CHAPTER I.

GENERAL DESCRIPTION OF THE STEAM ENGINE.

THE BOILER.

83. *Q.*—WHAT are the chief varieties of the steam engine in actual practical use?

A.—There is first the single-acting engine, which is used for pumping water; the rotative land engine, which is employed to drive mills and manufactories; the rotative marine engine, which is used to propel steam vessels; and the locomotive engine, which is employed on railways. The last is always a high-pressure engine; the others are, for the most part, condensing engines.

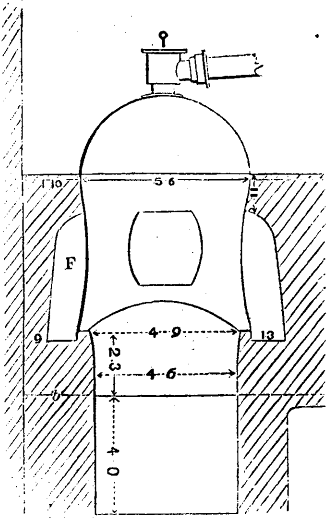
84. *Q.*—Will you explain the construction and action of the single-acting engine, used for draining mines?

A.—Permit me then to begin with the boiler, which is common and necessary to all engines; and I will take the example of a wagon boiler, such as was employed by Boulton and Watt universally in their early engines, and which is still in extensive use. This boiler is a long rectangular vessel, with a rounded top, like that of a carrier's wagon, from its resemblance to which it derives its name. A fire is set beneath it, and flues constructed of brickwork encircle it, so as to keep the flame and smoke in contact with the boiler for a sufficient time to absorb the heat.

85. *Q.*—This species of boiler has not an internal furnace, but is set in brickwork, in which the furnace is formed?

A.—Precisely so. The general arrangement and configuration will be at once understood by a reference to the annexed figure (*fig.* 3), which is a transverse section of a wagon boiler. The line b represents the top of the grate or fire bars, which slope downward from the front at an angle of about 25°, giving the fuel a tendency to move toward the back of the grate. The supply of air ascends from the ash pit through the grate bars, and the flame passes over a low wall or bridge, and traverses the bottom of the boiler. The smoke rises up at the back of the boiler, and proceeds through the flue F along one side to the front, and returns along the other side of the boiler, and then ascends the chimney. The performance of this course by the smoke is what is termed a wheel draught, as the smoke wheels once round the boiler, and then ascends the chimney.

Fig. 3.



86. *Q.*—Is the performance of this course by the smoke universal in wagon boilers?

A.—No; such boilers sometimes have what is termed a split draught. The smoke and flame, when they reach the end of the boiler, pass in this case through an iron flue or tube, reaching from end to end of the boiler; and on arriving at the front of the boiler, the smoke splits or separates—one half passing through a flue on the one side of the boiler, and the other half passing through a flue on the other side of the boiler—both of these flues having their debouch in the chimney.

87. *Q.*—What are the appliances usually connected with a wagon boiler?

A.—On the top of the boiler, near the front, is a short cylinder, with a lid secured by bolts. This is the manhole door, the purpose of which is to enable a man to get into the inside of the boiler when necessary for inspection and repair. On the top of this door is a small valve opening downward, called the atmospheric valve. The intention of this valve is to prevent a vacuum from being formed accidentally in the boiler, which might collapse it; for if the pressure in the boiler subsides to a point materially below the pressure of the atmosphere, the valve will open and allow air to get in. A bent pipe, which rises up from the top of the boiler, immediately behind the position of the manhole, is the steam pipe for conducting the steam to the engine; and a bent pipe which ascends from the top of the boiler, at the back end, is the waste-steam pipe for conducting away the steam, which escapes through the safety valve. This valve is set in a chest, standing on the top of the boiler, at the foot of the waste-steam pipe, and it is loaded with iron or leaden weights to a point answerable to the intended pressure of the steam.

88. *Q.*—How is the proper level of the water in the boiler maintained?

A.—By means of a balanced buoy or float. This float is attached to a rod, which in its turn is attached to a lever set on the top of a large upright pipe. The upper part of the pipe is widened out into a small cistern, through a short pipe in the middle of which a chain passes to the damper; but any water emptied into this small cistern cannot pass into the pipe, except through a small valve fixed to the lever to which the rod is attached. The water for replenishing the boiler is pumped into the small cistern on the top of the pipe; and it follows from these arrangements that when the buoy falls, the rod opens the small valve and allows the feed water to enter the pipe, which communicates with the water in the boiler; whereas, when the buoy rises, the feed cannot enter the pipe, and it has, therefore, to run to waste through an overflow pipe provided for the purpose.

89. *Q.*—How is the strength of the fire regulated?

A.—The draught through the furnaces of land boilers is regulated by a plate of metal or a damper, as it is called, which slides like a sluice up and down in the flue, and this damper is closed more or less when the intensity of the fire has to be moderated. In wagon boilers this is generally accomplished by self-acting mechanism. In the small cistern pipe, which is called a stand pipe, the water rises up to a height proportional to the pressure of the steam, and the surface of the water in this pipe will rise or fall with the fluctuations in the pressure of the steam. In this pipe a float is placed, which communicates by means of a chain with the damper. If the pressure of the steam rises, the float will be raised and the damper closed, whereas, if the pressure in the boiler falls, the reverse of this action will take place.

90. *Q.*—Are all land boilers of the same construction as that which you have just described?

A.—No; many land boilers are now made of a cylindrical form, with one or two internal flues in which the furnace is placed. A boiler of this kind is represented in Figs. 4 and 5, and which is the

Fig. 4.

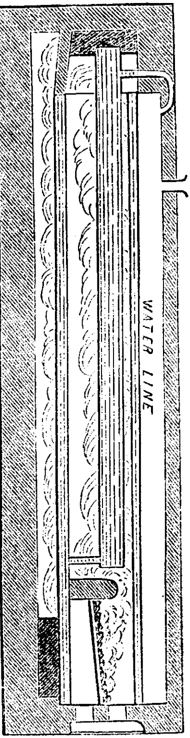
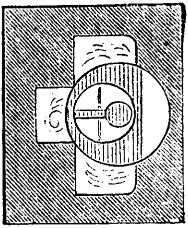


Fig. 5.

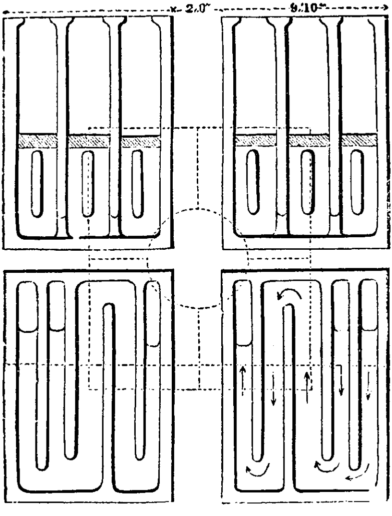


species of boiler principally used in Cornwall. In this boiler a large internal cylinder or flue runs from end to end. In the fore part of this cylinder the furnace is placed, and behind the furnace a large tube filled with water extends to the end of the boiler. This internal tube is connected to the bottom part of the boiler by a copper pipe standing vertically immediately behind the furnace bridge, and to the top part of the boiler by a bent copper pipe which stands in a vertical position near the end of the boiler. The smoke, after passing through the central flue, circulates round the sides and beneath the bottom of the boiler before its final escape into the chimney. The boiler is carefully covered over to prevent the dispersion of the heat.

91. *Q.*—Will you describe the construction of the boilers used in steam vessels?

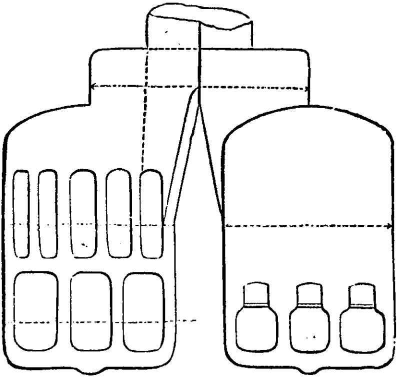
A.—These are of two classes, flue boilers and tubular boilers, but the latter are now most used. In the flue boiler the furnaces are set within the boiler, and the flues proceeding from them wind backwards and forwards within the boiler until finally they meet and enter the chimney. Figs. 6, 7, and 8 are different views of the flue boilers of the steamer Forth. There are 4 boilers (as shown in plan, Fig. 6), with 3 furnaces in each, or 12 furnaces in all. Fig. 7 is an elevation of 2 boilers, the one to the right being the front view, and that to the left a transverse section. Fig. 8 is

Fig. 6.



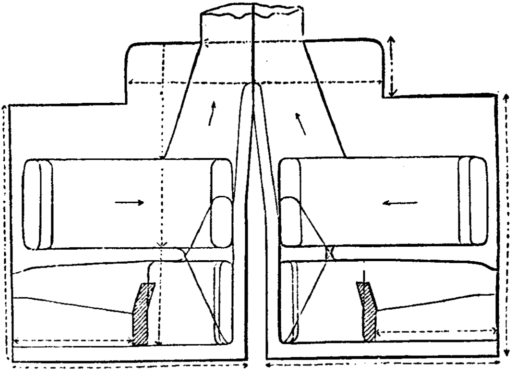
a longitudinal section through 2 boilers. The direction of the arrows in plan and longitudinal section will explain the direction of the smoke current.

Fig. 7.



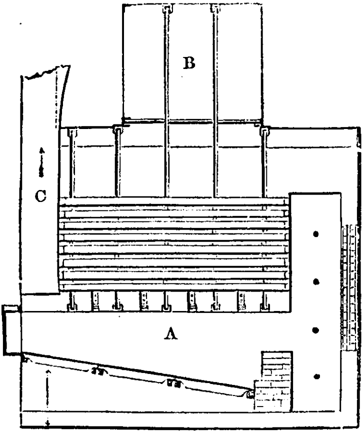
92. *Q.*—Is this arrangement different from that obtaining in tubular boilers?

Fig. 8.



A.—In tubular boilers, the smoke after leaving the furnace just passes once through a number of small tubes and then enters the chimney. These tubes are sometimes of brass, and they

Fig. 9.



are usually about 3 inches in diameter, and 6 or 7 feet long.

Fig. 10.

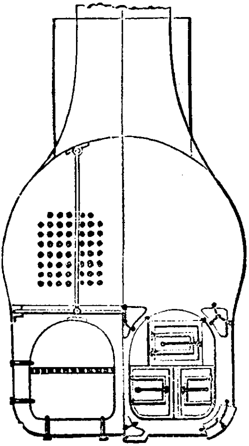
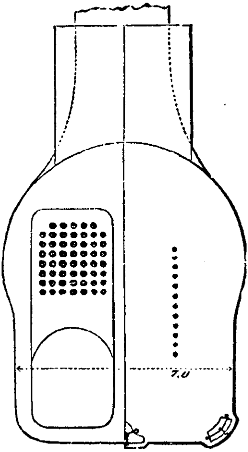


Fig. 11.



Figs. 9, 10, and 11 represent a marine tubular boiler; fig. 9 being a vertical longitudinal section, fig. 10 half a front elevation and half a transverse section, and fig. 11 half a back elevation and half a transverse section near the end. There is a projecting part on the top of the boiler called the "steam chest," of which the purpose is to retain for the use of the cylinder a certain supply of steam in a quiescent state, in order that it may have time to clear itself of foam or spray. A steam chest is a usual part of all marine boilers. In fig. 9 A is the furnace, B the steam chest, and C the smoke box which opens into the chimney. The front of the smoke box is usually closed by doors which may be opened when necessary to sweep the soot out of the tubes.

The following are some forms of American boilers:

Figs. 12 and 13 are the transverse and longitudinal sections of a common form of American marine boiler.

Figs. 14 and 15 are the front and sectional elevation of one of the boilers of the U. S. steamer Water Witch.

Fig. 12.

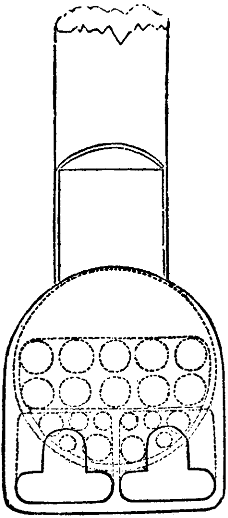
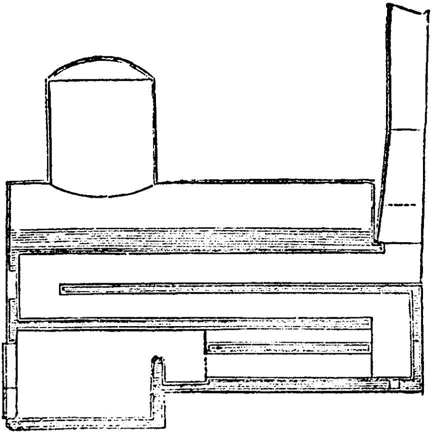


Fig. 13.



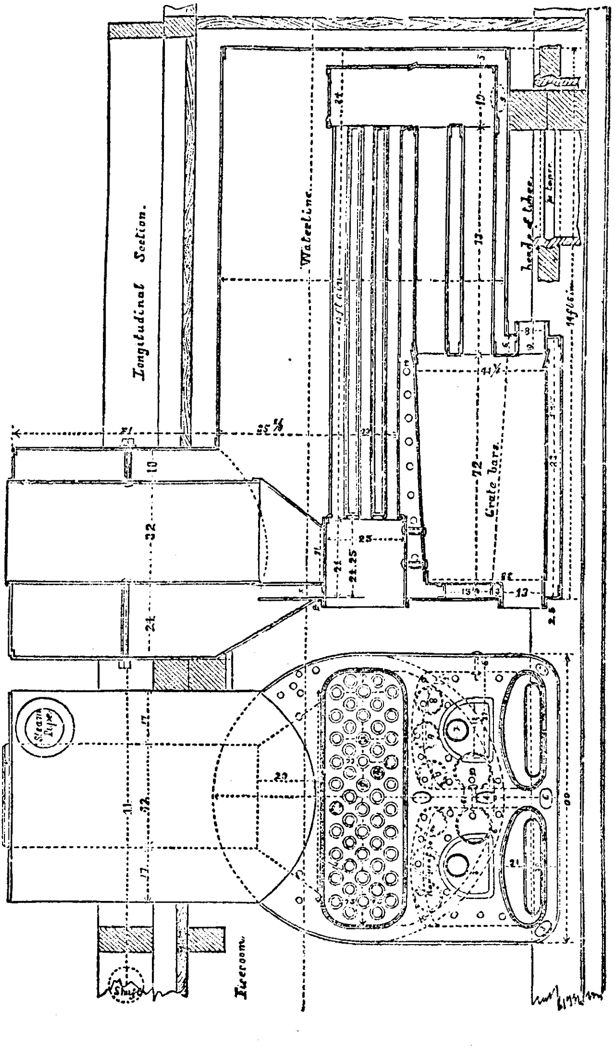

Longitudinal Section.
Waterline.
Grate bars.
Front Elevation.
Steam Pipe
Fireroom.

Fig. 15.

Fig. 14.

Fig. 16 is a longitudinal section of a boiler of the drop flue variety. For land purposes the lowest range of tubes is generally omitted, and the smoke makes a last return beneath the bottom of the boiler.

Figs. 17 and 18 are the transverse and longitudinal sections of a tubular boiler, built in 1837 by R. L. Stevens for the steamboat Independence.

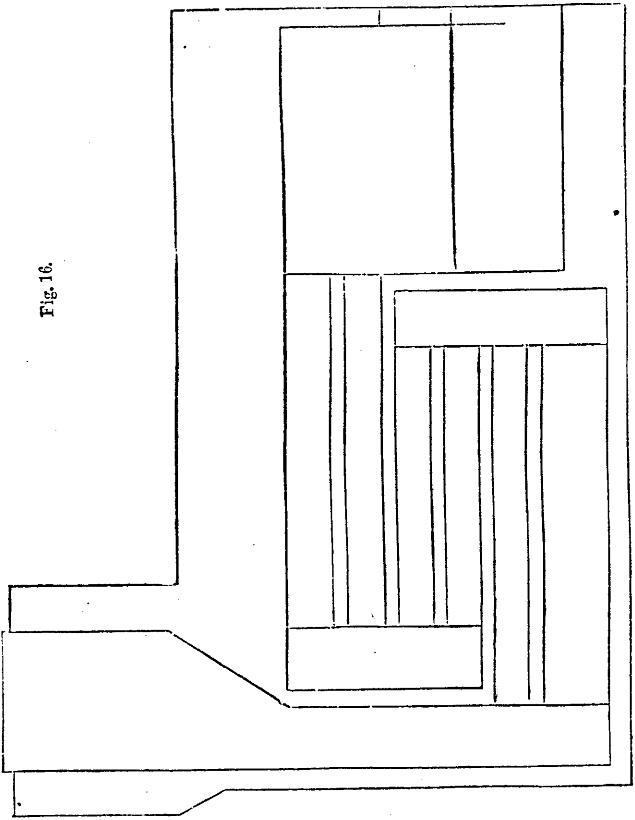


Fig. 16.

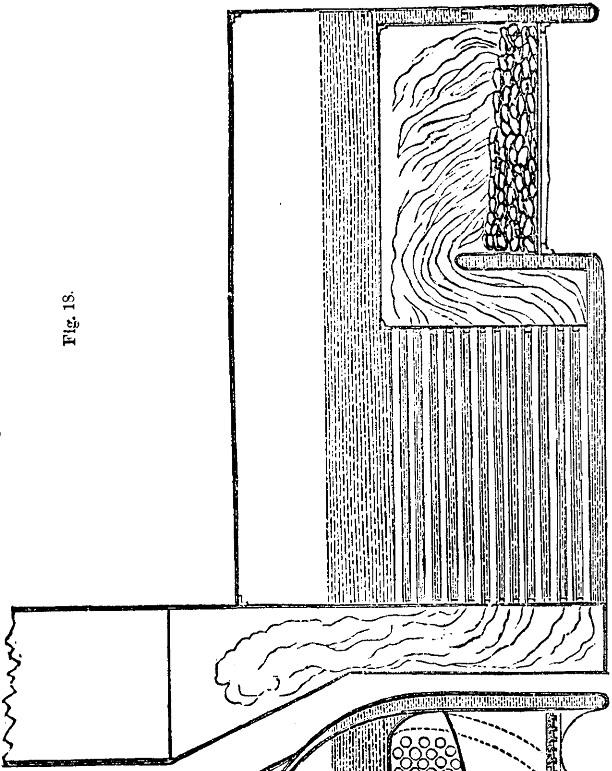


Fig. 18.

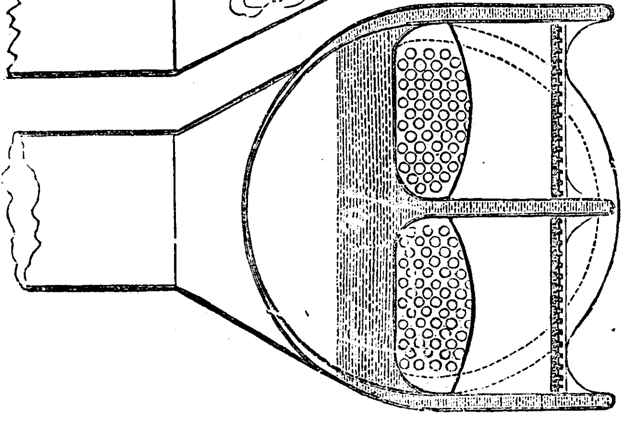


Fig. 17.

Fig. 19 is a longitudinal section of a common wood-burning locomotive.

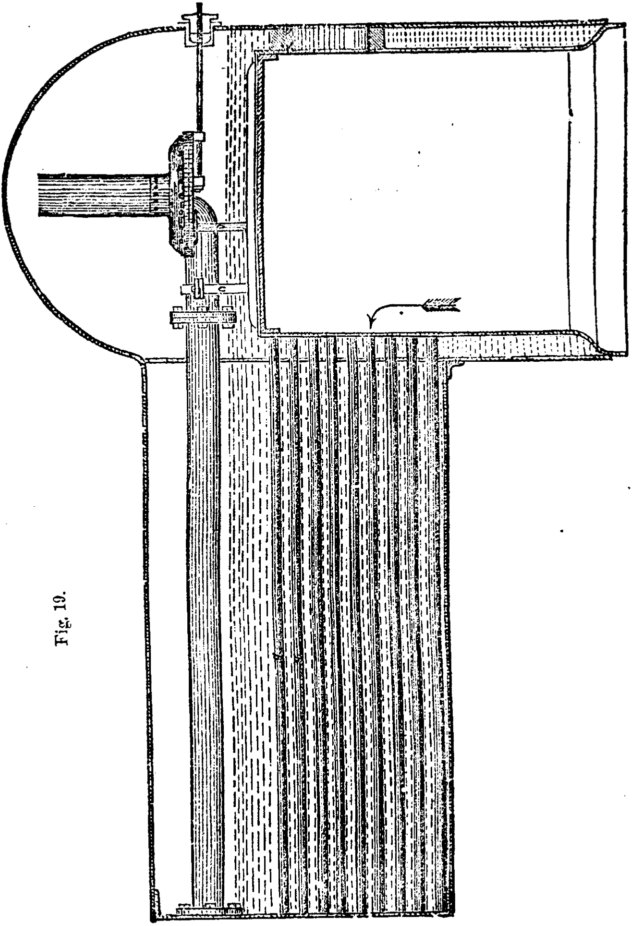


Fig. 19.

THE ENGINE.

93. *Q.*—The steam passes from the boiler through the steam pipe into the cylinder of the engine?

A.—And presses up and down the piston alternately, being admitted alternately above and below the piston by suitable valves provided for that purpose.

94. *Q.*—This reciprocating motion is all that is required in a pumping engine?

A.—The prevailing form of the pumping engine consists of a great beam vibrating on a centre like the beam of a pair of scales, and the cylinder is in connection with one end of the beam and the pump stands at the other end. The pump end of the beam is usually loaded, so as to cause it to preponderate when the engine is at rest; and the whole effort of the steam is employed in overcoming this preponderance until a stroke is performed, when, the steam being shut off, the heavy end of the beam again falls and the operation is repeated.

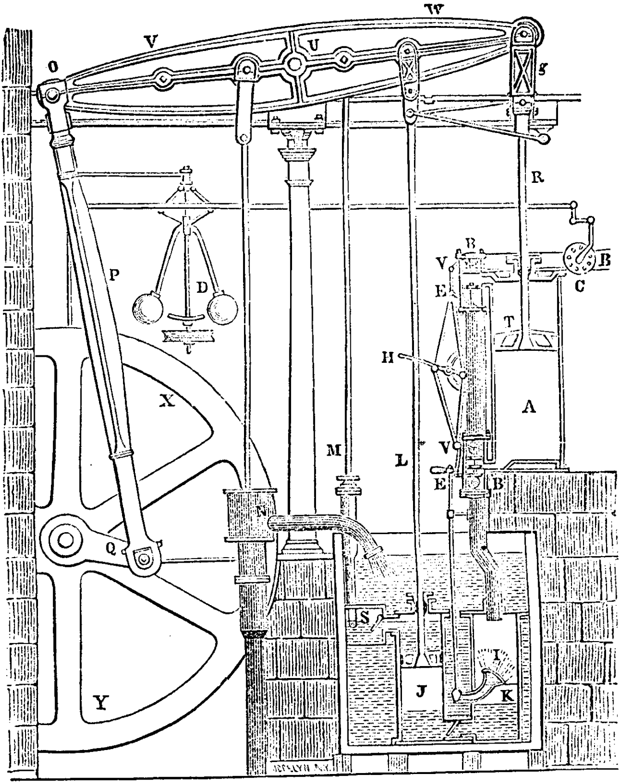
95. *Q.*—In the double-acting engine the piston is pushed by the steam both ways, whereas in the single-acting engine it is only pushed one way?

A.—The structure and action of a double-acting land engine of the kind introduced by Mr. Watt, will be understood by a reference to the annexed figure (fig. 20), where an engine of this kind is shown in section. A is the cylinder in which a movable piston, T, is forced alternately up and down by the alternate admission, to each side, of the steam from the boiler. The piston, by means of a rod called the piston rod, gives motion to the beam V W, which by means of a heavy bar, P, called the connecting rod, moves the crank, Q, and with it the fly wheel, X, from which the machinery to be driven derives its motion.

96. *Q.*—Where does the steam enter from the boiler?

A.—At the steam pipe, B. The throttle valve in that pipe is an elliptical plate of metal swivelling on a spindle passing through its edge from side to side, and by turning which more or less the opening through the pipe will be more or less closed. The extent to which this valve is opened or closed is determined by the governor, D, the balls of which, as they collapse or expand, move up or down a collar on the governor spindle, which motion is communicated to the throttle valve by suitable rods and bell-cranks. The governor, it will be seen, consists

Fig. 20.



substantially of two heavy balls attached to arms fixed upon an upright shaft, which is kept in revolution by means of a cord driven by a pulley on the fly wheel shaft. The velocity with which the balls of the governor revolve being proportional to that of the fly wheel, it will follow, that if by reason of too rapid a supply of steam, an undue speed be given to the fly wheel, and therefore to the balls, a divergence of the balls will take place to an extent corresponding to the excess of velocity, and this movement being communicated to the throttle valve it will be partly closed (see fig. 1), the supply of steam to the engine will be diminished, and the velocity of its motion will be reduced. If, on the other hand, the motion of the engine is slower than is requisite, owing to a deficient supply of steam through B, then the balls, not being sufficiently affected by centrifugal force, will fall towards the vertical spindle, and the throttle valve, C, will be more fully opened, whereby a more ample supply of steam will be admitted to the cylinder, and the speed of the engine will be increased to the requisite extent.

97. *Q.*—The piston must be made to fit the cylinder accurately so as to prevent the passage of steam?

A.—The piston is accurately fitted to the cylinder, and made to move in it steam tight by a packing of hemp driven tightly into a groove or recess round the edge of the piston, and which is squeezed down by an iron ring held by screws. The piston divides the cylinder into two compartments, between which there is no communication by which steam or any other elastic fluid can pass. A casing set beside the cylinder contains the valves, by means of which the steam which impels the piston is admitted and withdrawn, as the piston commences its motion in each direction. The upper steam box B, is divided into three compartments by two valves. Above the upper steam valve V, is a compartment communicating with the steam pipe B. Below the lower valve E is another compartment communicating with a pipe called the eduction pipe, which leads downwards from the cylinder to the condenser, in which vessel the steam is condensed by a jet of cold water. By the valve V, a communication may be opened or closed between the boiler and the top of the cylinder, so as to permit or prevent a supply of steam from the one to pass to the other. By the valve E a communication may be open or closed between the top of the cylinder and the condenser, so that the steam in the top compartment of the cylinder may either be permitted to escape into the condenser, or may be confined to the cylinder. The continuation of the steam pipe leads to the lower steam box B′, which, like the upper, is divided into three compartments by two valves V′ and E′, and the action of the lower valves is in all respects the same as that of the upper.

98. *Q.*—Are all these valves connected together so that they act simultaneously?

A.—The four valves V, E, V′, E′ are connected by rods to a single handle H, which handle is moved alternately up and down by means of pins or tappets, placed on the rod which works the air pump. When the handle H is pressed down, the levers in connexion with it open the upper exhausting valve E, and the lower steam valve V′, and close the upper steam valve V and the lower exhausting valve E′. On the other hand, when the handle H is pressed up it opens the upper steam valve V and the lower exhausting valve E′, and at the same time closes the upper exhausting valve E, and the lower steam valve V′.

99. *Q.*—Where is the condenser situated?

A.—The condenser K is immerged in a cistern of cold water. At its side there is a tube I, for the admission of water to condense the steam, and which is governed by a cock, by opening which to any required extent, a jet of cold water may be made to play in the condenser. From the bottom of the condenser a short pipe leads to the air pump J, and in this pipe there is a flap valve, called the foot valve, opening towards the air pump. The air pump is a pump set in the same cistern of cold water that holds the condenser, and it is fitted with a piston or bucket worked by the rod L, attached to the great beam, and fitted with a valve opening upwards in the manner of a common sucking pump. The upper part of the air pump communicates with a small cistern S, called the hot well, through a valve opening outwards and called the delivery valve. A pump M, called the hot water pump, lifts hot water out of the hot well to feed the boiler, and another pump N lifts cold water from a well or other source of supply, to maintain the supply of water to the cold water cistern, in which the condenser and air pump are placed.

100. *Q.*—Will you explain now the manner in which the engine acts?

A.—The piston being supposed to be at the top of the cylinder, the handle H will be raised by the lower pin or tappet on the air pump rod, and the valves V and E′ will be opened, and at the same time the other pair of valves V′ and E will be closed. Steam will therefore be admitted above the piston and the steam or air which had previously filled the cylinder below the piston will be drawn off to the condenser. It will there encounter the jet of cold water, which is kept constantly playing there by keeping the cock I sufficiently open. It will thus be immediately condensed or reduced to water, and the cylinder below the piston will have a vacuum in it. The steam therefore admitted from the steam pipe through the open valve V to the top of the cylinder, not being resisted by pressure below, will press the piston to the bottom of the cylinder. As it approaches that position, the handle H will be struck down by the upper pin or tappet on the air pump rod, and the valves V and E′, previously open, will be closed, while the valves V′ and E, previously closed, will be opened. The steam which has just pressed down the piston, and which now fills the cylinder above the piston, will then flow off, through the open valve E, to the condenser, where it will be immediately condensed by the jet of cold water; and steam from the boiler, admitted through the open valve V′, will fill the cylinder below the piston, and press the piston upwards. When the piston has reached the top of the cylinder, the lower pin on the air pump rod will have struck the handle upwards, and will thereby have closed the valves V′ and E, and opened the valves V and E′. The piston will then be in the same situation as in the commencement, and will again descend, and so will continue to be driven up and down by the steam.

101. *Q.*—But what becomes of the cold water which is let into the condenser to condense the steam?

A.—It is pumped out by the air pump in the shape of hot water, its temperature having been raised considerably by the admixture of the steam in it. When the air pump piston ascends it leaves behind it a vacuum; and the foot valve being relieved from all pressure, the weight of the water in the condenser forces it open, and the warm water flows from the condenser into the lower part of the air pump, from which its return to the condenser is prevented by the intervening valve. When the air pump piston descends, its pressure on the liquid under it will force open the valve in it, through which the hot water will ascend; and when the bucket descends to the bottom of the pump barrel, the warm water which was below it will all have passed above it, and cannot return. When the bucket next ascends, the water above it, not being able to return through the bucket valve, will be forced into the hot well through the delivery valve S. The hot water pump M, pumps a small quantity of this hot water into the boiler, to compensate for the abstraction of the water that has passed off in the form of steam. The residue of the hot water runs to waste.

102. *Q.*—By what expedient is the piston rod enabled to pass through the cylinder cover without leaking steam out of the cylinder or air into it?

A.—The hole in the cylinder lid, through which the piston rod passes, is furnished with a recess called a stuffing box, into which a stuffing or packing of plaited hemp is forced, which, pressing on the one side against the interior of the stuffing box, and on the other side against the piston rod, which is smooth and polished, prevents any leakage in this situation. The packing of this stuffing box is forced down by a ring of metal tightened by screws. This ring, which accurately fits the piston rod, has a projecting flange, through which bolts pass for tightening the ring down upon the packing; and a similar expedient is employed in nearly every case in which packing is employed.

103. *Q.*—In what way is the piston rod connected to the great beam?

A.—The piston rod is connected to the great beam by means of two links, one at each side of the beam shown at *f g*, (fig. 21.) These links are usually made of the same length as the crank, and their purpose is to enable the end of the great beam to move in the arc of a circle while the piston rod maintains the vertical position. The point of junction, therefore, of the links and the piston rod is of the form of a knuckle or bend at some parts of the stroke.

104. *Q.*—But what compels the top of the piston rod to maintain the vertical position?

A.—Some engines have guide rods set on each side of the piston rod, and eyes on the top of the piston rod engage these guide rods, and maintain the piston rod in a vertical position in every part of the stroke. More commonly, however, the desired end is attained by means of a contrivance called the parallel motion.

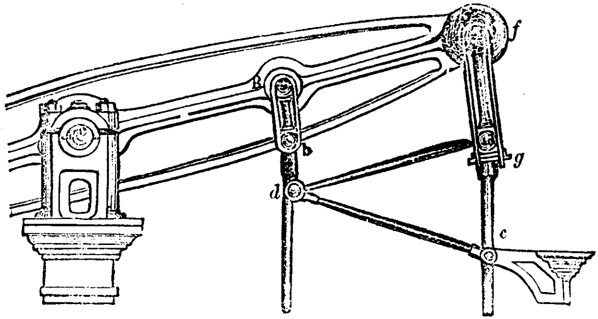
105. *Q.*—What is the parallel motion?

A.—The parallel motion is an arrangement of jointed rods, so connected together that the divergence from the vertical line at any point in the arc described by the beam is corrected by an equal and opposite divergence due to the arc performed by the jointed rods during the stroke; and as these opposite deviations mutually correct one another, the result is that the piston rod moves in a vertical direction.

106. *Q.*—Will you explain the action more in detail?

A.—The pin, fig 21, which passes through the end of the beam at *f* has a link *f g* hung on each side of the beam, and a short cross bar, called a cross head, extends from the bottom of one of these links to the bottom of the other, which cross head is perforated with a hole in the middle for the reception of the piston rod. There are similar links *b d* at the point of the main beam, where the air pump rod is attached. There are two rods *d g* connecting the links *b d* with the links *f g*, and these rods, as they always continue parallel to the main beam throughout the stroke, are called *parallel bars.* Attached to the end of these two rods at *d* are two other rods *c d*, of which the ends at *c* are attached to stationary pins, while the ends at *d* follow the motion of the lower ends of the links *b d*. These rods are called the *radius bars.* Now it is obvious that the arc described by the point *d*, with *c* as a centre, is opposite to the arc described by the point *g* with *d* as a centre. The rod *d g* is, therefore, drawn back horizontally by the arc described at *d* to an extent equal to the

Fig. 21.



versed sine of the arc described at *g*, or, in other words, the line described by the point *g* becomes a straight line instead of a curve.

107. *Q*—Does the air pump rod move vertically as well as the piston rod?

A.—It does. The air pump rod is suspended from a cross head, passing from the centre of one of the links *b d* to the centre of the other link, on the opposite side of the beam. Now, as the distance from the central axis of the great beam to the point *b* is equal to the length of the rod *c d*, it will follow that the upper end of the link will follow one arc, and the lower end an equal and opposite arc. A point in the centre of the link, therefore, where these opposite motions meet, will follow no arc at all, but will move up and down vertically in a straight line.

108. *Q.*—The use of the crank is to obtain a circular motion from a reciprocating motion?

A.—That is the object of it, and it accomplishes its object in a very perfect manner, as it gradually arrests the velocity of the piston towards the end of the stroke, and thus obviates what would otherwise be an injurious shock upon the machine. When the crank approaches the lowest part of its throw, and at the same time the piston is approaching the top of the cylinder, the motion of the crank becomes nearly horizontal, or, in other words, the piston is only advanced through a very short distance, for any given distance measured on the circle described by the crank pin. Since, then, the velocity of rotation of the crank is nearly uniform, it will follow that the piston will move very slowly as it approaches the end of the stroke; and the piston is brought to a state of rest by this gradually retarded motion, both at the top and the bottom of the stroke.

109. *Q.*—What causes the crank to revolve at a uniform velocity?

A.—The momentum of the machinery moved by the piston, but more especially of the fly wheel, which by its operation redresses the unequal pressures communicated by the crank, and compels the crank shaft to revolve at a nearly uniform velocity. Everyone knows that a heavy wheel if put into rapid rotation cannot be immediately stopped. At the beginning and end of the stroke when the crank is vertical, no force of torsion can be exerted on the crank shaft by the crank, but this force is at its maximum when the crank is horizontal. From the vertical point, where this force is nothing, to the horizontal point, where it is at its maximum, the force of torsion exerted on the crank shaft is constantly varying; and the fly wheel by its momentum redresses these irregularities, and carries the crank through that "dead point," as it is termed, where the piston cannot impart any rotative force.

110. *Q.*—Are the configuration and structure of the steam engine, as it left the hand of Watt, materially different from those of modern engines?

A.—There is not much difference. In modern rotative land engines, the valves for admitting the steam to the cylinder or condenser, instead of being clack or pot-lid valves moved by tappets on the air pump rod, are usually sluice or sliding valves, moved by an eccentric wheel on the crank shaft. Sometimes the beam is discarded altogether, and malleable iron is more largely used in the construction of engines instead of the cast iron, which formerly so largely prevailed. But upon the whole the steam engine of the present day is substantially the engine of Watt; and he who perfectly understands the operation of Watt's engine, will have no difficulty in understanding the operation of any of the numerous varieties of engines since introduced.

THE MARINE ENGINE.

111. *Q.*—Will you describe the principal features of the kind of steam engine employed for the propulsion of vessels?

A.—Marine engines are of two kinds,—paddle engines and screw engines. In the one case the propelling instrument is paddle wheels kept in rotation at each side of the ship: in the other case, the propelling instrument is a screw, consisting of two or more twisted vanes, revolving beneath the water at the stern. Of each class of engines there are many distinct varieties.

112. *Q.*—What are the principal varieties of the paddle engine?

A.—There is the side lever engine (fig. 26), and the oscillat-

Fig. 22.

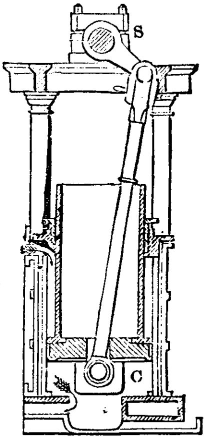
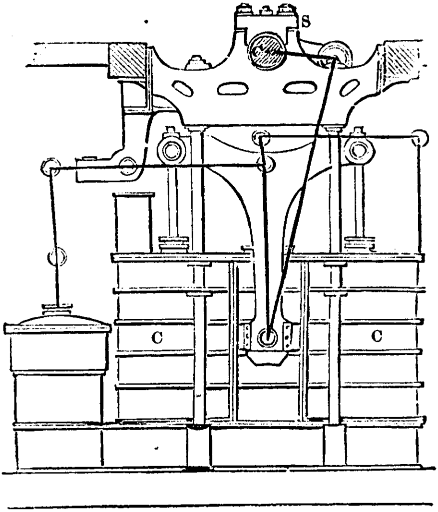
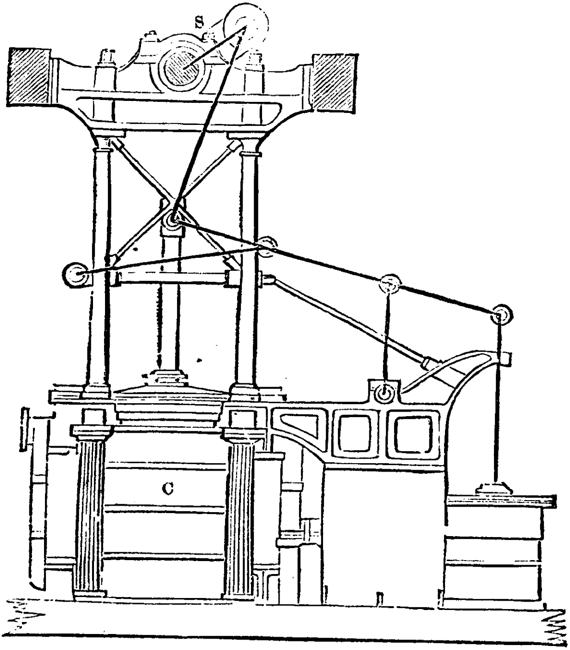


Fig. 23.



ing engine (fig. 27), besides numerous other forms of engine which are less known or employed, such as the trunk (fig. 22), double cylinder (fig. 23), annular, Gorgon (fig. 24), steeple (fig. 25), and many others. The side lever engine, however,

Fig. 24.

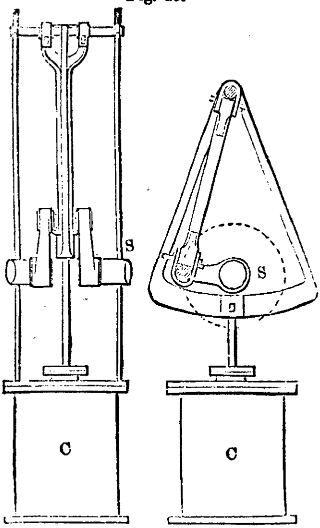


and the oscillating engine, are the only kinds of paddle engines which have been received with wide or general favor.

113. *Q.*—Will you explain the main distinctive features of the side lever engine?

A.—In all paddle vessels, whatever be their subordinate characteristics, a great shaft of wrought iron, s, turned round by the engine, has to be carried from side to side of the vessel, on which shaft are fixed the paddle wheels. The paddle wheels may either be formed with fixed float boards for engaging the water, like the boards of a common undershot water wheel, or they may be formed with *feathering* float boards as they are termed, which is float boards movable on a centre, and so governed by appropriate mechanism that they enter and leave the water in a nearly vertical position. The common fixed or radial floats, however, are the kind most widely employed, and they are attached to the arms of two or more rings of malleable iron which are fixed by appropriate centres on the paddle shaft. It is usual in steam vessels to employ two engines, the cranks of which are set at right angles with one another. When the paddle wheels are turned by the engines, the float boards engaging the water cause a forward thrust to be imparted to the shaft, which propels forward the vessel on the same principle that a boat is propelled by the action of oars.

Fig. 25.

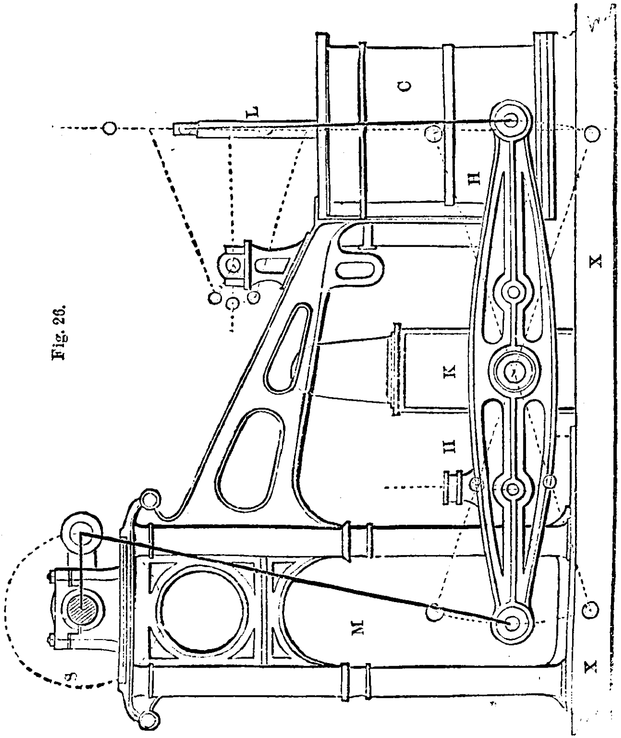


114. *Q.*—These remarks apply to all paddle vessels?

A.—They do. With respect to the side lever engine, it may be described to be such a modification of the land beam engine already described, as will enable it to be got below the deck of a vessel. With this view, instead of a single beam being placed overhead, two beams are used, one of which is set on each side of the engine as low down as possible. The cross head which engages the piston rod is made somewhat longer than the diameter of the cylinder, and two great links or rods proceed one from each end of the cross head to one of the side levers or beams. A similar cross bar at the other end of the beams serves to connect them together and to the connecting rod which, proceeding from thence upwards, engages the crank, and thereby turns round the paddle wheels.

115. *Q.*—Will you further illustrate this general description by an example?

Fig. 26.



A.—Fig. 26 is a side elevation of a side lever engine; x x represent the beams or keelsons to which the engines are attached, and on which the boilers rest. The engines are tied down by strong bolts passing through the bottom of the vessel, but the boiler keeps its position by its weight alone. The condenser and air pump are worked off the side levers by means of side rods and a cross head. A strong gudgeon, called the *main centre*, passes through the condenser at K, the projecting ends of which serve to support the side levers or beams. L is the piston rod, which, by means of the cross head and side rods, is connected to the side levers or beams, one of which is shown at H H. The line M represents the connecting rod, to which motion is imparted by the beams, through the medium of the cross tail extending between the beams, and which by means of the crank turns the paddle shaft S. The eccentric which works the slide valve is placed upon the paddle shaft. It consists of a disc of metal encircled by a hoop, to which a rod is attached, and the disc is perforated with a hole for the shaft, not in the centre, but near one edge. When, therefore, the shaft revolves, carrying the eccentric with it, the rod attached to the encircling hoop receives a reciprocating motion, just as it would do if attached to a crank in the shaft.

116. *Q.*—Will you describe the mode of starting the engine?

A.—I may first mention that when the engine is at rest, the connection between the eccentric and the slide valve is broken, by lifting the end of the eccentric rod out of a notch which engages a pin on the valve shaft, and the valve is at such times free to be moved by hand by a bar of iron, applied to a proper part of the valve gear for that purpose. This being so, the engineer, when he wishes to start the engine, first opens a small valve called the *blow through valve*, which permits steam from the boiler to enter the engine both above and below the piston, and also to fill the condenser and air pump. This steam expels the air from the interior of the engine, and also any water which may have accumulated there; and when this has been done, the blow through valve is shut, and a vacuum very soon forms within the engine, by the condensation of the steam. If now the slide valve be moved by hand, the steam from the boiler will be admitted on one side of the piston, while there is a vacuum on the other side, and the piston will, therefore, be moved in the desired direction. When the piston reaches the end of the stroke, the valve has to be moved in the reverse direction, when the piston will return, and after being moved thus by hand, once or twice, the connection of the valve with the eccentric is to be restored by allowing the notch on the end of the eccentric rod to engage the pin on the valve lever, when the valve will be thereafter moved by the engine in the proper manner. It will, of course, be necessary, when the engine begins to move, to open the injection cock a little, to enable water to enter for the condensation of the steam. In the most recent marine engines, a somewhat different mechanism from this is used for giving motion to the valves, but that mechanism will be afterwards described.

117. *Q.*—Are all marine engines condensing engines?

A.—Nearly all of them are so; but recently a number of gunboats have been constructed, with high pressure engines. In general, however, marine engines are low pressure or condensing engines.

118. *Q.*—Will you now describe the chief features of the oscillating paddle marine engine?

A.—In the oscillating paddle marine engine, the arrangement of the paddle shaft and paddle wheels is the same as in the case already described, but the whole of the side levers, side rods, cross head, cross tail, and connecting rod are discarded. The cylinder is set immediately under the crank; the top of the piston rod is connected immediately to the crank pin; and, to enable the piston rod to accommodate itself to the movement of the crank, the cylinder is so constructed as to be susceptible of vibrating or oscillating upon two external axes or trunnions. These trunnions are generally placed about half way up on the sides of the cylinder; and through one of them steam is received from the boiler, while through the other the steam escapes to the condenser. The air pump is usually worked by means of a crank in the shaft, which crank moves the air pump bucket up and down as the shaft revolves.

119. *Q.*—Will you give an example of a paddle oscillating engine?

A.—I will take as an example the oscillating engines constructed by Messrs. Ravenhill & Salked, for the Holyhead Packets. Fig. 27 is a longitudinal section of this vessel, showing an engine and boiler; and fig. 28 is a transverse section of one of the engines, showing also one of the wheels. There are two cylinders in this vessel, and one air pump, which lies in an inclined position, and is worked by a crank in the shaft which stretches between the cylinders, and which is called the *intermediate shaft.* A A, is one of the cylinders, B B the piston rod, and C C the crank. D is the crank in the intermediate shaft, which works the air pump E. There are double eccentrics fixed on the shaft, whereby the movement of the slide valves is regulated. The purpose of the double eccentrics is to enable an improved arrangement of valve gear to be employed, which is denominated the *link motion*, and which will be described hereafter. I I are the steam pipes leading to the steam trunnions K K, on which, and on the eduction trunnions connected with the pipe M, the cylinders oscillate.

120. *Q.*—By what species of mechanism are the positions of the paddle floats of feathering wheels governed?

A.—The floats are supported by spurs projecting from the rim of the wheel, and they may be moved upon the points of the spurs, to which they are attached by pins, by means of short levers proceeding from the backs of the floats, and connected to rods which proceed towards the centre of the wheel. The centre, however, to which these rods proceed is not concentric with the wheel, and the rods, therefore, are moved in and out as the wheel revolves, and impart a corresponding motion to the floats. In some feathering wheels the proper motion is given to the rods by means of an eccentric on the ship's side. The action of paddle wheels, whether radial or feathering, will be more fully described in the chapter on Steam Navigation.

SCREW ENGINES.

121. *Q.*—What are the principal varieties of screw engines?

A.—The engines employed for the propulsion of screw vessels

Fig. 27.

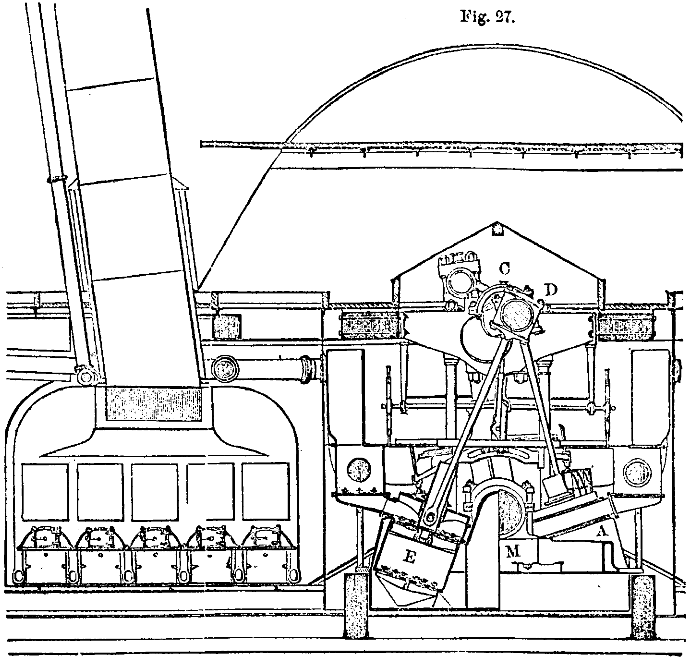
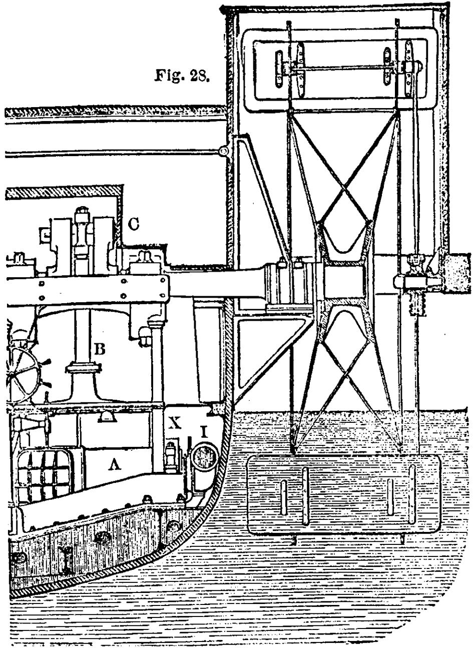


Fig. 28.



are divided into two great classes,—geared engines and direct acting engines; and each of these classes again has many varieties. In screw vessels, the shaft on which the screw is set requires to revolve at a much greater velocity than is required in the case of the paddle shaft of a paddle vessel; and in geared engines this necessary velocity of rotation is obtained by the intervention of toothed wheels,—the engines themselves moving with the usual velocity of paddle engines; whereas in direct acting engines the required velocity of rotation is obtained by accelerating the speed of the engines, and which are connected immediately to the screw shaft.

122. *Q.*—Will you describe some of the principal varieties of geared engines?

A.—A good many of the geared engines for screw vessels are made in the same manner as land engines, with a beam overhead, which by means of a connecting rod extending downwards, gives motion to the crank shaft, on which are set the cog wheels which give motion to pinions on the screw shaft,—the teeth of the wheels being generally of wood and the teeth of the pinions of iron. There are usually several wheels on the crank shaft and several pinions on the screw shaft; but the teeth of each do not run in the same line, but are set a little in advance of one another, so as to divide the thickness of the tooth into as many parts as there are independent wheels or pinions. By this arrangement the wheels work more smoothly than they would otherwise do.

123. *Q.*—What other forms are there of geared screw engines?

A.—In some cases the cylinders lie on their sides in the manner of the cylinders of a locomotive engine. In other cases vertical trunk engines are employed; and in other cases vertical oscillating engines.

124. *Q.*—Will you give an example of a geared vertical oscillating engine?

A.—The engines of a geared oscillating engine are similar to the paddle wheel engines (figs. 27 and 28), but the engines are placed lengthways of the ship, and instead of a paddle wheel on the main shaft, there is a geared wheel which connects with a pinion on the screw shaft. The engines of the Great Britain are made off the same patterns as the paddle engines constructed by Messrs. John Penn & Son, for H. M. S. Sphinx. The diameter of each cylinder is 82½ inches, the length of travel or stroke of the piston is 6 feet, and the nominal power is 500 horses. The Great Britain is of 3,500 tons burden, and her displacement at 16 feet draught of water is 2,970 tons. The diameter of the screw is 15½ feet, length of screw in the line of the shaft, 3 feet 2 inches, and the pitch of the screw, 19 feet.

125. *Q.*—What do you mean by the pitch of the screw?

A.—A screw propeller may be supposed to be a short piece cut off a screw of large diameter like a spiral stair, and the pitch of a spiral stair is the vertical height from any given step to the step immediately overhead.

126. *Q.*—What is the usual number of arms?

A.—Generally a screw has two arms, but sometimes it has three or more. The Great Britain had three arms or twisted blades resembling the vanes of a windmill. The multiple of the gearing in the Great Britain is 3 to 1, and there are 17½ square feet of heating surface in the boiler for each nominal horse power. The crank shaft being put into motion by the engine, carries round with it the great cog wheel, or aggregation of cog wheels, affixed to its extremity; and these wheels acting on suitable pinions on the screw shaft, cause the screw to make three revolutions for every revolution made by the engine.

127. *Q.*—What are the principal varieties of direct acting screw engines?

A.—In some cases four engines have been employed instead of two, and the cylinders have been laid on their sides on each side of the screw shaft. This multiplication of engines, however, introduces needless complication, and is now but little used. In other cases two inverted cylinders are set above the screw shaft on appropriate framing; and connecting rods attached to the ends of the piston rods turn round cranks in the screw shaft.

128. *Q.*—What is the kind of direct acting screw engine employed by Messrs. Penn.

A.—It is a horizontal trunk engine. In this engine a round pipe called a trunk penetrates the piston, to which it is fixed, being in fact cast in one piece with it; and the trunk also penetrates the top and bottom of the cylinder, through which it moves, and is made tight therein by means of stuffing boxes. The connecting rod is attached at one end to a pin fixed in the middle of the trunk, while the other end engages the crank in the usual manner. The air pump is set within the condenser, and is wrought by a rod which is fixed to the piston and derives its motion therefrom. The air pump is of that species which is called double-acting. The piston or bucket is formed without valves in it, but an inlet and outlet valve is fixed to each end of the pump, through the one of which the water is drawn into the pump barrel, and through the other of which it is expelled into the hot well.

THE LOCOMOTIVE ENGINE.

129. *Q.*—Will you describe the more important features of the locomotive engine?

A.—The locomotive employed to draw carriages upon railways, consists of a cylindrical boiler filled with brass tubes, through which the hot air passes on its progress from the furnace to the chimney, and attached to the boiler are two horizontal cylinders fitted with pistons, valves, connecting rods, and other necessary apparatus to enable the power exerted by the pistons to turn round the cranked axle to which the driving wheels are attached. There are, therefore, two independent engines entering into the composition of a locomotive, the cranks of which are set at right angles with one another, so that when one crank is at its dead point, the other crank is in a position to act with its maximum efficacy. The driving wheels, which are fixed on the crank shaft and turn round with it, propel the locomotive forward on the rails by the mere adhesion of friction, and this is found sufficient not merely to move the locomotive, but to draw a long train of carriages behind it.

130. *Q.*—Are locomotive engines condensing or high pressure engines.

A.—They are invariably high pressure engines, and it would be impossible, or at least highly inconvenient, to carry the water necessary for the purpose of condensation. The steam, therefore, after it has urged the piston to the end of the stroke, escapes into the atmosphere. In locomotive engines the waste steam is always discharged into the chimney through a vertical pipe, and by its rapid passage it greatly increases the intensity of the draught in the chimney, whereby a smaller fire grate suffices for the combustion of the fuel, and the evaporative power of the boiler is much increased.

131. *Q.*—Can you give an example of a good locomotive engine of the usual form?

A.—To do this I will take the example of one of Hawthorn's locomotive engines with six wheels represented in fig. 29; not one of the most modern construction now in use, nor yet one of the most antiquated. M is the cylinder, R the connecting rod, C C the eccentrics by which the slide valve is moved; J J is the steam pipe by which the steam is conducted from the steam dome of the boiler to the cylinder. Near the smoke stack end of this pipe is a valve K or regulator moved by a handle *p* at the front of the boiler, and of which the purpose is to regulate the admission of the steam to the cylinder; *f* is a safety valve kept closed by springs; N is the eduction pipe, or, as it is commonly termed in locomotives, the *blast pipe*, by which the steam, escaping from the cylinder after the stroke has been performed, is projected up the chimney H. The water in the boiler of course covers the tubes and also the top of the furnace or fire box. It will be understood that there are two engines in each locomotive, though, from the figure being given in section, only one engine can be shown. The cylinders of this engine are each 14 inches diameter; the length of the stroke of the piston is 21 inches. There are two sets of driving wheels, 5 feet diameter, with outside connections.

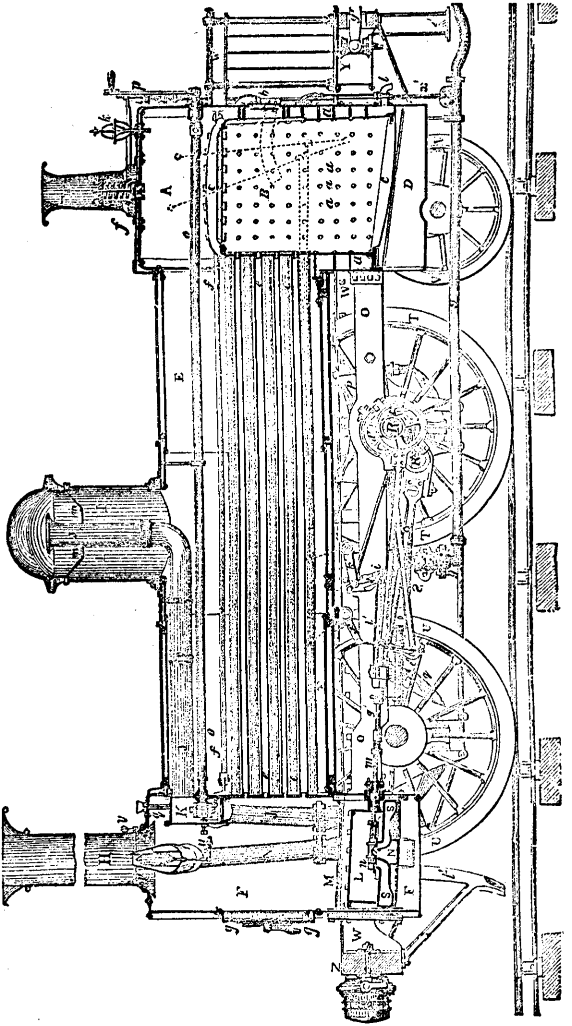


Fig. 29.

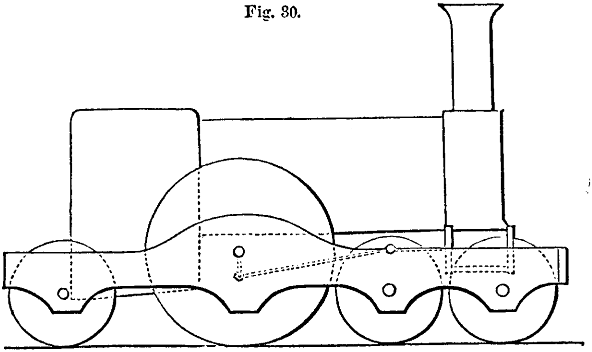
132. *Q.*—What is the tender of a locomotive?

A.—It is a carriage attached to the locomotive, of which the purpose is to contain coke for feeding the furnace, and water for replenishing the boiler.

133. *Q.*—Can you give examples of modern locomotives?

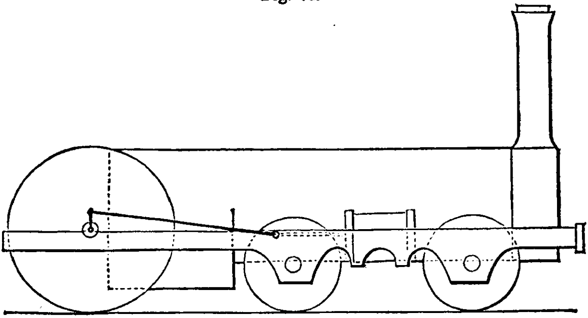
A.—The most recent locomotives resemble in their material features the locomotive represented in fig. 29. I can, however, give examples of some of the most powerful engines of recent

Fig. 30.



construction. Fig. 30 represents Gooch's express engine, adapted

Fig. 31.



for the wide gauge of the Great Western Railway; and fig. 31

represents Crampton's express engine, adapted for the ordinary or narrow gauge railways. The cylinders of Gooch's engine are each 18 inches diameter, and 24 inches stroke; the driving wheels are 8 feet in diameter; the fire grate contains 21 square feet of area; and the heating surface of the fire box is 153 square feet. There are in all 305 tubes in the boiler, each of 2 inches diameter, giving a heating surface in the tubes of 1799 square feet. The total heating surface, therefore, is 1952 square feet. Mr. Gooch states that an engine of this class will evaporate from 300 to 360 cubic feet of water in the hour, and will convey a load of 236 tons at a speed of 40 miles an hour, or a load of 181 tons at a speed of 60 miles an hour. The weight of this engine empty is 31 tons; of the tender 8½ tons; and the total weight of the engine when loaded is 50 tons. In one of Crampton's locomotives, the Liverpool, with one set more of carrying wheels than the fig., the cylinders are of 24 inches diameter and 18 inches stroke; the driving wheels are 8 feet in diameter; the fire grate contains 21½ square feet of area; and the heating surface of the fire box is 154 square feet. There are in all 300 tubes in the boiler of $2\frac{3}{16}$ inches external diameter, giving a surface in the tubes of 2136 square feet, and a total heating surface of 2290 square feet. The weight of this engine is stated to be 35 tons when ready to proceed on a journey. Both engines were displayed at the Great Exhibition in 1851, as examples of the most powerful locomotive engines then made. The weight of such engines is very injurious to the railway; bending, crushing, and disturbing the rails, and trying very severely the whole of the railway works. No doubt the weight may be distributed upon a greater number of wheels, but if the weight resting on the driving wheels be much reduced, they will not have sufficient bite upon the rails to propel the train without slipping. This, however, is only one of the evils which the demand for high rates of speed has produced. The width of the railway, or, as it is termed, the *gauge* of the rails, being in most of the railways in this kingdom limited to 4 feet 8½ inches, a corresponding limitation is imposed on the diameter of the boiler; which in its turn restricts the number of the tubes which can be employed. As, however, the attainment of a high rate of speed requires much power, and consequently much heating surface in the boiler, and as the number of tubes cannot be increased without reducing their diameter, it has become necessary, in the case of powerful engines, to employ tubes of a small diameter, and of a great length, to obtain the necessary quantity of heating surface; and such tubes require a very strong draught in the chimney to make them effective. With a draught of the usual intensity the whole of the heat will be absorbed in the portion of the tube nearest the fire box, leaving that portion nearest the smoke box nothing to do but to transmit the smoke; and with long tubes of small diameter, therefore, a very strong draught is indispensable. To obtain such a draught in locomotives, it is necessary to contract the mouth of the blast pipe, whereby the waste steam will be projected into the chimney with greater force; but this contraction involves an increase of the pressure on the eduction side of the piston, and consequently causes a diminution in the power of the engine. Locomotives with small and long tubes, therefore, will require more coke to do the same work than locomotives in which larger and shorter tubes may be employed.