CHAPTER X.

EXAMPLES OF ENGINES.

OSCILLATING PADDLE ENGINES.

618. *Q.*—Will you describe the structure of an oscillating engine as made by Messrs. Penn?

A.—To do this it will be expedient to take an engine of a given power, and then the sizes may be given as well as an account of the configuration of the parts: we may take for an example a pair of engines of $21\frac{1}{2}$ inches diameter of cylinder, and 22 inches stroke, rated by Messrs. Penn at 12 horses power each. The cylinders of this oscillating engine are placed beneath the cranks, and, as in all Messrs. Penn's smaller engines, the piston rod is connected to the crank pin by means of a brass cap, provided with a socket, by means of which it is cuttered to the piston rod. There is but one air pump, which is situated within the condenser between the cylinders, and it is wrought by means of a crank in the intermediate shaft—this crank being cut out of a solid piece of metal as in the formation of the cranked axles of locomotive engines. The steam enters the cylinder through the outer trunnions, or the trunnions adjacent to the ship's sides, and enters the condenser through the two midship trunnions—a short three ported valve being placed on the front of the cylinder to regulate the flow of steam to and from the cylinder in the proper manner. The weight of this valve on one side of the cylinder is balanced by a weight hung upon the other side of the cylinder; but in the most recent engines this weight is discarded, and two valves are used, which balance one another. The framing consists of an upper and lower frame of cast iron, bound together by eight malleable iron columns: upon the lower frame the pillow blocks rest which carry the cylinder trunnions, and the condenser and the bottom frame are cast in the same piece. The upper frame supports the paddle shaft pillow blocks; and pieces are bolted on in continuation of the upper frame to carry the paddle wheels, which are overhung from the journal.

619. *Q.*—What are the dimensions and arrangement of the framing?

A.—The web, or base plate of the lower frame is $\frac{3}{4}$ of an inch thick, and a cooming is carried all round the cylinder, leaving an opening of sufficient size to permit the necessary oscillation. The cross section of the upper frame is that of a hollow beam 6 inches deep, and about $3\frac{1}{2}$ inches wide, with holes at the sides to take out the core; and the thickness of the metal is $\frac{13}{16}$ths of an inch. Both the upper and the lower frame is cast in a single piece, with the exception of the continuations of the upper frame, which support the paddle wheels. An oval ring 3 inches wide is formed in the upper frame, of sufficient size to permit the working of the air pump crank; and from this ring feathers run to the ends of the cross portions of the frame which supports the intermediate shaft journals. The columns are $1\frac{1}{2}$ inches in diameter; they are provided with collars at the lower ends, which rest upon bosses in the lower frame, and with collars at the upper ends for supporting the upper frame; but the upper collars of two of the corner columns are screwed on, so as to enable the columns to be drawn up when it is required to get the cylinders out. The cross section of the bottom frame is also of the form of a hollow beam, 7 inches deep, except in the region of the condenser, where it is, of course, of a different form. The depth of the boss for the reception of the columns is a little more than 7 inches deep on the lower frame, and a little more than 6 inches deep on the upper frame; and the holes through them are so cored out, that the columns only bear at the upper and lower edges of the hole, instead of all through it—a formation by which the fitting of the columns is facilitated.

620. *Q.*—What are the dimensions of the condenser?

A.—The condenser, which is cast upon the lower frame, consists of an oval vessel 22½ inches wide, by 2 feet 4¼ inches long, and 1 foot 10½ inches deep; it stands 9 inches above the upper face of the bottom frame, the rest projecting beneath it; and it is enlarged at the sides by being carried beneath the trunnions.

621. *Q.*—What are the dimensions of the air pump?

A.—The air pump, which is set in the centre of the condenser, is 15¼ inches in diameter, and has a stroke of 11 inches. The foot valve is situated in the bottom of the air pump, and its seat consists of a disc of brass, in which there is a rectangular flap valve, opening upwards, but rounded on one side to the circle of the pump, and so balanced as to enable the valve to open with facility. The balance weight, which is formed of brass cast in the same piece as the valve itself, operates as a stop, by coming into contact with the disc which constitutes the bottom of the pump; the disc being recessed opposite to the stop to enable the valve to open sufficiently. This disc is bolted to the barrel of the pump by means of an internal flange, and before it can be removed the pump must be lifted out of its place. The air pump barrel is of brass to which is bolted a cast iron mouth piece, with a port for carrying the water to the hot well; within the hot well the delivery valve, which consists of a common flap valve, is situated. The mouth piece and the air pump barrel are made tight to the condenser, and to one another, by means of metallic joints carefully scraped to a true surface, so that a little white or red lead interposed makes an air tight joint. The air pump bucket is of brass, and the valve of the bucket is of the common pot lid or spindle kind. The injection water enters through a single cock in front of the condenser—the jet striking against the barrel of the air pump. The air pump rod is maintained in its vertical position by means of guides, the lower ends of which are bolted to the mouth of the pump, and the upper to the oval in the top frame, within which the air pump crank works; and the motion is communicated from this crank to the pump rod by means of a short connected rod. The lower frame is not set immediately below the top frame, but $2\frac{1}{2}$ inches behind it, and the air pump and condenser are $2\frac{1}{2}$ inches nearer one edge of the lower frame than the other.

622. *Q.*—What are the dimensions of the cylinder?

A.—The thickness of the metal of the cylinder is $\frac{9}{16}$ths of an inch; the depth of the belt of the cylinder is $9\frac{1}{2}$ inches, and its greatest projection from the cylinder is $2\frac{1}{2}$ inches. The distance from the lower edge of the belt to the bottom of the cylinder is $11\frac{1}{2}$ inches, and from the upper edge of the belt to the top flange of the cylinder is 9 inches. The trunnions are $7\frac{1}{4}$ inches diameter in the bearings, and $3\frac{1}{2}$ inches in width; and the flanges to which the glands are attached for screwing in the trunnion packings are $1\frac{1}{2}$ inch thick, and have $\frac{7}{8}$ths of an inch of projection. The width of the packing space round the trunnions is $\frac{5}{8}$ths of an inch, and the diameter of the pipe passing through the trunnion $4\frac{5}{8}$ths, which leaves $\frac{11}{16}$ths for the thickness of the metal of the bearing. Above and below each trunnion a feather runs from the edge of the belt or bracket between 3 and 4 inches along the cylinder, for the sake of additional support; and in large engines the feather is continued through the interior of the belt, and cruciform feathers are added for the sake of greater stiffness. The projection of the outer face of the trunnion flange from the side of the cylinder is $6\frac{1}{2}$ inches; the thickness of the flange round the mouth of the cylinder is $\frac{3}{4}$ of an inch, and its projection $1\frac{3}{8}$ inch; the height of the cylinder stuffing box above the cylinder cover is $4\frac{1}{8}$ inches, and its external diameter $4\frac{3}{8}$ inches—the diameter of the piston rod being $2\frac{1}{8}$ inches. The thickness of the stuffing box flange is $1\frac{1}{8}$ inch.

623. *Q.*—Will you describe the nature of the communication between the cylinder and condenser?

A.—The pipe leading to the condenser from the cylinder is made somewhat bell mouthed where it joins the condenser, and the gland for compressing the packing is made of a larger internal diameter in every part except at the point at which the pipe emerges from it, where it accurately fits the pipe so as to enable the gland to squeeze the packing. By this construction the gland may be drawn back without being jammed upon the enlarged part of the pipe; and the enlargement of the pipe toward the condenser prevents the air pump barrel from offering any impediment to the free egress of the steam. The gland is made altogether in four pieces: the ring which presses the packing is made distinct from the flange to which the bolts are attached which force the gland against the packing, and both ring and flange are made in two pieces, to enable them to be got over the pipe. The ring is half checked in the direction of its depth, and is introduced without any other support to keep the halves together, than what is afforded by the interior of the stuffing box; and the flange is half checked in the direction of its thickness, so that the bolts which press down the ring by passing through this half-checked part, also keep the segments of the flange together. The bottom of the trunnion packing space is contracted to the diameter of the eduction pipe, so as to prevent the packing from being squeezed into the jacket; but the eduction pipe does not fit quite tight into this contracted part, but, while in close contact on the lower side, has about $\frac{1}{32}$nd of an inch of space between the top of the pipe and the cylinder, so as to permit the trunnions to wear to that extent without throwing a strain upon the pipe. The eduction pipe is attached to the condenser by a flange joint, and the bolt holes are all made somewhat oblong in the perpendicular direction, so as to permit the pipe to be slightly lowered, should such an operation be rendered necessary by the wear of the trunnion bearings; but in practice the wear of the trunnion bearings is found to be so small as to be almost inappreciable.

624. *Q.*—Will you describe the valve and valve casing?

A.—The length of the valve casing is 16½ inches, and its projection from the cylinder is 3½ inches at the top, 4¼ inches at the centre, and 2½ inches at the bottom, so that the back of the valve casing is not made flat, but is formed in a curve. The width of the valve casing is 9 inches, but there is a portion of the depth of the belt $1\frac{1}{2}$ inch wider, to permit the steam to enter from the belt into the casing. The valve casing is attached to the cylinder by a metallic joint; the width of the flange of this joint is $1\frac{1}{4}$ inch, the thickness of the flange on the casing $\frac{1}{2}$ inch, and the thickness of the flange on the cylinder $\frac{5}{8}$ths of an inch. The projection from the cylinder of the passage for carrying the steam upwards, and downwards, from the valve to the top and bottom of the cylinder, is $2\frac{1}{4}$ inches, and its width externally $8\frac{5}{8}$ inches. The valve is of the ordinary three ported description, and both cylinder and valve faces are of cast iron.

625. *Q.*—What description of piston is used?

A.—The piston is packed with hemp, but the junk ring is made of malleable iron, as cast iron junk rings have been found liable to break: there are four plugs screwed into the cylinder cover, which, when removed, permit a box key to be introduced, to screw down the piston packing. The screws in the junk ring are each provided with a small ratchet, cut in a washer fixed upon the head, to prevent the screw from turning back; and the number of clicks given by these ratchets, in tightening up the bolts, enables the engineer to know when they have all been tightened equally. In more recent engines, and especially in those of large size, Messrs. Penn employ for the piston packing a single metallic ring with tongue piece and indented plate behind the joint; and this ring is packed behind with hemp squeezed by the junk ring as in ordinary hemp-packed pistons.

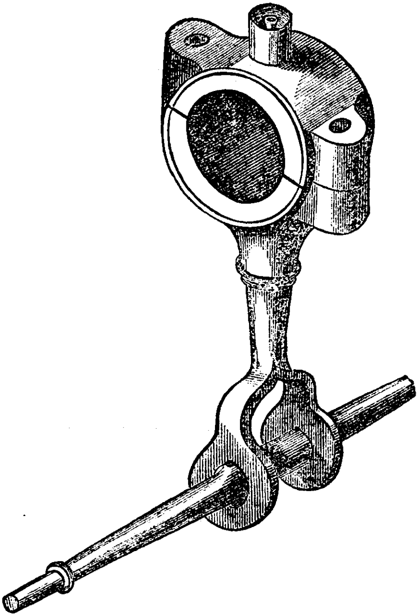
626. *Q.*—Will you describe the construction of the cap for connecting the piston rod with the crank pin?

A.—The cap for attaching the piston rod to the crank pin, is formed altogether of brass, which brass serves to form the bearing of the crank pin. The external diameter of the socket by which this cap is attached to the piston rod is $3\frac{5}{16}$ inches. The diameter of the crank pin is 3 inches, and the length of the crank pin bearing $3\frac{7}{8}$ inches. The thickness of the brass around the crank pin bearing is 1 inch, and the upper portion of the brass is secured to the lower portion by means of lugs, which are of such a depth that the perpendicular section through the centre of the bearing has a square outline measuring 7 inches in the horizontal direction, $3\frac{7}{8}$ inches from the centre of the pin to the level of the top of the lugs, and $2\frac{1}{2}$ inches from the centre of the pin to the level of the bottom of the lugs. The width of the lugs is 2 inches, and the bolts passing through them are $1\frac{1}{4}$ inch in diameter. The bolts are tapped into the lower portion of the cap, and are fitted very accurately by scraping where they pass through the upper portion, so as to act as steady pins in preventing the cover of the crank pin bearing from being worked sideways by the alternate thrust on each side. The distance between the centres of the bolts is 5 inches, and in the centre of the cover, where the lugs, continued in the form of a web, meet one another, an oil cup $1\frac{5}{8}$ inch in diameter, $1\frac{1}{8}$ inch high, and provided with an internal pipe, is cast upon the cover, to contain oil for the lubrication of the crank pin bearing. The depth of the cutter for attaching the cap to the piston rod is $1\frac{1}{4}$ inch and its thickness is $\frac{3}{8}$ths of an inch.

627. *Q.*—Will you describe the means by which the air pump rod is connected with the crank which works the air pump?

A.—A similar cap to that of the piston rod attaches the air pump crank to the connecting rod by which the air pump rod is moved, but in this instance the diameter of the bearing is 5 inches, and the length of the bearing is about 3 inches. The air pump connecting rod and cross head are shown in perspective in *fig.* 50. The thickness of the brass encircling the bearing of the shaft is three fourths of an inch upon the edge, and $1\frac{1}{8}$ inch in the centre, the back being slightly rounded; the width of the lugs is $1\frac{5}{8}$ inch, and the depth of the lugs is 2 inches upon the upper brass, and 2 inches upon the lower brass, making a total depth of 4 inches. The diameter of the bolts passing through the lugs is 1 inch, and the bolts are tapped into the lower brass, and accurately fitted into the upper one, so as to act as steady pins, as in the previous instance. The lower eye of the connecting rod is forked, so as to admit the eye of the air pump rod; and the pin which connects the two together is prolonged into a cross head, as shown in *fig.* 50. The ends of this cross head move in guides. The forked end of the connecting rod is fixed

Fig. 50.



Air Pump Connecting Rod and Cross Head. Messrs. Penn.

upon the cross head by means of a feather, so that the cross head partakes of the motion of the connecting rod, and a cap, similar to that attached to the piston rod, is attached to the air pump rod, for connecting it with the cross head. The diameter of the air pump rod is $1\frac{1}{2}$ inch, the external diameter of the socket encircling the rod is $2\frac{1}{8}$ inches, and the depth of the socket $4\frac{1}{2}$ inches from the centre of the cross head. The depth of the cutter for attaching the socket to the rod is 1 inch, and its thickness $\frac{5}{16}$ inch. The breadth of the lugs is $1\frac{3}{8}$ inch, the depth $1\frac{1}{4}$ inch, making a total depth of $2\frac{1}{2}$ inches; and the diameter of the bolts seven eighths of an inch. The diameter of the cross head at the centre is 2 inches, the thickness of each jaw around the bearing 1 inch, and the breadth of each $\frac{9}{16}$ inch.

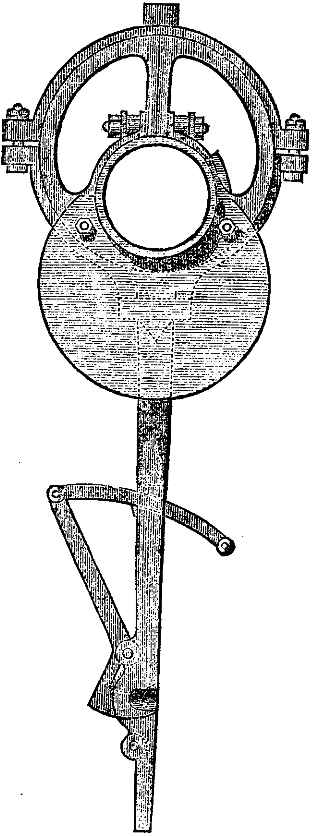
628. *Q.*—What are the dimensions of the crank shaft and cranks?

A.—The diameter of the intermediate shaft journal is $4\frac{3}{16}$ inches, and of the paddle shaft journal $4\frac{3}{8}$ inches; the length of the journal in each case is 5 inches. The diameter of the large eye of the crank is 7 inches, and the diameter of the hole through it is $4\frac{3}{8}$ inches; the diameter of the small eye of the crank is $5\frac{1}{4}$ inches, the diameter of the hole through it being 3 inches. The depth of the large eye is $4\frac{1}{4}$ inches, and of the small eye $3\frac{3}{4}$ inches; the breadth of the web is 4 inches at the shaft end, and 3 inches at the pin end, and the thickness of the web is $2\frac{5}{8}$ inches. The width of the notch forming the crank in the intermediate shaft for working the air pump is $3\frac{1}{2}$ inches, and the width of each of the arms of this crank is $3\frac{15}{16}$ inches. Both the outer and inner corners of the crank are chamfered away, until the square part of the crank meets the round of the shaft. The method of securing the cranks pins into the crank eyes of the intermediate shaft consists in the application of a nut to the end of each pin, where it passes through the eye, the projecting end of the pin being formed with a thread upon which the nut is screwed.

629. *Q.*—Will you describe the eccentric and eccentric rod?

A.—The eccentric and eccentric rod are shown in *fig.* 51 The eccentric is put on the crank shaft in two halves, joined in the diameter of largest eccentricity by means of a single bolt passing through lugs on the central eye, and the back balance is made in a separate piece five eighths of an inch thick, and is attached by means of two bolts, which also help to bind the halves of the eccentric together. The eccentric strap is half an inch thick, and $1\frac{1}{4}$ inch broad, and the flanges of the eccentric, within which the strap works, are each three eighths of an inch thick. The eccentric rod is attached to the eccentric hoop by means of two bolts passing through lugs upon the rod, and tapped into a square boss upon the hoop; and pieces of iron, of a greater or less thickness, are interposed between the surfaces in setting the valve, to make the eccentric rod of the right length. The eccentric rod is kept in gear by the push of a small horizontal rod, attached to a vertical blade spring, and it is thrown out of gear by means of the ordinary disengaging apparatus, which acts in opposition to the spring, as, in cases where the eccentric rod is not vertical, it acts in opposition to the gravity of the rod.

Fig. 51



Eccentric and Rod. Messrs. Penn.

630. *Q.*—Will you explain in detail the construction of the valve gearing, or such parts of it as are peculiar to the oscillating engine?

A.—The eccentric rod is attached by a pin, 1 inch in diameter, to an open curved link or sector with a tail projecting upward and passing through an eye to guide the link in a vertical motion. The link is formed of iron case-hardened, and is $2\frac{3}{4}$ inches deep at the middle, and $2\frac{3}{8}$ inches deep at the ends, and 1 inch broad.

The opening in the link, which extends nearly its entire length, is $1\frac{5}{16}$ inch broad; and into this opening a brass block 2 inches long is truly fitted, there being a hole through the block $\frac{3}{4}$ inch diameter, for the reception of the pin of the valve shaft lever. The valve shaft is $1\frac{3}{4}$ inch diameter at the end next the link or segment, and diminishes regularly to the other end, but its cross section assumes the form of an octagon in its passage round the cylinder, measuring mid-way $1\frac{1}{4}$ inch deep, by about $\frac{3}{4}$ inch thick, and the greatest depth of the finger for moving the valve is about 1 inch. The depth of the lever for moving the valve shaft is 2 inches at the broad, and $1\frac{1}{4}$ inch at the narrow end. The internal breadth of the mortice in which the valve finger moves is $\frac{5}{16}$ inch, and its external depth is $1\frac{3}{4}$ inch, which leaves three eighths of an inch as the thickness of metal round the hole; and the breadth, measuring in the direction of the hole, is 1^1 inch. The valve rod is three fourths of an inch in diameter, and the mortice is connected to the valve rod by a socket 1 inch long, and $1\frac{1}{8}$ inch diameter, through which a small cutter passes. A continuation of the rod, eleven sixteenths of an inch diameter, passes upward from the mortice, and works through an eye, which serves the purpose of a guide. In addition to the guide afforded to the segment by the ascending tail, it is guided at the ends upon the columns of the framing by means of thin semicircular brasses, 4 inches deep, passing round the columns, and attached to the segment by two $\frac{3}{8}$ inch bolts at each end, passing through projecting feathers upon the brasses and segment, three eighths of an inch in thickness. The curvature of the segment is such as to correspond with the arc swept from the centre of the trunnion to the centre of the valve lever pin when the valve is at half stroke as a radius; and the operation of the segment is to prevent the valve from being affected by the oscillation of the cylinder, but the same action would be obtained by the employment of a smaller eccentric with more lead. In some engines the segment is not formed in a single piece, but of two curved blades, with blocks interposed at the ends, which may be filed down a little, to enable the sides of the slot to be brought nearer, as the metal wears away.

631. *Q.*—What kind of plummer blocks are used for the paddle shaft bearings?

A.—The paddle shaft plummer blocks are altogether of brass, and are formed in much the same manner as the cap of the piston rod, only that the sole is flat, as in ordinary plummer blocks, and is fitted between projecting lugs of the framing, to prevent side motion. In the bearings fitted on this plan, however, the upper brass will generally acquire a good deal of play after some amount of wear. The bolts are worked slack in the holes, though accurately fitted at first; and it appears expedient, therefore, either to make the bolts very large, and the sockets through which they pass very deep, or to let one brass fit into the other.

632. *Q.*—How are the trunnion plummer blocks made?

A.—The trunnion plummer blocks are formed in the same manner as the crank shaft plummer blocks; the nuts are kept from turning back by means of a pinching screw passing through a stationary washer. It is not expedient to cast the trunnion plummer blocks upon the lower frame, as is sometimes done; for the cylinders, being pressed from the steam trunnions by the steam, and drawn in the direction of the condenser by the vacuum, have a continual tendency to approach one another; and as they wear slightly toward midships, there would be no power of readjustment unless the plummer blocks were movable. The flanges of the trunnions should always fit tight against the plummer block sides, but there should be a little play sideways at the necks of the trunnions, so that the cylinder may be enabled to expand when heated, without throwing an undue strain upon the trunnion supports.

633. *Q.*—What kind of paddle wheel is supplied with these oscillating engines?

A.—The wheels are of the feathering kind, 9 feet 8 inches in diameter, measuring to the edges of the floats; and there are 10 floats upon each wheel, measuring 4 feet 6 inches long each, and $18\frac{1}{2}$ inches broad. There are two sets of arms to the wheel, which converge to a cast iron centre, formed like a short pipe with large flanges, to which the arms are affixed. The diameter of the shaft, where the centre is put on, is $4\frac{1}{2}$ inches, the external diameter of the pipe is 8 inches, and the diameter of the flanges is 20 inches, and their thickness $1\frac{1}{4}$ inch. The flanges are 12 inches asunder at the outer edge, and they partake of the converging direction of the arms. The arms are $2\frac{1}{4}$ inches broad, and half an inch thick; the heads are made conical, and each is secured into a recess upon the side of the flange by means of three bolts. The ring which connects together the arms, runs round at a distance of 3 feet 6 inches from the centre, and the projecting ends of the arms are bent backward the length of the lever which moves the floats, and are made very wide and strong at the point where they cross the ring, to which they are attached by four rivets. The feathering action of the floats is accomplished by means of a pin fixed to the interior of the paddle box, set 3 inches in advance of the centre of the shaft, and in the same horizontal line. This pin is encircled by a cast iron collar, to which rods are attached $1\frac{3}{8}$ inch diameter in the centre, proceeding to the levers, 7 inches long, fixed on the back of the floats in the line of the outer arms. One of these rods, however, is formed of nearly the same dimensions as one of the arms of the wheel, and is called the driving arm, as it causes the cast iron collar to turn round with the revolution of the wheel, and this collar, by means of its attachments to the floats, accomplishes the feathering action. The eccentricity in this wheel is not sufficient to keep the floats in the vertical position, but in the position between the vertical and the radial. The diameter of the pins upon which the floats turn is $1\frac{3}{8}$ inch, and between the pins and paddle ring two stud rods are set between each of the projecting ends of the arms, so as to prevent the two sets of arms from being forced nearer or further apart; and thus prevent the ends of the arms from hindering the action of the floats, by being accidentally jammed upon the sides of the joints. Stays, crossing one another, proceed from the inner flange of the centre to the outer ring of the wheel, and from the outer flange of the centre to the inner ring of the wheel, with the view of obtaining greater stiffness. The floats are formed of plate iron, and the whole of the joints and joint pins are steeled, or formed of steel. For sea-going vessels the most approved practice is to make the joint pins of brass, and also to bush the eyes of the joints with brass; and the surface should be large to diminish wear.

634. *Q.*—Can you give the dimenions of any other oscillating engines?

A.—In Messrs. Penn's 50 horse power oscillating engine, the diameter of the cylinder is 3 feet 4 inches, and the length of the stroke 3 feet. The thickness of the metal of the cylinder is 1 inch, and the thickness of the cylinder bottom is 1¾ inch, crossed with feathers, to give it additional stiffness. The diameter of the trunnion bearings is 1 foot 2 inches, and the breadth of the trunnion bearings 5½ inches. Messrs. Penn, in their larger engines, generally make the area of the steam trunnion less than that of the eduction trunnion, in the proportion of 32 to 37; and the diameter of the eduction trunnion is regulated by the internal diameter of the eduction pipe, which is about ⅕th of the diameter of the cylinder. But a somewhat larger proportion than this appears to be expedient: Messrs. Rennie make the area of their eduction pipes, in oscillating engines, $\frac{1}{22}$d of the area of the cylinder. In the oscillating engines of the Oberon, by Messrs. Rennie, the cylinder is 61 inches diameter, and 1½ inch thick above and below the belt, but in the wake of the belt it is 1¼ inch thick, which is also the thickness of metal of the belt itself. The internal depth of the belt is 2 feet 6 inches, and its internal breadth is 4 inches. The piston rod is 6¾ inches in diameter, and the total depth of the cylinder stuffing box is 2 feet 4 inches, of which 18 inches consists of a brass bush—this depth of bearing being employed to prevent the stuffing box or cylinder from wearing oval.

635. *Q.*—Can you give any other examples?

A.—The diameter of cylinder of the oscillating engines of the steamers Pottinger, Ripon, and Indus, by Miller & Ravenhill, is 76 inches, and the length of the stroke 7 feet. The thickness of the metal of the cylinder is $1\frac{11}{16}$ inch; diameter of the piston rod 8¾ inches; total depth of cylinder stuffing box 3 feet; depth of bush in stuffing box 4 inches; the rest of the depth, with the exception of the space for packing, being occupied with a very deep gland, bushed with brass. The internal diameter of the steam pipe is 13 inches; diameter of steam trunnion journal 25 inches; diameter of eduction trunnion journal 25 inches; thickness of metal of trunnions $2\frac{1}{4}$ inches; length of trunnion bearings 11 inches; projection of cylinder jacket, 8 inches; depth of packing space in trunnions, 10 inches; width of packing space in trunnions, or space round the pipes, $1\frac{1}{2}$ inch; diameter of crank pin $10\frac{1}{4}$ inches; length of bearing of crank pin $15\frac{1}{2}$ inches. There are six boilers on the tubular plan in each of these vessels; the length of each boiler is 10 feet 6 inches, and the breadth 8 feet; and each boiler contains 62 tubes 3 inches in diameter, and 6 feet 6 inches long, and two furnaces 6 feet $4\frac{1}{2}$ inches long, and 3 feet $1\frac{1}{2}$ inch broad.

636. *Q.*—Is it the invariable practice to make the piston rod cap of brass in the way you have described?

A.—In all oscillating engines of any considerable size, the cover of the connecting brass, which attaches the crank pin to the connecting rod, is formed of malleable iron; and the socket also, which is cuttered to the end of the piston rod, is of malleable iron, and is formed with a T head, through which bolts pass up through the brass, to keep the cover of the brass in its place.

637. *Q.*—Is the piston of an oscillating engine made deeper than in common engines?

A.—It is expedient, in oscillating engines, to form the piston with a projecting rim round the edge above and below, and a corresponding recess in the cylinder cover and cylinder bottom, whereby the breadth of bearing of the solid part of the metal will be increased, and in many engines this is now done.

638. *Q.*—Would any difficulty be experienced in keeping the trunnions tight in a high pressure oscillating engine?

A.—It is very doubtful whether the steam trunnions of a high pressure oscillating engine will continue long tight if the packing consists of hemp; and it appears preferable to introduce a brass ring, to embrace the pipe, cut spirally, with an overlap piece to cover the cut, and packed behind with hemp.

639. *Q.*—How is the packing of the trunnions usually effected?

A.—The packing of the trunnions, after being plaited as hard as possible, and cut to the length to form one turn round the pipe, is dipped into boiling tallow, and is then compressed in a mould, consisting of two concentric cylinders, with a gland forced down into the annular space by three to six screws in the case of large diameters, and one central screw in the case of small diameters. Unless the trunnion packings be well compressed, they will be likely to leak air, and it is, therefore, necessary to pay particular attention to this condition. It is also very important that the trunnions be accurately fitted into their brasses by scraping, so that there may not be the smallest amount of play left upon them; for if any upward motion is permitted, it will be impossible to prevent the trunnion packings from leaking.

DIRECT ACTING SCREW ENGINE.

640. *Q.*—Will you describe the configuration and construction of a direct acting screw engine?

A.—I will take as an example of this species of engine, the engine constructed by Messrs. John Bourne & Co., for the screw steamer Alma, a vessel of 500 tons burden. This engine is a single steeple engine laid on its side, and in its general features it resembles the engines of the Amphion already described, only that there is one cylinder instead of two. The cylinder is of 42 inches diameter and 42 inches stroke, and the vessel has been propelled by this single engine at the rate of fourteen miles an hour.

641. *Q.*—Is not a single engine liable to stick upon the centre so that it cannot be started or reversed with facility?

A.—A single engine is no doubt more liable to stick upon the centre than two engines, the cranks of which are set at right angles with one another; but numerous paddle vessels are plying successfully that are propelled by a single engine, and the screw offers still greater facility than paddles for such a mode of construction. In the screw engine referred to, as the cylinder is laid upon its side, there is no unbalanced weight to be lifted up every stroke, and the crank, whereby the screw shaft is turned round, consists of two discs with a heavy side intended to balance the momentum of the piston and its connections; but these counter-weights by their gravitation also prevent the connecting rod and crank from continuing in the same line when the engine is stopped, and in fact they place the crank in the most advantageous position for starting again when it has to be set on.

642. *Q.*—Will you explain the general arrangement of the parts of this engine?

A.—The cylinder lies on its side near one side of the vessel, and from the end of the cylinder two piston rods extend to a cross head sliding athwartships, in guides, near the other side of the vessel. To this cross head the connecting rod is attached, and one end of it partakes of the motion of the cross head or piston, while the other end is free to follow the revolution of the crank on the screw shaft.

643. *Q.*—What is the advantage of two discs entering into the composition of the crank instead of one?

A.—A double crank, such as two discs form with the crank pin, is a much steadier combination than would result if only one disc were employed with an over-hung pin. Then the friction on the neck of the shaft is made one half less by being divided between the two bearings, and the short prolongation of the shaft beyond the journal is convenient for the attachment of the eccentrics to work the valves.

644. *Q.*—Will you enumerate some of the principal dimensions of this engine?

A.—The bottom frame, on which also the condenser is cast, forms the base of the engine: on one end of it the cylinder is set; on the other end are the guides for the cross head, and in the middle are the bearings for the crank shaft. The part where the cylinder stands is two feet high above the engine platform, and the elevation to the centre of the guides or the centre of the shaft is 10 inches higher than this. The metal both of the side frames and bottom flange is $1\frac{1}{4}$ inch thick. The cylinder has flanges cast on its sides, upon which it rests on the bottom frame, and it is sunk between the sides of the frame so as to bring the centre of the cylinder in the same plane as the centre of the screw shaft. The opening left at the guides for the reception of the guide blocks is 6 inches deep, and the breadth of the bearing surface is 11 inches. The cover of the guides is 8 inches deep at the middle, and about half the depth at the ends, and holes are cored through the central web for two oil cups on each guide. The brass for each of the crank shaft bearings is cut into four pieces so that it may be tightened in the up and down direction by the bolts, which secure the plummer block cap, and tightened in the athwartship direction, which is the direction of the strain, by screwing up a wedge-formed plate against the side of the brass, a parallel plate being applied to the other side of the brass, which may be withdrawn to get out the wedge piece when the shaft requires to be lifted out of its place. The air pump is bolted to one side of the bottom frame, and a passage is cast on it conducting from the condenser to the air pump. In this passage the inlet and outlet valves at each end of the air pump are situated, and appropriate doors are formed above them to make them easily accessible. The outlet passage leading from the air pump communicates with the waste water pipe, through which the water expelled by the air pump is discharged overboard.

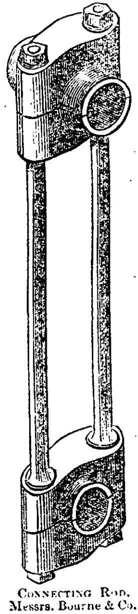
645. *Q.*—Is the cylinder of the usual strength and configuration?

A.—The cylinder is formed of cast iron in the usual way, and is $1\frac{1}{8}$ inch thick in the barrel. The ends are of the same thickness, but are each stiffened with six strong feathers. The piston is cast open. The bottom of it is $\frac{5}{8}$ths of an inch thick, and it is stiffened by six feathers $\frac{3}{4}$ of an inch thick; but the feather connecting the piston rod eyes is $1\frac{1}{4}$ inch thick, and the metal round the eyes is 2 inches thick. The piston is closed by a disc or cover $\frac{5}{8}$ths of an inch thick, secured by 15 bolts, and this cover answers also the purpose of a junk ring. The piston packing consists of a single cast iron ring $3\frac{1}{2}$ inches broad, and $\frac{1}{2}$ inch thick, packed behind with hemp. This ring is formed with a tongue piece, with an indented plate behind the cut; and the cut is oblique to prevent a ridge forming in the cylinder. The total thickness of the piston is $5\frac{1}{2}$ inches. The piston rods are formed with conical ends for fitting into the piston, but are coned the reverse way as in locomotives, and are secured in the piston by nuts on the ends of the rods, these nuts being provided with ratchets to prevent them from unscrewing accidentally.

646. *Q.*—What species of slide valve is employed?

A.—The ordinary three ported valve, and it is set on the top of the cylinder. The cylinder ports are $4\frac{1}{2}$ inches broad by 24 inches long; and to relieve the valve from the great friction due to the pressure on so large a surface, a balance piston is placed over the back of the valve, to which it is connected by a strong link; and the upward pressure on this piston being nearly the same as the downward pressure on the valve, it follows that the friction is extinguished, and the valve can be moved with great ease with one hand. The balance piston is 21 inches in diameter. In the original construction of this balance piston two faults were committed. The passage communicating between the condenser and the top of the balance piston was too small, and the pins at the ends of the link connecting the valve and balance piston were formed with an inadequate amount of bearing surface. It followed from this misproportion that the balance piston, being adjusted to take off nearly the whole of the pressure, lifted the valve off the face at the beginning of each stroke. For the escape of the steam into the eduction passage momentarily impaired the vacuum subsisting there, and owing to the smallness of the passage leading to the space above the balance piston, the vacuum subsisting in that space could not be impaired with equal rapidity. The balance piston, therefore, rose by the upward pressure upon it momentarily predominating over the downward pressure on the valve; but this fault was corrected by enlarging the communicating passage between the top of the balance piston and the eduction pipe. The smallness of the pins at the ends of the link connecting the valve and balance piston, caused the surfaces to cut into one another, and to wear very rapidly, and the pins and eyes in this situation should be large in diameter, and as long as they can be got, as they are not so easily lubricated as the other bearings about the engine, and are moreover kept at a high temperature by the steam. The balance piston is packed in the same way as the main piston of the engine. Its cylinder, which is only a few inches in length, is set on the top of the valve casing, and a trunk projects upwards from its centre to enable the connecting link to rise up in it to attain the necessary length.

Fig. 52.



Connecting Rod. Messrs. Bourne & Co.

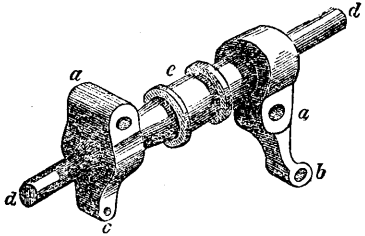
647. *Q.*—What is the diameter of the piston rods and connecting rod?

A.—The piston rods, which are two in number, are 3 inches diameter, and 12 feet 10 inches long over all. They were, however, found to be rather small, and have since been made half an inch thicker. The connecting rod consists of two rods, which are prolongations of the bolts that connect the sides of the brass bushes which encircle the crank pin and cross head. The connecting rod is shown in perspective in *fig.* 52. The rods composing it are each $2\frac{3}{4}$ inches in diameter.

648. *Q.*—Will you describe the configuration of the cross head.

A.—The cross head, exhibited in *fig.* 53, is a round piece of iron like a short shaft, with two unequal arms keyed upon it, the longer of which *b* works the air pump, and the shorter *c* works the feed pump. The piston rods enter these arms at *a a*. The cross head is 8 inches diameter where it is embraced by the connecting rod at *e*, and 7 inches diameter where the air pump and feed pump arms are fixed on. The ends of the cross head *d d*, for a length of 12 inches, are reduced to 3 inches diameter where they fit into round holes in the centre of the guide blocks. Those blocks are of cast iron 6 inches deep, 11 inches wide, and 14 inches long, and they are formed with flanges 1

Fig. 53.



Cross Head and Pump Arms. Messrs. Bourne & Co.

inch thick on the inner sides of the blocks. The projection of the air pump lever from the centre of the cross head is 1 foot 9 inches, and it is bent $5\frac{3}{4}$ inches to one side to enable it to engage the air pump rod. The eye of this arm is 6 inches broad and about 2 inches thick. At the part where one of the piston rods passes through it, the arm is 8 inches deep and 6 inches wide; but the width thereafter narrows to 3 inches, and finally to 2 inches; and the depth of the web of the arm reduces from 8 inches at the piston rod, to 4 inches at the eye, which receives the end of the air pump rod. The feed pump arm is only 3 inches thick, and has 9 inches of projection from the centre of the cross head; but the eye attached to it on the opposite side of the cross head for the reception of the other piston rod is of the same length as that part of the air pump arm which one of the piston rods passes through. The piston rods have strong nuts on each side of each of these arms to attach them to the arms, and also to enable the length of the piston rods to be suitably adjusted, to leave equal clearance between the piston and each end of the cylinder at the termination of the stroke.

649. *Q.*—Will you recapitulate the main particulars of the air pump?

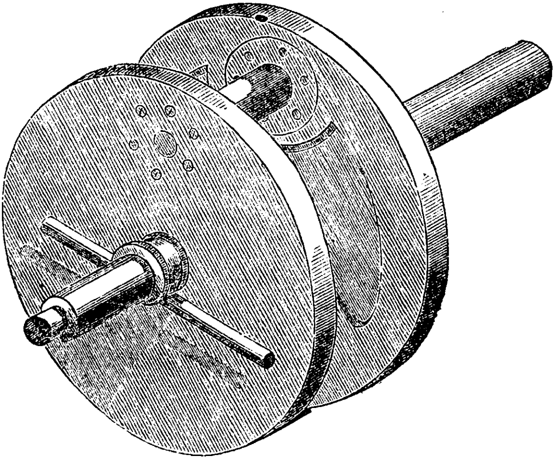
A.—The air pump is made of brass $12\frac{1}{2}$ inches diameter and

42 inches stroke, and the metal of the barrel is $\frac{9}{16}$ths of an inch thick. The air pump bucket is a solid piston of brass, $6\frac{1}{2}$ inches deep at the edge, and 7 inches deep at the eye; and in the edge three grooves are turned to hold water which answers the purpose of packing. The inlet and outlet valves of the air pump consist of brass plates $\frac{1}{2}$ inch with strong feathers across them, and in each plate there are six grated perforations covered by india rubber discs 7 inches in diameter. These six perforations afford collectively an area for the passage of the water equal to the area of the pump. The air pump rod is of brass, $2\frac{1}{2}$ inches diameter.

650. *Q.*—What are the constructive peculiarities of the discs and crank pin?

A.—The discs, which are 64 inches diameter, are formed of cast iron, and are $2\frac{1}{2}$ inches thick in the body, and 5 inches broad at the rim. The crank shaft is $8\frac{1}{2}$ inches diameter, and the central boss of the disc which receives the shaft measures 10 inches through the eye, and the metal of the eye is 3 inches thick. In the part of the disc opposite to the crank pin, the web is thickened to 10 inches for nearly the whole semicircle, with the view of making that side of the disc heavier than the other side; and when the engine is stopped, the gravitation of this heavy side raises the crank pin to the highest point it can attain, whereby it is placed in mid stroke, and cannot rest with the piston rods and connecting rod in a horizontal line. The crank pin is $8\frac{1}{2}$ inches diameter, and the length of the bearing or rubbing part of it is 16 inches. It is secured at the ends to the discs by flanges 18 inches diameter, and 2 inches thick. These flanges are indented into thickened parts of the discs, and are each attached to its corresponding disc by six bolts 2 inches diameter, countersunk in the back of the disc, and tapped into the malleable iron flange. Besides this attachment, each end of the pin, reduced to $4\frac{1}{2}$ inches diameter, passes through a hole in its corresponding disc, and the ends of the pin are then riveted over. The crank pin is perforated through the centre by a small hole about $\frac{3}{4}$ of an inch in diameter, and three perforations proceed from this central hole to the surface of the pin. Each crank shaft bearing is similarly perforated, and pipes are cast in the discs connecting these perforations together. The result of this arrangement is, that a large part of the oil or water fed into the bearings of the shaft is driven by the centrifugal action of the discs to the surface of the crank pin, and in this way the crank pin may be oiled or cooled with water in a very effectual manner. To intercept the water or oil which the discs thus drive out by their centrifugal action, a light paddle box or splash board of thin sheet brass is made to cover the upper part of each of the discs, and an oil cup with depending wick is supported by the tops of these paddle boxes, which wick is touched at each revolution of the crank by a bridge standing in the middle of an oil cup attached to the crank pin. The oil is wiped from the wick by the projecting bridge at

Fig. 54.



Double Disc Crank. Messrs. Bourne & Co.

each revolution, and subsides into the cup from whence it proceeds to lubricate the crank pin bearing. This is the expedient commonly employed to oil the crank pins of direct acting engines; but in the engine now described, there are over and above this expedient, the communicating passages from the shaft bearings to the surface of the pin, by which means any amount of cooling or lubrication can be administered to the crank pin bearing, without the necessity of stopping or slowing the engine.

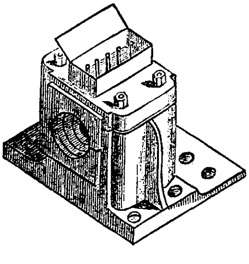
651. *Q.*—What is the diameter of the screw shaft?

A.—The screw shaft is $7\frac{1}{2}$ inches diameter, but the bearings on each side of the disc are $8\frac{1}{2}$ inches diameter, and 16 inches long. Between the side of the disc and the side of the contiguous bearings there is a short neck extending $4\frac{3}{4}$ inches in the length of the shaft, and hollowed out somewhat to permit the passage of the piston rod; for one piston rod passes immediately above the shaft on the one side of the discs, and the other piston rod passes immediately below the shaft on the other side of the discs. A short piece of one piston rod is shown in *fig.* 54.

652. *Q.*—How is the thrust of the screw shaft received?

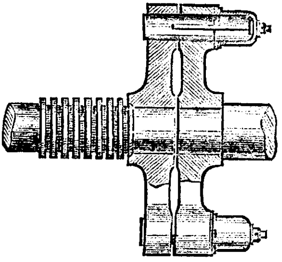
A.—The thrust of the screw shaft is received upon 7 collars, each 1 inch thick, and with 1 inch of projection above the shaft. The plummer block for receiving the thrust of the shaft is shown in *fig.* 55, and the coupling to enable the screw pro-

Fig. 55.



THRUST BEARING.
Messrs. Bourne & Co.

Fig. 56.



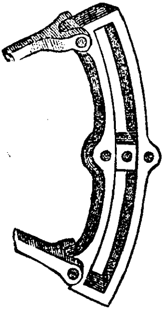
COUPLING CRANKS.
Messrs. Bourne & Co.

peller to be disconnected from the engine, so that it may revolve freely when the vessel is under sail, is shown in *fig.* 56. When it is required to disengage the propeller from the engine, the pins passing through the opposite eyes shown in *fig.* 56, are withdrawn by means of screws provided for that purpose, and the propeller and the engine are thenceforth independent of one another.

653. *Q.*—Will you describe the arrangement of the valve gearing?

A.—The end of the screw shaft, after emerging from the bearing beside the disc, is reduced to a diameter of 4 inches, and is prolonged for 4½ inches to give attachment to the cam or curved plate which gives motion to the expansion valve. This plate is 3½ inches thick, and a stud 3½ inches diameter is fixed in the plate at a distance of 5 inches from the centre of the shaft. To this stud an arm is attached which extends to a distance of 2 inches from the centre of the shaft in the opposite direction, and the end of this arm carries a pin of 2½ inches diameter. From the pin most remote from the centre of the shaft, a rod 2¼ inches broad and 1 inch thick extends to the upper end of the link of the link motion; and from the pin least remote from the centre of the shaft, a similar rod extends to the lower end of the link of the link motion. This link, which is represented in *fig.* 57, is 2¼ inches broad, 1 inch thick, and is capable of being raised or lowered 25 inches in all. In the open part of the link is a brass block, which, by raising or lowering the link, takes either the position in which it is represented at the centre of the link, or a position at either end of it. Through the hole in the brass block a pin passes to attach the brass to the end of a lever fixed on the valve shaft; so that whatever motion is imparted to the brass block is communicated to the valve through the medium of this lever. If the brass block be set in the middle of the link, no motion is communicated to it, and the valve being consequently kept stationary and covering both ports, the engine stops. If the link be lowered until the

Fig. 57.



LINK MOTION.
Messrs. Bourne & Co.

brass block comes to the upper end of the link, the valve receives the motion of the eccentric for going ahead, and the engine moves ahead; whereas if the link be raised until the brass block comes to the lower end of the link, the valve receives the motion of the backing eccentric, and the engine moves astern. Instead of eccentrics, however, pins at the end of the shaft are employed in this engine, the arrangement partaking of the nature of a double crank; but the backing pin has less throw than the going ahead pin, whereby the efficient length of the link for going ahead is increased; and the operation of backing, which does not require to be performed at the highest rate of speed, is sufficiently accommodated by about half the throw being given to the valve that is given in going ahead. A valve shaft extends across the end of the cylinder with two levers standing up, which engage horizontal side rods extending from a small cross head on the end of the valve rod. A lever extends downwards from the end of the valve shaft, which is connected by a pin to the brass block within the link; and the link is moved up or down by the starting handle, which, by means of a spring bolt shooting into a quadrant, holds the starting handle at any position in which it may be set.

654. *Q.*—What is the diameter and pitch of the screw propeller?

A.—The diameter is 7 feet and the pitch 14 feet. The propeller is Holm's conchoidal propeller. Its diameter is smaller than is advisable, being limited by the draught of water of the vessel; and the vessel was required to have a small draught of water to go over a bar. This engine makes, under favorable circumstances, 100 strokes per minute. The speed of piston with this number of strokes is 700 feet per minute, and the engine works steadily at this speed, the shock and tremor arising from the arrested momentum of the moving parts being taken away by the counterbalance applied at the discs.

LOCOMOTIVE ENGINE.

655. *Q.*—Will you describe the principal features of a modern locomotive engine?

A.—I will take for this purpose the locomotive Snake, constructed by John V. Gooch for the London and South Western Railway, as an example of a modern locomotive of good construction, adapted for the narrow gauge. The length of the wheel base of this engine is 12 feet 8½ inches. There are two cylinders, each 14¼ inches diameter and 21 inches stroke. The total weight of the engine is 19 tons; and this weight is so distributed on the wheels as to throw 8 tons on the leading wheels, 6 tons on the driving wheels, and 5 tons on the hind wheels. The engine is made with outside cylinders, and the cylinders are raised somewhat out of the horizontal line to enable them better to clear the leading wheels.

656. *Q.*—What are the dimensions of the boiler?

A.—The interior of the fire box is 3 feet 7¼ inches wide by 3 feet 5½ inches long, measuring in the direction of the rails. The area of the fire grate is consequently 12.4 square feet. The bars are somewhat lower on the side next the fire door than at the side next the tubes, and the mean height of the crown of the fire box above the bars is 3 feet 10 inches. The top edge of the fire door is about 7 inches lower than the crown of the fire box. The fire box is divided transversely by a corrugated feather or bridge of plate iron, containing water, about 3½ inches wide, and of about one-third of the height of the fire box in the centre of the feather, and about two-thirds the height of the fire box at the sides where it joins the sides of the fire box. The internal shell of the fire box tapers somewhat upwards to facilitate the disengagement of the steam. It is about 2 inches narrower and shorter at the top than at the bottom; the water space between the external and internal shell of the fire box being 2 inches at the bottom and 3 inches at the top.

657. *Q.*—Of what material is the fire box composed?

A.—The external shell of the fire box is formed of iron plates ⅜ths of an inch thick, and the internal shell is formed of copper plates ½ inch thick, but the tube plate is ¾ inch thick. The fire grate is rectangular, and the internal and external shells are tied together by iron stay bolts ¾ inch diameter, and pitched about 4 inches apart. The roof of the fire box is stiffened by six strong bars extending from side to side of the fire box like beams, and the top of the fire box is secured to these bars, so that it cannot be forced down without breaking or bending them.

658. *Q.*—What are the dimensions of the barrel of the boiler?

A.—The barrel of the boiler is 3 feet $7\frac{1}{2}$ inches in diameter, and 10 feet long. It is formed of iron plates $\frac{3}{8}$ths of an inch thick, riveted together. It is furnished with 181 brass tubes $1\frac{7}{8}$ inch diameter and 10 feet long, secured at the ends by ferules. The tube plate at the smoke box end is $\frac{5}{8}$ths of an inch thick, and the tube plates above the tubes are tied together by eight iron rods $\frac{7}{8}$ths of an inch thick, extending from end to end of the boiler. The metal of the tubes is somewhat thicker at the end next the fire, being 13 wire gauge at fire box end, and 14 wire gauge at smoke box end. The rivets of the boiler are $\frac{3}{4}$ inch diameter and $1\frac{1}{2}$ inch pitch. The plating of the ash pan is $\frac{5}{16}$ths of an inch thick, and the plating of the smoke box is $\frac{3}{16}$ths of an inch thick.

659. *Q.*—Will you describe the structure of the framework on which the boiler and its attachments rest, and in which the wheels are set?

A.—The framework or framing consists of a rectangular structure of plate iron circumscribing the boiler, with projecting lugs or arms for the reception of the axles of the wheels. In this engine the sides of the rectangle are double, or, as far as regards the sides, there are virtually two framings, one for the reception of the driving axles, and the other for the reception of the axles not connected with the engine. The whole of the parts of the outer and inner framings are connected together by knees at the corners, and the double sides are elsewhere connected by intervening brackets and stays, so as to constitute the whole into one rigid structure. The whole of the plating of the inside frame is $\frac{3}{4}$ inch thick and 9 inches deep. The plating of the outside frame is of the same thickness and depth at the fore part, until it reaches abaft the position of the cylinders and guides, where it reduces to $\frac{1}{2}$ inch thick. The axle guard of the leading wheels is formed of $\frac{3}{4}$ plate bolted to the frame with angle iron guides. The axle guards of the trailing wheels are formed of two $\frac{1}{2}$ inch plates, with cast iron blocks between them to serve as guides. The ends of the rectangular frame are formed of plates $\frac{3}{4}$ thick, and at the front end there is a buffer beam of oak $4\frac{1}{2}$ inches thick and 15 inches deep. The draw bolt is 2 inches diameter. There are two strong stays on each side, joining the barrel of the boiler to the inside framing, and one angle iron on each side joining the bottom of the smoke box to the inside framing.

660. *Q.*—Of what construction are the wheels?

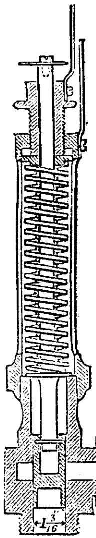
A.—The wheels and axles are of wrought iron, and the tires of the wheels are of steel. The driving wheels are 6 feet $6\frac{1}{2}$ inches in diameter, and the diameter of crank pin is $3\frac{1}{2}$ inches. The diameter of the smaller wheels is $48\frac{1}{2}$ inches. The axle boxes are of cast iron with bushes of Fenton's metal, and the leading axle has four bearings. The springs are formed of steel plates, 3 feet long, 4 inches broad, and $\frac{1}{2}$ inch thick. The axle of the driving wheel has two eccentrics, forged solid upon it, for working the pumps.

661. *Q.*—Will you specify the dimensions of the principal parts of the engine?

A.—Each of the cylinders which is $14\frac{1}{4}$ inches diameter, has the valve casing cast upon it. The steam ports are 13 inches long and $1\frac{5}{8}$ inches broad, and the exhaust port is $2\frac{1}{2}$ inches broad. The travel of the valve is $4\frac{1}{8}$ inches, the lap 1 inch, and the lead $\frac{1}{4}$ inch. The piston is 4 inches thick: its body is formed of brass with a cover of cast iron, and between the body and the cover two flanges, forged on the piston rod, are introduced to communicate the push and pull of the piston to the rod. The piston rod is of iron, $2\frac{1}{8}$ inches diameter. The guide bars for guiding the top of the piston rod are of steel, 4 inches broad, fixed to rib iron bearers, with hard wood $\frac{1}{4}$ of an inch thick, interposed. The connecting rod is 6 feet long between the centres, and is fitted with bushes of white metal. The eccentrics are formed of wrought iron, and have $4\frac{1}{8}$ inches of throw. The link of the link motion is formed of wrought iron.

It is hung by a link from a pin attached to the framing; and instead of being susceptible of upward and downward motion, as in the case of the link represented in *fig.* 57 a rod connecting the valve rod with the movable block in the link, is susceptible of this motion, whereby the same result is arrived at as if the link were moved and the block was stationary. One or the other expedient is preferable, according to the general nature of the arrangements adopted. The slide valve is of brass, and the regulator consists of two brass slide valves worked over ports in a chest in the steam pipe, set in the smoke box. The steam pipe is of brass, No. 14. wire gauge, perforated within the boiler barrel with holes $\frac{1}{12}$th of an inch in diameter along its upper side. The blast pipe, which is of copper, has an orifice of $4\frac{1}{4}$ inches diameter. There is a damper, formed like a venetian blind, with the plates running athwartships at the end of the tubes.

Fig. 58.



SAFETY VALVE.
Gooch.

662. *Q.*—Of what construction is the safety valve?

A.—There are two safety valves, consisting of pistons $1\frac{3}{16}$ inch in diameter, and which are kept down by spiral springs placed immediately over them. A section of this valve is given in *fig.* 58.

663. *Q.*—What are the dimensions of the feed pumps?

A.—The feed pumps are of brass, with plungers 4 inches diameter and $3\frac{1}{4}$ inches stroke. The feed pipe is of copper, 2 inches diameter. A good deal of trouble has been experienced in locomotives from the defective action of the feed pump, partly caused by the leakage of steam into the pumps, which prevented the water from entering them, and partly from the return of a large part of the water through the valves at the return stroke of the pump, in consequence of the valve lifting too high. The pet cock—a small cock communicating with the interior of the pump—will allow any steam to escape which gains admission, and the air which enters by the cock cools down the barrel of the pump, so that in a short time it will be in a condition to draw. The most ordinary species of valve in the feed pumps of locomotives, is the ball valve.

Notwithstanding the excellent performance of the best examples of locomotive engines, it is quite certain that there is still much room for improvement; and indeed various sources of economy are at present visible, which, if properly developed, would materially reduce the expense of the locomotive power. In all engines the great source of expense is the fuel; and although the consumption of fuel has been greatly reduced within the last ten or fifteen years, it is capable of being still further reduced by certain easy expedients of improvement, which therefore it is important should be universally applied. One of these expedients consists in heating the feed water by the waste steam; and the feed water should in every case be sent into the boiler *boiling hot*, instead of being quite cold, as is at present generally the case. The ports of the cylinders should be as large as possible; the expansion of the steam should be carried to a greater extent; and in the case of engines with outside cylinders, the waste steam should circulate entirely round the cylinders before escaping by the blast pipe. The escape of heat from the boiler should be more carefully prevented; and the engine should be balanced by weights on the wheels to obviate a waste of power by yawing on the rails. The most important expedient of all, however, lies in the establishment of a system of registering the performance of all new engines, in order that competition may stimulate the different constructors to the attainment of the utmost possible economy; and under the stimulus of comparison and notoriety, a large measure of improvement would speedily ensue. The benefits consequent on public competition are abundantly illustrated by the rapid diminution of the consumption of fuel in the case of agricultural engines, when this stimulus was presented.