

## DESCRIPTION OF A FLUID-PRESSURE REVERSING GEAR FOR LOCOMOTIVE ENGINES.

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BY MR. DAVID JOY, OF LONDON.

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*Single-Eccentric Valve-Gear.*—Ever since his former paper to this Institution in 1880 (Proceedings page 418) describing the radial valve-gear which he was then introducing, the writer has entertained the idea of a yet simpler and more direct form of Reversing and Expansion Valve-Gear than either the radial itself or any other plan hitherto in use. Notwithstanding the success achieved with the radial gear, the difficulties encountered in its introduction convinced him that a better plan was required, and enabled him to see the direction in which to work. From the outset the idea kept prominently in view was that only a single set of pieces of mechanism should be employed, instead of a duplicate set, for actuating the valve from the crank axle, and also for reversing from forward to backward gear; and further, that reversal should be accomplished by the change of position of the gear, as in the radial gear, and not by the addition, as in the link gear, of other and distinct parts for backward running. Accordingly the single eccentric with shifting position on the crank axle, as in Dodds' wedge-motion, naturally recommended itself for adoption: while the difficulties and complication involved in any attempt to effect the shifting by mechanical connections through levers, links, screws, or friction gear, which would have been fatal to practical success, led the writer to throw all such expedients aside, and to have recourse to the employment of fluid pressure, by means of oil or other fluid conveyed through the centre of the axle itself for shifting the position of the eccentric. The purpose of the present paper is to describe the construction and working of the Fluid-Pressure Reversing Gear designed in conformity with the foregoing ideas, and already in practical use for locomotive running.

The general principle of the fluid-pressure reversing gear will be readily understood from a comparison of the skeleton diagrams, Figs. 14 and 15, Plate 62, showing the main centre lines of the ordinary link gear and of the fluid-pressure gear. In the link gear, Fig. 14, with its two eccentrics F and B for forward and backward going respectively, the motion of either is transmitted to the valve spindle V through the motion link L coupling the outer ends of the two eccentric rods. In the fluid-pressure gear, Fig. 15, the same result is obtained more correctly and with less than half the number of parts, by employing only a single eccentric, and shifting it transversely across the axle from side to side for forward or backward gear. For this purpose the axle is squared where the eccentric is mounted upon it; and an oblong slot through the eccentric allows it to be slid across from side to side of the axle. In each end of the slot is formed a small cylinder, which works over a corresponding ram fixed on opposite faces of the square on the axle. It only remains to force oil or other fluid under pressure into either end of the axle, and thence into one or other of the two small cylinders, according as it is required to move the eccentric into either position for forward or backward gear, or to hold it between these extremes for any point of expansion or for mid gear. The oil is made to pass into either end of the axle by a small cylinder, placed on the footplate of the engine, and fitted with a piston which is moved either by a handwheel and screw or by steam, or by both.

The arrangement is shown in Plates 56 to 62, as adapted for locomotives.

Fig. 6, Plate 60, is a cross section through the crank axle and the square block mounted upon it, on which the eccentric slides. Fig. 7 is a plan showing the square block and the two pairs of rams upon it, with the near halves of the eccentrics removed. Fig. 8 is a longitudinal section through the centre line of the axle. Figs. 11 and 12, Plate 61, are longitudinal and cross sections through the axle and block, the former view being taken diagonally through the corners of the block, in order to show the passages for the oil from either end of the axle into the respective cylinders for moving

the eccentrics into forward or backward gear. This is also shown by the small model exhibited.

Fig. 1, Plate 58, is a side view of a locomotive, showing specially the reversing cylinder C on the footplate, from which the oil is forced into either end of the axle through the pipes PP. Fig. 2 is a back view and Fig. 3 a plan of this part.

In Plate 56 is shown a photograph of the "Sussex" locomotive, a passenger engine on the London Brighton and South Coast Railway, which has been fitted with this reversing gear. Also in Plate 57 a photograph of the driving wheels stripped, showing one set of valve gear complete, and the eccentric on the other side removed to show the rams and cylinders.

*Construction of Gear.*—The square block B, Figs. 6 and 7, Plate 60, mounted on the crank axle, is parted diagonally and bolted together at the corners, its four faces being planed to the square. On two opposite faces are cast the rams R working in the small cylinders cast in the two halves of the eccentric E, which are bolted together on the centre line as usual. The internal faces of the slot in the eccentric are planed to slide upon the parallel faces of the block. The slot is long enough to allow the eccentric to slide across the centre line of the axle into the extreme positions of forward and backward gear; and the block is so set on the axle as to give this motion at right angles across the line of the crank (when the piston is at either extremity of its stroke) and outside the centre line of the axle. If however the centre line of the valve spindle is not parallel with the centre line of the piston rod when both are projected upon the same vertical plane, then the block must be slightly turned round upon the axle, until at either extremity of the piston stroke the slot is at right angles to the centre line of the valve spindle, instead of to that of the crank.

*Oil.*—The oil enters at each end of the axle, Plates 59 to 61, and passes along the central hole to nearly the middle of the length, whence it is led radially into the two longitudinal channels I and J formed in the corners of the block B. From one of these channels I it passes to the two rams for giving forward gear, and from the other

channel J to the other two opposite rams for giving backward motion. The oil forced from the reversing cylinder C through one of the pipes P to either pair of rams displaces that from the opposite pair, and drives it back through the other pipe P into the opposite end of the reversing cylinder C. It thus acts as a continuous non-elastic medium, transmitting exactly the motion of the piston in the stationary reversing cylinder C on the footplate, through the pipes PP, to the rams actuating the eccentrics; and the eccentrics are thereby shifted and held in any position, without being affected in the slightest by the revolution of the axle, and quite independently thereof. The fluid-pressure reversing gear thus serves all the purposes of the levers, links &c., which have hitherto been used in other reversing gears, but is devoid of parts subject to wear and tear and requiring repair. In place of adding the square block B, as is done for existing engines, for new work the part of the axle carrying the eccentrics may itself be squared, thereby saving the cost of fitting the block.

As an additional security for the stability of the eccentrics in any position, and in order to keep them both relatively in the same grade of gear, they are locked together in the manner shown dotted in Fig. 10, Plate 61, by means of a pin and block K, fixed in the inner face of one eccentric, and sliding diagonally in a slot S formed at an angle of  $45^\circ$  in the inner face of the other eccentric. Thus when one eccentric is falling vertically from full forward to full backward gear, the other is simultaneously sliding horizontally through precisely the same extent of shifting; and for all intermediate positions the two eccentrics are maintained both of them in the same grade. As each is in its best position to sustain the strain of driving its own valve at the time when the other is in its worst position, they mutually assist in keeping each other in place, and so to a considerable extent relieve the pressure upon the oil.

The oil pipes PP enter the ends of the axle through stuffing-boxes, as shown in Fig. 5, Plate 59; the gland is screwed into the axle, and is prevented from unscrewing itself during the revolution of the axle by a squared head and bridle D. A collar C screwed and pinned on the inner extremity of the pipe prevents it from being

forced out of the gland by the pressure of the oil, which has varied from 60 to 100 lbs. per square inch.

*Reversing Cylinder.*—The reversing cylinder, filled with oil, is shown in Fig. 13, Plate 62. It is placed at C, Figs. 1 to 3, Plate 58, on the engine footplate; and from its opposite ends the pipes PP convey the oil to the opposite ends of the crank axle. The piston in the cylinder is moved in either direction by a screw on the piston-rod, which works in a nut forming the boss of the handwheel H; or else, as shown in Fig. 13, the piston-rod is itself the nut, in which works a screw rotated by the handwheel. Any movement of the handwheel thus produces a corresponding movement of the eccentrics. The movement of the handwheel is assisted by a small air cylinder A added in front of the oil cylinder, Plate 58; by admitting compressed air from the Westinghouse brake reservoir into either end of the air cylinder through a four-way cock, the reversing is rendered so easy that it can be done with only a couple of fingers on the handwheel, even when the engine is running with full steam on.

*Principles.*—From the foregoing description of the arrangement it will be seen that the two leading ideas in this plan of reversing are:—firstly, that the same mechanism is employed for forward and backward running, reversal and expansion being effected simply by the change of position of the mechanism; and secondly, that this change of position is effected, not by any mechanical combination—which would necessarily be complicated, because the adjusting power must be stationary while the adjusted mechanism is in rapid motion—but by fluid pressure, of which the efficiency is independent of and unaffected by variety of movement between the adjusting and the adjusted mechanism.

*Advantages.*—The advantages attending this plan may be enumerated in the following order.

First, simplicity and largely reduced number of parts. Hence follows reduced liability to failure, because with fewer parts there are fewer to break down, and the parts retained may be made

stronger; the fewer joints to be looked after and lubricated may also be better attended to. If any part of the fluid-pressure gear should fail, the only result is that the eccentrics gradually slip into full gear for whichever direction the engine may be running in at the time. Thus the engine is still perfectly competent to bring the train home, with the only disadvantage of not being able to use expansion for the time.

Second, truer distribution of steam. The distribution is indeed almost mathematically correct, both for the front and back ends of the cylinder, and also for forward and backward gear alike. This is prominently shown by the exactly equal beat of the engine at all grades of expansion and when running in either direction.

Third, reduced cost of repairs. This reduction is a consequence not merely of the reduced number of parts, but also of the fact that the parts retained have so much larger wearing surfaces and so much smaller an amount of motion.

Fourth, considerably reduced first cost. In the construction of the gear there are no costly forgings, involving also expensive tooling. Nearly all the parts are castings, like cylinder castings, calling chiefly for boring and turning, which are not only the least costly of the operations in the tool shop, but also the least dependent on the workman for accuracy and finish. For every mechanical detail in the construction of the gear there are numerous and satisfactory precedents.

Furthermore, this gear can be adapted to every position where link gear is used, without any alteration of the engine; and for compounds it can be arranged to give varied cut-off for the high and low-pressure cylinders, in which case the two eccentrics are of course not connected with each other in any way. It is so simple in its construction that it is within the comprehension of any workman; and after it has originally been set in the workshop there is nothing left for the driver to adjust. It is therefore not liable to the objection sometimes raised against the radial gear, that the drivers know the link gear but cannot be got to understand the radial: an imputation however, which from his own experience the writer thinks not fair upon their intelligence.

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*Discussion.*

Mr. Joy said that, since the paper had been prepared nearly six months ago, considerable advance had been made, especially in the mode of packing the rams in the eccentrics, which had been the subject of some criticism; and the fear had been expressed that, if the crank-axle got heated in running, the leather packings would be burnt and rendered useless. As a matter of fact however these leather packings had been working for months; and he had adopted them originally on account of their having been used so long for the Westinghouse compressed-air brake, and having scarcely ever been found to fail. On the table was shown a small ram and cylinder, which were practically the same as the rams and cylinders of the eccentrics; and also various kinds of packings which had been tested, including a simple ring of metal of U section, Fig. 9, Plate 60, which had been suggested by Mr. Billinton. Finally he had come to asbestos, because fire would not touch it. The testing cylinder exhibited, having been packed with asbestos, had been subjected to a hydraulic pressure of 250 lbs. per square inch, and perfect tightness had been obtained. Then it had been put on a red-hot plate in a smith's forge, in order to get as nearly as possible the conditions of a ram on a red-hot axle: although a locomotive axle never did get red-hot. After having been kept there for half an hour, it was again tested, and the asbestos packing was found to be still tight. Then the packing was taken out for examination, and was now exhibited; and it would be seen that it was as good as when put in. A model was also shown of the centre part of the crank-axle with the square block upon it, which could be pulled to pieces so as to show the channels inside, whereby the oil passed from either end of the axle to the middle of its length. The channels in the block were made by cores in casting it, not drilled out afterwards in the corners of the block. The model also showed distinctly the inclined slot, whereby the two eccentrics were kept together in exactly their correct positions relatively to each other, so that each assisted the other by means of the fluid pressure in their

two rams. The fluid need not be all oil, or any one fluid in particular; a mixture of water and oil answered equally well, to the extent of even ten parts of water to only one of oil. Drawings were also exhibited, Figs. 16 to 19, Plates 63 and 64, representing the marine engines of the "Apollo" type of cruiser in the royal navy. These engines were well known to have done remarkably good work; in every case they had gone considerably beyond their contract power, and there had been practically no breakdowns. They had therefore been taken as a good type upon which to illustrate the application of the fluid-pressure reversing gear to marine engines generally. Plate 63 represented the existing arrangement of link gear; Plate 64 represented the same engines with the fluid-pressure gear, and the simplicity of its application was seen at a glance. By means of the full-size working model exhibited of the locomotive gear, the effect was exemplified of any accidental failure of the fluid pressure: on turning the axle round by hand, as it would revolve in working, it was seen that, if the fluid pressure failed, the eccentrics would simply drop quietly into full forward or backward gear, according to the direction of running at the time, and the engine would still be in a position to go along. In this respect the action of the fluid-pressure gear was so far similar to that of the old hand reversing gear, where the eccentric had a snug or toggle fast on it, allowing it to slip part way round the axle in either direction, backward or forward, till it engaged with a similar snug on the axle; and the eccentric being driven by this snug had always the tendency to slip towards it, that is to fall into full gear. The engine "Sussex" shown in Plate 56 had now been running over twelve months, and every facility had been given by the Brighton Railway Company through their locomotive superintendent, Mr. Billinton, for enabling any experiments to be tried with the gear, even to the extent of a breakdown; and on one occasion a breakdown had been arranged, which took place while the engine was 35 miles away from home with a train; but the passengers knew nothing about it. The engine brought the train home, and there was no difference beyond burning a little more coal, on account of having to run the whole of that distance in full gear without



(Mr. Joy.)

expansion. By the kindness of Mr. Billinton the engine had been on view in steam during the day at the Victoria Station of the London Brighton and South Coast Railway.

MR. LEWIS RICHARDS asked if the lead would not vary as the throw of the eccentric was increased. As the centre of the eccentric travelled here in a straight line when shifting from one extreme position to the other, the length of its throw must diminish from full gear to mid gear, which with the obliquity of the eccentric rod seemed to him to mean some variation of the lead in mid gear.

Mr. Joy replied it was quite true that the lead did vary towards mid gear; but the variation was so minute that in the full-size model exhibited it was scarcely visible, as was at once verified by placing the crank on either the front or the back centre, and shifting the eccentric across from one extreme of full gear to the other; it was seen that the valve remained practically motionless. In fact with 63 inches length of eccentric rod, as here shown, and  $1\frac{1}{2}$  inch throw of the eccentric, the actual amount of the variation was only 0.02 inch, which was almost inappreciable. The result was therefore practically an even lead for all grades of expansion.

MR. T. HURRY RICHES, Member of Council, noticed that the drawings showed the application of the plan to engines having outside axle-boxes and single drivers; and so long as there were no coupling rods to contend with and no outside cranks, there seemed no difficulty in getting the fluid pressure into the driving axle in the manner described in the paper. But it did not seem quite clear how it would be got in where there were outside cylinders and where there were coupling rods. Again in attaching the square block upon the axle there appeared to be the difficulty of efficient packing for ensuring security from leakage of the oil where it passed out of the hole in the axle into the hole in the block. After the eccentric had run for some time, he feared the bearing surface of the block must inevitably get somewhat worn; and it appeared to him that there would be a difficulty in maintaining for any length of time an

absolute security against waste. If any leakage did occur, he gathered from the description already given that the slack so occasioned inside the fluid passages and rams would allow the eccentric gradually to fall into full gear, and thereby some fuel would be wasted. Economy of fuel was of such importance to all railways, that they naturally looked at these matters with a rather critical eye; and before launching out into any new contrivance which would have to be applied largely in order to obtain its full advantage, every point had to be carefully considered. As to the general idea of the plan now described, it was certainly a great advance in simplicity; and it seemed to him a most desirable improvement, if it could be accomplished so satisfactorily as represented by the author.

Mr. GEORGE CAWLEY noticed that in the drawing of the reversing cylinder, Fig. 13, Plate 62, there was only one handwheel for working the two eccentrics. For pushing the eccentrics over into full gear from one extreme to the other he could understand that a single handwheel would suffice to actuate the fluid through the whole extent of the stroke of the rams. But supposing that the friction on one eccentric was a little greater than on the other, was there any possibility that in an intermediate position of gear one eccentric might have a greater cut-off than the other? It seemed to him that the correct action of the gear depended on the exact balancing of the friction of the two eccentrics; and that if one of them had a slightly easier travel than the other, then, although the fluid pressure would still in some way be balanced between them, yet they would not both have the same cut-off.

Mr. HENRY DAVEY recollected that the beautiful oscillating engines of the late Mr. Penn's design, which used to be seen in the steamers on the Thames, had the shifting eccentric and the old gab or gap device by which the eccentric-rod end was disengaged from the valve-rod, leaving the valve to be moved by hand, so that it could be brought over for forward or backward running while the shaft was turned round to engage again with the eccentric in the reversed

(Mr. Henry Davey.)

position. If it ever happened in that arrangement that the eccentric was not quite free on the shaft, but was binding upon it, the eccentric might be held in a false position; but immediately the friction disappeared, the obvious tendency was always to run into its true position.

In the application of the fluid-pressure reversing gear, it had been explained clearly what would happen if the pressure leaked off while the locomotive was in motion; but what would be the result of such an accident if it occurred whilst the engine was standing at a station, and if it was then required to be reversed for running in the opposite direction? How was the gear going to be started from a state of rest?

With respect to the adoption of a fluid consisting of ten parts of water and one of oil, he had himself had about twenty years' experience with fluid valve-gears, and having commenced with oil had then gone on to oil and water mixed. For many years however he had now used nothing but distilled water, and had avoided putting the slightest drop of oil into the gear; and he had found this plan to answer best. With regard to the packing, in the fluid gears with which he had had experience the fluid was used as a brake, and the distilled water naturally got hot, because it had to absorb mechanical power. The packing which he used was simply a gun-metal packing-ring, which was very accurately fitted. Some of the gears had been working for twenty years, and he believed no new packing had been put into them. It was necessary however that the water should be absolutely clean and free from grit. The great difficulty experienced at first was that the sand had not been washed out from the ports of the cylinders before the gear was put to work. Asbestos for packing he had never tried; but he was afraid, if it were attempted to be used with water in the fluid-pressure reversing gear, it would be attended with a difficulty. Asbestos would stand extreme heat; but it would not stand water. So long as it could be kept dry, the metal in contact with it might be made red-hot without destroying the asbestos; but if it were exposed to water or oil he was afraid it would be found that it would be quickly destroyed. On this account he thought Mr. Joy would eventually come to a metallic packing.

He asked whether any difficulty had been found from the expansion of the fluid. It was in a confined space, and there did not seem to be any safety-valve anywhere. If the fluid happened to be cold when the gear was started in the morning, and got warm during the day, there would be some amount of expansion. What provision was there for giving room for the increased volume? The greatest fear he had for the gear was with regard to leakage; but he thought this was not an insurmountable obstacle, and he had no doubt it would be got over and that no practical difficulty would be experienced. If there was any considerable amount of leakage, it seemed to him that it would rather upset the arrangement. The little oil-cup which he noticed was placed on the fluid-pressure cylinder, and connected therewith by a two-way cock, he supposed was for the purpose of admitting a little more oil, should there be a vacant space left by leakage. That was a device which he had constantly used himself in his own gears. Using water as he did instead of oil, he had sometimes connected a small pipe from the steam-pipe to each end of the water cylinder, having a non-return valve on the pipe, so that the condensation of steam from the steam-pipe automatically supplied the loss from leakage.

Mr. J. LYONS SAMPSON asked what provision was made to prevent the fluid from freezing in the pipes. If the fluid were frozen solid, it would be rather awkward to start with a gear of this kind. The exposed position and small size of the pipes would render them specially liable to this defect in frosty weather.

Mr. WILLIAM SCHÖNHEYDER thought the gear seemed to have most of the advantages which were ascribed to it in the paper. It was certainly simple, and must be cheap to make; and there was practically no wear on it. The difficulty mentioned (page 260) as to the slackness of the eccentric on the square block he thought would hardly arise, especially if the gear were applied to a new engine, in which the square would be forged on the axle, and the rams also would be forged on the axle. By that means the pressure for driving the eccentric round was exerted by surfaces which were forged solid

(Mr. William Schönheyder.)

on the axle, and were at a considerable distance from the centre of it, and he thought the wear would therefore be exceedingly small. At the same time there seemed to him to be also some considerable disadvantages connected with the fluid-pressure gear. How was the driver on the footplate to know the position of the eccentrics? From the position of the piston in the reversing cylinder it did not follow that the eccentrics were in a corresponding position, because if there was leakage in either of the passages the eccentrics might have shifted their position without the driver knowing it. Unless there was some kind of tell-tale, it seemed impossible to know what position the gear was in. Moreover if the leakage would cause the eccentrics to go into full gear, it seemed to him that they must be always going into full gear, because it appeared unlikely that any arrangement of this kind would last tight for any length of time; if there was the slightest leakage, it was only a matter of time for the eccentrics to go into full gear. In the application of the plan to marine engines, it seemed simple enough to provide pipe connections to a couple of eccentrics, as in locomotives; but he did not understand how three eccentrics were provided for, unless instead of only one hole two holes were drilled in the shaft, because in a triple engine the passage drilled into the forward end of the shaft and that drilled into the after end must cross each other somewhere, in order to get to the third eccentric situated midway in the length of the shaft. If the gear was to be the success that he hoped it would be, he would suggest that, instead of using two pairs of rams and cylinders for reversing two eccentrics, one pair alone might be made to do for both eccentrics: instead of a pair of rams and cylinders taking hold of each eccentric, one pair alone might be made to take hold of the pin connecting the two eccentrics by the slanting slot shown in Fig. 10, Plate 61. It seemed to him that it could be done in that way, with the great advantage that there would be only one pair of rams and cylinders instead of two. Moreover in that way the leathers or other packing could be got at for tightening or renewing, without taking the eccentrics to pieces. It was highly objectionable he considered to have to take eccentrics to pieces after they had once been fitted together; they might be got right in

putting them together again, or more probably they might be a little wrong, so that they would heat when set to work again. In most inside-cylinder locomotives there was room for four eccentrics in the middle of the axle between the two crank-throws. If therefore only two eccentrics were used, it would be quite possible he thought for the one pair of rams and cylinders to be put in between the two eccentrics. He asked what kind of packing was employed at either end of the axle: whether it was an ordinary stuffing-box packing set up by a screw, in which case he feared it would wear and get leaky; or whether it was a leather, of some shape which would keep itself tight. In the application to marine engines it seemed to him that in this particular there would be much more difficulty in arranging the gear than for a locomotive, because the larger stuffing-box suitable for the size of the screw-shaft was more difficult to keep tight than the smaller stuffing-box just large enough for the pressure pipe in a locomotive.

Mr. FREDERICK EDWARDS thought that in the application of the fluid-pressure reversing gear to marine engines it would be objectionable not to have the means of independent adjustment for the several cylinders. In most of his own engines the valve gear could be adjusted separately for each cylinder, which he thought was very necessary. In the new gear he did not understand how it would be possible to modify the working of the engine by shifting one eccentric alone without the others. Then again the locomotive crank-axles were all solid, whereas all the marine crank-shafts that he used were built up. If these were to be bored for making all the oil passages shown in the drawings of the locomotive axle, he feared there would be a good deal of leakage of oil through the numerous joints of a built-up shaft during the working of the engine. In this matter he had had rather a curious experience with one shaft. Many marine engineers believed, as he himself had done years ago, that, if by applying the turning gear the oil could be wrung out of any joint or flaw in the shaft, it stood to reason that the shaft was not sound. A question having arisen about the soundness of a shaft in an old steamer, he had tested it with the

(Mr. Frederick Edwards.)

turning gear, and had found he could wring the oil out of so many of the joints, that he decided to try a comparatively new shaft. Having a new steamer handy, which had been only one voyage, he tried the shaft in it, and found that the oil could in some parts be wrung out; it was true that not much came out, but there was enough to prove this could be done with a shaft which, so far as it was possible to tell, was perfectly sound and good. The stress put on the shaft with the turning gear during this test would be far less than the ordinary working load. When he first found oil could be wrung out of the comparatively new shaft, he thought it might give trouble; but in fact it never gave any trouble at all. In view however of the possibility of thus wringing oil out of the present crank-shafts of marine engines, it seemed to him that, if all the oil passages shown in the drawings came to be drilled in a built-up shaft, there would be leakage of oil, and consequent trouble. In regard also to taking up the wear of the eccentric, he certainly was afraid that would be a trouble, which he should not at all like to encounter. Any trouble of that sort in a steamer abroad on a long voyage would be very objectionable. Moreover he did not understand exactly how the fluid pressure was made to act upon the eccentric of the middle cylinder; the first and third eccentrics being on the ends of the crank-shaft corresponded with the two eccentrics shown on the locomotive axle, and would receive the pressure in the same way as in the locomotive. But how was the pressure to be conveyed to and from the middle eccentric on the crank-shaft of a marine engine, when the oil on each side of it, that is between itself and the other eccentrics, had leaked out?

Mr. SIDNEY STONE understood from the description given in the paper that the driving of the eccentrics was done by the square block on the axle. That being so, and supposing the length of each side of the square was 8 inches, the area of driving surface on each side of the axle would be not more than 4 inches, or together 8 inches, multiplied by the thickness or breadth of the eccentric where it bore against the block. On the Brighton engines the late Mr. Stroudley had introduced an eccentric which had across its outer face a pair

of projecting lips fitting on the web of the crank, and extending along it for about five inches length, as far as the radius of the eccentric itself would admit. The same plan had also been used largely on the Great Eastern engines, but had now for some time been discontinued, because it was found that before the engines had been running long there was a considerable amount of play between the web and the lips. It occurred to him therefore that, if there was so much play with eccentrics fixed on in that way with the lip bearing on the crank web, and screwed up tightly one to the other with square-headed bolts and the holes filled in with white metal, some little trouble would probably be experienced in the same direction with the fluid-pressure gear, in which the eccentric did not fit tightly but must be sufficiently free to slide for reversing. To make up for the oil passage drilled along the crank web, he supposed the web would be strengthened up with more metal in it; because the general experience he believed was that the webs of locomotive cranks gave the most trouble. In the case of an axle having the square block forged solid upon it in the first instance, he asked how the author managed with regard to the passages I and J in the corners of the square block shown in Figs. 11 and 12, Plate 61.

Mr. CHARLES E. COWPER mentioned that asbestos was successfully used for the packing of steam cocks, such as blow-off cocks for boilers, which were of course subjected to the heat of the water in the boilers. Asbestos was also extensively used dry as packing for spindles of large valves employed for controlling blast heated to the temperature of red-hot iron.

Mr. G. S. YOUNG asked how much the diameter of the eccentric was increased for the application of the fluid-pressure gear. It appeared to him that in quick-running engines especially, in order to reduce the friction, the smaller the eccentric could be kept, the better gear it made. With the shifting eccentric now described it seemed to him that the diameter was materially increased.



Mr. BASIL H. JOY mentioned that in the first form of the gear there were no rams in the eccentric, and the oil acted direct on the square block, the eccentric being enclosed between discs, whereby the slot in the eccentric was made to perform the function of the cylinder, and the block that of the ram. There was consequently a large circular surface to be kept oil-tight over the face of each disc; and though it was made pretty nearly tight, it was not quite satisfactory. Now however in the present form shown in the drawings it was all right. As to the packing remaining tight for a length of time, he had recently visited the Tower Bridge works, where the rams of the hydraulic lifts, packed with ordinary hemp packing, were working at 800 lbs. pressure per square inch, and they were perfectly water-tight; the rams were quite dry as they came out of the packing. In the eccentrics it must be borne in mind that the rams were not continuously working, as in a hydraulic engine or a lift; but the eccentric was moved over only when the engine was reversed or linked up. The motion was only through a certain short distance of three or four inches, and it was not continuous.

The even lead in all grades of expansion was a marked feature of the gear. In running both with expresses and with slow trains, the beat of the engine was perfectly regular, thereby showing how much better the single-eccentric gear was than the link, with which the beat so often seemed to follow a sort of three-legged rhythm.

In the reversing cylinder on the footplate, shown in Fig. 13, Plate 62, there was a margin of 50 per cent. more oil than was contained in the whole of the pipes, passages, and rams: so that a large amount would have to leak out before anything detrimental could happen.

The asbestos packings which had been exposed experimentally both to water and to heat had all proved perfectly tight both before and after exposure to heat, when tried by means of the small testing machine shown; the packings themselves were also exhibited for examination of their condition after having been so tested. The simple form of packing suggested by Mr. Billinton, consisting of a brass ring of U section, Fig. 9, Plate 60, was made with a very fine edge, which pressed against the ram, and was held up tight

against it by the fluid pressure. It could be made absolutely tight ; but it was so delicate that, as soon as it was taken out for repair, the fine edge, which had to be practically like a razor, was difficult to preserve ; and of course as soon as ever there was a little burr on the edge the whole efficiency of the ring was done away with.

In regard to independent adjustment of the reversing gear for the several cylinders of a marine engine (page 265), the drawing shown in Plate 63 had been copied from a published drawing of an existing engine built for the government, fitted with the usual link reversing gear, and devoid of any independent adjustment for the different cylinders. The omission therefore of independent adjustment had nothing to do with the fluid-pressure reversing gear ; but its introduction in both cases would tell, as far as simplicity was concerned, very much in favour of the fluid-pressure gear.

Mr. Joy explained that in locomotives having outside cylinders or coupling rods (page 260) the fluid pressure was got into the driving axle by adding an outside overhanging crank or fly-crank, as was so commonly done in fast-running agricultural engines for the purpose of lubricating ; then the fluid was got into the axle through the fly-crank just in the same way that it was led through the main cranks shown in the drawings.

In order to prevent leakage between the axle and the square block bolted upon it (page 261), a leather packing ring was placed round the orifice of each of the two holes in the axle through which the fluid passed into the block. Then when the block was placed on the axle and bolted up tight, the leather packings made a joint that would carry any pressure desired ; and at these joints there had never been the slightest trouble with the engine. It had been running now more than twelve months, and had done all manner of work, from the fastest expresses to trains stopping every two miles, and shunting. Again, supposing a joint did leak, it was only water or oil that leaked ; and the leakage could be made up to any extent from the reversing cylinder, which, small as it was, contained enough fluid to enable the engine to continue running through a long journey, leaking all the time, yet still with margin enough to go on.

(Mr. Joy.)

Even if the margin were exhausted, as had once been the case with a bad leather, with which the engine had been allowed to go on for the sake of seeing what the result would be, the reversing cylinder could be replenished by pouring in water while the engine was running, just as the steam cylinders could be lubricated when the engine was running downhill. The reversing cylinder sucked in the oil or water, and the engine continued running just as if there had been no leakage. Although there was only one reversing cylinder for shifting the two eccentrics (page 261), yet through the pipes from each end of the cylinder and through the passages in the axle the reversing handwheel acted alike on both eccentrics; and meanwhile also they were coupled together by the inclined slot and block, which kept them in their correct positions relatively to each other. One eccentric could not move the other; but the two went together, and were held at the same point of cut-off by means of the inclined slot. The result was that the beat of the engine was so perfectly regular that the revolutions could not be counted by the beat at all.

If while there was a bad leakage from the reversing gear the engine were stopped at a station (page 262), it would start and go on again in the same direction without any trouble, because the position of the gear was not altered in stopping, and wherever the eccentrics were when it stopped, they were left in the right position ready to go on again in the same direction. Supposing however it were wanted to reverse for shunting, or in order to take a vehicle on or off, then if the fluid had all leaked away the engine could be backed by pinching the driving wheels round through a quarter of a turn back, which was enough to slip the eccentrics back. But if an equally serious accident happened with the link gear, the engine could neither go back nor forward, but would have to be taken off the train and another engine supplied. With the fluid gear however it could still go either backwards or forwards. If the engine was attached to too heavy a train for pinching back through a quarter of a turn, it was only necessary to detach it and run a turn forward, and then pinch back a turn; the eccentrics would then be in the right position for backing.

The actual area of driving surface (page 266) for the eccentric of  $6\frac{1}{2}$  inches breadth on a locomotive crank-axle with block 8 or 9 inches square was altogether from 52 to 58 square inches. Where the block was forged solid upon the axle, the oil passages in the corners of the block would be drilled through the corners of the crank webs. Fracture never took place in the web in the neighbourhood where the oil passage was drilled, because the hole was in the middle of the substance of the web, where it was under no strain.

Owing to Mr. Davey's long experience in the working of hydraulic machinery, his information with regard to the use of distilled water was of much value, and he would try it for the fluid-reversing gear. If also he should come ultimately to metallic packing for the rams in the eccentrics, he should himself like it, because nothing he believed was so simple and so scientific as the brass packing ring designed by Mr. Billinton, Fig. 9, Plate 60. With regard to the asbestos packing not standing water (page 262), in the experiment he had made it had stood half an hour with water, and with a red-hot plate of iron under it; and in blow-off cocks, in which it was largely used to form the lining of the body of the cock, it was constantly subject to the pressure and temperature of the water in the boiler, and there it stood perfectly. Of course an engine would stop long enough before its driving axle got red-hot; and therefore, in trying the experiment with a red-hot plate of iron under the water press in which the packing was tested, he had done so only with the view of going to the utmost limit of the objection which had been urged against the fluid gear.

To prevent freezing (page 263), a fluid could be used which would not freeze down to  $6^{\circ}$  Fahr.; and he thought the temperature did not often fall so low in England. Even if it did, the engine would of course become warmed up sufficiently in getting up steam for starting.

As to any fear that the packings would always be leaking and the eccentrics consequently always falling into full gear (page 264), even if there was a leaky leather on the engine he believed it would not be detected by the driver while on the footplate; because even

(Mr. Joy.)

with a burst leather the leakage was so slow that the effect on the engine was extremely slight over a long journey; if the eccentrics did fall back at all from the position into which they were moved by the reversing cylinder, the change was so slight that it could not be noticed in the working of the engine. So far from the driver wanting anything like an index to show him the position of the eccentrics, all his own experience of locomotives—and in former years he had himself driven tens of thousands of miles, and had had to teach his drivers to drive—was that the drivers did not go nearly so much by the position of the reversing lever and regulator as by hearing and feeling what the engine was doing. The driver had his finger upon the handwheel of the reversing gear, and when he came to an up or down gradient he just gave the engine a little more or less steam, and never looked at the index at all, even if he had an index to go by. Meanwhile either at the end of the journey or at a station on the road he could at any time bring up the two eccentrics to their proper position, by replenishing the reversing cylinder while the engine was still running. The leakage did not really matter at all.

As had already been explained by his son (page 269), the drawing shown of a marine engine fitted with the usual link reversing gear, Plate 63, was simply a copy of the "Apollo" type of marine engines, some of which were fitted with adjusting gear so as to cut off in the various cylinders at various points, and some were not. At the present time the government were building them with that adjustment, while other builders seemed to follow no rule, but to depend upon specifications, which mostly required it. In the application of the fluid-pressure gear it could be arranged so as to cut off in any cylinder at any desired point. Thus it could be set to cut off in the high-pressure cylinder at 60 per cent., in the intermediate at 65 per cent., and in the low-pressure at 70 per cent. of the stroke, or in any other proportions, simply by adjusting the quantity of the fluid in either ram of each eccentric. Then the instant the order was given for full speed ahead or astern, there was nothing to do but to throw over the reversing lever into full gear, and all the three eccentrics went at once into full gear ahead or into

full gear astern. With the link motion on the contrary the position of the links had to be adjusted separately for each cylinder by means of a hand-screw acting upon a sliding block: so that, when it was required suddenly to go into full gear astern or full gear ahead, although the former position might be assumed at once, the latter could not be got without a re-adjustment of all three of the hand-screws. It was not so with the fluid-pressure gear; the three eccentrics all went at once into full gear with one movement of the reversing lever; and all came back to full gear in the reverse position by the reverse movement of the lever.

The middle eccentric on the crank-shaft of a marine engine (page 266) was worked conscentively from either end of the shaft according to the direction of the fluid pressure, which acted first on the eccentric nearest to the end of the shaft at which the pressure was entering; thence it passed on to the middle eccentric, and thence again to the furthest eccentric at the exhaust end of the shaft, and so back to the reversing cylinder. Practically indeed, though here described as if consecutive, the movements of all three eccentrics were simultaneous, owing to the instantaneous transmission of the fluid pressure in either direction in consequence of the oil or water being incompressible.

Mr. FREDERICK EDWARDS asked how then was the cut-off regulated for different points of the stroke in the three cylinders independently.

Mr. JOY said it was done by means of the arrangement shown in Figs. 20 to 23, Plates 65 and 66, which represented one of the eccentrics for engines of the "New York" type, like those illustrated in Plate 64. The independent adjustment was obtained of each separate eccentric, together with the means of securing full gear either way for all three eccentrics at once on reversing. Starting with all three eccentrics in full gear, the adjustment of each separately and independently was effected by producing a difference between the amounts of fluid in the two small cylinders on opposite sides of the shaft, thereby pushing the eccentric over towards mid-gear to the

(Mr. Joy.)

extent necessary for the grade of expansion desired. This operation was effected in any one of the eccentrics without disturbing either of the others, by means of a small ram-pump P, formed in the flange of the eccentric itself, with a small drilled passage I I leading from the "ahead" cylinder H on one side of the shaft to the pump, and a similar passage J J from the pump to the "astern" cylinder S on the other side; the latter passage was fitted with a non-return delivery valve. The ram of the pump was actuated by the movement of the eccentric itself, and was always pressed outwards by a spring at its base, so that its head was kept bearing against the inner surface of the ring R carried on the eccentric clasp. In its normal position, when the pump was at rest, the ring was concentric with the eccentric; but on setting it out of centre by half a turn of the small hand-wheel W, a relative movement was set up between the eccentric and the ring, and the pump was set in action, drawing fluid out of the cylinder H and passing it into the cylinder S, thereby to any desired extent varying the position of the eccentric towards mid-gear, and so altering the point of cut-off. Supposing all three eccentrics to have been thus brought into different relative positions for different points of cut-off, then at any time on passing the reversing fluid in the direction for full gear ahead it at once moved all three eccentrics in that direction; and if, owing to its previously altered position, the "ahead" cylinder H in any one eccentric did not contain sufficient fluid to pass on for completing the full movement of the next eccentric, then on arriving at the end of its stroke the ram in the cylinder H uncovered a small drilled port and passage V, through which the fluid was free to pass on to the next eccentric; and so on, for completing the movement of all three. On the instant of reversal for full gear astern, the small port V was closed by the movement of the ram H. Thus without valves or any machinery liable to derangement, the position of full reversal in either direction was secured to each eccentric, whatever their former relative positions might have been. The effect of full reversal in either direction was at once to obliterate the different grades of expansion to which the several eccentrics had previously been pumped; and when again going ahead, these grades

could quickly be restored by setting the three small pumps to work during a few revolutions. All the small channels or passages were arranged so as to be easily cleaned by a wire at any time.

There was no difficulty with the larger stuffing-box at the after end of the crank-shaft in a marine engine (page 265), because it had to do duty only during the few seconds occupied in throwing the engine over from backward to forward gear, and had no sustained work upon it. The pressure was applied at the forward end of the shaft to lift the eccentrics from full forward gear to any desired point of cut-off; and at this end the pipe was small, and might if required be double or treble packed, having successive cup-leathers one after another.

The eccentrics were a little larger in diameter (page 267) than for the link motion, but not much; but they were made much thicker or wider. Instead of only  $1\frac{1}{2}$  to 2 inches width, the eccentrics were now made 3 or  $3\frac{1}{2}$  inches wide, by which means the frictional load per square inch was so largely reduced on the wearing surfaces that in the course of twelve months' running of the locomotive no heating whatever had occurred, nor any appreciable wear.

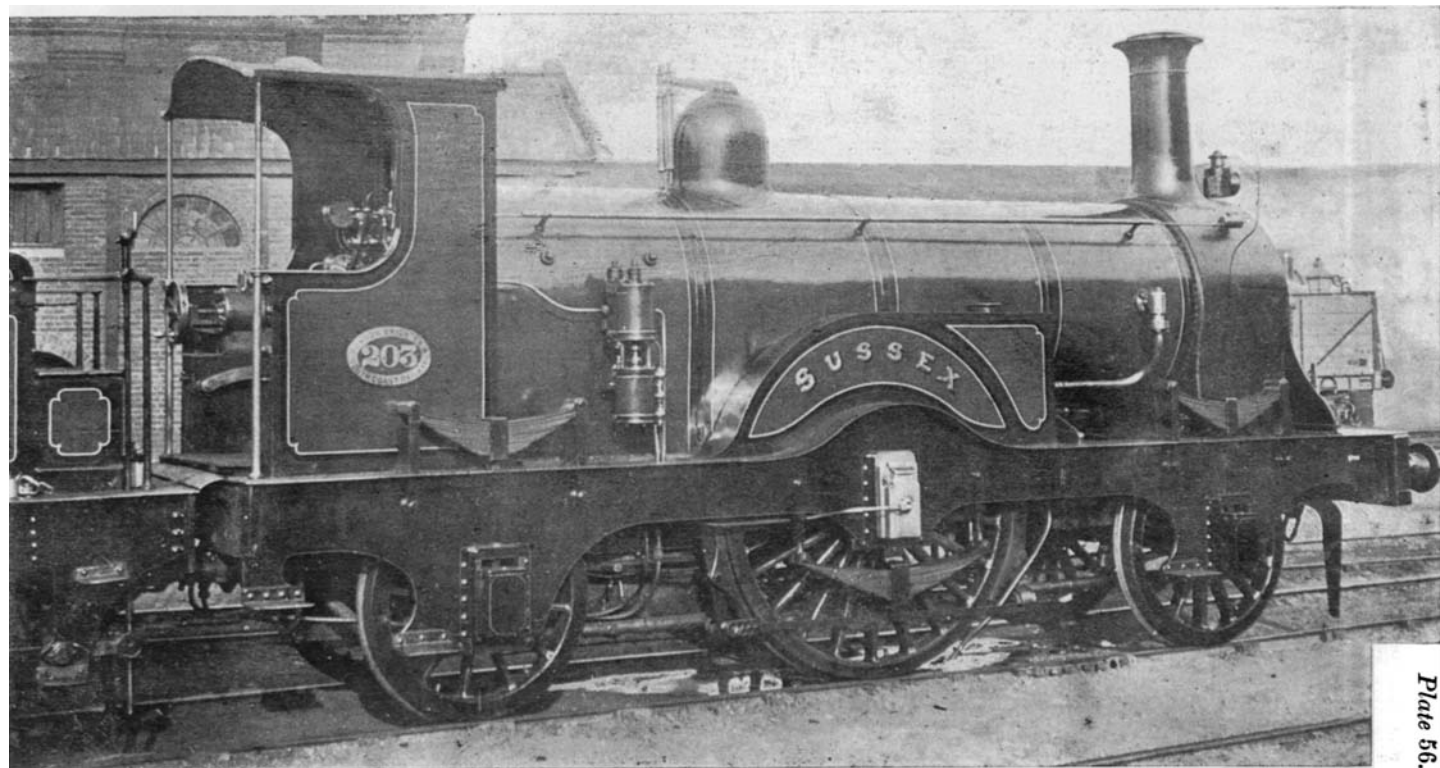
Mr. JEREMIAH HEAD, Past-President, asked whether the boiler had to be lifted up higher in the locomotive, to admit of the larger eccentrics working beneath it.

Mr. JOY replied that the increase in diameter was not so great as to necessitate raising the boiler, because no new part was so high as the crank and connecting-rod end. But even if this had been requisite, he should not object to the boiler being raised as much as was needed; for from long experience of engines with high boilers he knew that, within reasonable limits, the higher the pitch of the boiler in a locomotive, the more easily would the engine run.

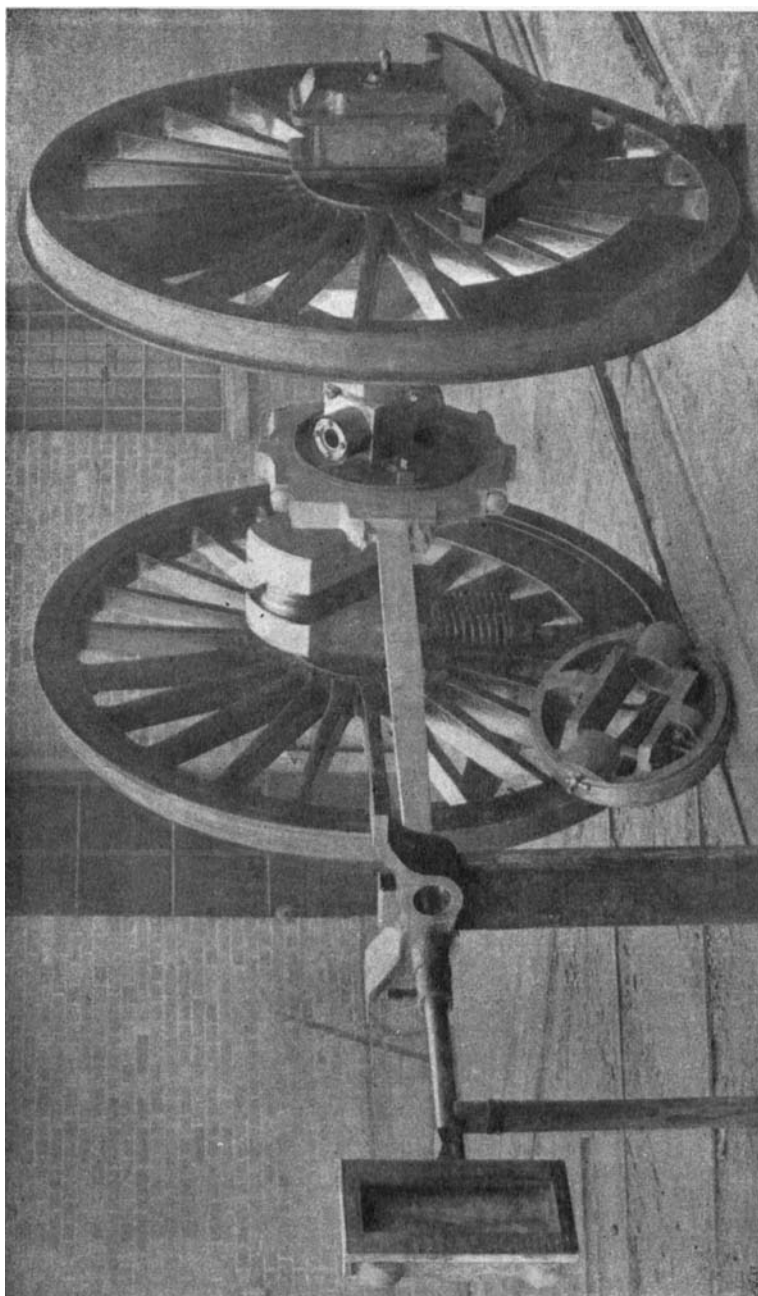
The PRESIDENT was sure the members would desire to present a cordial vote of thanks to Mr. Joy for his paper.

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**FLUID-PRESSURE REVERSING GEAR. *Plate 57.***



# FLUID-PRESSURE REVERSING GEAR.

Plate 58.

Fig 1. *Side Elevation.*

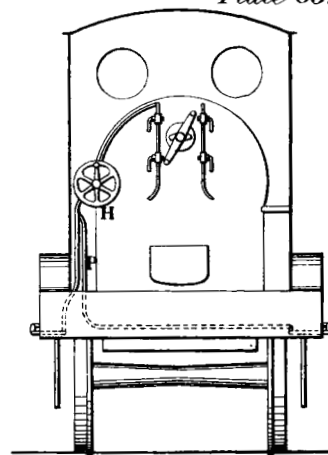
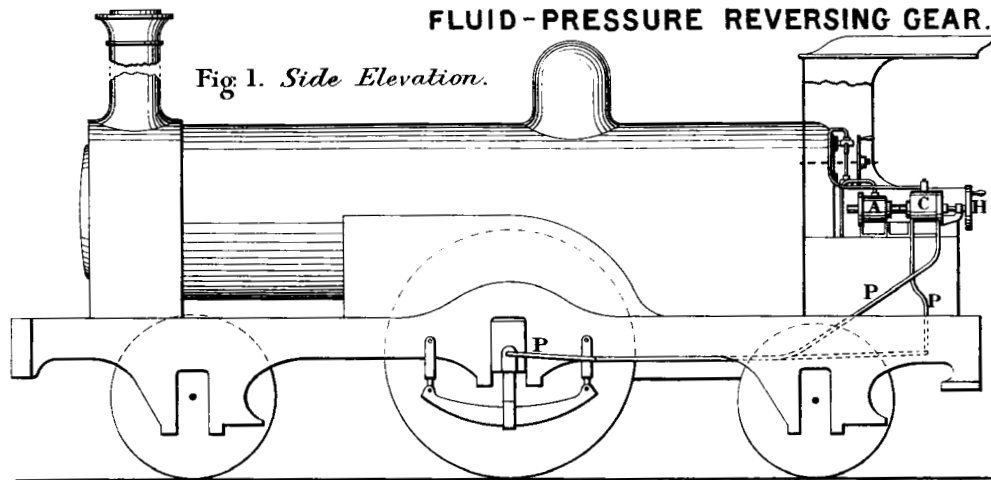
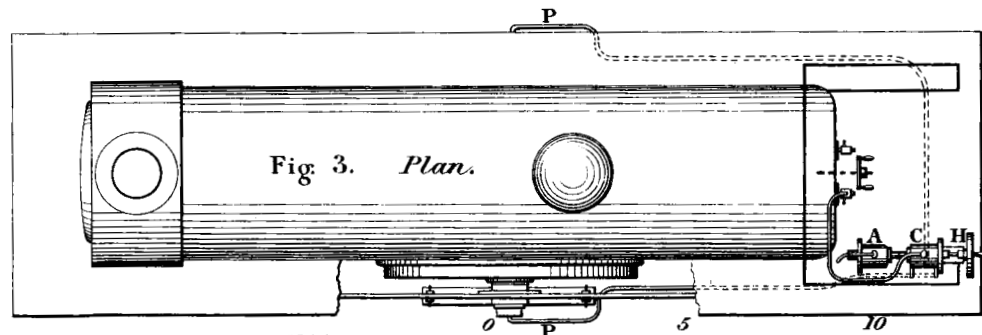


Fig 2. *End Elevation.*

Fig 3. *Plan.*



Scale  $\frac{1}{60}^{th}$

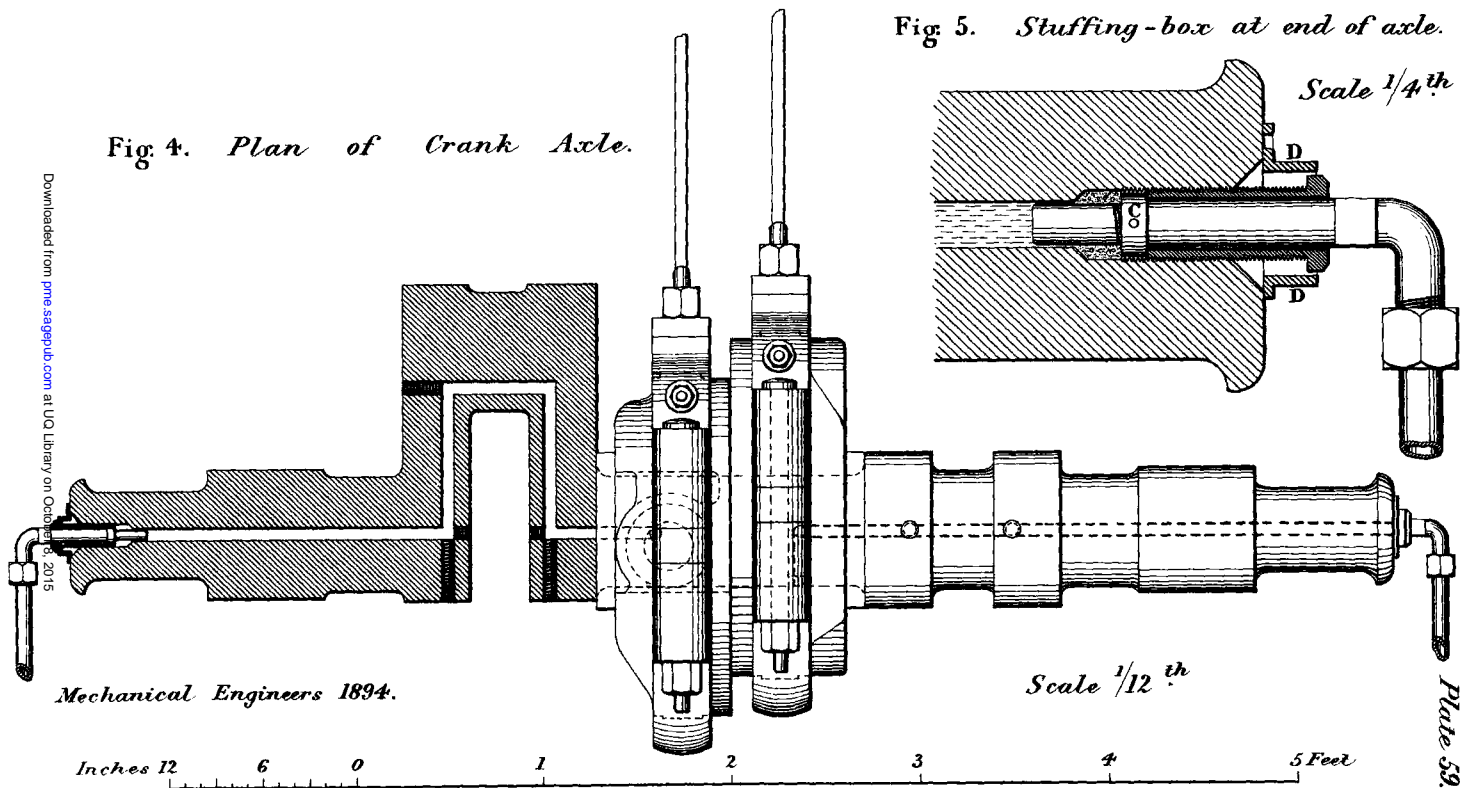
15 20 Feet

# FLUID-PRESSURE REVERSING GEAR.

Plate 59.

Fig. 4. Plan of Crank Axle.

Fig. 5. Stuffing-box at end of axle.



# FLUID-PRESSURE REVERSING GEAR.

Plate 60.

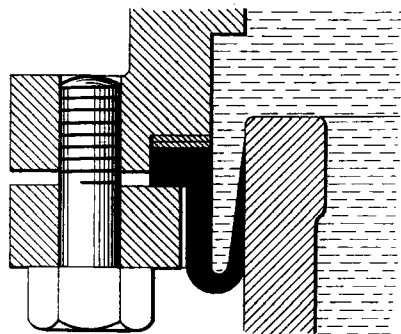


Fig. 9.  
*Metallic  
Packing.  
Full size.*

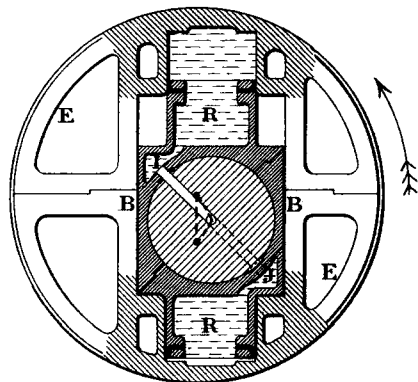


Fig. 6. *Transverse Section.*

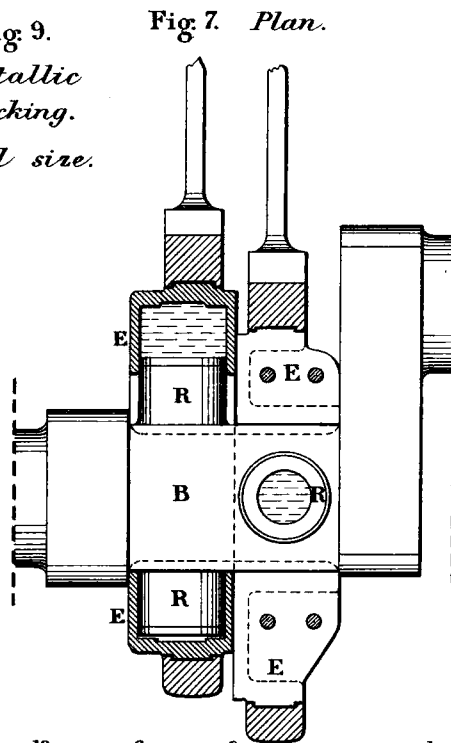
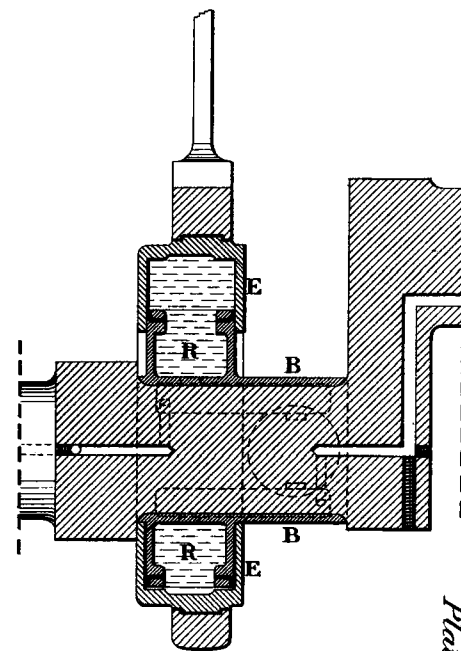


Fig. 7. *Plan.*

Fig. 8. *Longitudinal Section.*



Scale  $\frac{1}{12}^{th}$

Inches 12

Mechanical Engineers 1894.

Downloaded from [me.sagepub.com](http://me.sagepub.com) at UCL Library on October 6, 2015

0

1

2

3 Feet

Plate 60.

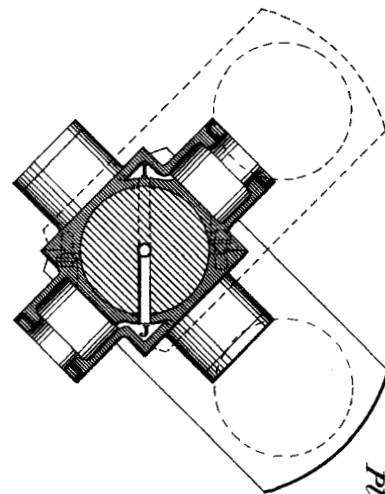
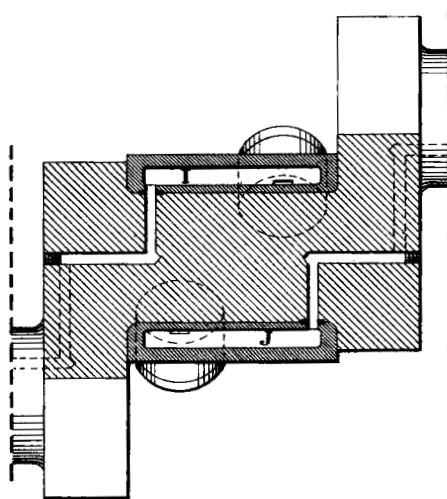
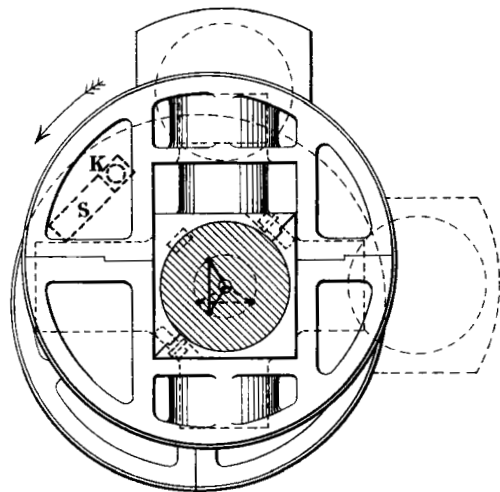
# FLUID - PRESSURE REVERSING GEAR.

Plate 61.

Fig. 11.

*Longitudinal Section.*

Fig. 12. *Transverse Section.*

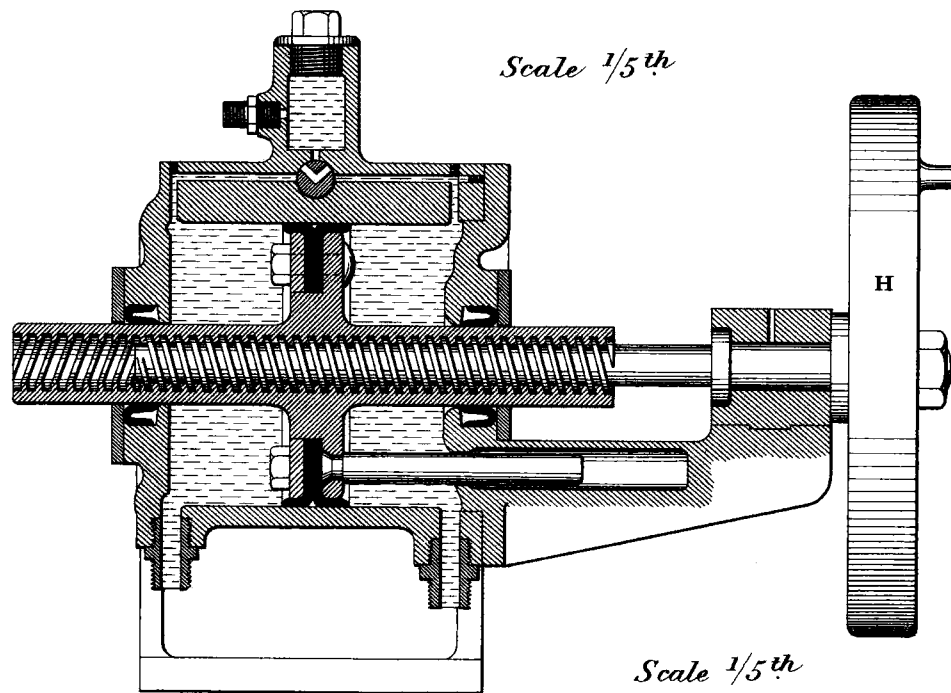


Scale  $\frac{1}{12}^{th}$

# FLUID-PRESSURE REVERSING GEAR.

Plate 62.

Fig. 13. *Longitudinal Section of Reversing Cylinder.*



Scale  $\frac{1}{5}^{th}$

Scale  $\frac{1}{5}^{th}$

Fig. 14. *Link Gear.*

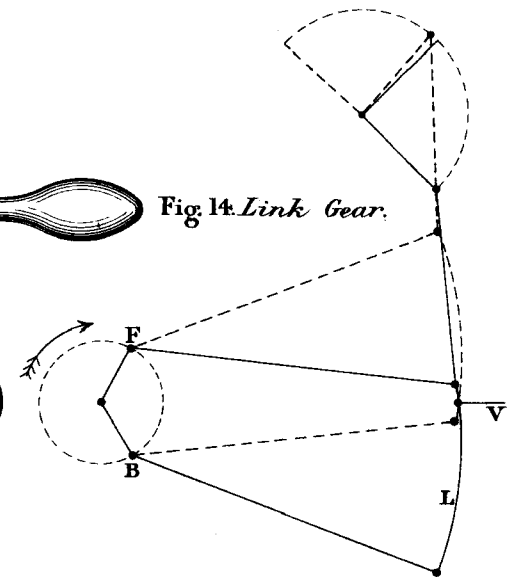
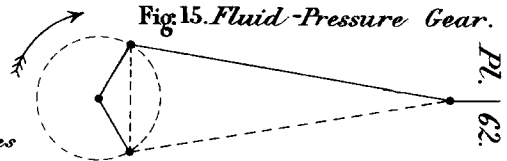


Fig. 15. *Fluid-Pressure Gear.*



# FLUID-PRESSURE REVERSING GEAR.

Plate 63.

*Link Gear of Marine Engines.*

Fig 16. *End Elevation.*

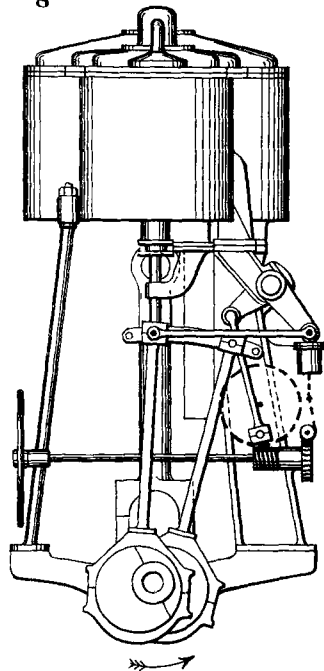
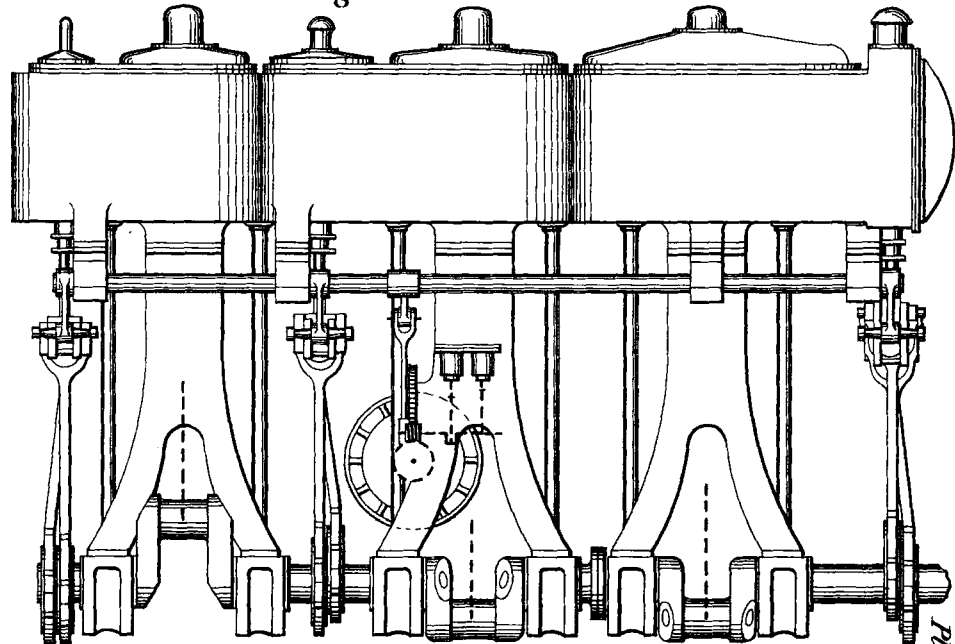


Fig 17. *Side Elevation.*



Scale  $\frac{1}{60}^{th}$

Plate 63.



# FLUID-PRESSURE REVERSING GEAR.

*Application to Marine Engines.*

*Plate 64.*

Fig. 18. *Side Elevation.*

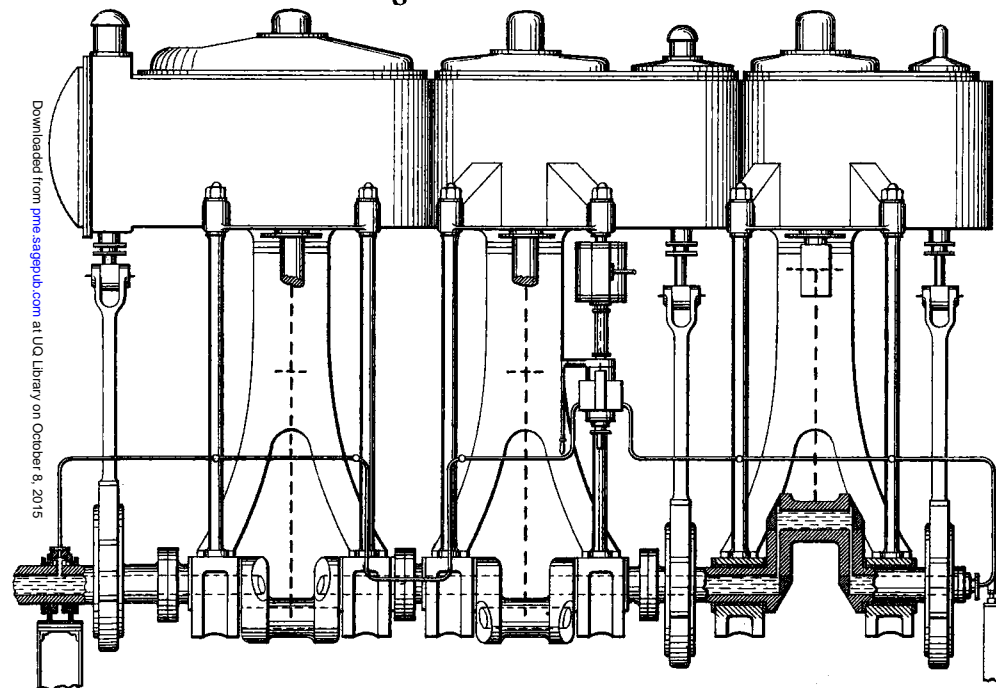
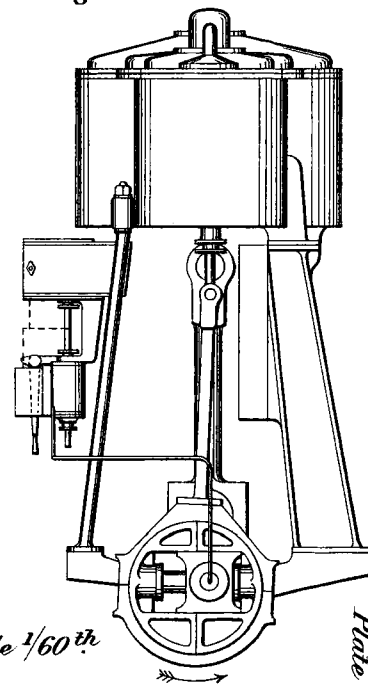


Fig. 19. *End Elevation.*



Scale  $\frac{1}{60}^{\text{th}}$

0 5 10 15 20 Feet 25

*Mechanical Engineers 1894.*

*Plate 64.*

*Adjustable Eccentric  
for Marine Engines.*

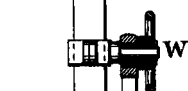
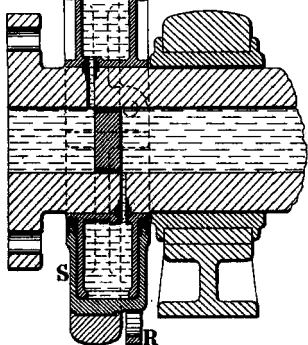


Fig. 20.  
*Longitudinal  
Section.*



*Mechanical Engineers 1894.*

Inches 12 6 0 1 2 3 4 5 Feet

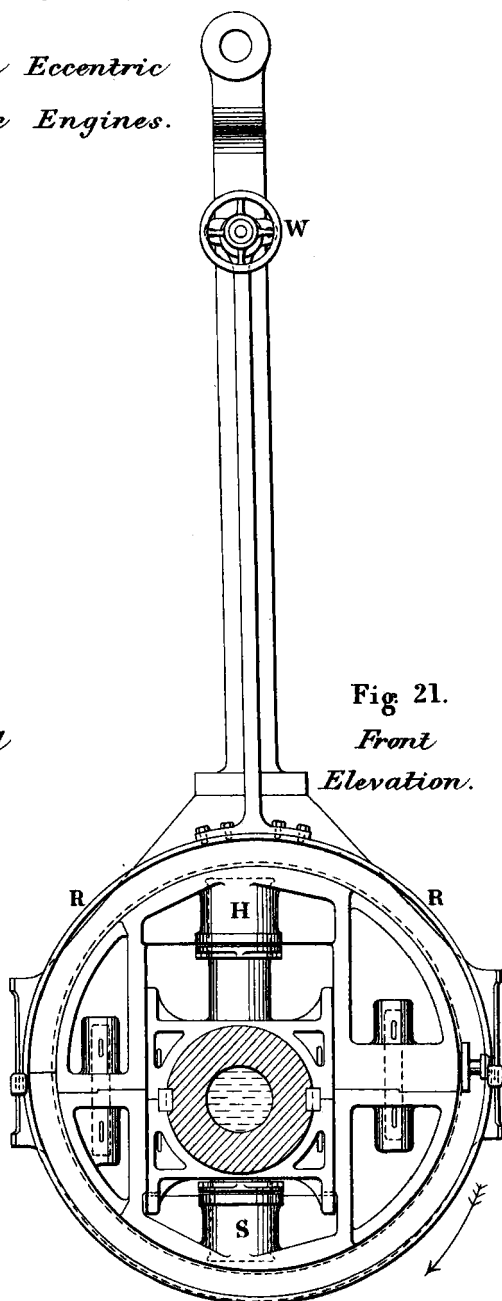


Fig. 21.  
*Front  
Elevation.*

Scale  $\frac{1}{24}^{th}$

*Adjustable Eccentric for Marine Engines.*

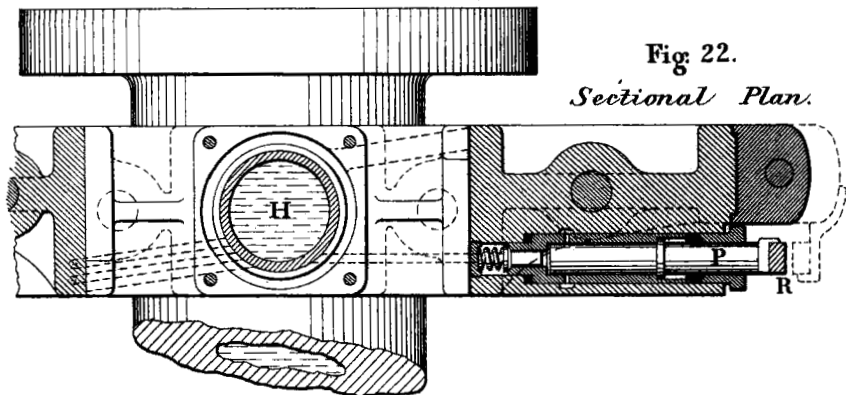


Fig. 22.

*Sectional Plan.*

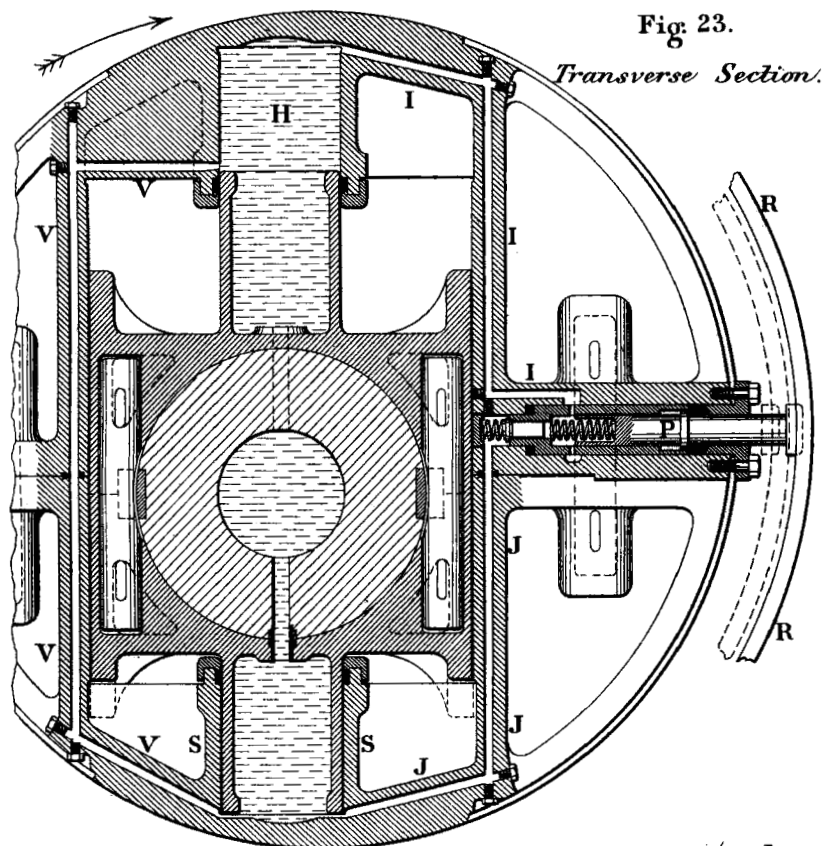


Fig. 23.

*Transverse Section.*

*Mechanical Engineers 1894.*

*Scale 1/12 in*

Inches 12 6 0 1 2 Feet