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"LOCOMOTIVE STEAM CHESTS AND VALVES."

BY

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The economical working of an engine largely depends upon the efficient distribution of steam to the cylinder by means of the valve, which opens and closes ports or passages for the flow of steam. The form and proportions of the valve, together with its location, will be the primary object of this paper ; but so much depends upon the distribution and flow of the steam that the size and arrangement of the ports will be first of all considered. The steam passages should be protected in every way to prevent radiation losses, and should be isolated from the cold outer air and the exhaust passages, wherein the temperature is much below that of the live steam, by means of air spaces ; and it is well to add to this the further protection of some non-conducting material. The passages should be laid out in elastic curves to reduce stresses due to expansion, and should be clean and roomy, especially for the exhaust, as it is found difficult to get rid of low pressure steam in fast running engines.

The ports from valve to cylinder should be of uniform section and as short and direct as possible, and well rounded in the curves to facilitate the flow of steam. The volume of the ports, however, is of importance when considering the total clearance volume in the cylinder.

The length of ports is about two inches less than the bore of the cylinder, and in the case of piston valves decreases on approaching the steam chest on account of the smaller diameter of the valve. The ports extend round the steam chest, and are made wider here than the width of port in the valve bushing.

The width of the ports affects the whole of the valve motion, and some variation is necessary on account of the different amount of steam to be admitted to the cylinders of various classes of engines, such as express passenger and goods.

Generally, the area of port in the port face is from one-ninth to one-twelfth of that of the cross sectional area of the cylinder, but the port areas should be such that the velocity of the entering steam does not exceed 7,000 feet per minute and the exhaust steam 4,000 feet per minute. When the same ports are used for admission and exhaust, the area is determined by the requirements of the exhaust. With superheated steam the size of ports may be somewhat reduced, owing to the lesser density of the steam. The width of exhaust ports should be such that the distance between edge of port at inner or exhaust edge of valve, when valve is at the end of its travel, is at least equal to the width of steam port.

Piston valves are usually given 50 per cent. longer circumferential port than slide valves, on account of the more or less checked flow of steam beyond the edge of valve. For a given port opening the area is proportional to the length, and a longer port is obtainable with piston valves. The area can also be increased by the adoption of "trick" valves or double-ported valves.

Slide valves are usually of gunmetal or bronze, and sometimes of cast iron. A wrought iron spindle shaped to fit round the valve is generally used to move the valve. The spindle should not grip the valve, but be an easy fit, so that the valve is free to move towards the port face as wear takes place.

With steam pressure acting on the back of the valve the frictional resistance and wear is great, especially with large valves and high pressure steam. To relieve the valve of excessive pressure, a portion of the back is cut off from the action of the steam, thus partially balancing the pressures on the two sides.

It is recorded in Mr. J. A. F. Aspinall's experiments on the friction of slide valves that the average pull on the valve spindle was reduced from 1946 lbs. to 854 lbs. by balancing the valve. The co-efficient of friction, obtained by dividing the force to move the valve by the nett pressure on the valve, is given as .068 for valves working on a vertical face, .088 for valves on a horizontal face, for a partially balanced valve .092.

Of the many forms of balanced flat slide valves the "Richardson" is the most common (Fig. 1). A rectangular groove is cut in the back of the valve into which cast iron strips are fitted, these being pressed by springs against a face on the steam chest cover. A hole in the back

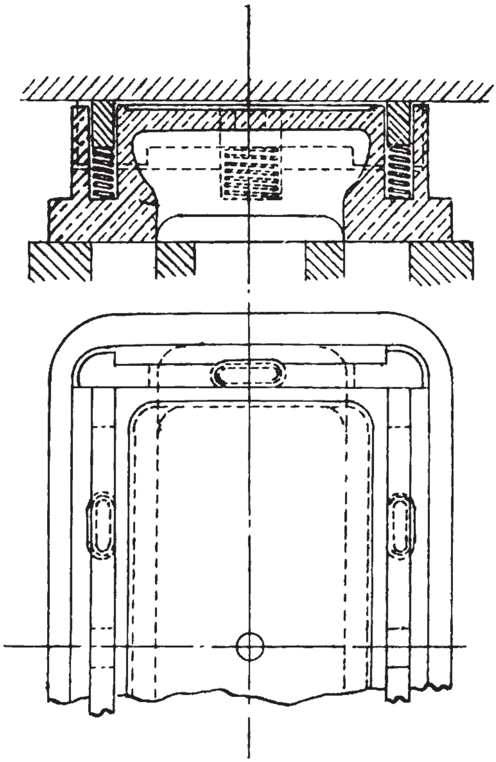

FIG. 1.

of the valve connects the space enclosed by the strips with the exhaust, thus allowing any leakage of steam to escape.

A modification of this valve is the hollow-backed valve, in which a portion of the back is cut away, and a large hole in the balance plate allows the exhaust steam a direct passage to the blast pipe without further contact with the cylinder walls or steam passages (Fig. 2).

A balanced valve giving good results is used on De Glehn compound engines, the relief frame being in the form of a ring bored out to suit a circular projection on the back of the valve packed with ordinary split

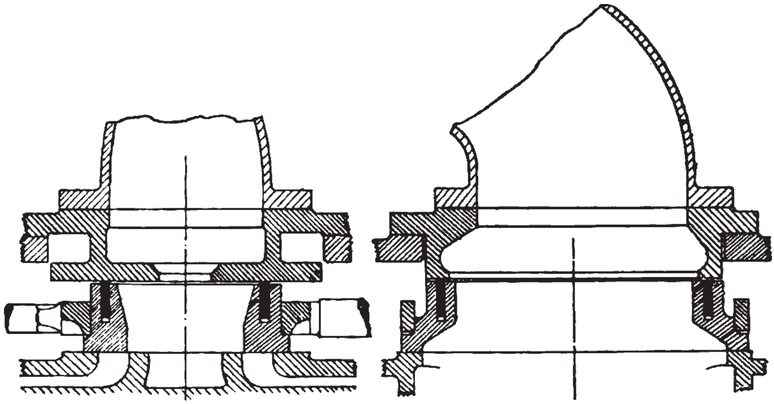

FIG. 2.

rings. The frame is pressed against the balance plate by means of springs (Fig. 3).

A design used in the United States consists of a conical ring cut through at one point and fitted with a cover plate over the joint. The

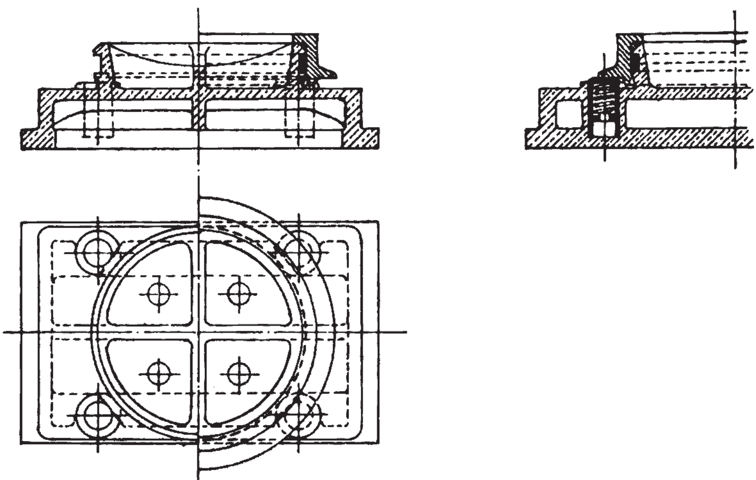

FIG. 3.

ring is fitted on a taper bearing on the valve, and no springs are required, as the reaction of the ring on the taper bearing, due to its elasticity and steam pressure, press it against the balance plate.

When springs are employed each spring should exert equal pressure for uniform wear to take place, a condition that is difficult to attain and which is a drawback to the "Richardson" type of valve.

The "trick" valve has the proportions of the common slide valve,

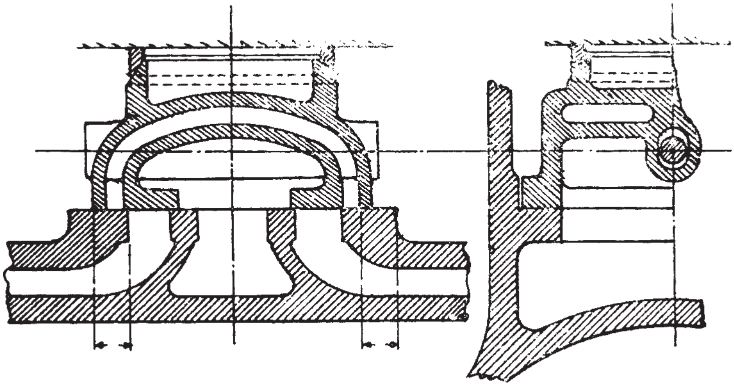

FIG. 4.

but in addition a passage passes round through the valve from one side to the other (Fig. 4). When the edge of the valve opens the port a little, the channel at the reverse end opens beyond the table, and steam enters and passes into the port. Owing to unequal bearing

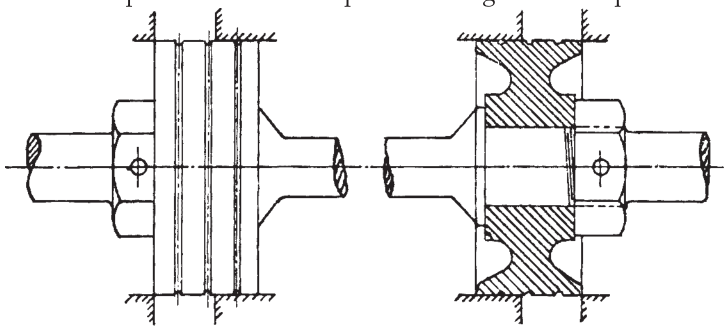

FIG. 5.

surface this form of valve wears badly, but when balanced gives good results.

Theoretically, the slide valve can be relieved of all pressure by making it in cylindrical form, obtaining what is known as the piston valve. This change in form does not involve any change in the distribution of steam.

Fig. 5 shows a piston valve with solid cast-iron heads fixed on a wrought-iron spindle, with collars forged upon it, against which the heads are held by means of nuts screwed on the spindle. The valve is arranged to work in bushes easily replaced in case of wear, in which the ports are cut.

The piston valve possesses many advantages. It is easily arranged for inside admission, which secures good insulation for the steam passages from the exhaust and outer air, and also relieves the glands and covers of high pressure and temperature. For a given valve travel, a larger area of port opening is obtainable, a cleaner cut off given, and the exhaust

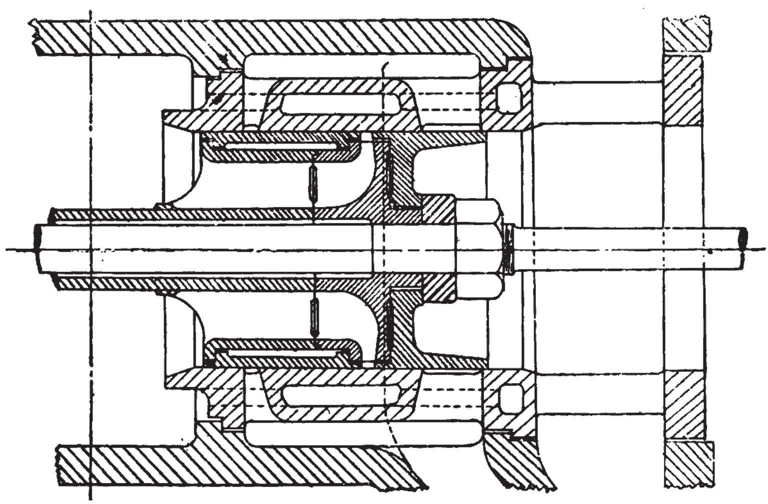

Fig. 6.

steam got rid of more quickly. There is practically no friction, thus minimising risk of failure of the valve gear. The valve is cheap to manufacture and is not liable to breakage in service. The chief disadvantage of the plug piston valve is the larger leakage of steam into the exhaust. Various packed valves are used for preventing leakage, but all more or less give rise to greater friction, and the bodies and spindles should be well carried in bushes to relieve the rings of anything save the function of sealing the parts steam tight. An improvement is to fit the valve with floating rings, solid or split, free to move in a lateral direction, and so accommodate themselves to the bush.

With the object of obtaining a practically steam-tight valve working with a minimum of friction, the bush is jacketted and heated with live steam, so that all the parts of valve and bushing are uniformly heated. The ports are ground true to standard gauges, allowing .002″ clearance. Fig. 6 shows a valve of this type largely adopted in conjunction with the "Schmidt" superheater, arranged for double admission, which allows of a smaller diameter of valve than one arranged for single admission. Both valve and bush are of cast iron, which is found to be most serviceable with superheated steam. The rings are easily fitted and renewed. A less expensive valve may be manufactured by using split rings, and it remains absolutely steam-tight as long as there is any elasticity in the rings.

Fig 7 shows a novel method of preventing steam from blowing

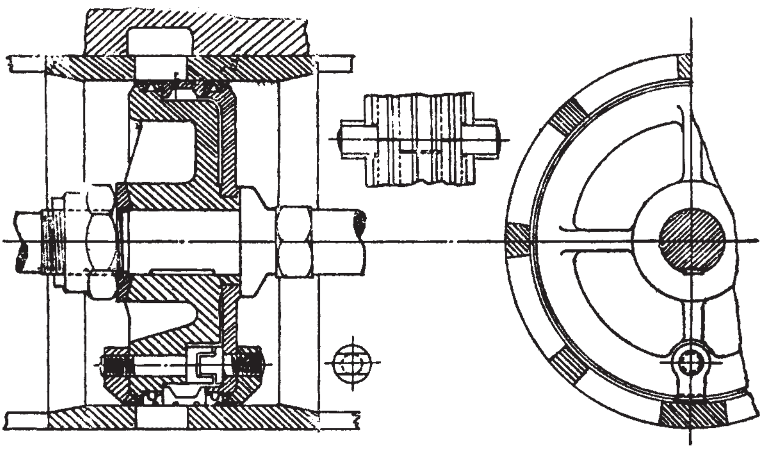

FIG. 7.

through the split in rings, and which also prevents the rings from turning. This piston valve may be designed with a "trick" channel (Fig. 8), which offers the advantage of double admission, and permits a smaller diameter of valve and higher piston speed than a valve with single admission.

The use of narrow piston rings has the objection that the bridges in the steam ports are worn more quickly than the remaining portion, and consequently the rings are more liable to seize and break. This may be reduced by inclining the bridges, thus distributing the wearing surface more over the ring.

Wide rings overcome this difficulty, but have other disadvantages. By steam leaking behind the rings, they are forced with great pressure against the bush, and excessive wear soon takes place. On the other hand, during compression they are unable to withstand the excessive pressure on the outer surfaces, being forced inwards, and leakage occurs.

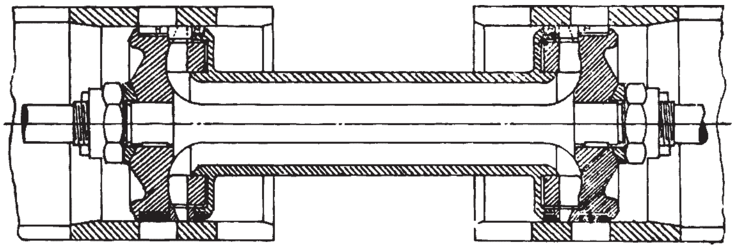

Fig. 8.

To overcome these drawbacks the valve shown is provided with a steam-tight space on the inside of each ring which communicates with the steam port by radial holes arranged circumferentially round the ring. Thus the pressure on both sides of the ring is equalised, so that

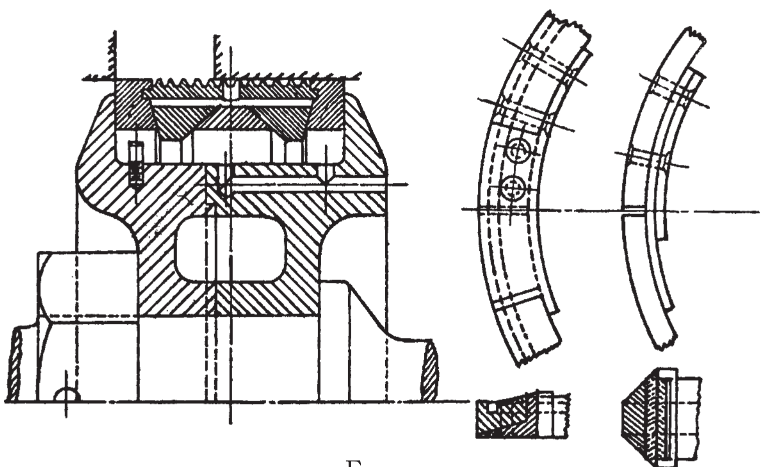

Fig. 9.

the ring is only pressed against the bush by its own tension, which is sufficient to secure steam tightness. Leakage of steam between ring and valve body is prevented by the steam pressure in steam chest pressing the ring against the valve body.

Another type of valve is the semi-plug piston valve (Fig. 9), so called because when steam is shut off it acts like a split ring valve, but when steam is turned on it becomes a plug valve, due to the pressure acting on the wedges, and locking the split rings at a fixed diameter. The design of the packing is such, however, that in case the packing is locked at a point in the bush that is larger in diameter than at some other point, the movement of the valve will force it down to the small diameter, where it will remain. It is evident that this valve will not wear a bush out of truth, and also that it is important to have a true cage to begin with. Lateral wear causing leakage of steam is prevented with this valve.

It will be seen in Fig. 9 that the packing consists of two split rings provided with tongue pieces which form the working edges of the valve, the outer face bearing against the valve-head, which is in two parts ; the inner face of split ring is bevelled. Inside of these are a pair of solid rings (wall rings) which are bevelled at different angles on the two sides. Between these fits a split ring with tongue-piece, called a wedge ring. A split ring with grooves (the wide ring), which forms the actual packing and bears on the bush, fits between and interlocks with the split rings. This ring is wide enough to carry the split rings across the port when drifting, and it also acts to keep them parallel with each other. The operation of the packing is as follows : When steam is turned on it enters through the holes in valve-head, and thus gains admission beneath the packing. Its first action is to force out the split rings which carry with them the wide packing ring, and then acts to force out the wedge ring, which wedges outwards the solid rings, which in turn force the split rings against the valve-head and hold them solidly in position. The angles on either side of the solid rings are calculated so that the pressure is just sufficient to hold the split rings in position, but not sufficient to reduce them in diameter. Fig. 10 shows the type of bush used ; it is turned slightly larger in diameter than the cylinder casting, which is heated to allow the bush to be inserted, and the distance between the ports is checked to gauge. The bushes are then bored out to-finished size.

The piston valve cannot lift off its seat, as the flat slide-valve does, to allow of the escape of trapped water, which has collected in such quantity as to more than fill the clearance spaces, and relief valves are therefore necessary, which have to be large to be effective.

To relieve trapped water is the main object in the design of valve used on the M.R. and N.E.R., known as Smith's Segmental Piston Valve (Fig. 11). There are two rings of packing—one a split ring narrow in width, and the other, relatively much wider, is cut into three segments. The head of the valve is formed by a washer clamped to the valve body. The washer carries three horns, arranged so that they form radial guides for the segments ; steam gets to the under side of the segments through holes in the washer, and presses them on to the bush. The segments are also free to move inwards a slight distance radially under the action of a sudden rise of pressure in the ports due to the presence of trapped water. The spaces between the ends of the segments are brought over bridges in the steam ports of the bush.

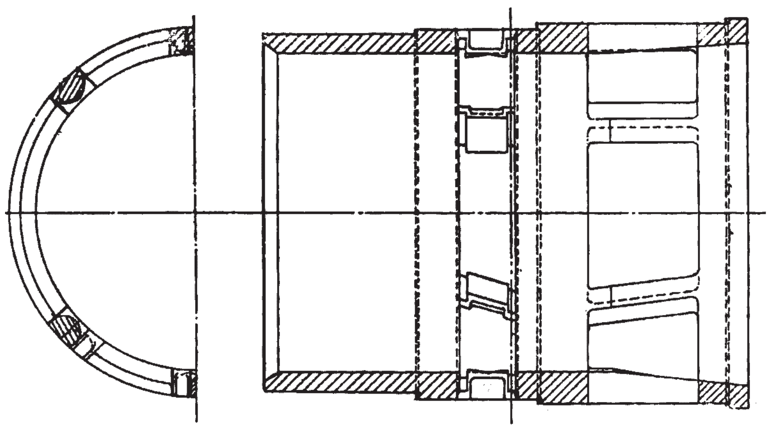

Fig. 10.

Another form of piston valve which allows of the escape of trapped water (Fig. 12) is that used on the L. & Y.R. It was designed by Mr. George Hughes for use with the high pressure cylinder on compound locomotives. The packing ring is provided with a number of passages controlled by valves which open or close communication between the cylinders and the receiver. One side of these when closed is subject to the pressure in the cylinder, and the other side to the pressure in the receiver. As there is a ratio of pressures between the high pressure steam and the receiver, these auxiliary valves work on the differential principle, the area exposed to the receiver being larger than the area exposed to the cylinder. The pressure in the receiver holds these

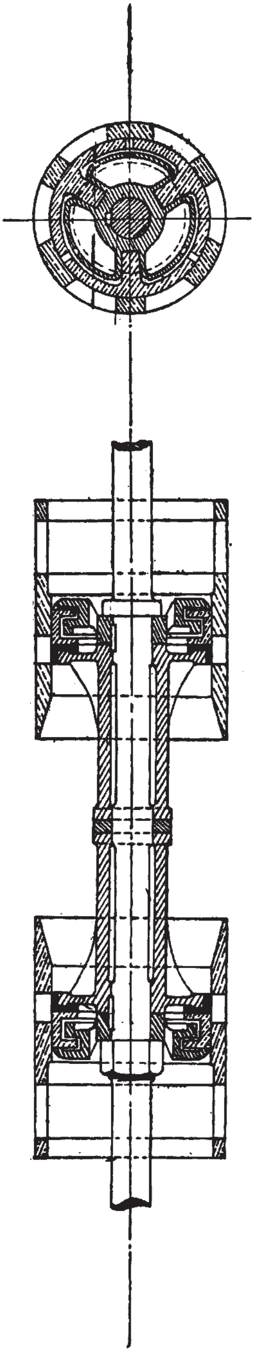

Fig. 11.

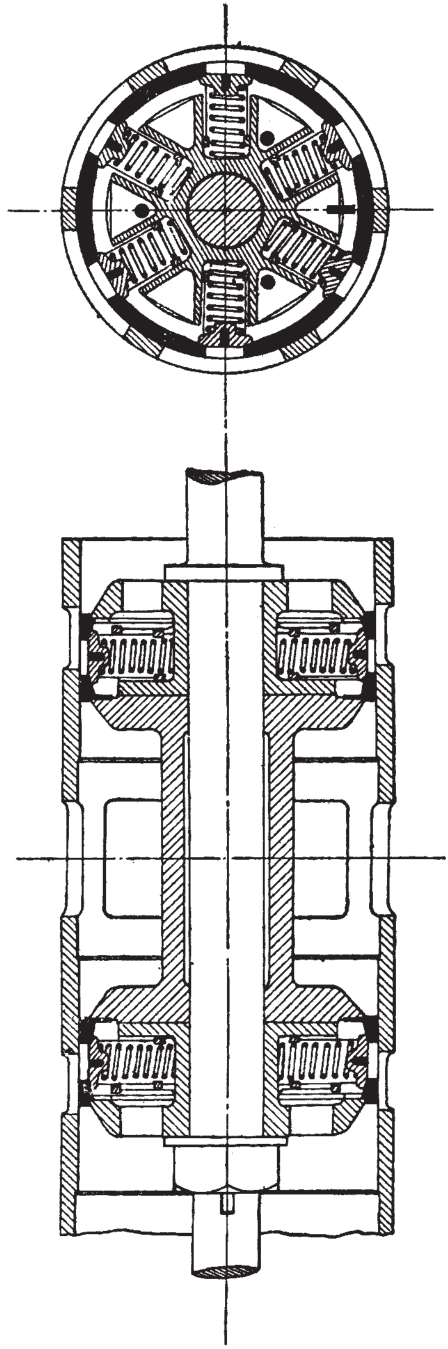

Fig. 12.

valves on their seats against the pressure in the cylinder, providing the latter does not rise beyond the working pressure. An excess of pressure in the cylinder displaces these valves and discharges into the receiver.

Fig. 13 shows a form of valve common to American practice. The packing shown is of L section split rings. It is designed for inside admission, and is made hollow, with as large a passage through the centre as possible. The object of this is to secure a large area for the exhaust, so that at the instant of release the pressure is reduced to a minimum. The hollow valve permits an escape through the exhaust passages at each end, which should meet at the base of the blast pipe. Insulation of the live steam from the exhaust is not obtained with this valve. A

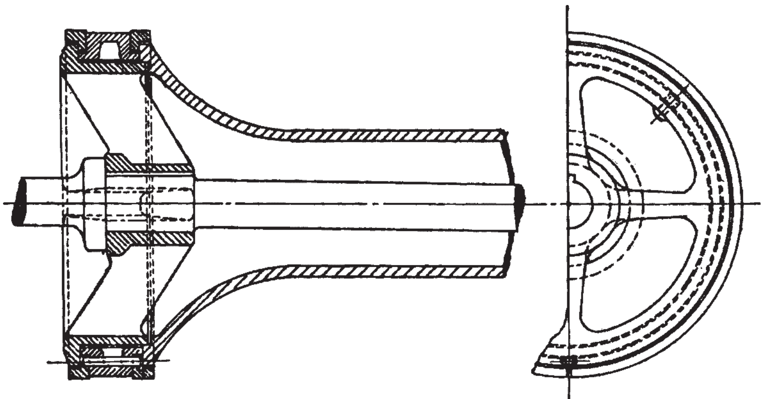

Fig. 13.

valve of the closed variety is a better design, and if the exhaust passages are sufficiently roomy, results equally as good are obtained.

For low pressures the common D slide valve suffices. Inside cylinders, with the valves located between the cylinders on the horizontal cylinder centre and working over ports in a vertical face, are found to give the best results. The valve is worked by a direct motion. The weight of the valve is supported by the valve spindle and glands, and when the engine is running with closed regulator there is no pressure between the valve and port face. It is claimed that this arrangement lends itself to very efficient lubrication, and the need of balancing the valve is not so urgent. This arrangement is very compact, gives the lightest cylinder casting, and the steam chest covers give little trouble from blowing. The largest cylinder diameter attainable is about 18″, with a distance of 2′ 4½″ between centres. The valve has of necessity to be very flat. With cylinder diameters of this size or larger, the valves are generally placed above or below the cylinder, but the valves may be located in a vertical position with the steam chest extending through to the outside of the frames, and also in an inclined position above and between the cylinders. Valves located in either of these ways permit the cylinder centres to be placed closer together, which gives a steadier running engine. When the valves are placed above, the ports are somewhat restricted as to length, and it entails the use of a rocking shaft unless a Walschaert or Joy valve gear is used. As the valve is always bearing on the port faces, it needs good lubrication, and a balanced valve is generally used. When the valves are placed below they may be worked by a direct motion, but that means an inclined motion on inclined cylinders, resulting in bad valve setting, owing to the disturbing effect of the rise and fall of the driving axle on the springs. The steam passages, which are longer and in contact with the cylinder walls, must produce condensation, but the valve in this position allows of good drainage from the cylinder, and the presence of some water helps to lubricate the valve faces. The valve in this case has the disadvantage that it is very apt to fall away from the face when steam is shut off. When steam is admitted to steam chest again, it blows through at first until there is sufficient pressure of steam to lift the valve up to the face, when it is brought up with a violent blow, which is injurious to both valve and face. Some arrangement has to be made to hold the valve up to the face, and this is usually combined with the relieving of some steam pressure from the back of valve.

With larger cylinder diameters and higher steam pressures advantages are gained for the engine by placing the cylinders outside the frames. In this case the valves are conveniently placed horizontally above the cylinders and a rocking shaft used to connect to the inside valve gear. The valves are invariably balanced.

Valves for outside cylinders are sometimes located inside the frames, the valves being upright and operated by direct valve gear without the intervention of rocking shafts. Some differences are made in the location of piston valves from that of the directly above or below of the flat side valves, being so disposed as to form a compact arrangement and give as direct steam passages as possible. The piston valve arranged for inside admission has to have its motion reversed to that of a valve for outside admission. This may be brought about by introducing a rocking lever into the valve gear in the case of the Stephenson, and by attaching the valve spindle to the combining lever on the cross-head connection side of the connection of the radius bar instead of on the opposite side to the cross-head connection for outside admission.