A CATECHISM

OF THE

TEAM ENGINE

IN ITS VARIOUS APPLICATIONS TO

INES, MILLS, STEAM NAVIGATION, RAILWAYS,
AND AGRICULTURE.

WITH

PRACTICAL INSTRUCTIONS

FOR THE

ACTURE AND MANAGEMENT OF ENGINES OF EVERY CLASS.

BY

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1864.

illustrations from American practice, of steam engines [illegible] applied to different purposes, and of appliances and m[illegible] chines necessary to them. But with the exception [illegible] some of the illustrations and the description of the[illegible] and the correction of a few typographical errors, th[illegible] edition is a faithful transcript of the latest Engl[illegible] edition.

CONTENTS.

MECHANICAL PRINCIPLES

OF

THE STEAM ENGINE.

CLASSIFICATION OF ENGINES.

1. Q.—WHAT is meant by a vacuum?

A.—A vacuum means an empty space; a space in which there is neither water nor air, nor anything else that we know of.

2. Q.—Wherein does a high pressure differ from a low pressure engine?

A.—In a high pressure engine the steam, after having pushed the piston to the end of the stroke, escapes into the atmosphere, and the impelling force is therefore that due to the difference between the pressure of the steam and the pressure of the atmosphere. In the condensing engine the steam, after having pushed the piston to the end of the stroke, passes into the condenser, in which a vacuum is maintained, and the impelling force is that due to the difference between the pressure of the steam above the piston, and the pressure of the vacuum beneath it, which is nothing; or, in other words, you have then the whole pressure of the steam urging the piston, consisting of the pressure shown by the safety-valve on the boiler, and the pressure of the atmosphere besides.

3. Q.—In what way would you class the various kinds of condensing engines?

A.—Into single acting, rotative, and rotatory engines. Single acting engines are engines without a crank, such as are used for pumping water. Rotative engines are engines provided with a crank, by means of which a rotative motion is produced; and in this important class stand marine and mill engines, and all engines, indeed, in which the rectilinear motion of the piston is changed into a circular motion. In rotatory engines the steam acts at once in the production of circular motion, either upon a revolving piston or otherwise, but without the use of any intermediate mechanism, such as the crank, for deriving a circular from a rectilinear motion. Rotatory engines have not hitherto been very successful, so that only the single acting or pumping engine, and the double acting or rotative engine can be said to be in actual use. For some purposes, such, for example, as forcing air into furnaces for smelting iron, double acting engines are employed, which are nevertheless unfurnished with a crank; but engines of this kind are not sufficiently numerous to justify their classification as a distinct species, and, in general, those engines may be considered to be single acting, by which no rotatory motion is imparted.

4. *Q.*—Is not the circular motion derived from a cylinder engine very irregular, in consequence of the unequal leverage of the crank at the different parts of its revolution?

A.—No; rotative engines are generally provided with a fly wheel to correct such irregularities by its momentum; but where two engines with their respective cranks set at right angles are employed, the irregularity of one engine corrects that of the other with sufficient exactitude for many purposes. In the case of marine and locomotive engines, a fly-wheel is not employed; but for cotton spinning, and other purposes requiring great regularity of motion, its use with common engines is indispensable, though it is not impossible to supersede this necessity by new contrivances.

5. *Q.*—You implied that there is some other difference between single acting and double acting engines, than that which lies in the use or exclusion of the crank?

A.—Yes; single acting engines act only in one way by the

force of the steam, and are returned by a counter-weight; whereas double acting engines are urged by the steam in both directions. Engines, as I have already said, are sometimes made double acting, though unprovided with a crank; and there would be no difficulty in so arranging the valves of all ordinary pumping engines, as to admit of this action; for the pumps might be contrived to raise water both by the upward and downward stroke, as indeed in some mines is already done. But engines without a crank are almost always made single acting, perhaps from the effect of custom, as much as from any other reason, and are usually spoken of as such, though it is necessary to know that there are some deviations from the usual practice.

NATURE AND USES OF A VACUUM.

6. *Q.*—The pressure of a vacuum you have stated is nothing; but how can the pressure of a vacuum be said to be nothing, when a vacuum occasions a pressure of 15lbs. on the square inch?

A.—Because it is not the vacuum which exerts this pressure, but the atmosphere, which, like a head of water, presses on everything immerged beneath it. A head of water, however, would not press down a piston, if the water were admitted on both of its sides; for an equilibrium would then be established, just as in the case of a balance which retains its equilibrium when an equal weight is added to each scale; but take the weight out of one scale, or empty the water from one side of the piston, and motion or pressure is produced; and in like manner pressure is produced on a piston by admitting steam or air upon the one side, and withdrawing the steam or air from the other side. It is not, therefore, to a vacuum, but rather to the existence of an unbalanced plenum, that the pressure made manifest by exhaustion is due, and it is obvious therefore that a vacuum of itself would not work an engine.

7. *Q.*—How is the vacuum maintained in a condensing engine?

A.—The steam, after having performed its office in the cylinder, is permitted to pass into a vessel called the condenser, where a shower of cold water is discharged upon it. The steam is condensed by the cold water, and falls in the form of hot water to the bottom of the condenser. The water, which would else be accumulated in the condenser, is continually being pumped out by a pump worked by the engine. This pump is called the air pump, because it also discharges any air which may have entered with the water.

8. *Q.*—If a vacuum be an empty space, and there be water in the condenser, how can there be a vacuum there?

A.—There is a vacuum above the water, the water being only like so much iron or lead lying at the bottom.

9. *Q.*—Is the vacuum in the condenser a perfect vacuum?

A.—Not quite perfect; for the cold water entering for the purpose of condensation is heated by the steam, and emits a vapor of a tension represented by about three inches of mercury; that is, when the common barometer stands at 30 inches, a barometer with the space above the mercury communicating with the condenser, will stand at about 27 inches.

10. *Q.*—Is this imperfection of the vacuum wholly attributable to the vapor in the condenser?

A.—No; it is partly attributable to the presence of a small quantity of air which enters with the water, and which would accumulate until it destroyed the vacuum altogether but for the action of the air pump, which expels it with the water, as already explained. All common water contains a certain quantity of air in solution, and this air recovers its elasticity when the pressure of the atmosphere is taken off, just as the gas in soda water flies up so soon as the cork of the bottle is withdrawn.

11. *Q.*—Is a barometer sometimes applied to the condensers of steam engines?

A.—Yes; and it is called the vacuum gauge, because it shows the degree of perfection the vacuum has attained. Another gauge, called the steam gauge, is applied to the boiler, which indicates the pressure of the steam by the height to which the steam forces mercury up a tube. Gauges are also

applied to the boiler to indicate the height of the water within it, so that it may not be burned out by the water becoming accidentally too low. In some cases a succession of cocks placed a short distance above one another are employed for this purpose, and in other cases a glass tube is placed perpendicularly in the front of the boiler and communicating at each end with the interior. The water rises in this tube to the same height as in the boiler itself, and thus shows the actual water level. In most of the modern boilers both of these contrivances are adopted.

12. *Q.*—Can a condensing engine be worked with a pressure less than that of the atmosphere?

A.—Yes, if once it be started; but it will be a difficult thing to start an engine, if the pressure of the steam be not greater than that of the atmosphere. Before an engine can be started, it has to be blown through with steam to displace the air within it, and this cannot be effectually done if the pressure of the steam be very low. After the engine is started, however, the pressure in the boiler may be lowered, if the engine be lightly loaded, until there is a partial vacuum in the boiler. Such a practice, however, is not to be commended, as the gauge cocks become useless when there is a partial vacuum in the boiler; inasmuch as, when they are opened, the water will not rush out, but air will rush in. It is impossible, also, under such circumstances, to blow out any of the sediment collected within the boiler, which, in the case of the boilers of steam vessels, requires to be done every two hours or oftener. This is accomplished by opening a large cock which permits some of the supersalted water to be forced overboard by the pressure of the steam. In some cases, in which the boiler applied to an engine is of inadequate size, the pressure within the boiler will fall spontaneously to a point considerably beneath the pressure of the atmosphere; but it is preferable, in such cases, partially to close the throttle valve in the steam pipe, whereby the issue of steam to the engine is diminished; and the pressure in the boiler is thus maintained, while the cylinder receives its former supply.

CHAPTER I.

GENERAL DESCRIPTION OF THE STEAM ENGINE.

THE BOILER.

83. *Q.*—WHAT are the chief varieties of the steam engin[e] actual practical use?

A.—There is first the single-acting engine, which is use[d] pumping water; the rotative land engine, which is employe[d] drive mills and manufactories; the rotative marine eng[ine] which is used to propel steam vessels; and the locomotive [en]gine, which is employed on railways. The last is always a hi[gh] pressure engine; the others are, for the most part, conden[sing] engines.

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

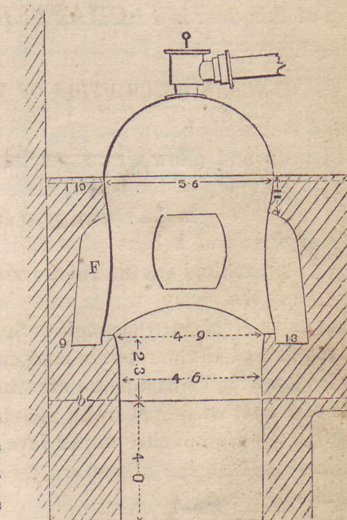
A.—Permit me then to begin with the boiler, which is co[m]mon and necessary to all engines; and I will take the exam[ple] of a wagon boiler, such as was employed by Boulton [and] Watt universally in their early engines, and which is still in [ex]tensive use. This boiler is a long rectangular vessel, wit[h a] rounded top, like that of a carrier's wagon, from its res[em]blance 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 level 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 towards the back of the grate. The supply of air ascends from the ash pit through the fire bars, and the flame passes over a low wall or bridge, and traverses the bottom of the boiler. The flame 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 passes 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, extending 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 o[illegible] half passing through a flue on the other side of the boiler—b[illegible] of these flues having their debouch in the chimney.

87. *Q.*—What are the appliances usually connected wi[illegible] wagon boiler?

A.—On the top of the boiler, near the front, is a short cy[illegible] der, with a lid secured by bolts. This is the manhole d[illegible] the purpose of which is to enable a man to get into the insid[illegible] the boiler when necessary for inspection and repair. On [illegible] top of this door is a small valve opening downward, called [illegible] atmospheric valve. The intention of this valve is to preve[illegible] vacuum from being formed accidentally in the boiler, w[illegible] might collapse it; for if the pressure in the boiler subsides [illegible] point materially below the pressure of the atmosphere, the v[illegible] will open and allow air to get in. A bent pipe, which r[illegible] up from the top of the boiler, immediately behind the posi[illegible] of the manhole, is the steam pipe for conducting the stea[illegible] the engine; and a bent pipe which ascends from the to[illegible] the boiler, at the back end, is the waste-steam pipe for cond[illegible] ing away the steam, which escapes through the safety v[illegible] This valve is set in a chest, standing on the top of the bo[illegible] at the foot of the waste-steam pipe, and it is loaded with [illegible] or leaden weights to a point answerable to the intended p[illegible] ure of the steam.

88. *Q.*—How is the proper level of the water in the bo[illegible] maintained?

A.—By means of a balanced buoy or float. This flo[illegible] attached to a rod, which in its turn is attached to a leve[illegible] on the top of a large upright pipe. The upper part o[illegible] pipe is widened out into a small cistern, through a short [illegible] in the middle of which a chain passes to the damper; bu[illegible] water emptied into this small cistern cannot pass into the [illegible] except through a small valve fixed to the lever to which [illegible] rod is attached. The water for replenishing the boi[illegible] pumped into the small cistern on the top of the pipe; a[illegible] follows from these arrangements that when the buoy falls [illegible] rod opens the small valve and allows the feed water to [illegible]

[illegible] which communicates with the [illegible] boiler; whereas, when the [illegible] the feed cannot enter the pipe, [illegible] it has, therefore, to run to waste [illegible] overflow pipe provided for the [illegible]

[illegible] *Q.*—How is the strength of the [illegible]

[illegible] draught through the furnaces [illegible] is regulated by a plate of [illegible] damper, as it is called, which [illegible] a sluice up and down in the [illegible] damper is closed more or less [illegible] intensity of the fire has to be [illegible] In wagon boilers this is gen- [illegible] accomplished by self-acting mech- [illegible] small cistern pipe, which [illegible] stand pipe, the water rises up [illegible] proportional to the pressure [illegible] and the surface of the water [illegible] will rise or fall with the fluc- [illegible] pressure of the steam. In [illegible] float is placed, which commu- [illegible] means of a chain with the dam- [illegible] pressure of the steam rises, [illegible] will be raised and the damper [illegible] whereas, if the pressure in the [illegible] the reverse of this action will [illegible]

[illegible] all land boilers of the [illegible] as that which you have [illegible]

[illegible] many land boilers are now [illegible] cylindrical form, with one or [illegible] flues in which the furnace is [illegible] A boiler of this kind is repre- [illegible] Figs. 4 and 5, and which is the

Fig. 4.

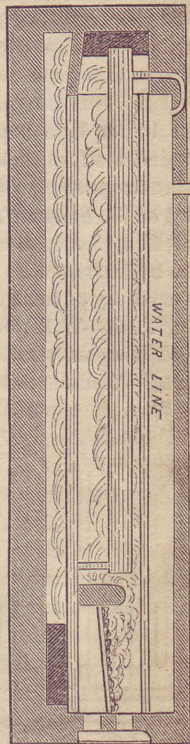
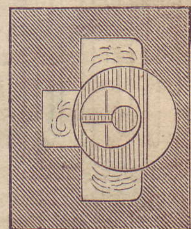


Fig. 5.

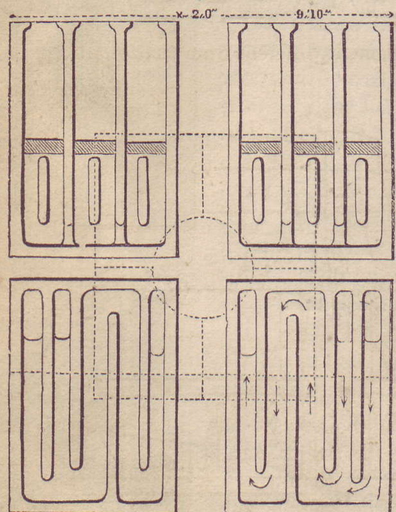


species of boiler principally used in Cornwall. In this b[oiler] a large internal cylinder or flue runs from end to end. In [the] fore part of this cylinder the furnace is placed, and behind [the] furnace a large tube filled with water extends to the end of [the] boiler. This internal tube is connected to the bottom par[t of] the boiler by a copper pipe standing vertically immedi[ately] behind the furnace bridge, and to the top part of the boile[r by] a bent copper pipe which stands in a vertical position near [the] end of the boiler. The smoke, after passing through the c[en]tral flue, circulates round the sides and beneath the bottom [of] the boiler before its final escape into the chimney. The b[oiler] is carefully covered over to prevent the dispersion of the he[at].

91. *Q.*—Will you describe the construction of the bo[ilers] used in steam vessels?

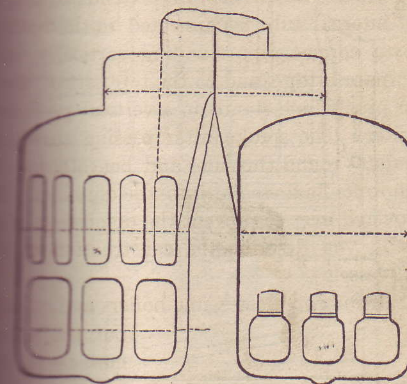
A.—These are of two classes, flue boilers and tubular boi[lers] but the latter are [...] most used. In the [...] boiler the furnaces [...] set within the bo[iler] and the flues proc[eed]ing from them w[ind] backwards and [for]wards within the b[oil]er until finally t[hey] meet and enter [the] chimney. Figs. 6, [7] and 8 are diffe[rent] views of the flue b[oilers] of the steamer F[...]. There are 4 boilers [...] shown in plan, Fig. [6], with 3 furnaces in ea[ch], or 12 furnaces in a[ll]. Fig. 7 is an eleva[tion] of 2 boilers, the o[ne to] the right being [...] front view, and that to the left a transverse section. Fig. [...]

Fig. 6.



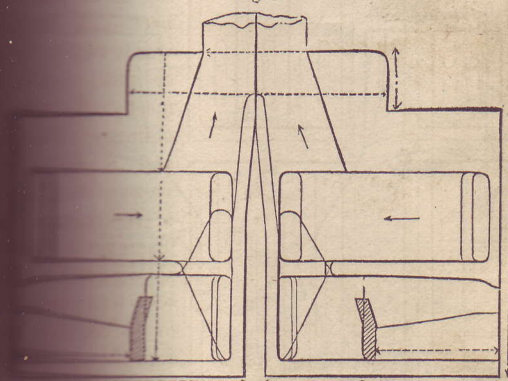
[...] section through 2 boilers. The direction of the [...] and longitudinal section will explain the direc[tion of the] smoke current.

Fig. 7.



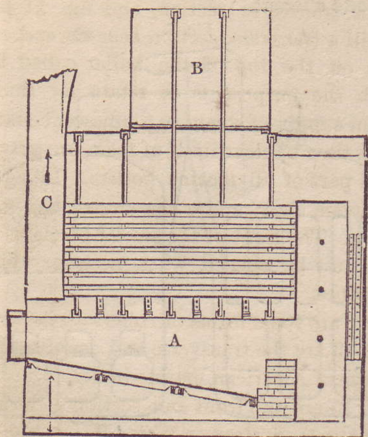
[...]—Is this arrangement different from that obtaining in [...] boilers?

Fig. 8.



[...] tubular boilers, the smoke after leaving the furnace [...] through a number of small tubes and then enters the chimney. These tubes are sometimes of brass, and [illegible]

Fig. 9.



are usually about 3 inches in diameter, and 6 or 7 feet [illegible]

Fig. 10.

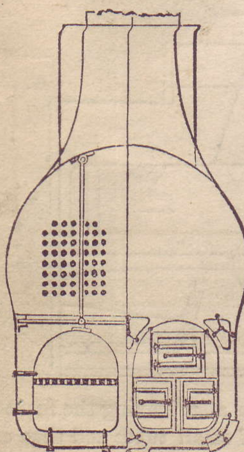
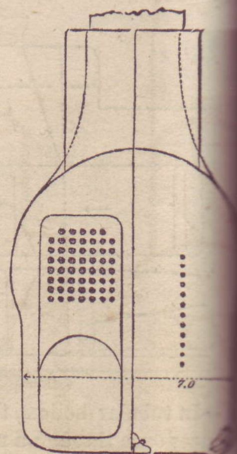


Fig. 11.



[illegible] 10, and 11 represent a marine tubular boiler; fig. 9 [illegible] vertical longitudinal section, fig. 10 half a front eleva- [illegible] half a transverse section, and fig. 11 half a back [illegible] and half a transverse section near the end. There is a [illegible] part on the top of the boiler called the "steam [illegible] which the purpose is to retain for the use of the [illegible] certain supply of steam in a quiescent state, in order [illegible] have time to clear itself of foam or spray. A steam [illegible] usual part of all marine boilers. In fig. 9 A is the [illegible] the steam chest, and C the smoke box which opens [illegible] chimney. The front of the smoke box is usually closed [illegible] which may be opened when necessary to sweep the [illegible] of the tubes.

[illegible] following are some forms of American boilers:

[illegible] and 13 are the transverse and longitudinal sections [illegible] form of American marine boiler.

[illegible] and 15 are the front and sectional elevation of one [illegible] of the U. S. steamer Water Witch.

Fig. 13.

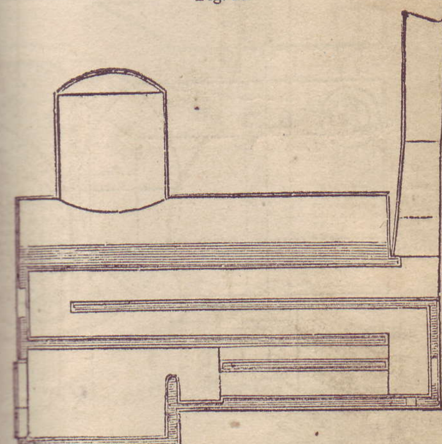


Fig. 15.

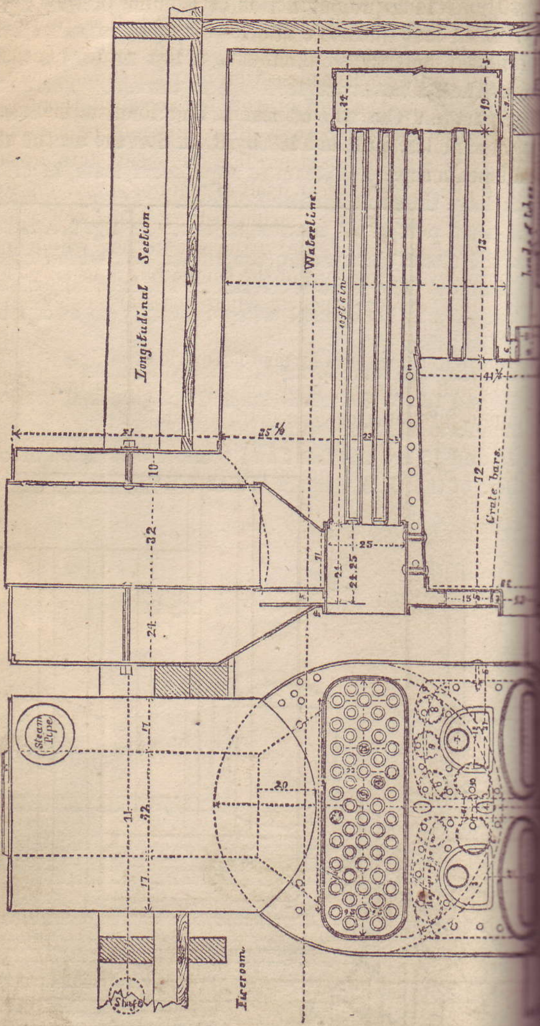
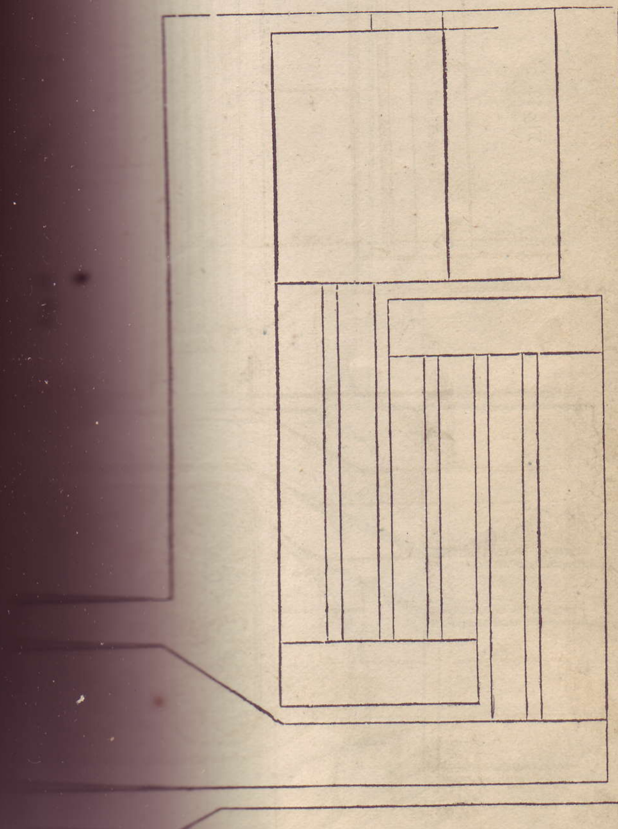


Fig. 14.

Fig. 16 is a longitudinal section of a boiler of the drop flue [pattern]. For land purposes the lowest range of tubes is gen[erally] 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 tu]bular boiler, built in 1837 by R. L. Stevens for the steam[boat] Independence.



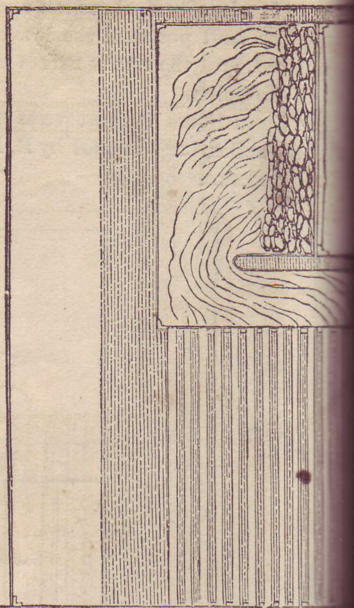


Fig. 18.

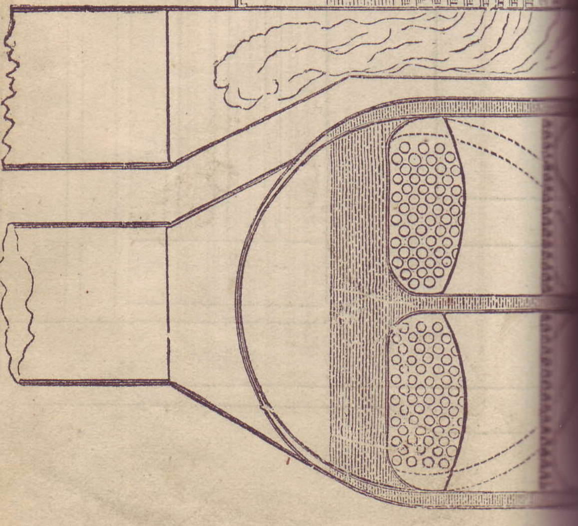
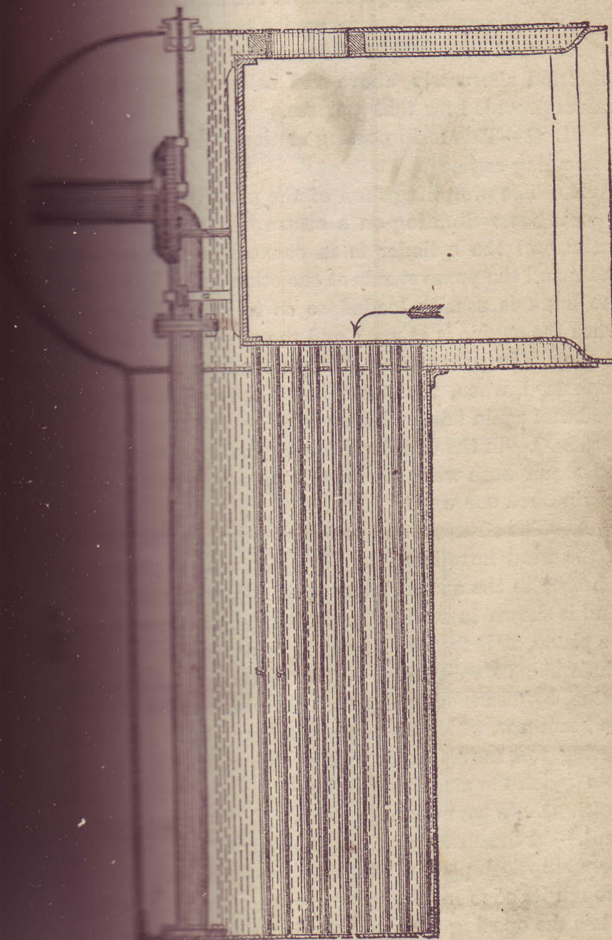


Fig. 17.

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



THE ENGINE.

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

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

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

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

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

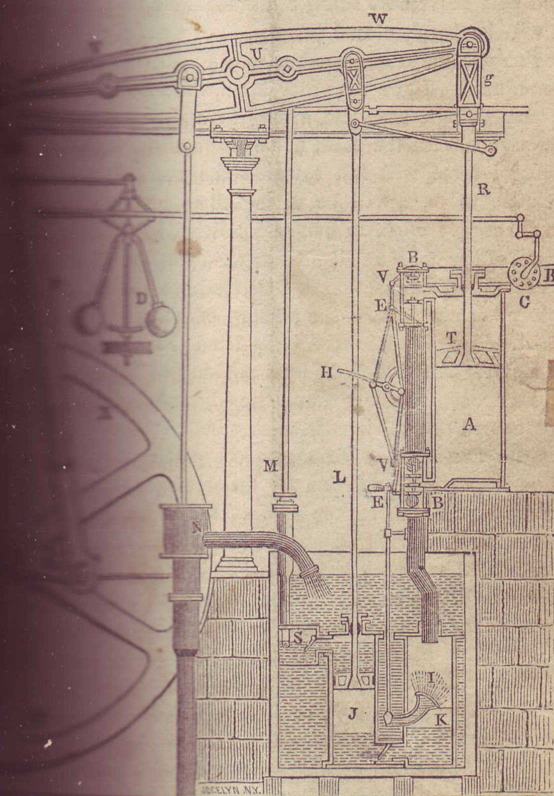
A.—The structure and action of a double-acting land of the kind introduced by Mr. Watt, will be understoo reference to the annexed figure (fig. 20), where an engine kind is shown in section. A is the cylinder in which a ble piston, T, is forced alternately up and down by the admission, to each side,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

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

A.—At the steam pipe, B. The throttle valve in th is an elliptical plate of metal swivelling on a spindle through its edge from side to side, and by turning whic or less the opening through the pipe will be more or less The extent to which this valve is opened or closed is

governor, D, the balls of which, as they collapse up or down a collar on the governor spindle, communicated to the throttle valve by suitable bell-cranks. The governor, it will be seen, consists

Fig. 20.



balls attached to arms fixed upon an is kept in revolution by means of a cord on the fly wheel shaft. The velocity with

which the balls of the governor revolve being proport
that of the fly wheel, it will follow, that if by reaso
rapid a supply of steam, an undue speed be given t
wheel, and therefore to the balls, a divergence of the b
take place to an extent corresponding to the excess of v
and this movement being communicated to the thrott
it will be partly closed (see fig. 1), the supply of steam
engine will be diminished, and the velocity of its mot
be reduced. If, on the other hand, the motion of the e
slower than is requisite, owing to a deficient supply o
through B, then the balls, not being sufficiently affected
trifugal force, will fall towards the vertical spindle,
throttle valve, C, will be more fully opened, whereby
ample supply of steam will be admitted to the cylinder,
speed of the engine will be increased to the requisite e

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

A.—The piston is accurately fitted to the cylinder, a
to move in it steam tight by a packing of hemp driven
into a groove or recess round the edge of the piston, a
is squeezed down by an iron ring held by screws. Th
divides the cylinder into two compartments, betwe
there is no communication by which steam or any oth
fluid can pass. A casing set beside the cylinder con
valves, by means of which the steam which impels th
is admitted and withdrawn, as the piston commences it
in each direction. The upper steam box B, is divi
three compartments by two valves. Above the upp
valve V, is a compartment communicating with the st
B. Below the lower valve E is another compartment c
cating with a pipe called the eduction pipe, which lea
wards from the cylinder to the condenser, in which
steam is condensed by a jet of cold water. By the v
communication may be opened or closed between the b
the top of the cylinder, so as to permit or prevent a
steam from the one to pass to the other. By the v
communication may be open or closed between the

perature having been raised considerably by the
the steam in it. When the air pump piston
behind it a vacuum; and the foot valve being
pressure, the weight of the water in the con-
open, and the warm water flows from the con-
lower part of the air pump, from which its re-
condenser is prevented by the intervening valve.
pump piston descends, its pressure on the liquid
open the valve in it, through which the hot
; and when the bucket descends to the bottom
barrel, the warm water which was below it will all
above it, and cannot return. When the bucket
the water above it, not being able to return
bucket valve, will be forced into the hot well
delivery valve S. The hot water pump M, pumps
of this hot water into the boiler, to compensate
of the water that has passed off in the form
The residue of the hot water runs to waste.

—By what expedient is the piston rod enabled to
the cylinder cover without leaking steam out of
or air into it?

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

—In what way is the piston rod connected to the

The piston rod is connected to the great beam by means
one at each side of the beam shown at *f g*, (fig. 21.)
are usually made of the same length as the crank,

and their purpose is to enable the end of the great beam to [illegible] as a centre. The rod $d\ g$ is, therefore, drawn back
in the arc of a circle while the piston rod maintains the ve[illegible] by the arc described at d to an extent equal to the
position. The point of junction, therefore, of the links an[illegible]
piston rod is of the form of a knuckle or bend at some pa[illegible]
the stroke.

104. *Q.*—But what compels the top of the piston r[illegible]
maintain the vertical position?

A.—Some engines have guide rods set on each side o[illegible]
piston rod, and eyes on the top of the piston rod engage [illegible]
guide rods, and maintain the piston rod in a vertical positi[illegible]
every part of the stroke. More commonly, however, the de[illegible]
end is attained by means of a contrivance called the pa[illegible]
motion.

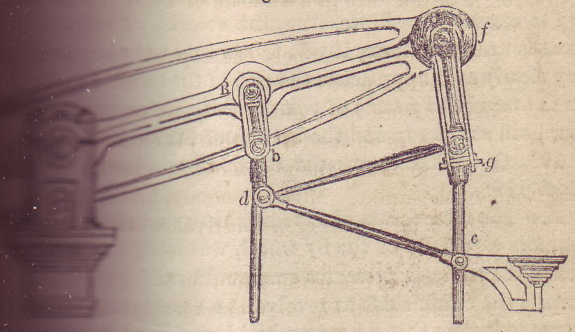
105. *Q.*—What is the parallel motion?

A.—The parallel motion is an arrangement of jointed [illegible]
so connected together that the divergence from the vertic[illegible]
at any point in the arc described by the beam is corrected [illegible]
equal and opposite divergence due to the arc performed b[illegible]
jointed rods during the stroke; and as these opposite d[illegible]
tions mutually correct one another, the result is that the p[illegible]
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 be[illegible]
f has a link *f g* hung on each side of the beam, and a short cro[illegible]
called a cross head, extends from the bottom of one of these [illegible]
to the bottom of the other, which cross head is perforated [illegible]
a hole in the middle for the reception of the piston rod. T[illegible]
are similar links *b d* at the point of the main beam, whe[illegible]
air pump rod is attached. There are two rods *d g* conn[illegible]
the links *b d* with the links *f g*, and these rods, as they s[illegible]
continue parallel to the main beam throughout the strok[illegible]
called *parallel bars*. Attached to the end of these two r[illegible]
d are two other rods *c d*, of which the ends at *c* are attach[illegible]
stationary pins, while the ends at *d* follow the motion o[illegible]
lower ends of the links *b d*. These rods are called the r[illegible]
bars. Now it is obvious that the arc described by the p[illegible]
with *c* as a centre, is opposite to the arc described by the [illegible]

Fig. 21.



[illegible] of the arc described at *g*, or, in other words, the line [illegible] by the point *g* becomes a straight line instead of a [illegible]

[illegible] *Q.*—Does the air pump rod move vertically as well as [illegible] rod?

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

[illegible] *Q.*—The use of the crank is to obtain a circular motion [illegible] reciprocating motion?

[illegible] That is the object of it, and it accomplishes its object [illegible] perfect manner, as it gradually arrests the velocity of [illegible] towards the end of the stroke, and thus obviates [illegible] otherwise be an injurious shock upon the machine. [illegible] the crank approaches the lowest part of its throw, and at

the same time the piston is approaching the top of the cy
the motion of the crank becomes nearly horizontal, or, in
words, the piston is only advanced through a very sho
tance, for any given distance measured on the circle des
by the crank pin. Since, then, the velocity of rotation
crank is nearly uniform, it will follow that the piston wil
very slowly as it approaches the end of the stroke; and th
ton is brought to a state of rest by this gradually retard
tion, both at the top and the bottom of the stroke.

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

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

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

A.—There is not much difference. In modern rotati
engines, the valves for admitting the steam to the cyli
condenser, instead of being clack or pot-lid valves mo
tappets on the air pump rod, are usually sluice or sliding
moved by an eccentric wheel on the crank shaft. So
the beam is discarded altogether, and malleable iron is
largely used in the construction of engines instead of th
iron, which formerly so largely prevailed. But upon the

pot-lid

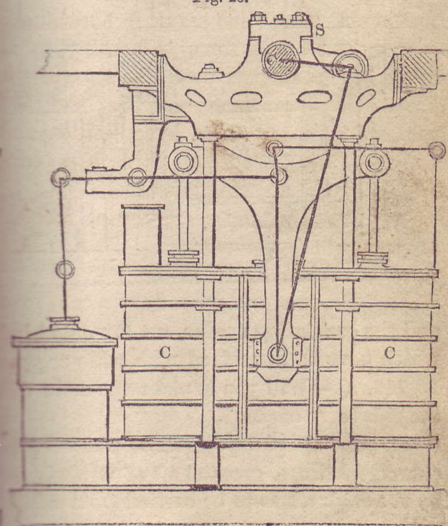
engine of the present day is substantially the engine
and he who perfectly understands the operation of
engine, will have no difficulty in understanding the oper-
of the numerous varieties of engines since intro-

THE MARINE ENGINE.

Q.—Will you describe the principal features of the
engine employed for the propulsion of vessels?
engines are of two kinds,—paddle engines and
In the one case the propelling instrument is
kept in rotation at each side of the ship: in the
the propelling instrument is a screw, consisting of
twisted vanes, revolving beneath the water at the
class of engines there are many distinct varieties.
Q.—What are the principal varieties of the paddle

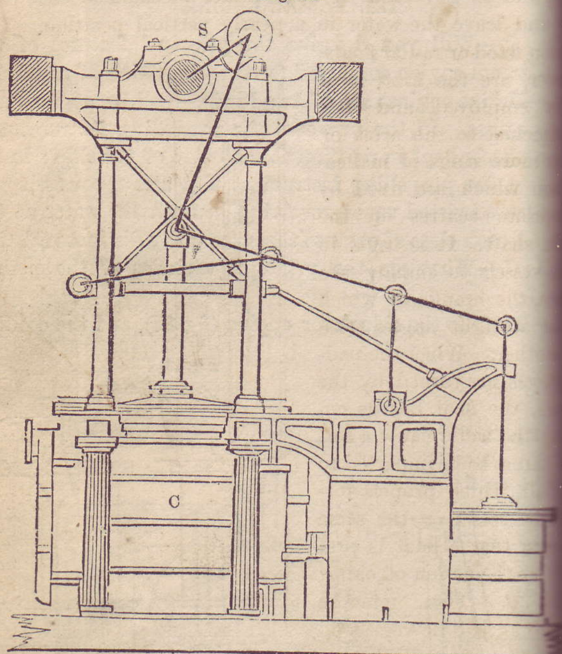
the side lever engine (fig. 26), and the oscillat-

Fig. 23.



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

Fig. 24.



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

113. *Q.*—Will you explain the main distinctive featu[illegible] the side lever engine?

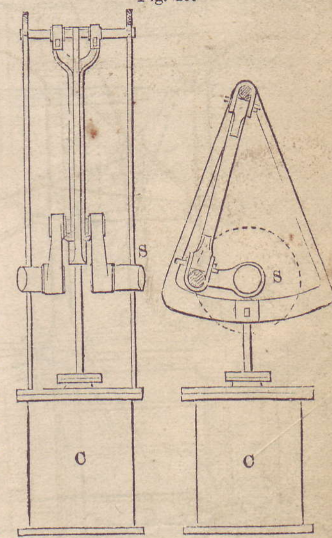
A.—In all paddle vessels, whatever be their subor[illegible] characteristics, a great shaft of wrought iron, s, turned [illegible] by the engine, has to be carried from side to side of the [illegible]

[illegible] shaft are fixed the paddle wheels. The paddle [illegible] either be formed with fixed float boards for en- [illegible] water, like the boards of a common undershot [illegible] or they may be formed with *feathering* float [illegible] they are termed, which is float boards movable on a [illegible] so governed by appropriate mechanism that they [illegible] leave the water in a nearly vertical position. The [illegible] fixed or radial floats, [illegible] the kind most [illegible] employed, and they [illegible] to the arms of [illegible] rings of mallea- [illegible] which are fixed by [illegible] centres on the [illegible] shaft. It is usual in [illegible] to employ two [illegible] cranks of which [illegible] right angles with [illegible] When the pad- [illegible] are turned by the [illegible] the float boards en- [illegible] water cause a for- [illegible] to be imparted to [illegible] which propels for- [illegible] on the same [illegible] a boat is pro- [illegible] the action of oars.

[illegible] Q.—These remarks [illegible] paddle vessels?

[illegible] do. With respect to the side lever engine, it may [illegible] to be such a modification of the land beam engine [illegible] described, as will enable it to be got below the deck of [illegible] With this view, instead of a single beam being placed [illegible] two beams are used, one of which is set on each side [illegible] as low down as possible. The cross head which [illegible] piston rod is made somewhat longer than the diam- [illegible] cylinder, and two great links or rods proceed one

Fig. 25.



from each end of the cross head to one of the side le[illegible] beams. A similar cross bar at the other end of the [illegible] serves to connect them together and to the connectin[illegible] which, proceeding from thence upwards, engages the [illegible] and thereby turns round the paddle wheels.

115. *Q.*—Will you further illustrate this general descr[illegible] by an example?

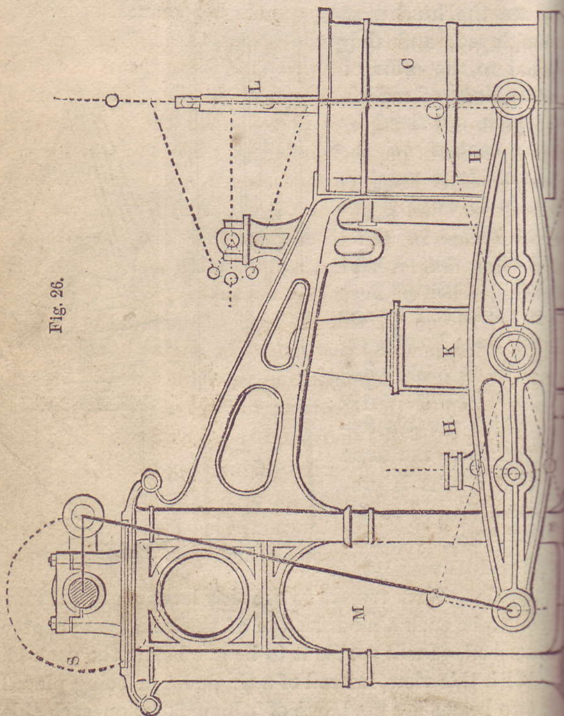


Fig. 26.

A.—Fig. 26 is a side elevation of a side lever engin[illegible] represent the beams or keelsons to which the engines [illegible] tached, and on which the boilers rest. The engines ar[illegible]

[illegible] strong bolts passing through the bottom of the vessel, [illegible] the boiler keeps its position by its weight alone. The [illegible] condenser and air pump are worked off the side levers by [illegible] side rods and a cross head. A strong gudgeon, called [illegible] passes through the condenser at K, the project- [illegible] of which serve to support the side levers or beams. [illegible] piston rod, which, by means of the cross head and side [illegible] connected to the side levers or beams, one of which is [illegible] The line M represents the connecting rod, to [illegible] is imparted by the beams, through the medium [illegible] cross tail extending between the beams, and which by [illegible] of the crank turns the paddle shaft S. The eccentric [illegible] the slide valve is placed upon the paddle shaft. [illegible] a disc of metal encircled by a hoop, to which a rod [illegible] and the disc is perforated with a hole for the shaft, [illegible] the centre, but near one edge. When, therefore, the [illegible] carrying the eccentric with it, the rod attached [illegible] hoop receives a reciprocating motion, just as it [illegible] attached to a crank in the shaft.

[illegible] Will you describe the mode of starting the engine?

[illegible] first mention that when the engine is at rest, the [illegible] between the eccentric and the slide valve is broken, [illegible] the end of the eccentric rod out of a notch which [illegible] on the valve shaft, and the valve is at such times [illegible] by hand by a bar of iron, applied to a proper [illegible] valve gear for that purpose. This being so, the [illegible] he wishes to start the engine, first opens a small [illegible] the *blow through valve*, which permits steam from [illegible] enter the engine both above and below the piston, [illegible] the condenser and air pump. This steam expels [illegible] the interior of the engine, and also any water [illegible] have accumulated there; and when this has been [illegible] blow through valve is shut, and a vacuum very soon [illegible] the engine, by the condensation of the steam. If [illegible] slide valve be moved by hand, the steam from the [illegible] admitted on one side of the piston, while there is [illegible] the other side, and the piston will, therefore, be moved in the desired direction. When the piston reach[illegible] end of the stroke, the valve has to be moved in the [illegible] direction, when the piston will return, and after being [illegible] thus by hand, once or twice, the connection of the valv[illegible] the eccentric is to be restored by allowing the notch [illegible] end of the eccentric rod to engage the pin on the valv[illegible] when the valve will be thereafter moved by the engine [illegible] proper manner. It will, of course, be necessary, whe[illegible] engine begins to move, to open the injection cock a li[illegible] enable water to enter for the condensation of the stea[illegible] the most recent marine engines, a somewhat different m[illegible] ism from this is used for giving motion to the valves, bu[illegible] mechanism will be afterwards described.

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

A.—Nearly all of them are so; but recently a num[illegible] gunboats have been constructed, with high pressure e[illegible] In general, however, marine engines are low pressure [illegible] densing engines.

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

A.—In the oscillating paddle marine engine, the [illegible] ment of the paddle shaft and paddle wheels is the sam[illegible] the case already described, but the whole of the side lev[illegible] rods, cross head, cross tail, and connecting rod are dis[illegible] The cylinder is set immediately under the crank; the [illegible] the piston rod is connected immediately to the crank pi[illegible] to enable the piston rod to accommodate itself to the mo[illegible] of the crank, the cylinder is so constructed as to be sus[illegible] of vibrating or oscillating upon two external axes or tr[illegible] These trunnions are generally placed about half way up [illegible] sides of the cylinder; and through one of them stea[illegible] ceived from the boiler, while through the other th[illegible] escapes to the condenser. The air pump is usually wo[illegible] means of a crank in the shaft, which crank moves the ai[illegible] bucket up and down as the shaft revolves.

119. *Q.*—Will you give an example of a paddle os[illegible] engine?

[illegible] will take as an example the oscillating engines con-[illegible] Messrs. Ravenhill & Salked, for the Holyhead [illegible] Fig. 27 is a longitudinal section of this vessel, show-[illegible] and boiler; and fig. 28 is a transverse section [illegible] engines, showing also one of the wheels. There [illegible] in this vessel, and one air pump, which lies in [illegible] position, and is worked by a crank in the shaft [illegible] between the cylinders, and which is called the [illegible] shaft. A A, is one of the cylinders, B B the pis-[illegible] the crank. D is the crank in the intermediate [illegible] works the air pump E. There are double eccen-[illegible] shaft, whereby the movement of the slide [illegible]. The purpose of the double eccentrics is to [illegible] arrangement of valve gear to be employed, [illegible] the *link motion*, and which will be de-[illegible]. I I are the steam pipes leading to the steam [illegible] which, and on the eduction trunnions con-[illegible] pipe M, the cylinders oscillate.

[illegible] what species of mechanism are the positions of [illegible] of feathering wheels governed?

[illegible] The floats are supported by spurs projecting from the [illegible] and they may be moved upon the points of [illegible] which they are attached by pins, by means of short [illegible] from the backs of the floats, and connected to [illegible] towards the centre of the wheel. The cen-[illegible] which these rods proceed is not concentric [illegible] the rods, therefore, are moved in and out [illegible] revolves, and impart a corresponding motion to [illegible] feathering wheels the proper motion is [illegible] by means of an eccentric on the ship's side. [illegible] paddle wheels, whether radial or feathering, will [illegible] described in the chapter on Steam Navigation.

SCREW ENGINES.

[illegible] What are the principal varieties of screw engines?

[illegible] employed for the propulsion of screw vessels

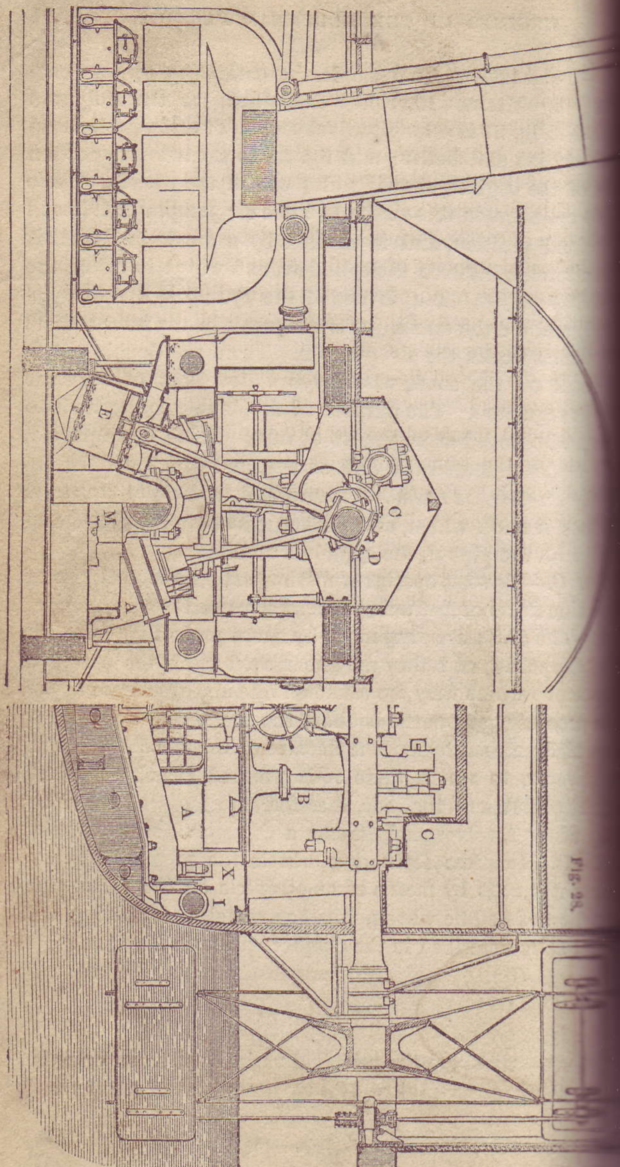


Fig. 23.

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

[illegible]—Will you describe some of the principal varieties [illegible] engines?

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

[illegible]—What other forms are there of geared screw en- [illegible]

[illegible] some cases the cylinders lie on their sides in the [illegible] the cylinders of a locomotive engine. In other cases [illegible] engines are employed; and in other cases vertical [illegible] engines.

[illegible]—Will you give an example of a geared vertical oscil- [illegible]?

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

125. *Q.*—What do you mean by the pitch of the screw [illegible]

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

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

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

127. *Q.*—What are the principal varieties of direct [illegible] screw engines?

A.—In some cases four engines have been employed [illegible] of two, and the cylinders have been laid on their sides [illegible] side of the screw shaft. This multiplication of engines [illegible] ever, introduces needless complication, and is now [illegible] used. In other cases two inverted cylinders are set a[illegible] screw shaft on appropriate framing; and connecting [illegible] attached to the ends of the piston rods turn round cra[illegible] the screw shaft.

[illegible]—What is the kind of direct acting screw engine [illegible] Messrs. Penn.

[illegible] a horizontal trunk engine. In this engine a [illegible] a trunk penetrates the piston, to which it is [illegible] cast in one piece with it; and the trunk also [illegible] and bottom of the cylinder, through which [illegible] made tight therein by means of stuffing boxes. [illegible] is attached at one end to a pin fixed in the [illegible], while the other end engages the crank in [illegible]. The air pump is set within the condenser, [illegible] a rod which is fixed to the piston and de[illegible] therefrom. The air pump is of that species [illegible] double-acting. The piston or bucket is formed [illegible] it, but an inlet and outlet valve is fixed to [illegible] pump, through the one of which the water is [illegible] pump barrel, and through the other of which it [illegible] the hot well.

[illegible] LOCOMOTIVE ENGINE.

[illegible] describe the more important features of [illegible]?

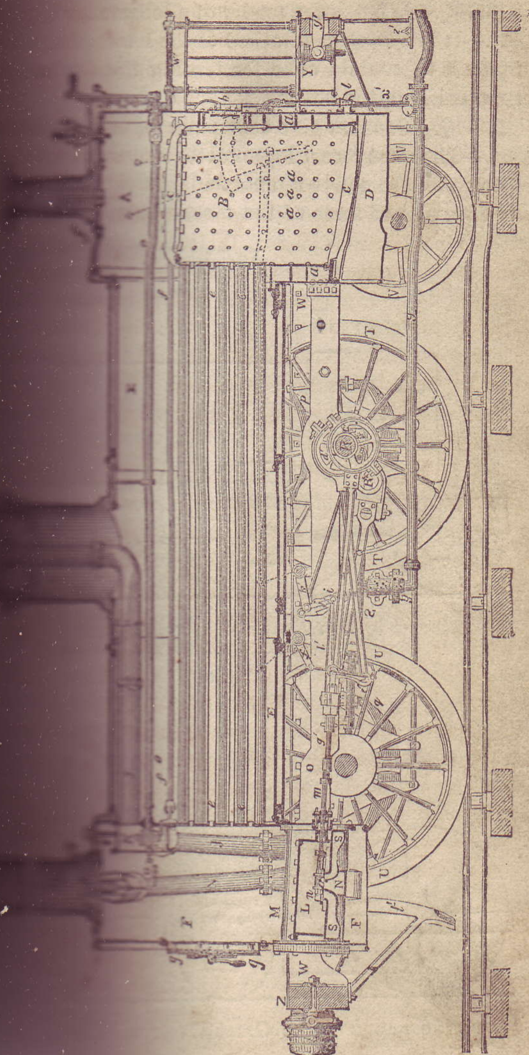
[illegible] employed to draw carriages upon rail[illegible] cylindrical boiler filled with brass tubes, [illegible] air passes on its progress from the fur[illegible], and attached to the boiler are two hori[illegible] with pistons, valves, connecting rods, and [illegible] apparatus to enable the power exerted by the [illegible] the cranked axle to which the driving [illegible]. There are, therefore, two independent [illegible] the composition of a locomotive, the [illegible] at right angles with one another, so that [illegible] dead point, the other crank is in a posi[illegible] maximum efficacy. The driving wheels, [illegible] crank shaft and turn round with it, [illegible] forward on the rails by the mere adhe[illegible] is found sufficient not merely to move the locomotive, but to draw a long train of carriag... hind it.

130. *Q.*—Are locomotive engines condensing or hig... sure engines.

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

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

A.—To do this I will take the example of one of Ha... locomotive engines with six wheels represented in fig. ... one of the most modern construction now in use, nor ye... the most antiquated. M is the cylinder, R the connecti... C C the eccentrics by which the slide valve is moved; ... steam pipe by which the steam is conducted from th... dome of the boiler to the cylinder. Near the smoke ... of this pipe is a valve K or regulator moved by a han... the front of the boiler, and of which the purpose is to ... the admission of the steam to the cylinder; *f* is a saf... kept closed by springs; N is the eduction pipe, or, as it ... monly termed in locomotives, the *blast pipe*, by wh... steam, escaping from the cylinder after the stroke has ... formed, is projected up the chimney H. The water in th... of course covers the tubes and also the top of the f... fire box. It will be understood that there are two ... each locomotive, though, from the figure being given i... only one engine can be shown. The cylinders of th... are each 14 inches diameter; the length of the stro... piston is 21 inches. There are two sets of driving ... feet diameter, with outside connections.



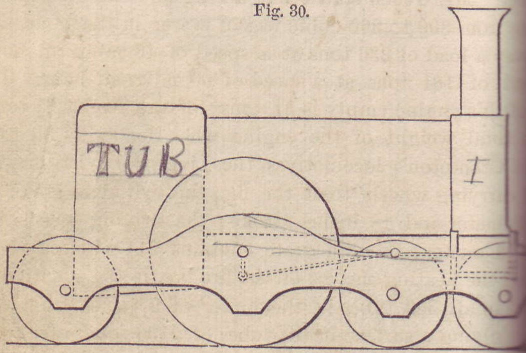
132. *Q.*—What is the tender of a locomotive?

A.—It is a carriage attached to the locomotive, of wh[illegible] purpose is to contain coke for feeding the furnace, an[illegible] for replenishing the boiler.

133. *Q.*—Can you give examples of modern locomo[illegible]

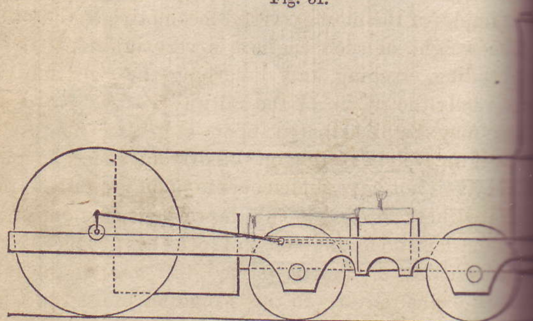
A.—The most recent locomotives resemble in their [illegible] features the locomotive represented in fig. 29. I can, [illegible] give examples of some of the most powerful engines [illegible]

Fig. 30.



construction. Fig. 30 represents Gooch's express engine [illegible]

Fig. 31.



for the wide gauge of the Great Western Railway; [illegible]

[illegible]'s express engine, adapted for the ordi[illegible] gauge railways. The cylinders of Gooch's engine [illegible] inches diameter, and 24 inches stroke; the [illegible] are 8 feet in diameter; the fire grate contains [illegible] area; and the heating surface of the fire box is [illegible] There are in all 305 tubes in the boiler, each [illegible] diameter, giving a heating surface in the tubes of [illegible] The total heating surface, therefore, is 1952 [illegible] Gooch states that an engine of this class will [illegible] to 360 cubic feet of water in the hour, and [illegible] of 236 tons at a speed of 40 miles an hour, [illegible] tons at a speed of 60 miles an hour. The [illegible] engine empty is 31 tons; of the tender 8½ tons; [illegible] weight of the engine when loaded is 50 tons. [illegible]'s locomotives, the Liverpool, with one set [illegible] wheels than the fig., the cylinders are of 24 [illegible] and 18 inches stroke; the driving wheels are [illegible]; the fire grate contains 21½ square feet of [illegible] heating surface of the fire box is 154 square feet. [illegible] tubes in the boiler of $2\frac{3}{16}$ inches external [illegible] a surface in the tubes of 2136 square feet, and [illegible] surface of 2290 square feet. The weight of this [illegible] be 35 tons when ready to proceed on a jour[illegible] were displayed at the Great Exhibition in [illegible] of the most powerful locomotive engines then [illegible] weight of such engines is very injurious to the [illegible] crushing, and disturbing the rails, and try[illegible] the whole of the railway works. No doubt [illegible] be distributed upon a greater number of [illegible] weight resting on the driving wheels be much [illegible] not have sufficient bite upon the rails to pro[illegible] slipping. This, however, is only one of the [illegible] demand for high rates of speed has produced. The [illegible] railway, or, as it is termed, the *gauge* of the rails, [illegible] of the railways in this kingdom limited to 4 feet [illegible] corresponding limitation is imposed on the diame[illegible] which in its turn restricts the number of the tubes which can be employed. As, however, the attai a high rate of speed requires much power, and con much heating surface in the boiler, and as the number cannot be increased without reducing their diamete become necessary, in the case of powerful engines, to tubes of a small diameter, and of a great length, to o necessary quantity of heating surface; and such tube a very strong draught in the chimney to make them With a draught of the usual intensity the whole of will be absorbed in the portion of the tube nearest the leaving that portion nearest the smoke box nothing to to transmit the smoke; and with long tubes of small therefore, a very strong draught is indispensable. To such a draught in locomotives, it is necessary to co mouth of the blast pipe, whereby the waste steam wil jected into the chimney with greater force; but this tion involves an increase of the pressure on the educ of the piston, and consequently causes a diminutio power of the engine. Locomotives with small and lo therefore, will require more coke to do the same locomotives in which larger and shorter tubes may be

CHAPTER II.

HEAT, COMBUSTION, AND STEAM.

HEAT.

What is meant by latent heat?

latent heat is meant the heat existing in bodies undiscoverable by the touch or by the thermometer, manifests its existence by producing a change of is absorbed in the liquefaction of ice, and in the of water, yet the temperature does not rise during and the heat absorbed is therefore said to become The term is somewhat objectionable, as the effect absorption of heat has in each case been made it would be as reasonable to call hot water latent heat, in the present acceptation of the term, liquefaction or vaporization; but to produce heat is as necessary as to produce the expansion in a thermometer tube, which is taken as the temperature; and it is hard to see on what ground be latent when its presence is made manifest which only heat can effect. It is the *temperature* and latent temperature means sensible va- liquefaction.