wheels—
Diameter, front ....29¼ inches
Journals ....6½x10½ inches
Diameter, back ....40 inches
Journals ....7½x12 inches

Wheel Base—Driving	19 feet 9 inches
Rigid	19 feet 9 inches
Total engine	35 feet 11 inches
Total Engine and Tender	67 feet 4½ inches
Weight—On Driving Wheels	233,350 lbs.
On Truck, front	24,800 lbs.
On Truck, back	22,300 lbs.
Total Engine	280,450 lbs.
Total Engine and Tender	about 430,000 lbs.
Tender—Number of Wheels	8
Diameter of Wheels	33 inches
Journals	5½x10 inches
Tank—Capacity	Water, 8500 gals.
	Coal, 14 tons

Service—Freight.

Engine equipped with Baldwin Super-heater. Super-heating surface, 762 square feet.

Freight Locomotive—Consolidation Type, with Walschaert Valve Gear. Built for Lake Shore & Michigan Southern Railway.

(See Fig. 90.)

Gauge of Track, 4 feet 8½ inches.

Loaded Weights

On leading track	25,000 pounds
On driving wheels	198,000 pounds
Total engine	223,000 pounds
Tender	141,500 pounds

Wheel Base

Driving	17 feet
Total of engine	25 feet 11 inches
Total of engine and tender	60 feet 6½ inches

Cylinders

Diameter	23 inches
Stroke of piston	32 inches
Valves, piston type	

Wheels

Diameter of engine truck wheels	33 inches
Diameter of driving wheels, outside	63 inches
Diameter of tender wheels	33 inches

Journals—Diameter and Length

Engine truck	6¼x10 inches
Driving	10 and 9½x12 inches
Tender	5½x10 inches

Type, 280-223

Boiler

Type	Straight Top
Outside diameter at front end	81⅝ inches
Length of fire-box, inside	106 inches
Width of fire-box, inside	76 inches
Number of tubes	460
Diameter of tubes	2 inches
Length of tubes	15 feet 6 inches
Working pressure per square inch	200 pounds
Heating surface in tubes	3,709.42 sq. feet
Heating surface in fire-box	182.5 sq. feet
Total heating surface	3,921.92 sq. feet
Grate area	54.9 sq. feet

Tender Capacity

Water	7,500 gallons
Fuel	12 tons

Clearance Limitations

Height of stack above rail	14 feet 9¾ inches
Width	10 feet 2½ inches
Length over all	70 feet 1¼ inches

Maximum Tractive Power, 45,685 pounds.
American Locomotive Company.

Switching Locomotive, with Walschaert Valve Gear—Built for the Lake Shore & Michigan Southern Railway.

(Heaviest Switching Locomotive Ever Built.)

(See Fig. 93.)

Gauge of Track, 4 feet 8½ inches

LOADED WEIGHTS

On driving wheels ....270,000 pounds
Total engine ....270,000 pounds
Tender ....149,000 pounds

WHEEL BASE

Driving ....19 feet
Total of engine ....19 feet
Total of engine and tender..........54 feet 5½ inches

CYLINDERS

Diameter .... 24 inches
Stroke of piston ....28 inches
Valves, piston type....................

WHEELS

Diameter of driving wheels, outside.........52 inches
Diameter of tender wheels ....33 inches

JOURNALS—DIAMETER AND LENGTH

Driving ....10½x9½x12 inches
Tender ....5½x10 inches
Type, 0100-270

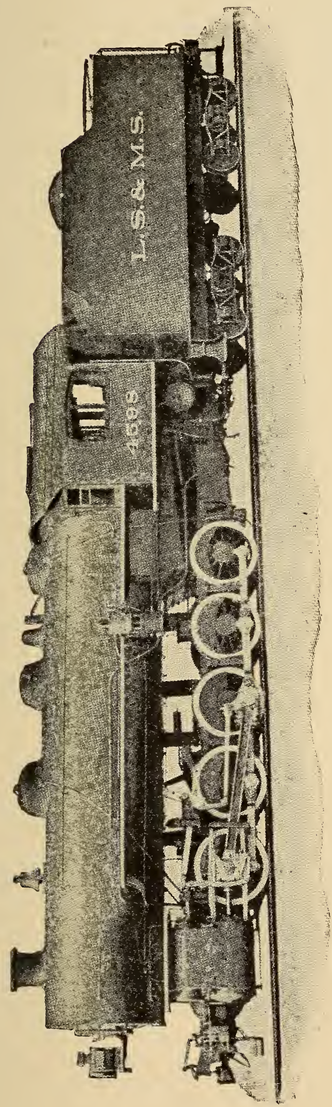


FIGURE 93. DECAPOD SWITCHING LOCOMOTIVE WITH WALSCHAERT VALVE GEAR. Built for Lake Shore & Michigan Southern Railway by the American Locomotive Company. The heaviest and most powerful switching locomotive ever built.

Boiler

Type	Extended Wagon Top
Outside diameter at front end	80 1/16 inches
Length of fire-box, inside	108⅛ inches
Width of fire-box, inside	73¼ inches
Number of tubes	447
Diameter of tubes	2 inches
Length of tubes	19 feet
Working pressure per square inch	210 pounds
Heating surface in tubes	4,422.4 sq. feet
Heating surface in fire-box	203 sq. feet
Total heating surface	4,625.4 sq. feet
Grate area	55 sq. feet

Tender Capacity

Water	8,000 gallons
Fuel	12 tons

Clearance Limitations

Height of stack above rail	14 feet 10½ inches
Width	10 feet 2 inches
Length over all	70 feet 4 inches

Maximum Tractive Power, 55,362 pounds.
American Locomotive Co.

Passenger Locomotive—Prairie Type, with Walschaert Valve Gear—Built for Pennsylvania Railroad.

(American Locomotive Co.)

(See Fig. 94.)

Gauge of Track, 4 feet 9 inches.

Loaded Weights

On leading truck	27,000 pounds
On driving wheels	166,800 pounds
On trailing truck	40,700 pounds
Total engine	234,500 pounds
Tender	139,300 pounds

Wheel Base

Driving	14 feet
Total of engine	34 feet 3 inches
Total of engine and tender	64 feet 6¾ inches

Cylinders

Diameter	21½ inches
Stroke of piston	28 inches
Valves, piston type	

Wheels

Diameter of engine truck wheels	42½ inches
Diameter of driving wheels, outside	80 inches
Diameter of trailing wheels	50 inches
Diameter of tender wheels	36 inches

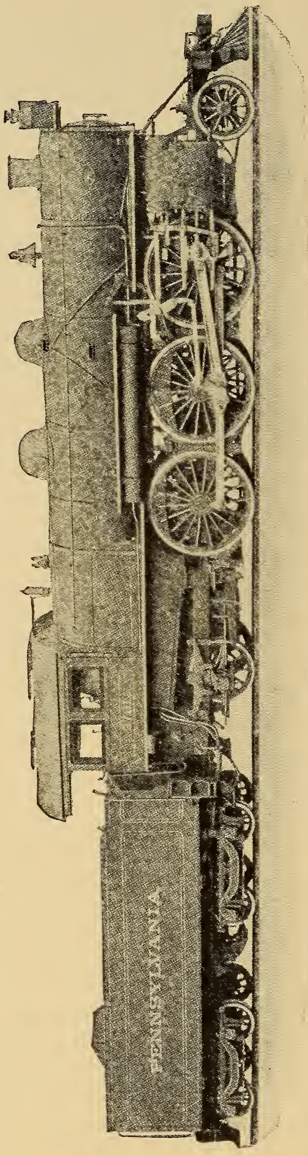


FIGURE 94. PRAIRIE TYPE PASSENGER LOCOMOTIVE, WITH WALSCHAERT VALVE GEAR.
Built for Pennsylvania Railroad by American Locomotive Co.

Journals—Diameter and Length

Engine truck	6½x12 inches
Driving	10x12 inches
Trailing	8x14 inches
Tender	5½x10 inches

Type 262-235

Boiler

Type	Straight Top
Outside diameter at front end	74½ inches
Length of fire-box, inside	108⅛ inches
Width of fire-box, inside	73¼ inches
Number of tubes	322
Diameter of tubes	2¼ inches
Length of tubes	19 feet 6 inches
Working pressure per square inch	200 pounds
Heating surface in tubes	3,678.9 square feet
Heating surface in fire-box	202.7 square feet
Total heating surface	3,881.6 square feet
Grate area	55 square feet

Tender Capacity

Water	7,000 gallons
Fuel	10 tons

Clearance Limitations

Height of stack above rail	14 feet 10⅜ inches
Width	10 feet ⅞ inches
Length over all	73 feet 10⅞ inches

Maximum Tractive Power, 27,520 pounds.

GENERAL DIMENSIONS.

(See Fig. 95.)

Gauge ....3 feet 6 inches
Cylinders...............16-inch diam. x 22-inch stroke
Valve ....Balanced Piston
Boiler—Type ....Straight
Material ....Steel
Diameter ....51 inches
Thickness of Sheets ....½ inch
Working Pressure ....200 lbs.
Fuel ....Lignite
Staying ....Radial
Firebox—Material ....Copper
Length ....82 inches
Width ....30 inches
Depth.........front, 56¾ inches; back, 47¾ inches
Thickness of Sheets.....sides, ½ inch; back, ½ inch;
..............crown, ⅝ inch; tubes, ¾ and ½ inch
Water Space......front, 3½ inches; sides, 2½ inches;
...........................back, 2½ inches
Tubes—Material ....Copper
Wire Gauge...................No. 11 and No. 12
Number, 197 ....Diameter, 1¾ inches
Length ....13 feet 10 inches
Heating Surface—Firebox..................81.8 sq. ft.
Tubes ....1238.5 sq. ft.
Total ....1320.3 sq. ft.
Driving Wheels—Diam. Outside..............49 inches
Diameter of Center...................44 inches
Journals ....6½x7 inches

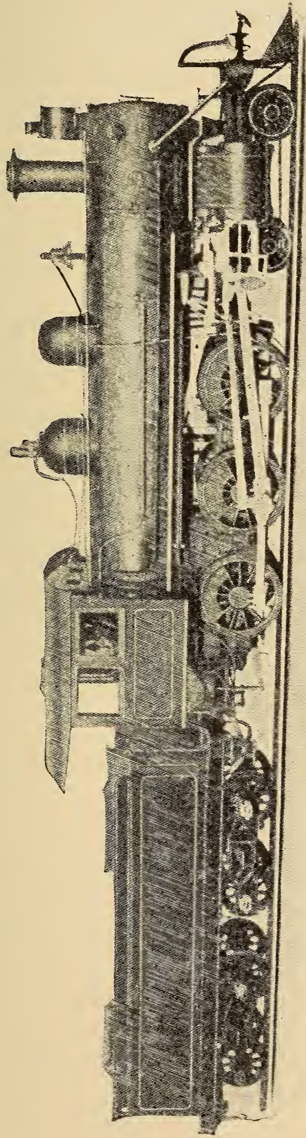


FIGURE 95. TEN WHEEL LOCOMOTIVE FOR THE GOVERNMENT RAILWAYS OF WEST AUSTRALIA.
Baldwin Locomotive Works.

Engine Truck Wheels—	
Diameter	26 inches
Journals	4¼x7½ inches
Wheel Base—Driving	10 feet
Rigid	10 feet
Total Engine	21 feet 5½ inches
Total Engine and Tender	47 feet
Weight—On Driving Wheels	61,570 lbs.
On Truck, front	23,180 lbs.
Total Engine	84,750 lbs.
Total Engine and Tender	145,000 lbs.
Tank—Capacity	Water, 3,000 gals.
	Coal, 6 tons
Tender—Number of Wheels	8
Diameter of Wheels	33 inches
Journals	4¼x8 inches

Figs. 96 and 97 are introduced for the purpose of illustrating the remarkable adaptability of the Walschaert valve gear to any and all conditions and requirements of locomotive service, no matter how rigid may be the demands.

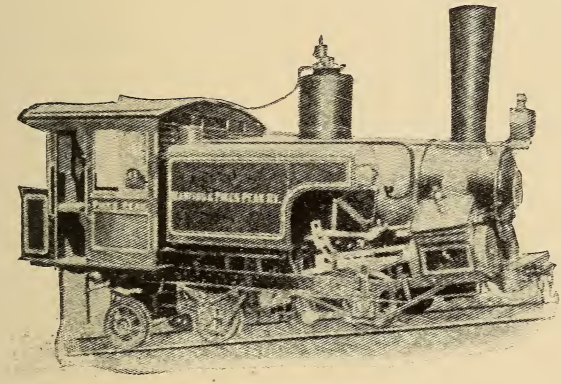


FIGURE 96. RACK LOCOMOTIVE FOR THE MANITOU AND PIKE'S PEAK RAILWAY, 1890.

Baldwin Locomotive Works.

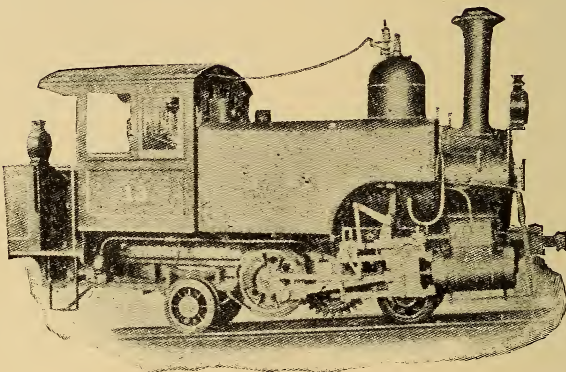


FIGURE 97. RACK LOCOMOTIVE FOR THE LEOPOLDINA RAILWAY, 1897.
Baldwin Locomotive Works.

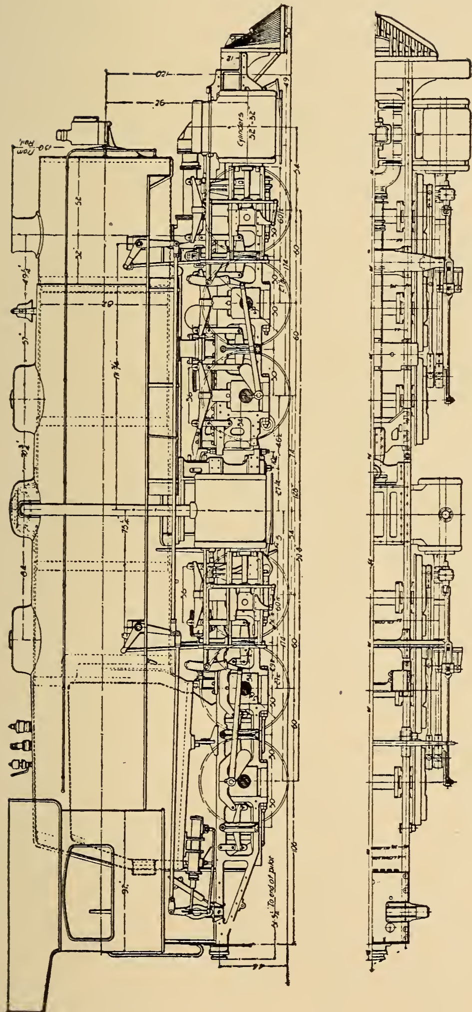


FIGURE 98. MALLET ARTICULATED COMPOUND FREIGHT LOCOMOTIVE—BALTIMORE & OHIO RAILROAD.
Side elevation and half plan illustrating Walschaert Valve Gear.

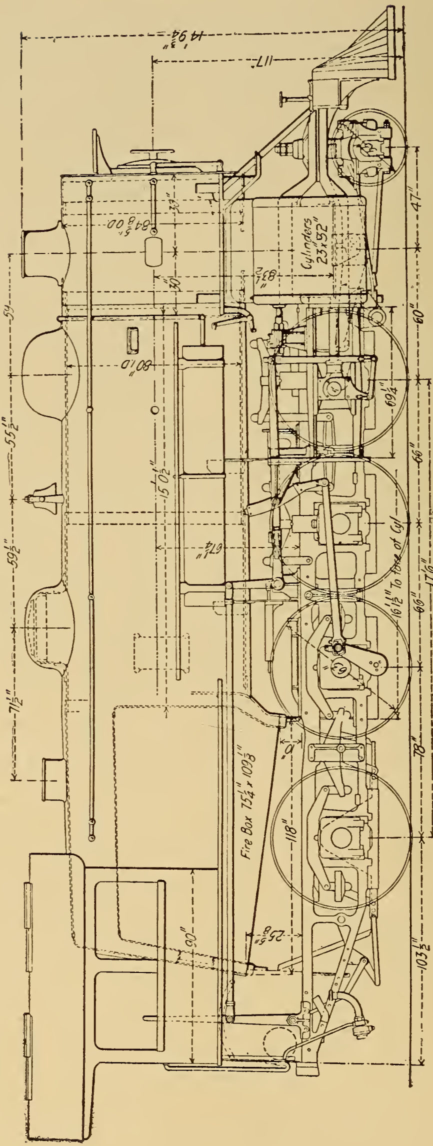
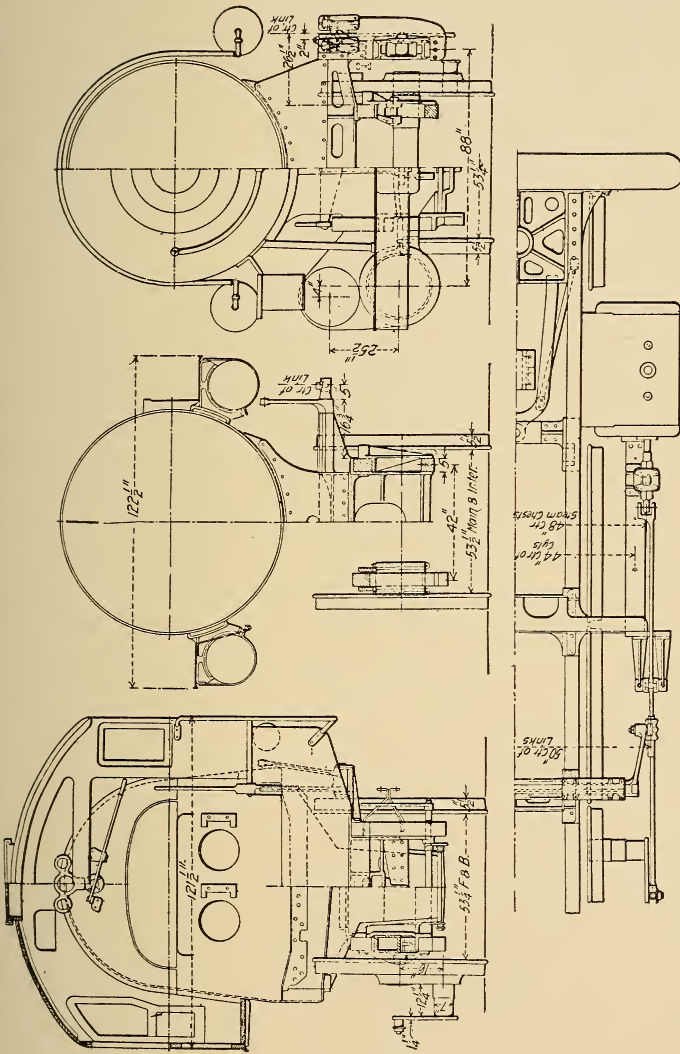


FIGURE 99.
CONSOLIDATION FREIGHT LOCOMOTIVE—NEW YORK CENTRAL & HUDSON RIVER R. R.
Illustrating Walschaert Valve Gear.



CONSOLIDATION FREIGHT LOCOMOTIVE—NEW YORK CENTRAL & HUDSON RIVER RAILROAD.
Plan and sections illustrating Walschaert Valve Gear.

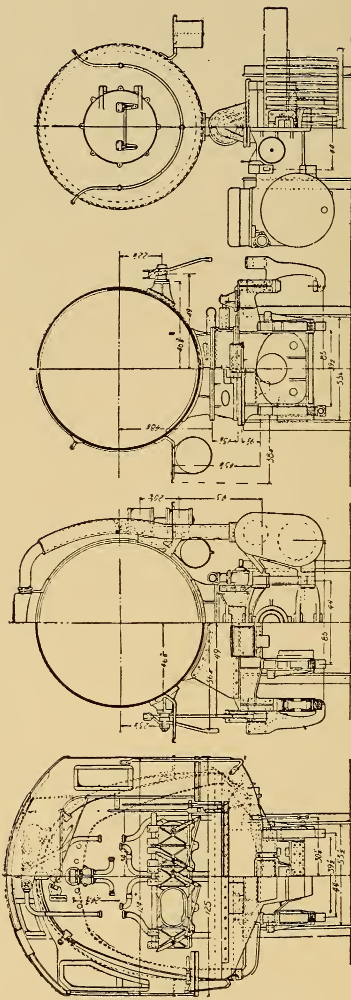


FIGURE 100. MALLET ARTICULATED COMPOUND FREIGHT LOCOMOTIVE—BALTIMORE & OHIO RAILROAD.
Sections illustrating Walschaert Valve Gear.

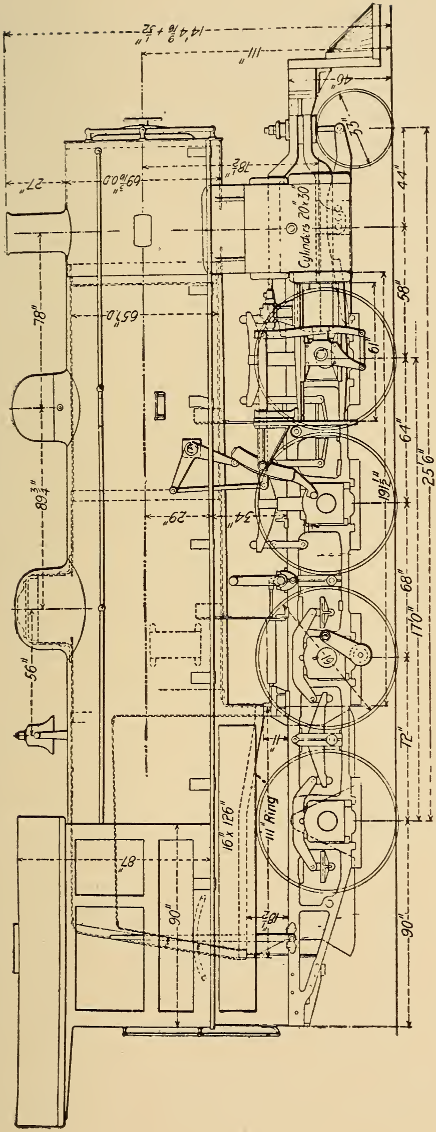
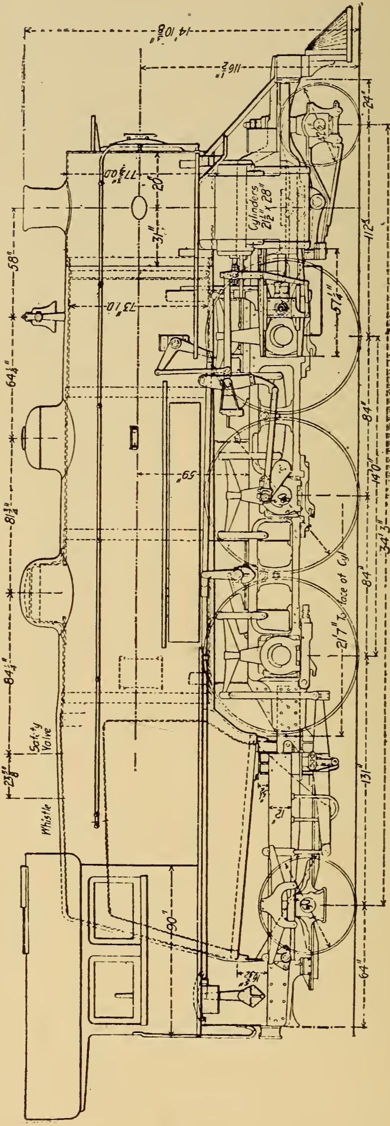
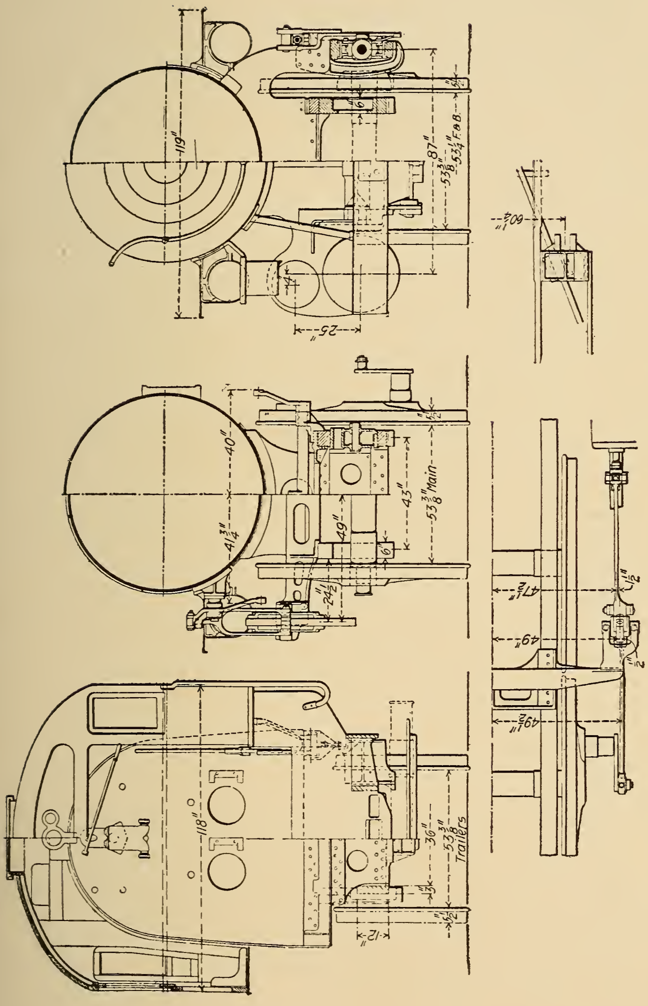


FIGURE 101. CONSOLIDATION FREIGHT LOCOMOTIVE—BOSTON & MAINE RAILROAD.
Illustrating Walschaert Valve Gear.


Cylinders 21½" x 28"
Safety Valve
Whistle



PRAIRIE TYPE PASSENGER LOCOMOTIVE—PENNSYLVANIA RAILROAD.
Illustrating Walschaert Valve Gear.

WALSCHAERT VALVE GEAR.

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