

DESCRIPTION OF THE CORNISH PUMPING ENGINE
WITH WROUGHT IRON BEAM
AND THE PIT WORK AT CLAY CROSS COLLIERY.

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At the commencement of the working of the Clay Cross Colliery the upper seams of coal were drained by the Clay Cross railway tunnel; but as the lower seams were sunk to and worked, the water could no longer run into the tunnel, and gradually increased in quantity until it became necessary first to put in pumps of small size worked by the winding engines then in use on the colliery, which were sufficient for draining the works for some years. Afterwards as the works extended further, one pump after another was added, until there were altogether six pumping stations, at two of which were independent pumping engines of 40 horse power each. The water still following to the dip of the measures, it was found that either more pumping power must be added in the same way that it had been increased from the commencement, by putting down more engines, or else a single large pumping engine must be erected to drain the whole of the works, which had extended to an area of several hundred acres and a depth of 420 feet. After much consideration it was determined to erect a single large pumping engine on the Cornish principle, to pump the whole of the water at one point of the colliery. When this was completed it at once threw out of use seven sets of pumps and engines requiring several enginemmen to look after them; and saved much expense in repairs, which had been continually necessary at one or other of the several pumping stations.

In adopting this plan of pumping it had to be taken into consideration that the drainage of the whole colliery would be

dependent on one engine alone, instead of on several independent engines distributed at various points of the works; but as the working of the minerals went on increasing, the water partially left the pumps at the upper part of the works and ran down to the lower level, necessitating increased pumping power at a greater depth. This led to the conclusion that a central pumping station would be the most effectual and convenient; and the general result of experience showed that the Cornish pumping engine was most to be relied on for pumping from a considerable depth, and when well constructed was least likely to require repairs. The result has completely carried out these anticipations, as the new engine has maintained the entire drainage of the colliery for the last three quarters of a year, and has proved itself completely satisfactory in requiring no repairs, and has effected a great saving in cost of enginemmen and repairs as well as in fuel and stores. It has to be remarked also that the plan of having pumps in connexion with winding engines, as was previously the case, involved the disadvantage that the engines when winding were not so perfectly under control for starting or stopping at particular points when required, on account of being burdened with the irregular load of the pumps: there was also the objection of having to disconnect the ropes when it was required to run the engine for pumping alone. A rotary pumping engine is also exposed to the dangers that inevitably arise with a pump, from an obstruction getting under the suction clacks and causing the pump to miss its stroke; or from the pump being only partially filled with water, so that when the plunger meets the water at half stroke, or at any other point short of the top, the concussion produced is so great that some portion of the machinery must give way.

The new Engine, forming the subject of the present paper, is an ordinary Cornish pumping engine, erected by the Butterley Company; and is shown in Fig. 1, Plate 67, which is a side elevation of the engine and a section of the house. The cylinder A is 84 inches diameter with a stroke of 10 feet. The engine house is a substantial building, on a foundation of concrete 18 inches thick. The cylinder

pillar B is built of large ashlar stones set on the concrete, and is $18\frac{3}{4}$ feet high and 10 feet thick, running the full width of the house and built into the side walls. A pair of heavy cast iron girders C C, shown black in section, run underneath the cylinder pillar and extend under the side walls of the house, the holding-down bolts of the cylinder passing through them. The beam wall D, which extends across the house and unites with the side walls, is also built of large ashlar stones up to the level of the cylinder pillar, and is 8 feet thick; on the top of this work a cast iron plate E is laid, 7 feet wide, extending nearly the full width of the engine house; the beam wall is then built up of brick to within $3\frac{1}{4}$ feet of the bedplate for the main plummer blocks to rest upon, and is then finished with two courses of ashlar stone. Eight large tie bolts pass down through the spring-beam boxes, the bedplate, and the plate E at the bottom of the brickwork, securing the whole in one solid mass. The rest of the engine house is built of brick with stone quoins.

The top nozzle F, Fig. 1, Plate 67, contains the regulating, steam, and equilibrium valves: the regulating and equilibrium valves are each 12 inches diameter, and the steam valve 14 inches. The bottom nozzle G contains the eduction valve, which is 18 inches diameter. All the valves are on the ordinary double-beat principle, of massive construction and made of gun-metal. The top and bottom nozzles are connected with two side pipes H, each 12 inches diameter, through which the steam passes from the top to the underside of the piston, forming a perfect equilibrium. The cylinder cover is double, having a false cover with a space between. The cylinder is not made with the steam-jacket usually employed in Cornish pumping engines, but it is covered with wood and dry hair felting; an air space of 5 inches is left between the outside of the cylinder and the first covering of rough 1 inch boards; outside of these is placed about 1 inch thickness of felt, and outside that a cleading of 2 inches thickness: the whole having sufficient non-conducting power to keep the engine house remarkably cool. The metal of the cylinder is $2\frac{1}{4}$ inches thick, with flanges in proportion well bracketed, and weighs upwards of 11 tons. The

piston has metallic packing, two outer rings and one inner one, all of cast iron ; eight springs are placed inside the inner ring, with pins and nuts for adjustment.

There are two plug rods I, Fig. 1, Plate 67, one carrying the tappet to shut the steam valve, which may be varied to work to any degree of expansion, and also a tappet to work the cataract J for opening the steam, eduction, and injection valves ; the other rod carries the tappets to close the eduction, equilibrium, and injection valves, and also a tappet to work the cataract K for opening the equilibrium valve. Generally, it is believed, Cornish pumping engines have only one cataract J, to open the steam, eduction, and injection valves at the conclusion of the outdoor stroke ; but in the present case the writer preferred having a second cataract K to open the equilibrium valve at the conclusion of the indoor stroke, so as to have a pause at each end of the stroke, before the opening of the equilibrium valve as well as before the admission of the steam, in order to allow ample time for the pump valves to close completely.

The air pump and condenser are placed within a cast iron cistern L, Fig. 1, Plate 67, $10\frac{3}{4}$ feet long, 7 feet wide, and $11\frac{1}{2}$ feet deep, bolted down upon two cast iron girders placed on a heavy ashlar stone and brick foundation. The foot and delivery valves and also the bucket valve are composed of india-rubber discs, with brass grid faces, having a guard above to prevent them from rising too high. The air pump bucket is packed with hemp, as is generally the case in such engines ; and the injection valve is fixed on one side of the condenser, inside the cistern. The injection pipe is a 4 inch pipe tapering to 3 inches diameter at the end, and is set pointing in such a direction as to throw the water against the side of the condenser, whereby it is distributed so as to meet the steam. The water in the condensing cistern is kept at a temperature of 50° Fahr., the temperature of the hot well being 113° .

The engine Beam M, Fig. 1, Plate 67, is of wrought iron, designed and made by the Butterley Company, and is shown in detail to a larger scale in Figs. 2 to 6, Plates 68 and 69. It is made of two wrought iron slabs M M, one on each side, each slab being

rolled in one piece 2 inches thick throughout, $36\frac{1}{2}$ feet long over all, 7 feet 1 inch deep in the middle and 3 feet 4 inches deep at the ends. Each slab weighs upwards of $7\frac{1}{2}$ tons, and the total weight of the beam is about 33 tons. The two wrought iron slabs are stayed and bolted together by large cast iron distance pieces N N with broad flat ends, the holes being bored and the bolts turned for bolting the slabs to the ends of the distance pieces. There is also a strong cast iron centre piece O, bored for the main centre gudgeon to pass through, Fig. 4, and keyed upon the gudgeon. Each end of this centre piece is turned, and has a projecting boss P also turned; the two large wrought iron slabs are bored to fit these bosses, and cast iron washer plates also bored are put on outside; and the whole is securely bolted together with twelve bolts on each side, turned and fitted into holes bored to receive them. The beam is stiffened on the lower side by a wrought iron plate Q, 12 feet long and 1 inch thick, underneath the main centre, connecting the two wrought iron slabs, which are 4 feet $1\frac{1}{2}$ inch clear apart; the plate Q is rivetted to the slabs by two heavy angle irons. The gudgeons, excepting the main centre, are turned and fitted into holes bored in the sides of the beam, as shown in Fig. 6, having a cast iron washer plate bolted on the slabs both outside and inside to give a longer bearing, the washer plates being bolted through the beam slabs with bolts turned and fitted accurately into bored holes. The gudgeons are rivetted over the outside washers, which are slightly countersunk for the purpose, and a key is put through before this is done to prevent the gudgeon from turning. The beam thus constructed is perfectly stiff, and no lateral vibration can be perceived; it is altogether a complete success.

The parallel motion R, Fig. 1, Plate 67, is placed inside the beam slabs M; it is of the ordinary construction, very substantial and got up bright. The crosshead is a massive block of wrought iron through which the piston rod passes loose; the rod is 8 inches diameter and is secured in the crosshead by two half rings of 1 inch larger diameter, fixed in a recess turned in the top of the rod, the hole in the crosshead being also bored out to 9 inches diameter for half the length from the top; so that, should the piston strike

the bottom of the cylinder, the piston rod would slide up free through the crosshead.

The engine is always started with high pressure steam without a vacuum, the steam and eduction cataract J, Fig. 1, Plate 67, being secured by a pin so that the valve catches cannot be lifted by the cataract. The regulating valve is opened by the handwheel and screw; the eduction and injection valves are opened by the handle; and the steam valve is opened by placing the foot in the stirrup on the rod. The engine thus makes the indoor stroke, and after a few strokes a vacuum is produced, and the engine regulated to the proper length of stroke by the regulating valve. The cataract J is then released so that it may liberate the valve catches; and the engine then works the desired length of stroke so long as the steam in the boilers remains at about the same pressure. The cataracts J and K which are charged with water are of the ordinary description, having a working barrel with a ram in it, which is placed inside a small circular cistern; the working barrel has only one clack or valve, which opens inwards. The outlet for the water is through a small orifice, the opening of which is regulated by raising or lowering a plug by means of a screw and handle. The speed of the engine is thus regulated by lengthening or shortening the interval between each stroke, so that it may be worked from a minimum speed of only one stroke in three or four minutes up to a maximum speed of about eight strokes per minute. The engine does not regularly make the full stroke of 10 feet length, but averages about 9 feet 7 inches; and the speed seldom exceeds four strokes per minute, the piston in that case attaining an average speed of about 76 feet per minute. The usual speed of the piston during the indoor stroke is about 290 feet per minute, and the outdoor stroke occupies about double the time of the indoor stroke. The speed of the indoor stroke varies of course according to the degree of expansion: when the steam is admitted to the cylinder at a higher pressure and cut off at about two thirds of the stroke, the indoor stroke is completed in about $1\frac{1}{2}$ seconds, or the piston travels at the rate of about 400 feet per minute. But when this is the case the concussion of the pump rods in the shaft is so great that it is not desirable to work at such a high degree of expansion at present.

The boilers are of the plain cylindrical form with hemispherical ends, and fired underneath: they are four in number, each being 35 feet long and 5 feet diameter. The steam stop-valves are placed on a dome 4 feet high and $2\frac{1}{2}$ feet diameter, rivetted on the top of each boiler; two horizontal steam receivers, each 13 feet long and 3 feet diameter, united by an expansion joint, form the main steam pipe, each passing over two boilers and connected with the boilers by elbow branches jointed on the stop-valve boxes: so that any condensation which may take place in the steam pipes between the boilers and the engine will run back into the boilers. It is intended to cover these steam receivers with dry hair felting and sheet iron, and also to place a house and roof over the boilers, in order to prevent radiation and condensation. The flues run from the fires up one side of the boilers and down the other side, being separated by a centre wall; and the flues of two boilers meet in one main flue leading to the chimney which is 101 feet high. The boilers are supplied with water from the hot well by a donkey engine.

The depth of the pit shaft is 418 feet, and the general arrangement of the pit work is shown in Figs. 7 and 8, Plates 70 and 71, which are vertical sections of the pit shaft with the pumps in elevation. The black portions represent the different seams of coal passed through in sinking.

A large stone 18 inches thick is bedded at the bottom of the shaft for the windbore of the bucket pump to rest upon. The remainder of the shaft bottom is filled in with hard burnt bricks and Barrow lime, forming a level bottom, so that the "sump" S, Figs. 7 and 8, may be cleaned as easily as possible when required. The bucket set of pumps, shown to a larger scale in Figs. 12 to 17, Plate 73, is 160 feet from the bottom of the windbore to the delivery pipe T, Figs. 7 and 10, the working barrel being 18 inches diameter and made for a 10 feet stroke. The pipes are 19 inches diameter, so that the bucket may easily be raised up through them if necessary. The bucket when at the top of the stroke is about 25 feet from the bottom of the windbore. The suction

clack A, Fig. 13, is $10\frac{1}{2}$ feet from the bottom of the windbore, and is shown enlarged in Figs. 18 to 21, Plate 74: it is made of brass, with wrought iron lids faced with leather, shown black in Figs. 18 and 19, working on a pin B which acts as the hinge. The hole through which the hinge pin passes in the clack is slightly oblong vertically, as shown in Figs. 18 and 20, allowing the clack falls to lift vertically about 1-8th inch as they open. The hinge pin B is kept in its place by the clack door, and when the door is removed the pin can be drawn out and the clack lids changed in a few seconds.

The bucket, shown enlarged in Figs. 16 and 17, Plate 73, is made of brass, and the lids of iron faced with leather, like those of the clack; and the hole in the bucket rod through which the hinge pin B passes is also slightly oblong, to allow the lids to lift a little in opening; the pin is secured endways by a cotter, but should the cotter by any means slip out of its place, the hinge pin cannot get out, so long as the bucket is in the working barrel. The top part of the bucket is flanged out to fit the working barrel, and the hoop C at the bottom of the bucket also nearly fits the barrel. The leather, shown black in Fig. 16, is placed on the bucket in the usual manner, and covered by the hoop C below: by this means it is hoped to prevent the leather from wearing out on one side of the bucket, as sometimes occurs, by the flange on the top of the bucket and the hoop on the bottom keeping the bucket in a truly central position in the working barrel in this case, the leather acting solely as the water-tight joint between the flange on the top and the hoop on the bottom of the bucket.

The bucket spears are 9 inches square, fixed on the side of the main spears by strong wrought-iron clamps. They are made of pitch pine with butt joints, secured by four wrought iron strapping plates to each joint, the two side ones being 14 feet long and the other two 12 feet long: holes are bored in these strapping plates to a gauge, and the outside of the plates are faced down to form a true bearing for the nuts and bolt heads. The holes in the plates next the bolt heads are bored 1-16th inch larger in diameter than those next the nuts, in order to allow the bolts to be driven in easily until they are nearly up to the head, when they are driven tightly

in; and the bolts also are turned to a gauge of 1-16th inch larger diameter for $1\frac{1}{2}$ inch length underneath the head, in order to get the full bearing through the hole in the plate. This mode of fixing gives an advantage also in getting the bolts out whenever repairs are required, because after they have once been moved they can then easily be driven out.

This bucket pump delivers into the drift D, Figs. 8 and 10, Plates 71 and 72, which is carried forward to the well E, whence the lower plunger pump F takes the water and delivers it at the drift near the top of the pit.

The lower plunger pump F, Figs. 7 and 8, Plates 70 and 71, is shown in section enlarged in Figs. 22 to 25, Plate 75. The clacks are of brass and fitted up the same as the clack already described in the bucket pump, as shown in Plate 74. The plunger G is 18 inches diameter, and the stuffing-box H of the plunger is fixed on the top of the cylinder so that it will admit of easy removal in case of wear or breakage. The rising main I is 19 inches diameter. This plunger pump forces the water about 270 feet from the bottom of the windbore in the well E, Figs. 7 and 10, to the delivery at the drift near the top of the shaft. The pump is carried on the substantial oak bunting J, which is 2 feet 8 inches square and 16 feet long, resting on a solid bearing of more than 4 feet length at each end, as seen in Fig. 10, leaving the middle unsupported part little more than 7 feet in length. The water raised by this plunger pump from the bucket pump below is not fit to be used for the boilers or condenser on account of its corrosive quality and the impurities it contains; it is therefore allowed to run away.

The upper plunger pump K, Figs. 7, 8, and 9, Plates 70, 71, and 72, is exactly the same in construction as the lower plunger pump, having the same size of plunger, 18 inches diameter; it pumps the water from an independent supply entering at the point L, which is 217 feet down the shaft. This water is collected in an extensive standage in an upper seam of coal shown black in the sections, Figs. 7 and 8; and being comparatively pure, so as not to injure the condensing apparatus or boilers, the whole of

it is delivered into the condensing cistern, which is thereby kept at the temperature of 50° . It is then used for all the boilers at the lower part of the works, and also for the tuyeres at the blast furnaces. This water not being of a corrosive nature, cast iron clacks are used in the upper plunger pump, fitted exactly the same as the brass clacks already described in the two other pumps.

The pipes of the rising main of 19 inches internal diameter are cast in 9 feet lengths, as shown in Fig. 26, Plate 76, the thickness of metal varying from $1\frac{5}{8}$ inch at the bottom of the rising main to 1 inch at the top of the pit, as shown in Figs. 26 and 27. The joints of the pipes are flanged joints, as shown enlarged to one quarter full size in the section, Fig. 29, and the end of each pipe is recessed 1 inch into the end of the next; the bearing faces O O are faced in the lathe, and between them is inserted a flat turned wrought iron ring, $\frac{1}{4}$ inch thick, wrapped round with tarred flannel, as shown black in Fig. 29. This is found to make a perfectly water-tight joint, the tarred flannel becoming squeezed up into the spigot and socket joint when the bolts are screwed up, as shown in Fig. 29. There are eight $1\frac{1}{2}$ inch bolts to each joint, with a bracket $1\frac{1}{2}$ inch thick cast between each bolt hole, as shown in the plan, Fig. 28; and the thickness of the flanges is the same at all the joints, as shown in Figs. 26 and 27, whatever the thickness of metal of the pipes themselves. In the whole of the pipes also the full thickness of metal, $1\frac{5}{8}$ inch, is retained for a length of $7\frac{1}{2}$ inches from the joint, to the ends of the brackets, as shown in Figs. 27 and 29.

The main pump spears, shown in the general vertical sections, Figs. 7 and 8, Plates 70 and 71, are made of pitch pine, the several lengths fitted together with butt joints in the same manner as the spears of the bucket pump already described; the joints being secured with four heavy wrought iron strapping plates, two of which are 18 feet long and the other two 16 feet long, all of them 7 inches wide and 2 inches thick in the middle, tapering to 1 inch thick at each end. The main spears are 16 inches square at the top and 15 inches square at the bottom; the five top lengths are each exactly 45 feet long, and the bottom length 50 feet long.

These spears work through heavy cast iron guides M, Figs. 30 to 32, Plate 77, which are supported on oak buntings 9 inches square resting on a cross bunting 12 inches deep by 10 inches wide, the latter serving also as a stay for the pumps. The part of the main spears which works through the cast iron guides is covered with hard wood liners or sliding pieces N about $1\frac{1}{2}$ inch thick and planed up quite true and parallel, which may be easily replaced when worn. These spear guides are placed at the third, fourth, and sixth lengths of the spears, as seen in Figs. 7 and 8. There is no guide on the fifth length of spear, passing the upper plunger pump K, Figs. 7 and 8, as there is no room on the spear to place one there; but the two plunger pumps being fixed one on each side of the main spears are so nearly balanced that little or no vibration takes place at that point. The top spear leading from the end of the engine beam is guided by the banging beams P, Fig. 33, Plate 78, on the two sides only, the back and front being left open, Fig. 34, to allow of the vibration of the spears consequent upon the arc described by the extremity of the engine beam. The second spear from the top is guided all round by wood buntings and liners fixed on the spears, as shown at Q in Figs. 7 and 8, and to a larger scale in Figs. 35 and 36, Plate 78; the front liner being made hollow and the back one convex, Fig. 36, to allow of the proper amount of vibration of the spears, which is about $3\frac{1}{2}$ inches at that point, as shown by the dotted centre lines in Fig. 36. In this view the spear is shown in the extreme position of vibration on one side of the vertical, being then at the bottom of its stroke.

There are two banging pieces RR, Figs. 33 and 34, Plate 78, clamped and bolted on each side of the main spears at the pit top, working down upon heavy oak buntings; and also two cast iron banging pieces SS, Figs. 30 and 31, Plate 77, about 130 feet down the shaft, which is as low as they can be placed. These are fixed by 2 inch bolts on the sides of the main spear, and work down upon two oak buntings 16 inches square, which rest at one end for about $2\frac{1}{2}$ feet length in the shaft side, and at their outer ends on another oak bunting in front of the main spears, 4 feet 11 inches deep and 14 inches thick, going fully 3 feet into the shaft side at each

end. These buntings with those at the top of the shaft form a secure resting place for the main spears when the engine is out of the house; and it is hoped they would be strong enough to stop the fall of the spears in case one of the clacks should ever break or any part of the pumps or rising main should burst. Figs. 30 to 34 show the spears at the bottom of the stroke, with the banging pieces R and S just clear of the banging beams. In ordinary working the equilibrium valve of the engine is shut at such a point that the banging pieces on the spears never touch the banging beams. The rising mains I of the pumps are stayed at every third pipe by wrought iron straps passing round the pipe and screwed through the buntings, as shown in Figs. 35 and 36, Plate 78, so that should a pipe require changing it would not be necessary to remove a single bunting; and the buntings are fixed so firmly in the shaft side that it would be rather a serious matter to remove one.

In Figs. 7, 8, and 11, Plates 70 to 72, is shown the recess U made in the shaft side for the purpose of packing and examining the glands of the plunger pumps F and K, so that the man may be entirely out of danger in the shaft. In Fig. 9 there is a recess for the suction pipe of the upper plunger pump K to pass through to the well L, and in Fig. 10 a similar recess to the well E for the suction pipe of the lower plunger pump F; the suction pipe is scaffolded over, and forms a platform to stand upon out of the shaft for changing and examining the clacks, thus keeping the shaft quite clear for repairs when needed.

In the rising main of each of the plunger pumps is placed a 2 inch valve with a pipe leading back to the well from which the pump draws, for the purpose of regulating the supply of water to each pump. These valves are worked by rods from the surface, and there are three floats, one in each of the plunger pump wells and the third in the well S at the bottom of the shaft, Figs. 7 and 8, Plates 70 and 71. The tops of the float rods are in sight of the engineman, so that by means of the return valves part of the water can be allowed to run back into either of the plunger pump wells, in order to keep the water level always above the top of the windbore, whereby the pumps are kept fully supplied with water, and always,

as it is termed, "working on the solid." From each of the plunger pump wells an overflow pipe V, Figs. 7 and 8, is taken, one 6 inches and the other 8 inches bore, to allow any irregularity of supply to run to the bottom of the shaft.

As the engine is single-acting, the moving pit work has to be heavy enough to balance not only the column of water in each of the two plunger pumps, but also the piston, parallel motion, plug rods, and all the work hanging on the beam inside the engine house. The moving pit work &c. on the outer end of the beam weighs a little more than 34 tons, and the weight of the two columns of water is about 24 tons, leaving a balance of more than 10 tons in excess upon the outer end of the beam to overcome the weight of the piston and the work on the inner end of the beam, which amounts to rather more than 7 tons, thereby leaving an excess of weight of about 3 tons to overcome the friction of the pit work, and to give the necessary speed of motion to the water in the rising mains.

This engine has purposely been made larger than is necessary for the present requirements of the colliery, in order to allow for considerable future extension of the workings without the need of again increasing the engine power for drainage. In consequence of the engine being thus too large at present for the work to be done, it does not yet admit of expansion being carried to any high degree; for the total mass set in motion by the engine amounts at present to only about 54 tons, taking the effective inertia of the beam as equal to 6 tons collected at the extremities; which is not sufficient to control the velocity of the stroke at starting within the limits that are safe for the pump work, unless the degree of expansion be very limited, so as to allow of a comparatively low initial pressure of steam.

The accompanying indicator diagrams, Figs. 37 to 40, Plate 79, show the working of the engine under different degrees of expansion. Fig. 37 shows the diagram obtained in an experiment in which the steam was cut off at 71 per cent. of the stroke, which is about the limit of expansion considered prudent for experiment, on

account of the risk of damage to the pit work from the concussion produced at the beginning of each steam stroke by the sudden snatch of the engine upon the pump rods. Fig. 38 shows a lower degree of expansion, with the steam cut off at 82 per cent. of the stroke; and Fig. 39 shows the diagram obtained when the steam is cut off at 84 per cent. of the stroke, and Fig. 40 at 91 per cent., which is about the range of expansion used in regular working. The boiler pressure was 14 lbs. per square inch above the atmosphere, but throttled down to about 8 lbs. on admission to the cylinder. The boilers are not at present roofed over nor covered at the top, nor are the steam pipes from them coated in any way; and the construction of the boilers, plain egg-ended boilers with the flue underneath divided by a middle wall, giving only one return of the heat under the boiler, is not adapted for an economical consumption of fuel; the evaporative duty obtained is consequently only about $3\frac{1}{2}$ to 4 lbs. of water per lb. of coal slack. Under these circumstances the duty at present attained by the engine amounts to only about 27 million lbs. raised 1 foot high by the consumption of 1 cwt. of slack.

Each of the two pumps delivers about 108 or 110 gallons of water at each stroke, according to the length of stroke allowed to the engine. The number of strokes the engine is making at the present time is 4 per minute for twelve hours, delivering about 52,000 gallons per hour, and the engine standing the other twelve hours. It has worked up to 7 or 8 strokes per minute for a very short time, and as slow as $\frac{3}{4}$ stroke per minute. The quantity of water in the colliery fluctuates a great deal, requiring a corresponding variation in the rate of working the engine: during the past summer about $1\frac{1}{2}$ strokes per minute during the twelve hours cleared the colliery of water; but now it requires about 4 strokes per minute to drain the workings in the same time.

The CHAIRMAN observed that the paper now read contained a great deal of practical information, and gave very ample details of the construction and working of the large pumping engine. The adoption of the wrought iron engine beam was a feature of particular interest after the terrible accident that had occurred at the Hartley Colliery by the breaking of the large cast iron beam. In the wrought iron beam described in the paper the two massive slabs composing it were of such dimensions that it would not have been thought practicable a few years earlier to produce them at any ironworks. Now however that this had been so successfully accomplished in the Clay Cross beam, it would probably lead to the introduction of similar large wrought iron beams wherever there were any great strains to be borne, in order to prevent any risk of the recurrence of such a terrible catastrophe as that at Hartley.

Mr. F. J. BRAMWELL observed that in reference to the reasons for adopting the Cornish pumping engine for draining the colliery at Clay Cross, in preference to a rotary pumping engine, it had been mentioned that with the latter, if the pump should ever be only half filled with water from any defect of the valves, the plunger meeting the water at half stroke would produce a concussion so violent as to risk breaking some of the machinery. But he thought the same objection applied equally to the Cornish engine, as he did not see what there was to restrain the violence of the concussion except the water itself in the pump barrel. He enquired whether there was any special self-acting arrangement in connexion with the equilibrium valve for partially closing the valve and wiredrawing the steam in the event of the plunger missing its stroke or the first portion of its stroke.

Mr. HOWE replied that there was no arrangement for closing the equilibrium valve in case of the engine ever going out of doors at an excessive speed; but the valve itself was of small area, and would thereby have some effect in checking though not entirely preventing too rapid an outdoor stroke. In crank pumping engines he had seen many serious breakages of the machinery in consequence of the plunger missing the first part of its stroke and then suddenly meeting the water in the pump; and in such engines the danger of

injury from the concussion was heightened by the circumstance that the force of the concussion arose not merely from the momentum of the moving parts, but was further increased by the engine power, in consequence of the steam continuing to act in the cylinders, so that the plunger was driven down upon the water by the full power of the engine. In the Cornish engine on the other hand, while the concussion was no doubt equally severe as far as it arose from the momentum of the plunger and pump rods, it was not further augmented by any engine power, as the pump rods made the down stroke by their own weight alone, without any aid from the steam. Moreover as the liability of a valve to stick once during any period of time was in proportion to the number of times it had to open and shut in that time, there would be greater risk of such concussions in the pumps with a rotary pumping engine running quick than with a large Cornish engine making a smaller number of strokes.

Mr. F. J. BRAMWELL concurred in the greater risk of a valve sticking in a large number of short strokes as compared with a few long strokes, since of course the oftener it had to open, the greater was the risk of its sticking. But in other respects he did not see that the Cornish engine possessed the advantage which had been attributed to it over a rotary engine with crank and flywheel, and thought on the contrary the advantage was on the other side. In the Cornish engine there was certainly nothing else beyond the momentum of the pump rods and plunger to produce a concussion when the plunger met the water at half stroke; but then, in consequence of the massiveness and weight of those parts in a Cornish engine, their momentum was far in excess of that in a crank engine: and though in the latter engine the steam was continuing to exert its force in the cylinder during the stroke of the pump, yet the addition of the heavy flywheel completely controlled the speed of the engine, and prevented it from running off instantly if ever the pump missed the beginning of its stroke; whereas in the Cornish engine, as soon as the equilibrium valve was once opened, the engine immediately went off unrestrained in the outdoor stroke, without any provision for checking its motion in the event of an accident. He therefore thought the concussion produced by such

an accident would be far greater in the Cornish engine than in a rotary pumping engine with crank and flywheel.

Mr. E. A. COWPER enquired what was the reason why double-beat valves were not employed in place of the clack valves in the pumps of the engine described in the paper. Double-beat valves were used he observed for the steam cylinder, and they were almost universally adopted in Cornish engines where it was desired to work the steam to a good degree of expansion.

Mr. HOWE replied that the clack valves in the pumps had been adopted because they were so simple in construction, and because there were not such skilled mechanics to be had at collieries as at waterworks for keeping the valves of the pump work in order. The simple clack valves in the pumps had been found to work remarkably well, and stood the work well, as they had not been looked at now for $\frac{3}{4}$ year since the pumps were first started. The concussion produced by the valve lids closing was very slight, and scarcely perceptible except when the engine was worked at a high speed; it was most apparent at the end of the indoor stroke of the engine, when the suction valves in the pumps were closing previous to the down stroke of the plunger.

Mr. E. A. COWPER observed that such valves were certainly not suitable for any high speed of working, on account of the violent concussion they would then produce in closing; but in the engine now described the degree of expansion of the steam was so limited that he thought it could scarcely be regarded as a Cornish engine, but rather as an example of the early Boulton and Watt style of engine. In the present instance however there was probably no particular need for economy in the consumption of coal; and this seemed to be the case from the boilers being of the plain cylindrical form, instead of Cornish boilers with an internal flue.

Mr. J. FERNIE believed the single-beat pump valves were generally adopted for collieries on account of the dirty water to be pumped, while the double-beat valves were confined to waterworks where the water was clear.

Mr. J. R. WARHAM said that was the case, and no doubt the double-beat valves were the best; but in collieries there was so

much dirt and sand mixed with the water in the process of sinking, all of which had to pass through the pump valves, that double-beat valves would involve too much trouble and expense in keeping them in working order.

Mr. E. A. COWPER enquired whether a sufficient degree of vacuum was obtained in the condenser in regular work; he thought the vacuum would be produced more quickly and efficiently if the injection water were admitted in a thinner stream and more divided form, by means of a conical injection valve throwing a thin conical sheet of water violently against the sides of the condenser, so as to present a greater extent of cooling surface for condensing the steam rapidly.

Mr. HOWE replied that at the usual working speed of not more than four strokes per minute the vacuum in the condenser was $13\frac{1}{2}$ lbs.; but in running at a higher speed, about five strokes per minute, the injection was found rather deficient, and had therefore subsequently been increased. The injection opening was so placed as to throw the water against the opposite side of the condenser, in order to make the water splash and expose a greater surface to the steam.

The CHAIRMAN asked what had been the extra cost of the wrought iron engine beam as compared with a cast iron beam of the same size.

Mr. HOWE replied that at the time of originally designing the engine it was intended to have a cast iron beam, but just then the Hartley accident occurred, and it was therefore determined to adopt a wrought iron beam; and the extra cost of the present wrought iron beam had been £480 above that of a cast iron beam for the same engine.

Mr. J. FERNIE had had an opportunity of seeing the engine at work at Clay Cross Colliery, and had been greatly pleased with the excellent workmanship and ample strength of all its parts and the substantial nature of the pump gear. The great feature was certainly the large wrought iron beam, made of two very strong wrought iron slabs rolled solid throughout their entire length of 36 feet, and 7 feet wide in the centre. There had been other designs also

for wrought iron engine beams since the Hartley accident, and he understood a large wrought iron beam was now being made at Wednesbury of thin plates rivetted together.

The CHAIRMAN said the wrought iron beam in process of construction at his own works at Wednesbury was being made of a number of plates rivetted together, simply as a cheaper mode of construction than the use of solid-rolled massive slabs of the large size required. The rivetted beam would of course not be so solid and not quite so strong for the same thickness as the solid-rolled beam at Clay Cross; but its strength might be made up to the required amount by adding a sufficient number of thicknesses of plates. The total length of the rivetted beam was 28 feet, and the depth in the centre 4 feet; it was composed of two slabs, each made up of three plates of $\frac{3}{4}$ inch thickness rivetted together, making a total thickness of $2\frac{1}{4}$ inches for each slab. He enquired what had been the total cost of the Clay Cross pumping engine without the boilers or pumps.

Mr. HOWE replied the total cost of the engine alone, including the wrought iron beam, but without the boilers, engine house, or pumps, was £3130; and including the boilers, engine house, and chimney, the total cost was under £5000. The pumps and pump rods cost about £2500 extra.

The CHAIRMAN asked how the joints of the rising main in the pumps were found to stand in work; and what means was provided for descending the pump shaft to examine the valves and pack the glands.

Mr. HOWE replied that he had found the whole of the joints of the rising main stood perfectly water-tight in work; the construction of the joints was very simple, having merely the turned wrought iron ring wrapped round with tarred flannel inserted between the turned bearing faces of the joint. For examining the valves and packing the glands a small separate winding engine was provided, for ascending and descending the shaft by means of a bucket, independent of the pumping engine.

Mr. J. FERNIE exhibited a new construction of indicator of American invention (Richards'), with which he had taken the

diagrams from the Clay Cross engine. It had a much shorter stroke than the ordinary indicator, with a proportionately stronger spring, and the motion was multiplied by the long arm of a very light lever carrying the pencil, which was made to move in a straight line by means of a light parallel motion; the movement of the pencil was more steady and free from jumping, in consequence of the diminution of speed of piston from the shortness of stroke and the greater strength of the spring, and the figures obtained showed a very clear and steady line.

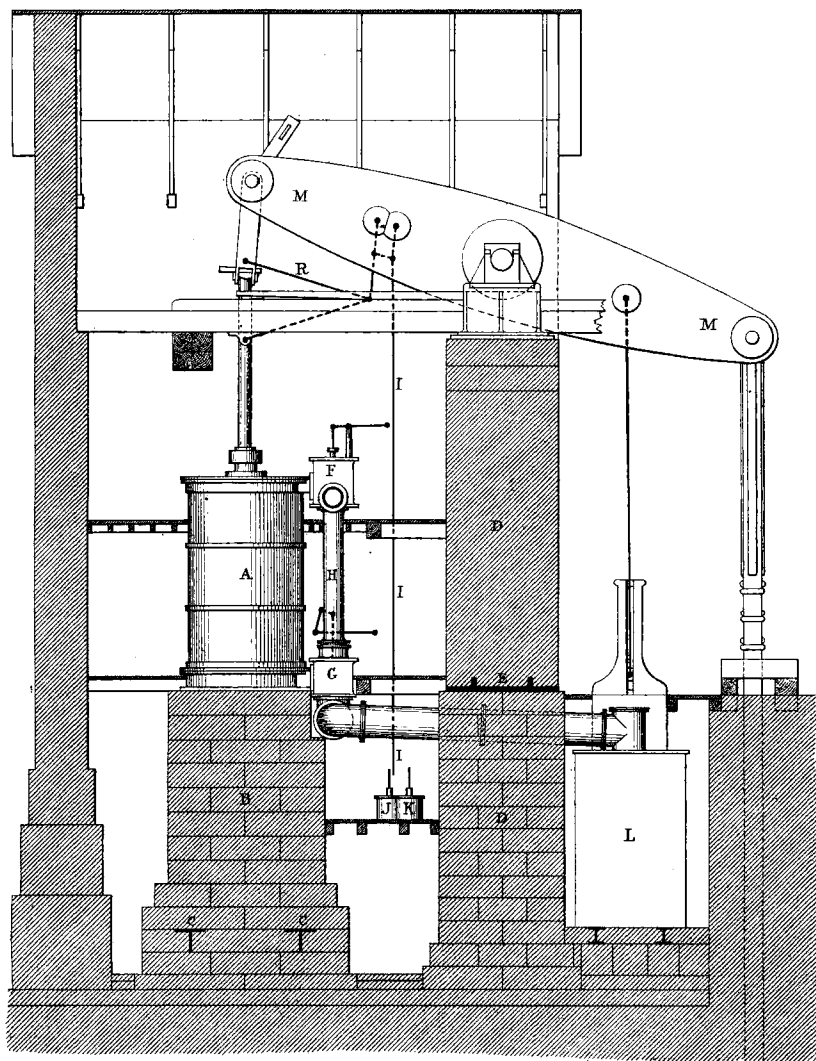
Mr. E. A. COWPER had no doubt such an indicator would work steadily; he had many years ago designed such a one, and Mr. Gooch made one on the same principle, with which steady diagrams had been obtained from locomotives on the Great Western Railway running up to a speed of more than 60 miles an hour.

Mr. F. W. WEBB said he had used the Richards' indicator for taking diagrams from the "Lady of the Lake" outside cylinder express locomotive on the London and North Western Railway the engine shown in the International Exhibition of 1862; and the diagrams obtained with it were perfectly steady up to 65 miles an hour. By having a second barrel for the paper, so as to change the paper quickly, as many as three dozen diagrams had been taken with the indicator from that engine in 40 minutes time, in running the 25 miles from Crewe to Stafford.

The CHAIRMAN proposed a vote of thanks to Mr. Howe for his paper; which was passed.

The following paper was then read:—

Fig. 1. *Side Elevation of Engine.*



Scale 1/150.th



CLAY CROSS PUMPING ENGINE.

Plate 68.

Fig 2. Longitudinal Section and Elevation of Wrought Iron Beam.

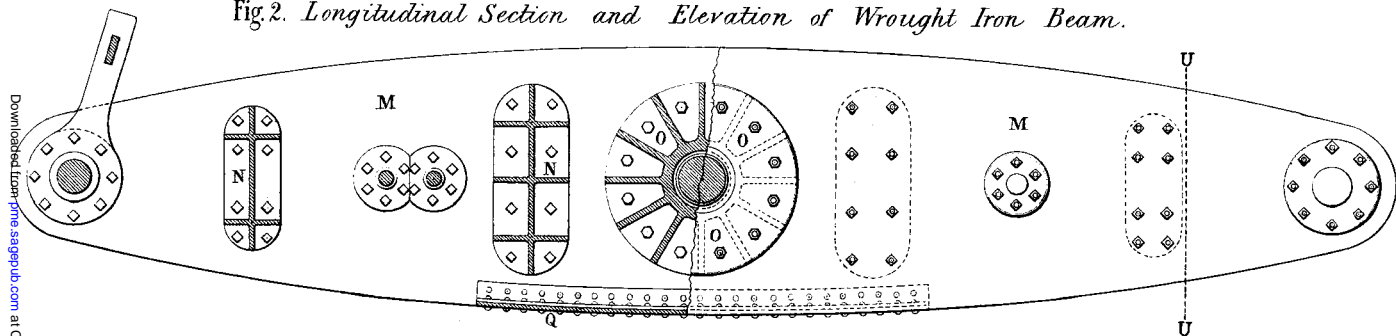
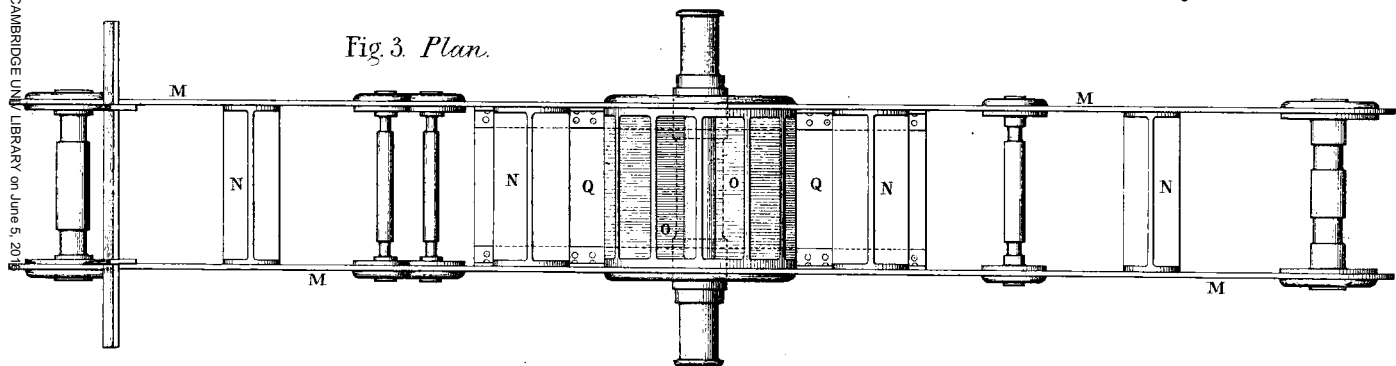


Fig 3. Plan.



Scale 1/60th 0 5 10 15 20 25 30 Feet.
(Proceedings Inst. M.E. 1863. Page 248.)

CLAY CROSS PUMPING ENGINE. *Plate 69.*
Transverse Sections of Wrought Iron Beam.

Fig 4. *At Centre.*

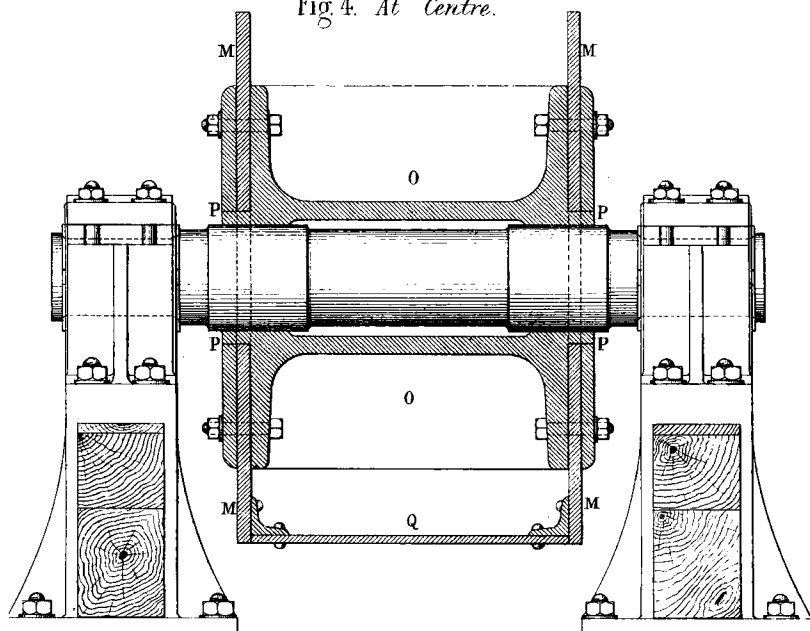


Fig 5. *At UU (Fig. 2)*

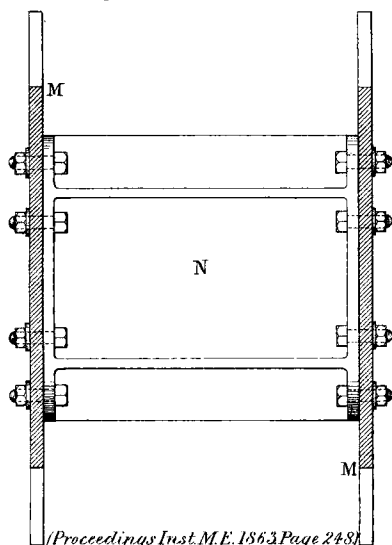
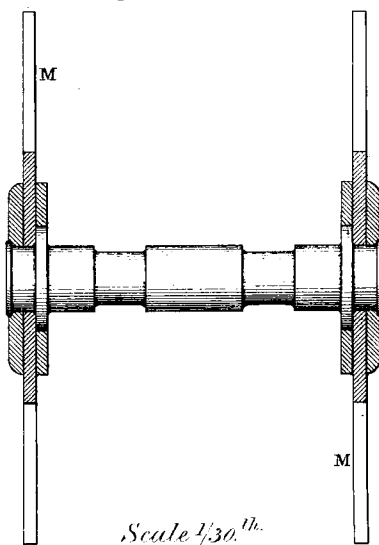
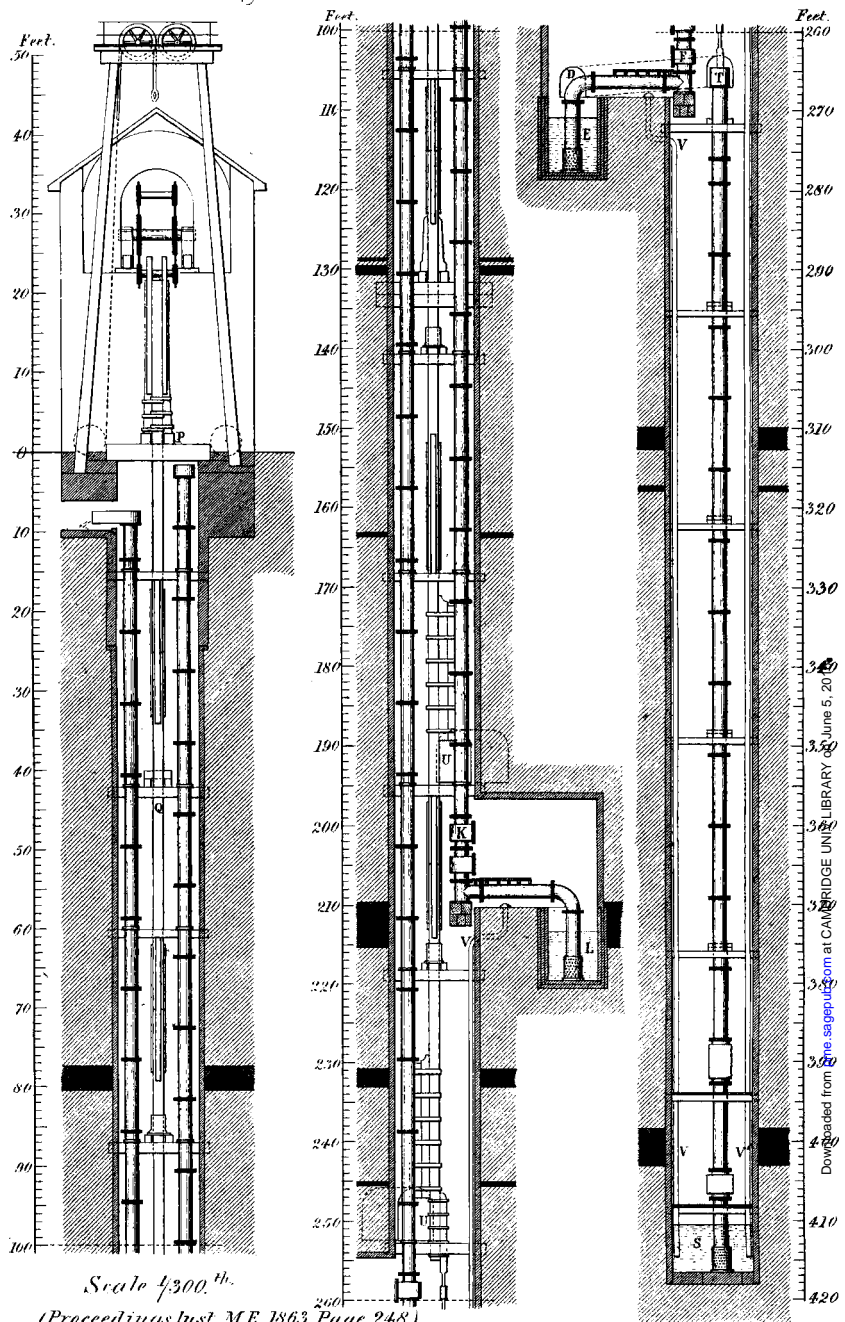


Fig 6. *At End.*



Scale 1/30th.

Fig 7. *Vertical Section of Pit.*



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CLAY CROSS PUMPING ENGINE.

Plate 71.

Fig. 8. *Vertical Section of Pit. taken at right angles to Fig. 7.*

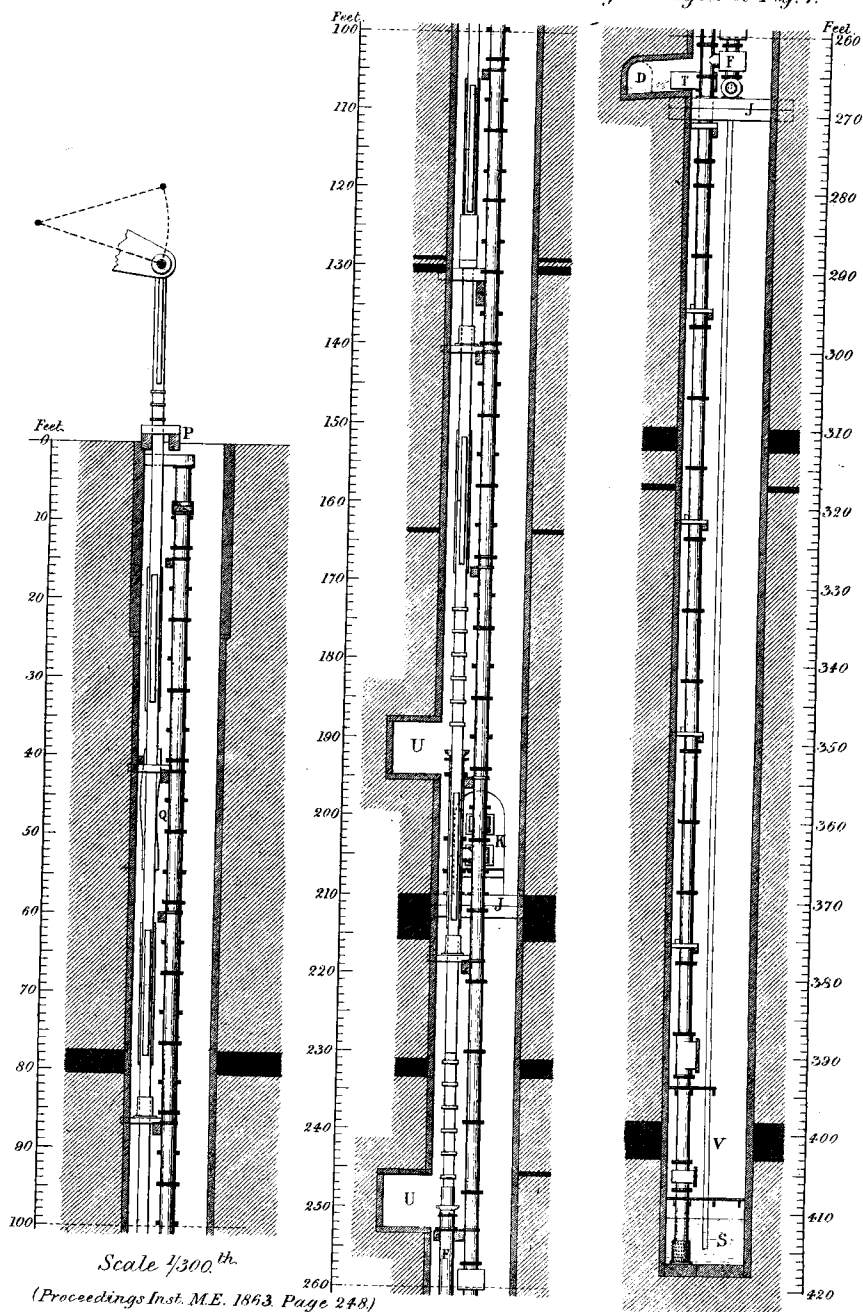


Fig. 9. *Sectional Plan of Pit at Upper Plunger Pump.*

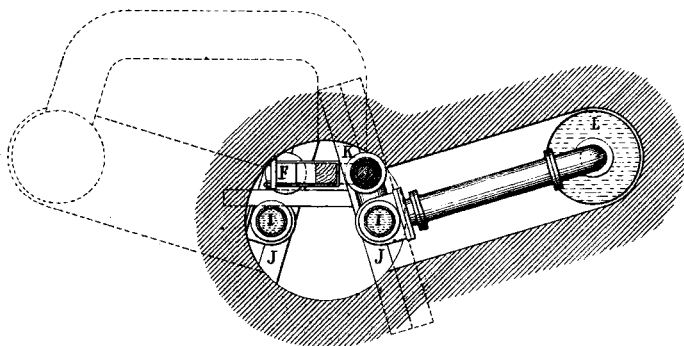


Fig. 10. *Sectional Plan of Pit at Lower Plunger Pump.*

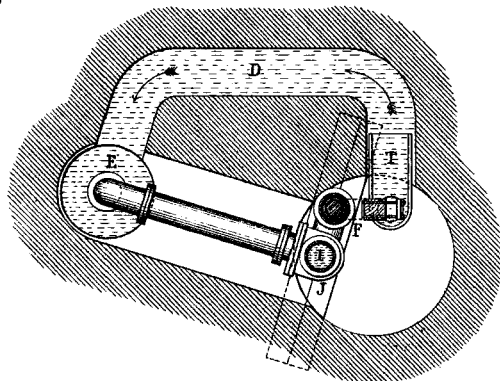
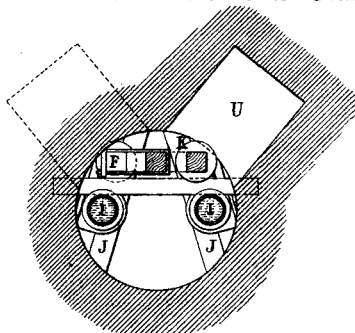


Fig. 11. *Sectional Plan of Pit at Gland of Plunger Pump.*



Scale $\frac{1}{150}^{th}$.

0 10 20 30 40 Feet.

CLAY CROSS PUMPING ENGINE. *Plate 73.*

Bucket Pump.

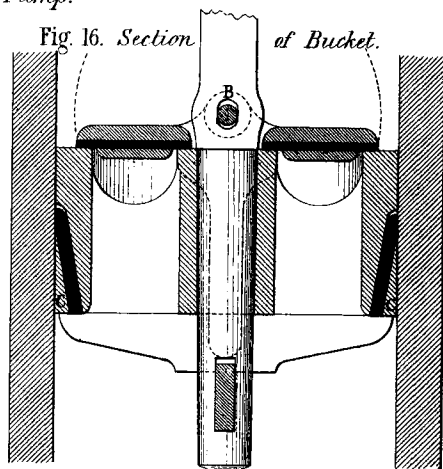
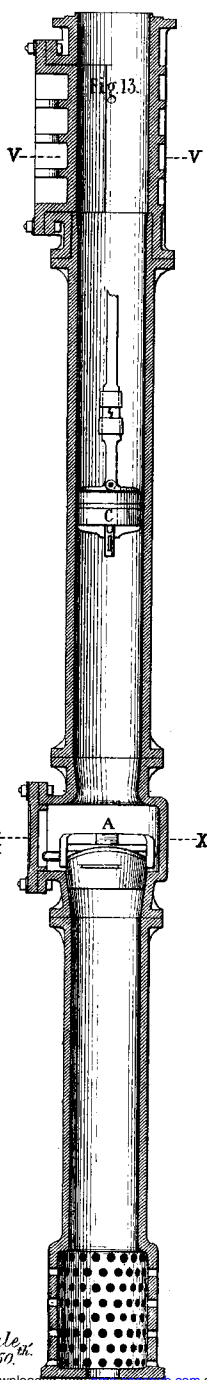
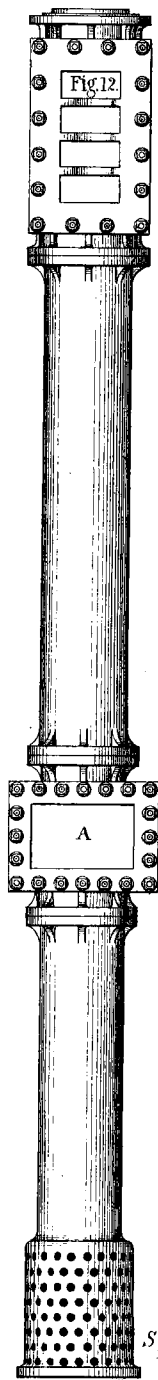
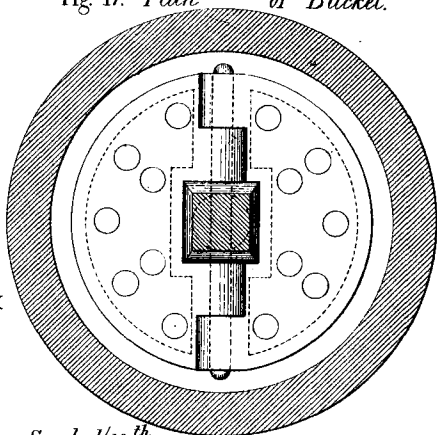


Fig. 17. Plan of Bucket.



Scale $\frac{1}{10}^{th}$.
0 5 10 15 Inches. 20

Fig. 14. Sectional Plan at VV.

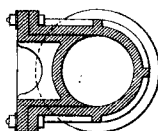
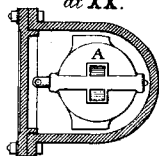


Fig. 15. Sectional Plan at XX.



Scale $\frac{1}{50}^{th}$.

(Proceedings Inst. M.E. 1863, Page 248.)

CLAY CROSS PUMPING ENGINE.

Plate 74.

Detail of Pump Clacks, enlarged.

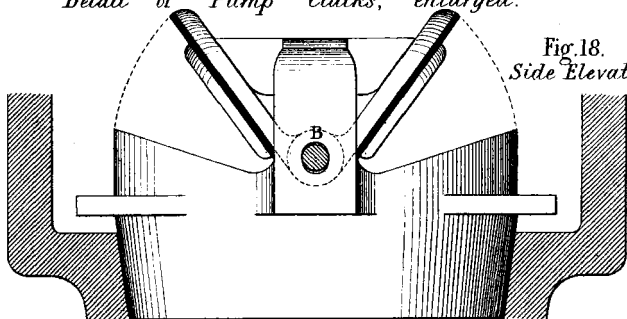


Fig. 18.
Side Elevation.

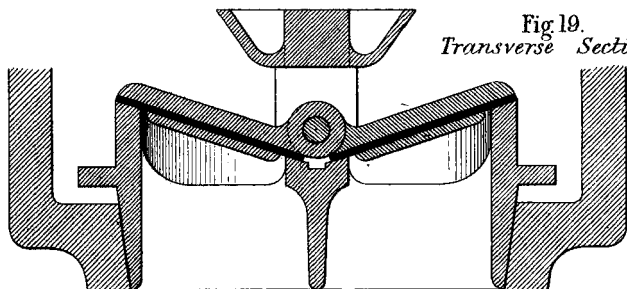


Fig. 19.
Transverse Section.

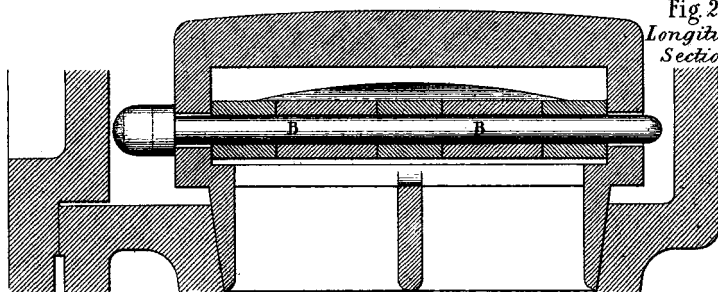


Fig. 20.
Longitudinal Section.

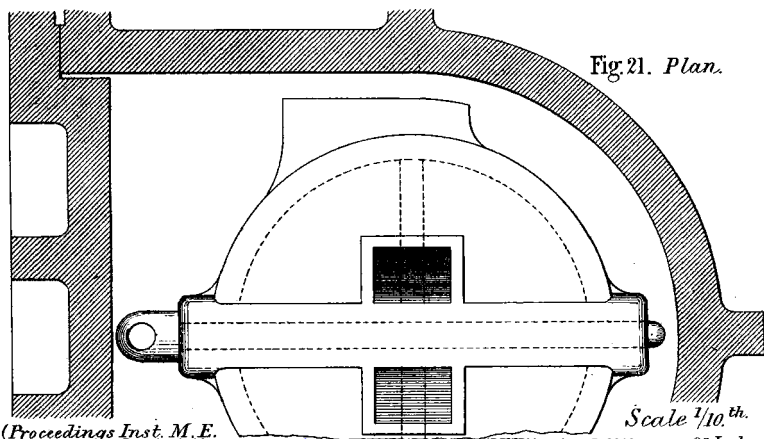


Fig. 21. *Plan.*

Scale $\frac{1}{10}$ th.
20 Inches.

CLAY CROSS PUMPING ENGINE.

Plate 75.

Plunger Pumps.

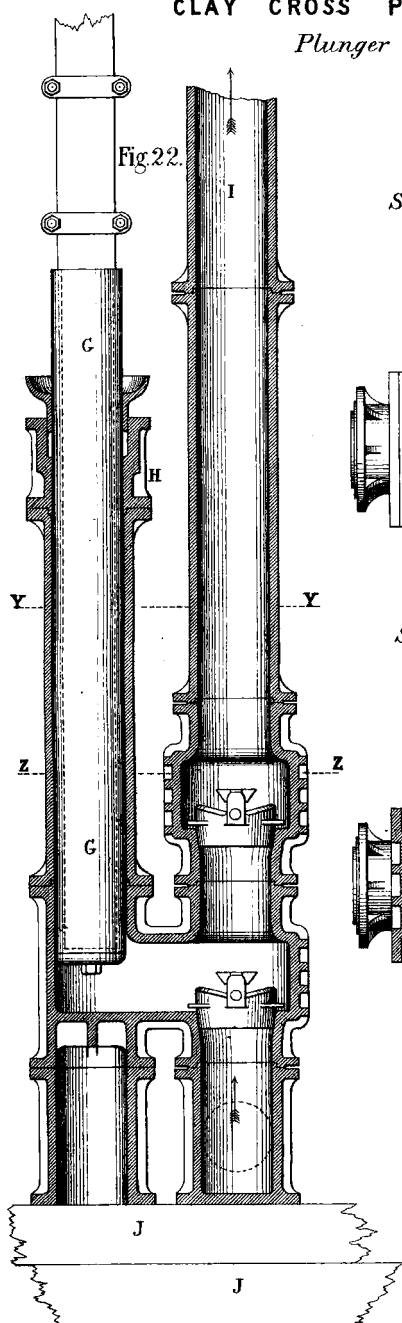


Fig. 22.

Fig. 24.
Sectional Plan
at YY.

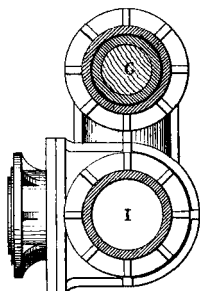


Fig. 25.
Sectional Plan
at ZZ.

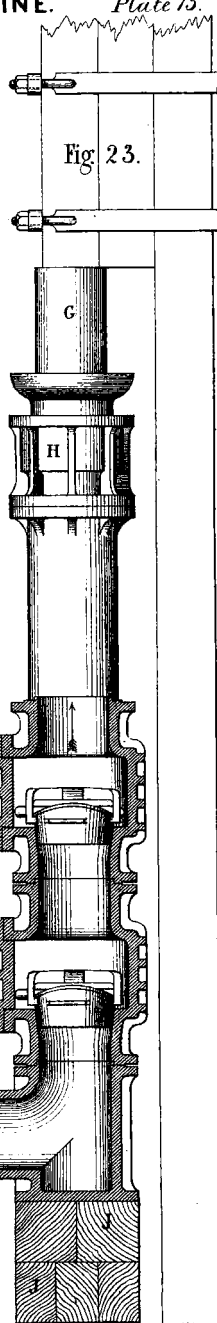
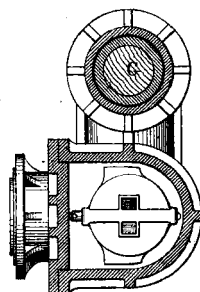


Fig. 23.

(Proceedings Inst. M.E. 1863, Page 248.)

Scale 1/50th.

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Feet.

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CLAY CROSS PUMPING ENGINE. *Plate 76.*

Joints of 19 inch Rising Mains of Pumps.

Fig.26. *At bottom of Main.*

Fig.27. *At top of Main.*

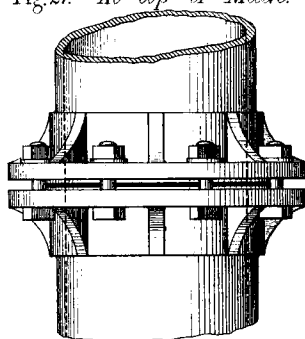
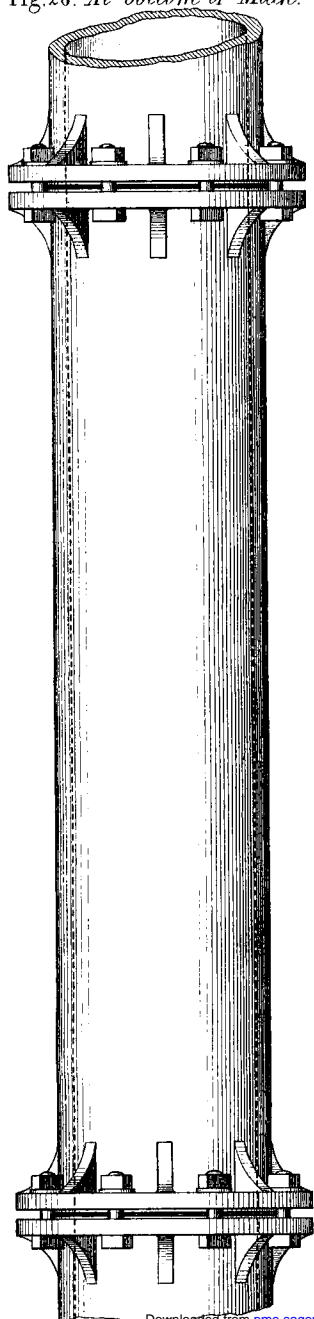


Fig.29. *Enlarged Section of Joint.*
Scale 1/4.th

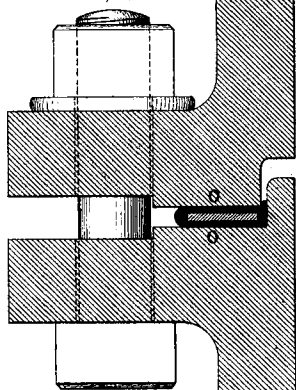
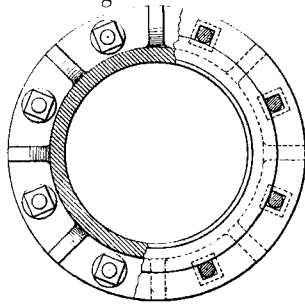


Fig.28. *Plan.*



Scale 1/20.th

10 5 0 10 20 30 Inches.

(*Proceedings Inst. M.E. 1863, Page 248.*)

Fig. 30.

*Banging Beams
and Spear Guides
in pit.*

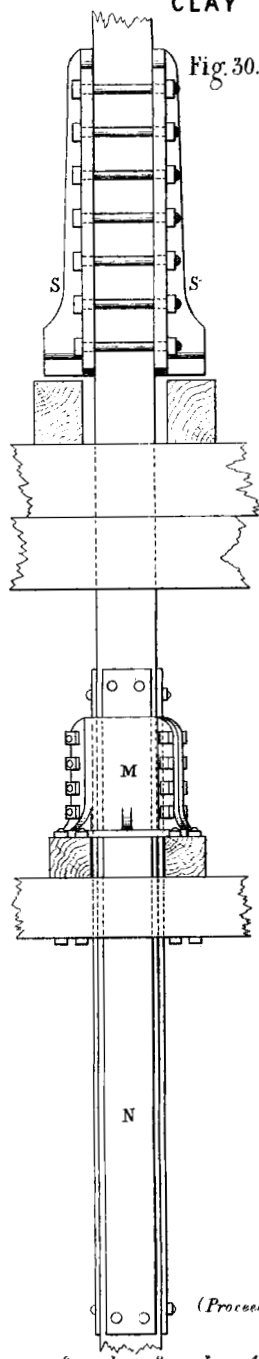


Fig. 31.

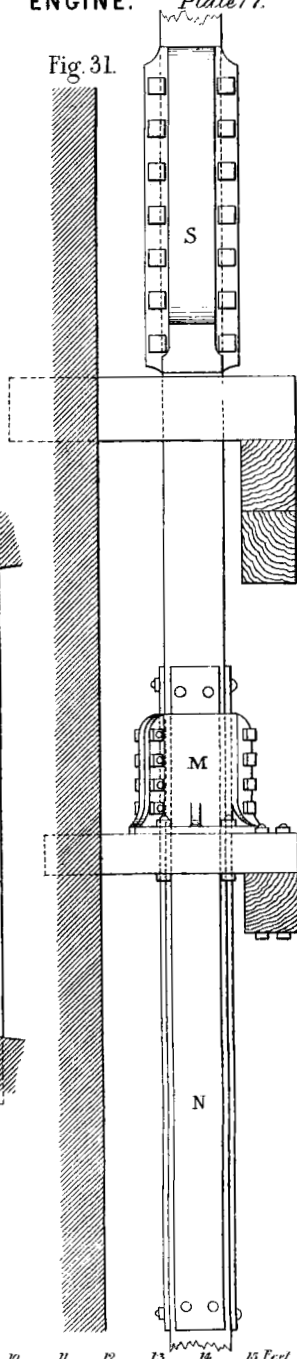
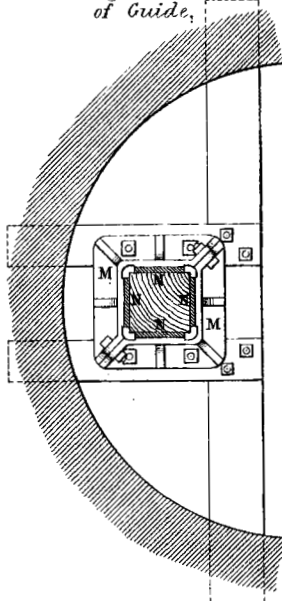


Fig. 32. *Plan
of Guide.*



(*Proceedings Inst. M.E. 1863. Page 248.*)

Scale 1/50th.

Banging Beams at top of Pit.

Fig. 33.

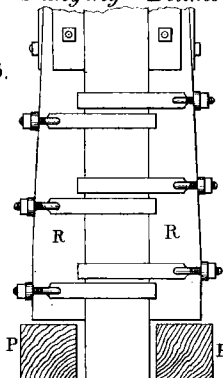


Fig. 34.

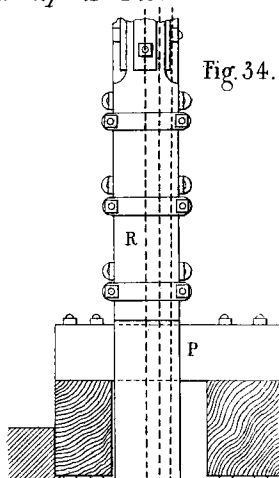
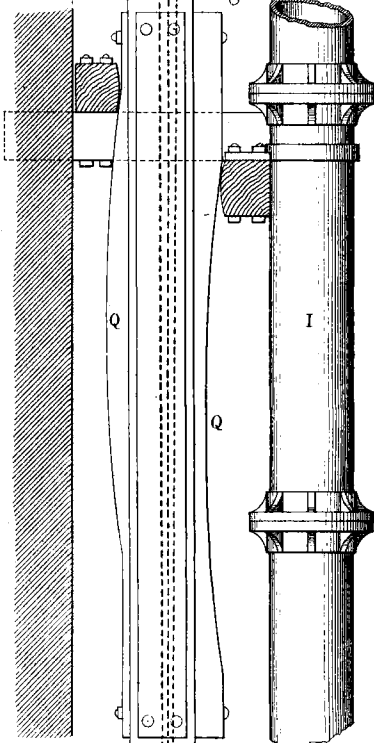
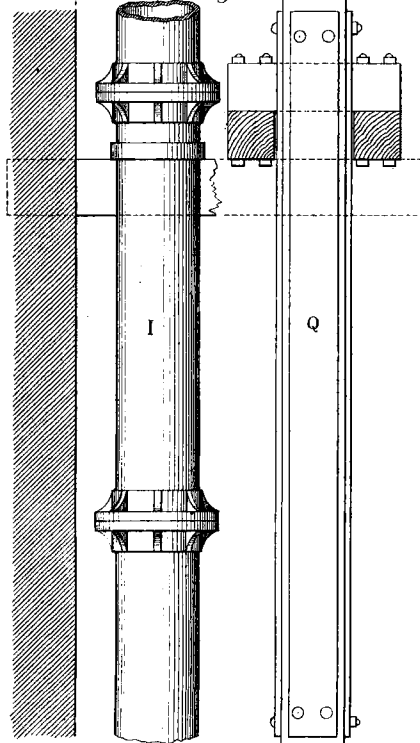


Fig. 35.

Top Spear Guide.

Fig. 36.



Indicator Diagrams.

Steam Pressure in Boilers 14 lbs. per square inch above atmosphere.

Fig 37. Steam cut off at 71 per cent. of stroke.

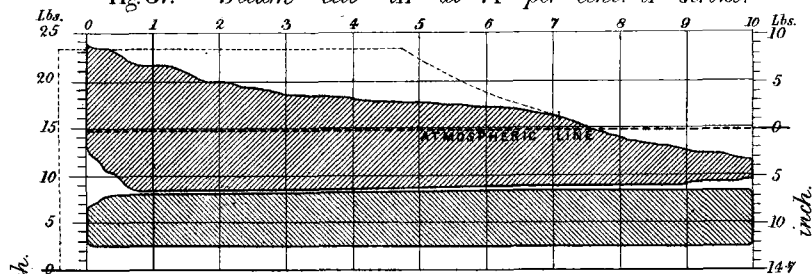


Fig 38. Steam cut off at 82 per cent. of stroke.

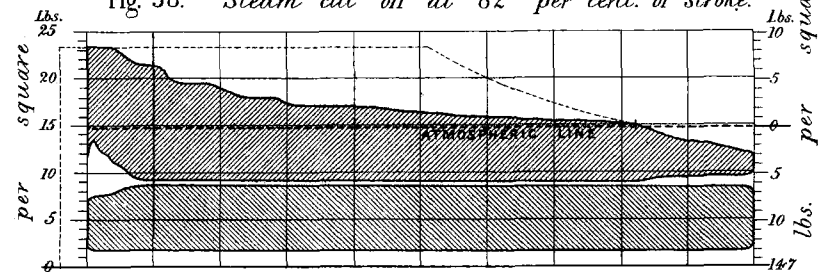


Fig 39. Steam cut off at 84 per cent. of stroke.

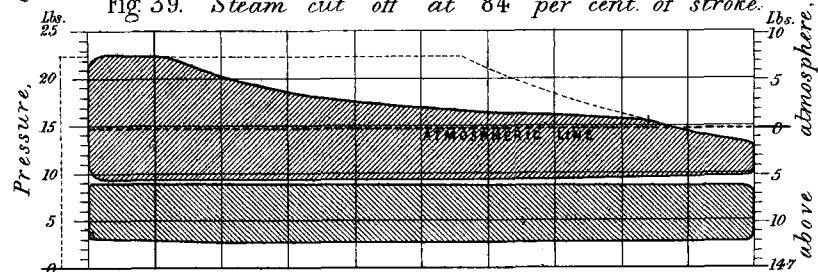


Fig 40. Steam cut off at 91 per cent. of stroke.

