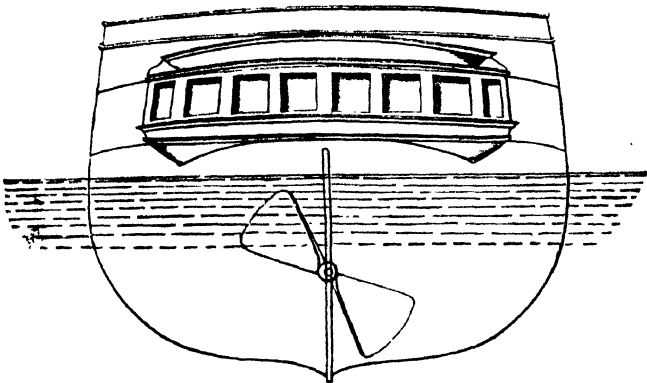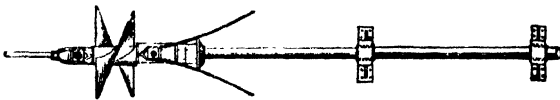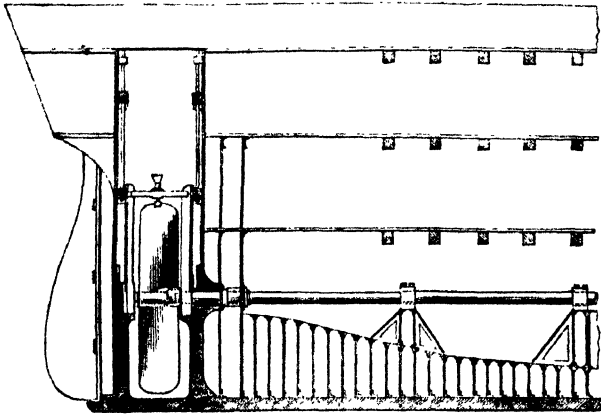# FRONTISPIECE.

SECTION OF STERN OF SCREW VESSEL IN THE ROYAL NAVY, SHOW-
ING THE TRUNK OR A PORTION THROUGH WHICH THE SCREW IS
RAISED OUT OF WATER WHEN DISCONNECTED.

RUDIMENTARY TREATISE

ON

MARINE ENGINES

AND

STEAM VESSELS;

TOGETHER WITH

Practical Remarks

ON THE

SCREW AND PROPELLING POWER

AS USED IN THE ROYAL AND MERCHANT NAVY.

By ROBERT MURRAY, C.E.

SECOND EDITION.

PREFACE.

In adding a treatise on the Management of Marine
Engines to Mr. Weale's Series of Rudimentary Works,
the Author trusts that it may prove a useful auxiliary to
the various classes of practical men interested in the per-
formance of our Steam Marine, whether in the Royal
Navy or Merchant Service.   Desirous of being under-
stood alike by the non-professional man of business, who
from his desk in the city controls the operations of a fleet
of steam ships, as by the humblest assistant in the duties
of the engine-room, he has endeavoured to express himself
in as concise and matter-of-fact a manner as possible, avoid-
ing as far as may be the use of technical language and
mathematical demonstration, without attempting, at the
same time, to render the text intelligible to the wholly
uninitiated, by perplexing it with notes and explanations
which ought to suggest themselves to every one acquainted
with the rudiments of mechanical science.   Some very es-
sential Tables of the details of Engines and Vessels are
added in the Appendix; and such technical terms as do
necessarily occur will be found explained in the Glossary
at the end, and several corrections made in this second
Edition.

March 10th, 1852.

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THE

MARINE STEAM ENGINE.

CHAPTER I.

GENERAL DESCRIPTION AND VARIETIES OF THE MARINE ENGINE.

A previous Acquaintance with the Principles of the Steam Engine presupposed.—As this little work professes to be a guide to the management of marine engines and steam vessels, and not a treatise on the steam engine, it will be necessary to presuppose a certain degree of knowledge of the facts and mechanical principles on which the structure and operation of steam engines depend. In short, to take it for granted that the reader has perused either Dr. Lardner's Rudimentary Treatise, in this series,* or some other work on the same subject. This being understood, we shall proceed at once to the consideration of the marine engine of the present day, as it is found in vessels of the Royal navy and merchant service.

General Description of the Marine Engine.—The principles upon which the marine engine is constructed, as well as its general plan of operation, are identical with those of the stationary or land condensing engine; the motive power

* Rudimentary Treatise on the Steam Engine, by D. Lardner, LL.D. John Weale, 1s.

B

in both being derived from the pressure of the steam actii
against a partial vacuum. Thus we have in each case
boiler to generate the steam; a *cylinder, piston,* and *valv*
to use it; a *condenser* in which to condense it, and therel
gain the pressure of the atmosphere by causing the stea
to work against a vacuum; and lastly, an *air pump* to witl
draw the condensing water, the condensed steam, and tl
uncondensed vapour, and gaseous matter. Such are tl
principal parts of every condensing or "low-pressure
steam engine, whether it be used on land or at sea; whethe
it be side-lever, direct-acting, oscillating, horizontal, c
rotatory.

Varieties of Form.—The terms last used are those em
ployed to designate different forms of the marine engin
which have been imposed upon it by wants and necessitie
of various kinds. For as the services which steam vessel
are called upon to perform are very different, so also mus
be their machinery, in order to suit the required form and
displacement of the hull, the minimum draught of water
the comparative value of stowage, or of passenger accom
modation, the necessity of protection from shot, the effi
ciency of the armament, and a hundred other consideration:
which may enter into the plans of a steamer.

In all marine engines the required object is to give a ro-
tatory motion to a horizontal shaft—either the paddle shafi
in the case of paddle-wheel steamers, or the screw shaft ir
the case of vessels propelled by the screw. The earliest
form of engine used for this purpose was the side-lever, oi
beam engine, in which the reciprocating motion of the
piston rod is transferred through upright side rods and
horizontal side levers to the connecting rod, which then
gives the shaft its continuous rotatory motion by means oi
the crank.

The Fly Wheel not applicable.—If such an engine were

used to drive machinery on shore it would be furnished with a fly wheel, which, by becoming a reservoir of momentum, would supply power to continue the rotatory motion past the top and bottom of the stroke, where the crank is evidently (from its nature) powerless, and in this way a uniform speed would be maintained throughout each revolution of the shaft. But in the case of a vessel at sea, the fly wheel is inadmissible. Considerable irregularity in the revolutions results from this want, but not to such an extent as to be attended with any bad results. In some engines where the moving parts are not arranged so as to balance each other in their ascent and descent, one part of the stroke is made at a greater velocity, but this is generally obviated by admitting a greater quantity of steam on one side of the piston than on the other, until the propelling power for the up and down strokes accords with the resistance. The air-pump bucket is generally arranged in such a manner, that by its ascent it may balance the weight of the piston in the cylinder in its descent.

Necessity for combining the Engines.—Hence arises the necessity for supplying the place of the fly wheel by combining two engines on one shaft, in such a manner that when the one engine is at its *least* effective point (at the top or bottom of the stroke) the other engine may be *most* effective—each alternately helping the other over its difficulties.

Single Engines sometimes employed.—River steamers, however, are occasionally fitted with only one engine, the moving parts of which are "balanced" (by means of a cast-iron paddle board, or otherwise) in such a manner as may best assist the crank in passing the centres; but such an arrangement is always objectionable from the difficulty experienced in starting, and from the impossibility of pre-

venting a disagreeable jumping motion in the vessel from
the unequal speed at which the paddle wheels are driven.

High-pressure Engines rarely used.—High-pressure en-
gines are very rarely put into steamers in this country, the
objections to their use being their increased consumption
of fuel in comparison with condensing engines, and the
presumed danger to passengers arising from explosion or
escape of steam, which has made them extremely unpopular.
As they possess, however, the countervailing advantages of
cheapness and lightness, they have been adopted in some
cases where economy of fuel is not so much considered as
first cost and light draught of water. While referring
hereafter to the marine engine, it should be understood
that the *condensing engine* alone is meant.

Side-lever Engine—its Advantages.—It has been said that
the side-lever engine was the first employed in steam boats.
This construction, with the arrangement of which the reader
is doubtless familiar, has several advantages which enabled
it for a long while to resist innovation. Perhaps its chief
merit consists in this, that the weights of the moving parts
are so balanced, the one against the other, that the piston
when not acted on by steam is nearly *in equilibrio*, and
equally ready to start in either direction with the smallest
application of force. The great length of the connecting
rod, also, admits of the motion of the piston being trans-
mitted to the crank in the most equable and effective
manner, and the moving parts of the engine are supposed
to do their work with less friction and wear than are to be
met with in any other kind of engine. It can hardly be
wondered at, therefore, that the side-lever engine was long
a favourite, and indeed that it still continues to be so in
certain cases, and under certain conditions. An example
of a side-lever engine is given in Plate 1.

PLATE I.*
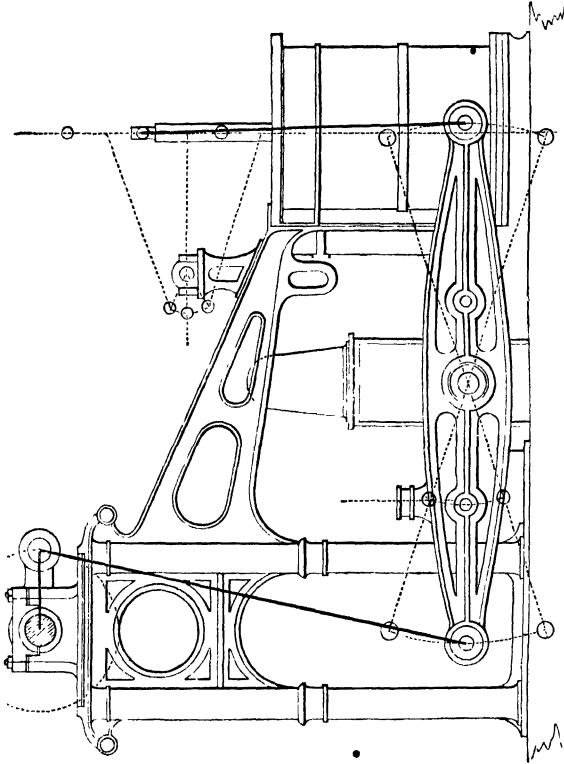
* For examples, see Tredgold on the Steam Engine, new edition, Division B, Marine.　John Weale.

Disadvantages of the Side-lever Engine.—There are two very important conditions, however, in the economy of a sea-going steamer which the side-lever engine *does not* fulfil —namely, lightness of weight, and compactness of form. As these properties were found to be most essential in the machinery of a war steamer, it soon became apparent that some other arrangement of parts must be adopted which would admit of the same power being stowed in less compass, and a portion of the weight of the machinery saved for additional coals, or stores, or armament.

Adoption of the Direct-acting Engine.—Hence the adaptation and general use of direct-acting engines in the Royal Navy, by which means (in conjunction with the adoption of tubular boilers) the length of the engine room was diminished by about one third, and the total weight of machinery by two fifths. It may be observed here, that the weight usually allowed for side-lever engines, flue boilers with water, and paddle wheels, is one ton per horse power; whilst direct-acting engines with tubular boilers and water, paddle wheels, &c., scarcely exceed 12 cwt. per horse power. The distinguishing feature of all direct-acting engines consists in the connecting rod being led at once from the head of the piston rod to the crank without the intervention of side levers: and as it happens (unfortunately, we think) that this kind of engine is capable of almost endless variety, each manufacturing engineer has introduced his own child into the steam navy, where scarcely two pairs of direct-acting engines are to be found alike.

Varieties of the Direct-acting Engine.—These may be all classed under three heads; namely, those which obtain the parallelism of the piston rod by means of the system of jointed rods called a "parallel motion;" those which use guides or sliding surfaces for this purpose; and those denominated "oscillating engines," in which the cylinder is

hung upon pivots and follows the oscillations of the crank.
Belonging to the first class are those of Seaward Rennie,
Fairbairn, Forrester: and to the second class, Maudslay,
Miller, Fawcett, Boulton and Watt, Bury, Robert Napier,
Joyce, &c. As these various arrangements cannot be ren-
dered intelligible in words, sketches of some of the most
characteristic are subjoined, in Plates 2, 3, 4, 5, 6, and 7.

PLATE II.
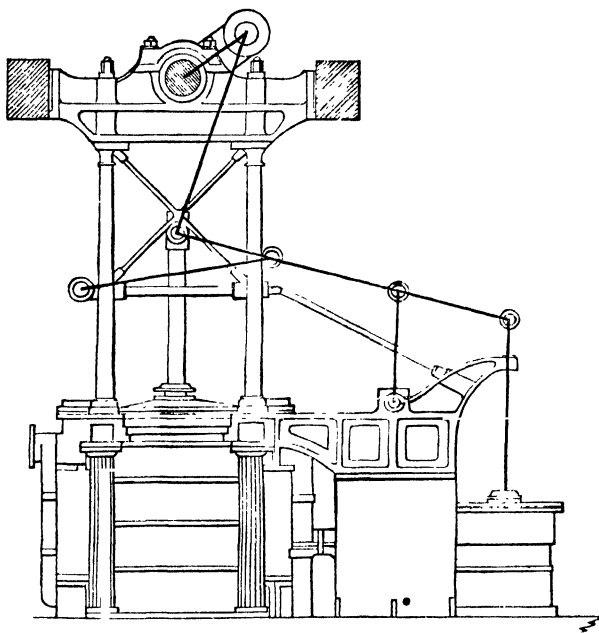
Direct-acting Engine, as constructed by MESSRS. SEAWARD,
CAPEL & Co.*

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* See pages 8 and 9; and for full details of the engines of the *Cyclops*
see the Appendices to Tredgold. John Weale.
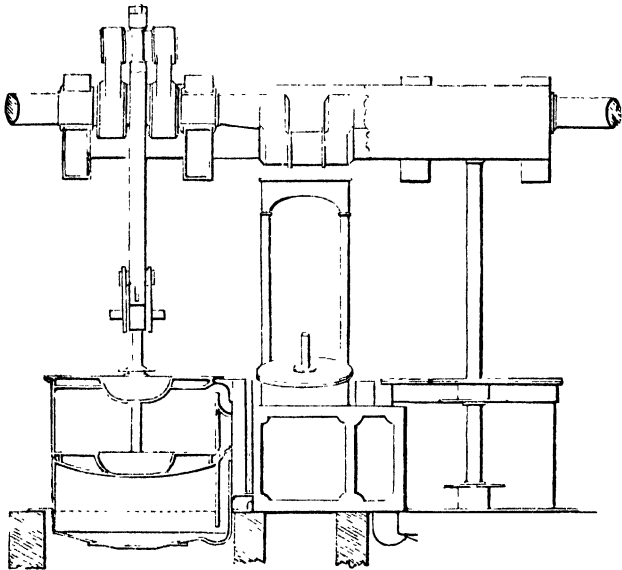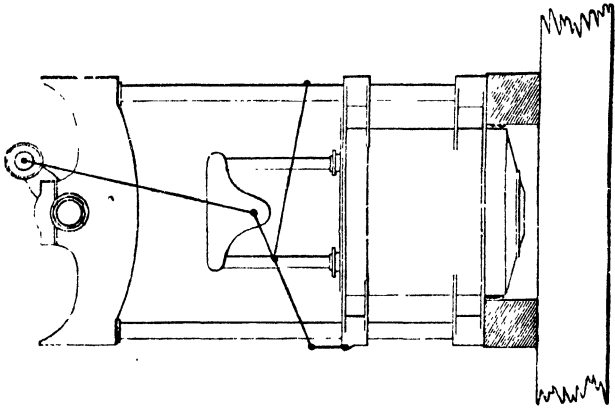
PLATE III.

Direct-Acting Engine of 500 *H. P. of H. M. S.* Bull-Dog, *constructed by* MESSRS. RENNIE.

PLATE IV.

End Elevation of Engines of H. M. S. Cyclops.
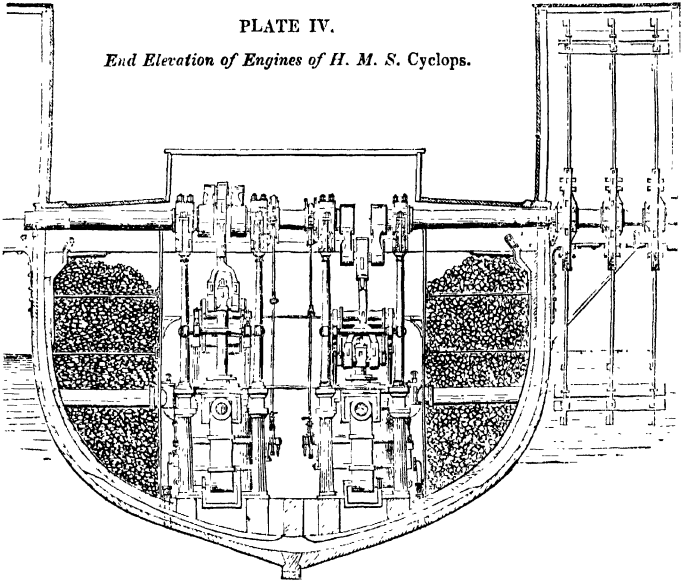
PLATE V.

Elevation of Main-lever of Parallel Motion of H. M. S. Cyclops.
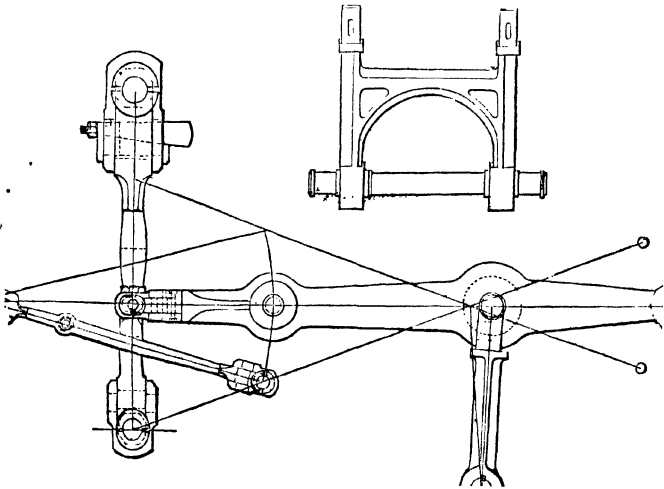
PLATE VI.

Direct-acting Engine as fitted on board H.M. Frigate
Vulture, by Messrs. Fairbairn & Co.

COAL BOX
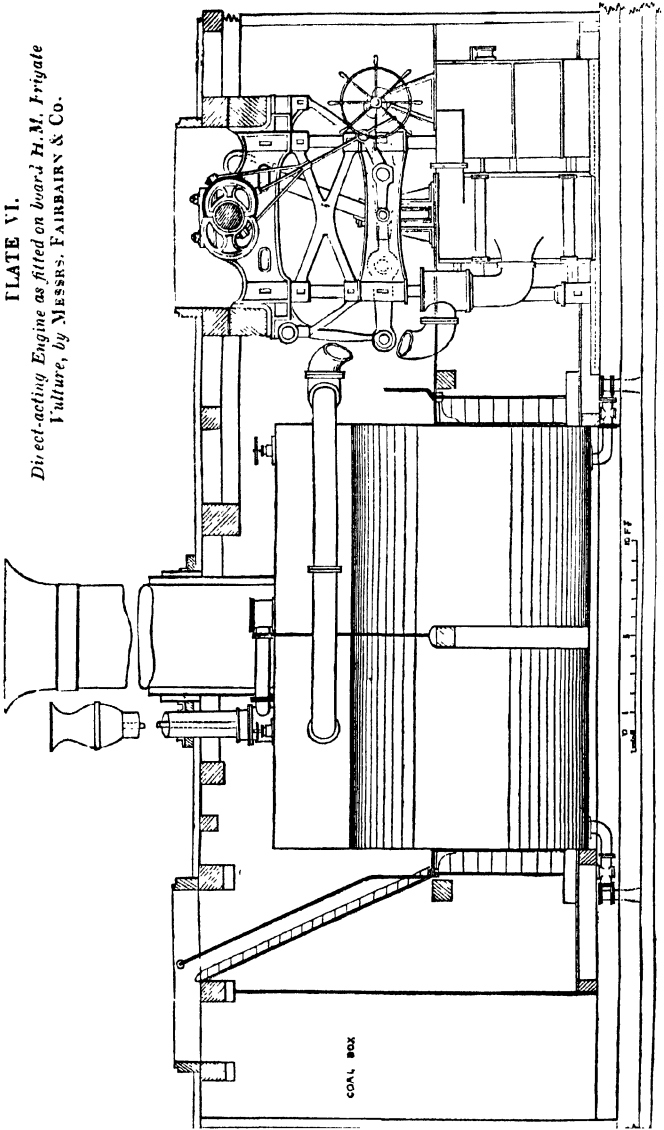
PLATE VII.

Direct-acting Engine as fitted on board
H.M. Frigate, Vulture, by Messrs. Fairbairn & Co.

COAL
BOX

COAL
BOX
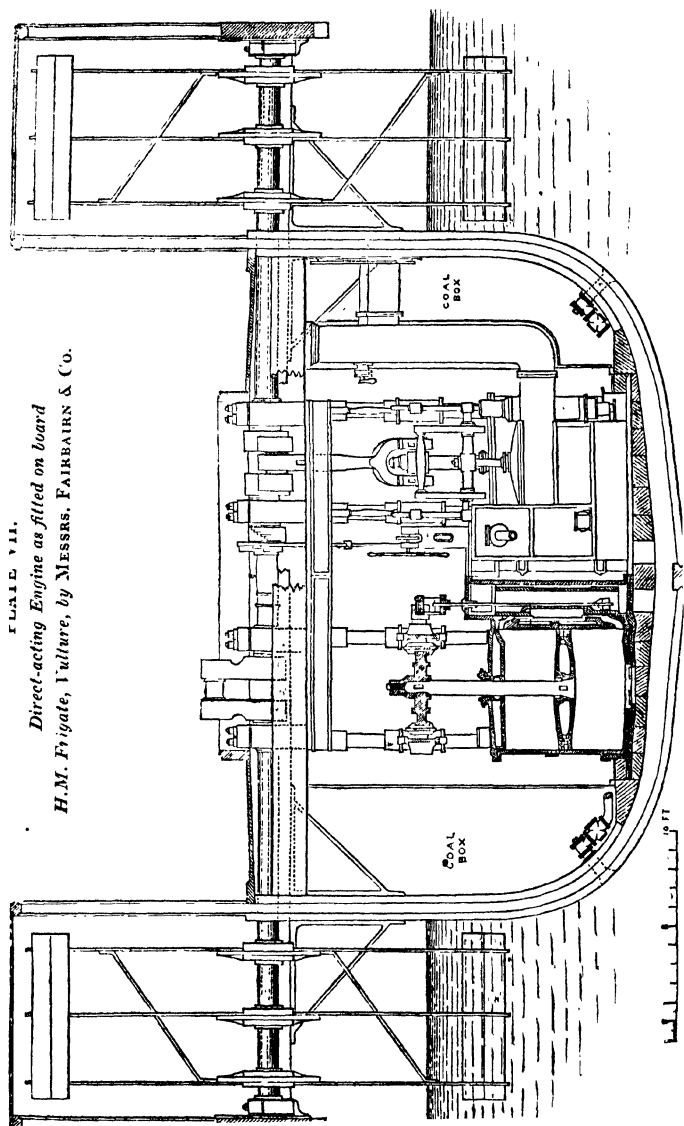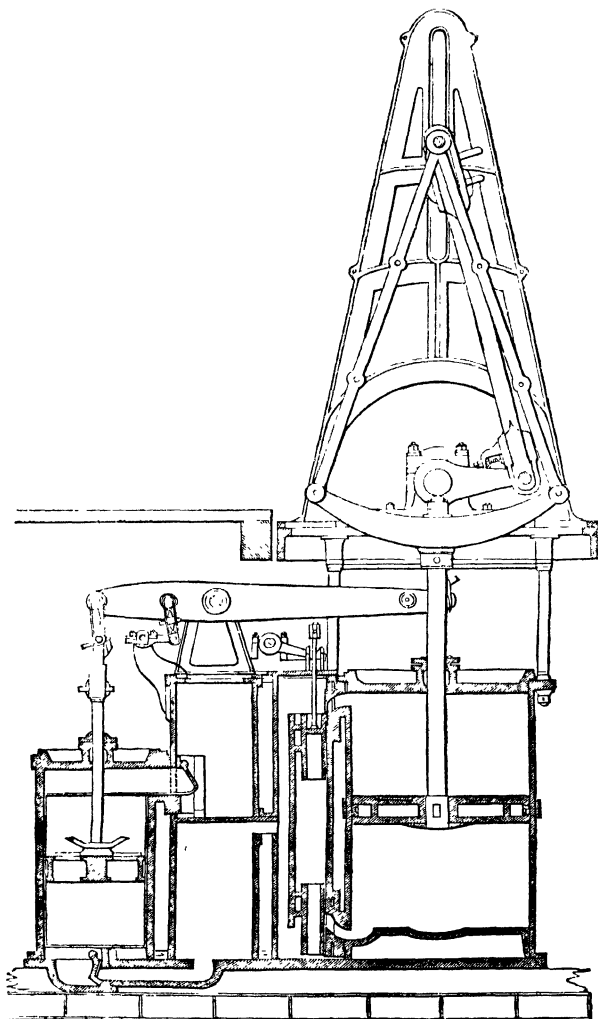
PLATE VIII.

Marine Engine of the Rainbow *Iron Steam Vessel, constructed by*
MESSRS. FORRESTER & Co., *Liverpool. See Appendices to Tredgold.*

Shortness of Stroke a Defect.—The unavoidable shortness of the stroke and of the connecting rod in the majority of direct-acting engines is certainly a defect, and becomes sensible in practice by the increased wear and tear of brasses and packings, and a greater consumption of tallow and oil when compared with the old side-lever engines. Several of the direct-acting varieties, it is true, are not necessarily confined in the length of stroke—as, for instance, the "steeple engine," which is such a favourite on the Clyde.

Steeple Engine.—The latter derives its name from the high erection on deck required by the guide to the connecting rod, which works *above* the crank shaft, and can be recommended only in the case of river steamers where the increased height of the centre of gravity, and the increased surface exposed on deck to the action of the winds and the waves, are not so detrimental as would be the case in a sea-going steamer. See page 12, a successful example. She made, notwithstanding, very rapid passages between London and Antwerp.

Double-cylinder Engine—Maudslay and Field's double-cylinder variety also makes a good engine, and may have a tolerably long stroke and connecting rod, but for small powers it is heavy and expensive. It also occupies more space in the engine room than several other kinds of direct-acting engines; but for very large powers, where the excessive diameter of a single cylinder may be considered objectionable, it appears to be most applicable, and has indeed proved itself to be highly efficient. See Plate 9.

PLATE IX.
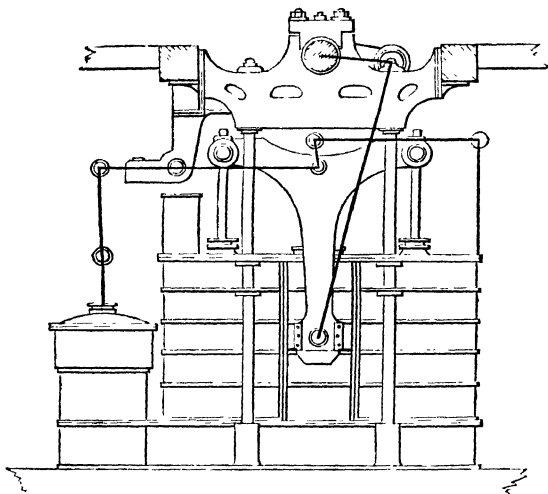
Direct-acting Double-cylinder Engine as constructed by
MESSRS. MAUDSLAY, SONS & FIELD.*

* See Tredgold on the Steam Engine, new edition, Division B, Marine
Engines.   John Weale.

Oscillating Engine.—Of all the direct kinds, however, the oscillating engine, which has derived from Mr. Penn so much of its elegant simplicity and present perfection of workmanship and arrangement, is generally preferred. It need hardly be explained that this engine derives its name from the fact of the cylinders "oscillating" upon hollow axes or "trunnions," through which the steam is admitted to, and withdrawn from, the valves—the piston rod by this means accommodating itself to the motion of the crank without any "parallel motion" being required. This construction has now been proved as applicable to ocean steamers as to the small boats on the Thames, where it has long been a favourite; and it appears to be also well adapted for driving the screw propeller. See Plate 10.

PLATE X.
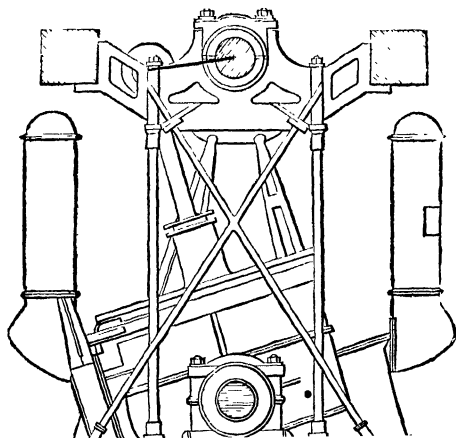
Oscillating Engine as constructed by MESSRS. JOHN PENN & SON.*

* See Tredgold on the Steam Engine, new edition, Division B, Marine Engines. John Weale.

Machinery for Propulsion by the Screw.—The introduction of the new mode of propulsion by the screw has created the necessity for new modifications of the marine engine; and as it is essential for the due performance of the screw propeller that it should revolve with a considerable velocity, it has been deemed necessary to employ gearing or straps, in many instances, to multiply the speed of the engines. The use of toothed gearing being objectionable, however, in sea-going vessels, from the liability of the teeth to be stripped or deranged by sudden shocks received by the screw in a rough sea, it is preferred to attach the engines directly to the screw shaft in all cases where the required speed of the screw renders this practicable. This can be readily accomplished when a great speed is not expected from the vessel, as in the case of auxiliary steam power; or where a long pitch in the screw, and a moderately short stroke in the engine, permit the requisite number of revolutions. For it is evident that the piston in an engine having a three-feet stroke will make twice the number of reciprocations per minute that it does in an engine with a six-feet stroke, supposing the actual speed of the piston to be the same in each case. Hence it is usual to subdivide the power of large screw engines amongst a number of small cylinders, all attached directly to the same screw shaft, and making short and frequent strokes. Where gearing cannot be dispensed with, toothed wheels are preferable to straps.

Internal Gearing.—With the view of affording additional security against accident, Mr. Fairbairn has introduced into a large pair of screw engines for the Royal Navy a system of *internal* gearing, where the small pinion on the screw shaft is driven by teeth on the internal periphery of the driving wheel attached to the engine. The advantage of this plan consists in the greater number of teeth which are thus brought into gear at one time, so that the strain is divi-

ded amongst *several*, in place of being wholly transmitted through *one* tooth.

Protection of the Machinery from an Enemy's Shot.—So long as the paddle wheel continued to be the propelling agent, it was plainly impossible to devise any means by which the machinery could be protected from an enemy's shot ; but the recent adoption of the screw propeller has facilitated this very desirable object to the navy. For as the screw itself revolves entirely beneath the surface of the water, we are now enabled to place all the machinery which gives it motion under the water line also, (in some cases, so much as six or eight feet,) by which means it gains a comparative though not perfect safety. It is well known that a shot will not penetrate more than a foot or two under the water unless it meet the surface at a high angle, but then the bottom of a vessel at sea must be often exposed, during both the rolling and pitching motion, to a position considerably beneath the level water line, when an enemy's shot would have a fair mark at the machinery, although in smooth water it might be perfectly protected. The additional security, however, which such machinery *does* enjoy renders it a question of the utmost importance to dispose the engines and boilers of a screw-propelled vessel quite under the water line. Hence another plea for the practice of subdividing the power of large engines amongst a number of small cylinders, these being ranged (generally in a horizontal position) on either side of the screw shaft, so as to require as little *height* as possible for the reciprocation of their moving parts.   The boilers are also made as low as practicable, and if a steam chest be added, provision should be made for shutting it off from the rest of the boiler in case of injury, the steam being in that case drawn directly from the top of the main boiler.

CHAPTER II.

DETAILS OF THE MARINE ENGINE: THEIR PROPORTIONS AND USES.

ALTHOUGH it is not here contemplated to supply rules and formulæ for proportioning the marine engine, a few remarks are made upon such proportions as the officer in charge of the engines may be able to alter or modify for himself if found necessary.

Steam Pipes.—The steam pipe from the boiler must not be too contracted, otherwise the pressure of the steam upon the piston moving in the cylinder is not kept up during its stroke, the steam being then what is called "wire-drawn" in the pipes. The usual area allowed to the steam pipe is one square inch per horse power, but this may be increased with advantage in the case of small engines. It is of much importance that the pipes should have as short and direct a route as possible from the boiler to the engines, with few angular bends or changes of direction, as all such impediments act most injuriously by checking the supply of the steam. Where bends are unavoidable, they should be made of as large a radius as convenient. Much care must also be taken to prevent the loss of heat by radiation, and the consequent condensation of steam in the pipes, which should therefore be clothed with sheets of hair felt wrapped round with spun yarn, the whole being sewn up in canvas, and painted. Copper is the only material which should be used for steam pipes between the boiler and engine, as wrought-iron pipes generate scales of rust which, becoming detached, are blown by the steam into the valves and cylinder, where they do

much mischief by scratching and cutting the surfaces. When a straight pipe forms the connection with the boiler, an expansion or "fawcett" joint must be provided, but this may be dispensed with when an elbow occurs in the length of pipe.

Throttle Valve.— The throttle valve of a marine engine is always worked by hand, and should be used only in controlling the speed of the engines for any temporary purpose, such as in passing through a crowded river, before stopping at a pier, &c., but should seldom or never be used for working the engines expansively at a permanent reduction of speed.

Expansion Valve.—This latter object is effected by the
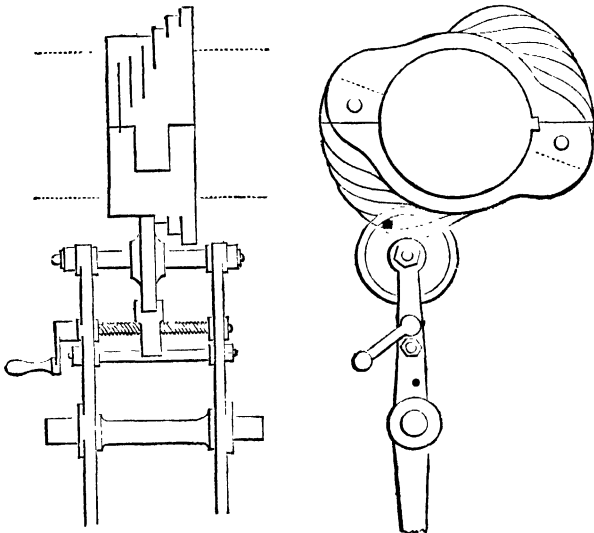
expansion valve, which should be fitted to all sea-going steamers. It usually derives its motion from the crank

shaft of the engine, the valve spindle being connected by a
series of rods and levers with a small brass pulley, which
presses against the periphery of a graduated cam on the
crank-shaft, by which means the steam is " cut off" in
the most advantageous manner at any required portion of
the stroke. The valve employed is usually of the description
called the " Cornish double-beat," or "equilibrium valve,"
which has the advantage of being opened and shut with
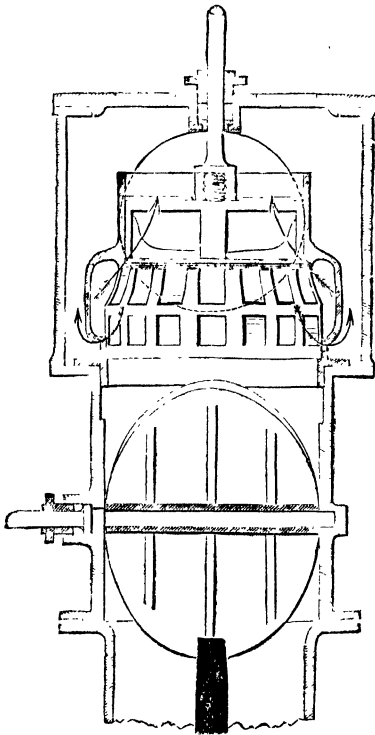
great facility, since, from its construction, the pressure of
the steam has no tendency to jam it against its seat—the
objection to which all flat or plate valves are subject. Also

by a slight rise of this valve, a very large opening is obtained
for the steam. This will be best understood by reference to
the annexed engraving. The principle on which this valve
is constructed is, that if steam be conducted by a branch
pipe into a larger perpendicular pipe between two common
conical valves placed in it, and connected together by a
centre spindle or rod, and resting on their seats, it would
exert a pressure on the under side of the upper valve, tend-
ing to raise it; and on the upper side of the lower one, tend-
ing to keep it down; these two pressures in opposite direc-
tions thus neutralizing each other. It is therefore evident
that these two valves form one double-seated valve, and may
be opened *in equilibrio,* by means of their spindle. The steam
then passes up one pipe and down the other, and, if desired,
these pipes may be again immediately united. By the pecu-
liar arrangement of the seats and partitions, this is done inside
the outer casing of the valve, as shown in the engraving.

Stephenson's Link Motion applied to give Expansion.—A
modification of Stephenson's elegant and simple link motion
for locomotives has been adapted to the marine engine, by
which means the length of stroke of the cylinder slide valves
may be varied at pleasure, so as themselves to act also as
expansion valves; but as their motion is derived from an
eccentric of the usual form, it has a different character
from that produced by the cam in the former instance; the
admission and exclusion of the steam now taking place more
gradually, and, as is generally admitted, with less effect.

To set the Slide Valves.—The manner of setting the cylin-
der slide valves so that they shall admit and shut out the
steam from the cylinder at the proper time, independently of
the action of the expansion valves, is a matter of the greatest
importance. The chief points to be attended to are these:
1st, that the steam shall be shut off a little before the end of
the stroke, by closing the aperture of the steam port, which
causes the piston to be brought gradually to rest without

jarring the engine, independently of the advantage derived from expanding the steam ; 2nd, that the eduction port, or the passage to the condenser, should be closed before the end of the stroke, which is termed " cushioning" the piston, because it then completes the stroke against an elastic *air cushion,* in consequence of a portion of uncondensed vapour being shut up between the piston and the top or bottom of the cylinder; 3rd, that the steam port on the same side of the piston should be opened a very little before the end of the stroke, so that the steam may have acquired its full pressure as soon as the crank shall have turned the centre; and, 4th, that the communication with the condenser should also be opened on the opposite side of the piston a little before the end of the stroke, so as to have a vacuum ready made in the cylinder before the return stroke begins.

" *Lap*" *of the Valve.*—Now, if the slide valves had simply to admit and shut off the steam at each instant that the piston arrived at the top and bottom of its stroke, the face of the valve would have exactly the same depth as the aperture to be covered ; but that the steam may be cut off a little before these points, it is necessary that the valve faces should be made deeper towards that side from which the steam comes, so that after closing the steam ports they may move past the aperture for a certain space at each end of the stroke.   This space, which they *lap over* the valve seating, is called the " lap" or " cover" of the valve on the steam side.   It is apparent that no lap is necessarily required on the exhaust side, because we want the communication with the condenser to *open* before the end of the stroke.   The general practice on this point is to make the edges of the valve faces flush with the edges of the cylinder ports, when the valves are placed exactly in the middle of their stroke.   The objection to lap on the education side is that the communication between the cylinder and the condenser will be closed too early, and the effect termed cushioning will take place to an injurious extent.   The uncon-

densed vapour is compressed sometimes even to such an extent as to exceed in pressure the steam in the boiler, and an erroneous opinion has then been formed in examining the lead corner of an indicator diagram that the valve has been set to open too soon. In these cases after due examination the cover on the eduction side should be cut off. By means of the *lap*, therefore, we are enabled to shut out the steam, and to open the passage to the condenser before the end of the stroke. But it is also necessary that the port should open to steam on the opposite side before the commencement of the return stroke.

"*Lead*" *of the Valve.*—Steam is admitted to act upon the piston before it has quite completed its stroke, by giving the valve a motion in advance of the crank. The extent to which the port may be open for the admission of steam, when the engine is on its top or bottom centre, is varied much, but an allowance of one square inch of opening to every sixteen horses' nominal power, will be found to give good results. In all engines where the velocity of the piston is greater, the lead may be increased beyond this extent with advantage. With common slide valves driven by an eccentric great breadth of port is evidently desirable, as a slight motion of the valve then gives at once a greater area of opening..

Reveri 1g the Engines.—If marine engines were required to work only in one direction, the eccentric pulley might then be permanently fixed on the paddle shaft, (as it is on the fly shaft of a land engine,) in the most advantageous position for *lead*, &c.; but as a steamer must be equally capable of reversing the motion of the wheels, such an arrangement becomes unsuitable. For let us suppose that the engine has been stopped at half stroke in the usual way, by throwing the eccentric out of gear and shutting off the steam, and that steam has been admitted by hand to the opposite side of the piston, the shaft will then commence revolving in the opposite direction. But it is evi-

dent that before the engine can be thus put into the proper
position for enabling the eccentric to continue the reversing
motion, the shaft must be free to rotate *backwards* within
the eccentric pulley through half a revolution. Hence a
necessity arises for placing the eccentric pulley loose upon
the paddle shaft, the latter being fitted with a "stop" or
" snug," with which another " stop" cast on the pulley comes
into contact after half a revolution in either direction, and thus
communicates motion to the valves with perfect indifference
as to which end of the eccentric stop may be in contact.

Expanding by Means of the Lap on the Slide Valves.—It is
apparent that the lap of the slide valve presents a simple
method of working the steam expansively to a small though
definite extent, which is then fixed beyond the power of
alteration until the valves are reset. The amount of ex-
pansion which can be thus given, is limited by the effect
produced upon the eduction port as before mentioned. It
is, however, objectionable to carry expansion by this means
to the full extent to which it is practicable, from the fact
that when the vessel is placed in the most difficult cir-
cumstances, struggling off a lee shore, with the speed of
her engines reduced by a head wind, so that there is an
abundant supply of steam, there are then no means of com-
pletely filling the cylinders, and the full amount of power
capable of being generated cannot be realized. The most
beneficial practice therefore, when the common slide valves
are used, is to have only a small amount of lap, so that it
may be possible to obtain the utmost power that the engines
are capable of exerting at such times as it may be essential,
and to have an additional valve for regulating the amount
of expansion to such extent as may be desired. The latter
system is in accordance with the growing intelligence of
those now generally entrusted with the working of marine
steam engines. An excessive and wasteful expenditure of
steam under circumstances when a corresponding result
cannot be obtained from it need not be feared with a good
superintending engineer on board, as so much interest has

of late been excited not only amongst those parties, but also amongst commanding officers, on this most important point.

Blow-through Valve.—Before the engines can be started it is necessary that the air should first be expelled from the cylinder, condenser, and air pump, and its place supplied by steam, in order that we may obtain a vacuum by its subsequent condensation. Hence a valve, called from its office the " Blow-through valve," is provided to open a temporary communication between the steam in the valve casing and the condenser, by which means a rush of steam is caused to pass through the internal parts of the engine. This operation is continued until the steam begins to issue, hot and transparent, from another valve on the condenser, called the " Snifting valve," situated at the opposite point from where the steam entered. These valves are of course closed as soon as the engine is set to work.

Clothing the Cylinders, &c.—As it is of much importance that the internal heat of the cylinders and valve casings should be preserved from radiation (especially when high steam is used expansively) these must be carefully clothed with felt and dry timber, bound round with metal hoops.

Clearance of the Piston.—The " clearance " of the piston at the top and bottom of the stroke should be just as little as is consistent with safety, and is usually made from one half-inch to five eighths or three fourths of an inch.

Priming Valves.—" Escape" or " Priming valves" are now generally fitted to the top and bottom of the cylinder, to permit the escape of water without danger to the machinery from the shock of the piston against the incompressible fluid. This water collects partly from the condensation of steam within the cylinder, but is chiefly carried over from the boiler, either as " priming," or in a state of mechanical suspension with the steam. It may also overflow through the valves from the condenser. These valves should be

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fitted with hoods to carry off the ejected water into the bilge, and prevent its being thrown about the engine room.

Packing for the Piston.—Metallic packing is now universally employed for the pistons of marine engines, this being made in the form of cast-iron rings, either possessed (from their construction) of elasticity in themselves, or deriving it from steel springs placed behind them. The cast-iron rings, unfortunately, lose their elasticity after being some time in use, in which case they must be taken out, and have this restored by hammering and thereby elongating their internal surface; or else steel springs must be added to press them out against the cylinder, when they are cut into segments to allow the springs greater freedom of action. The piston is lubricated with melted tallow through a grease cock on the cylinder cover, advantage being taken of the vacuum during the up-stroke to suck in the tallow. The grease-cock aperture also serves for applying the "Indicator" during the stroke above the piston.

Condenser.—The condenser should have a capacity of half the cylinder as a *minimum*, but may be made larger with advantage. The size should depend, to a certain extent, upon the temperature or density of the steam used, as plenty of room should be allowed for high steam to expand into low-pressure steam before being condensed, if this has not been previously effected by expansion within the cylinder.

Injection Valve.—The area of the injection valve should be about one square inch for every ten-horse power. This is an ample allowance in all cases, and is more than necessary when the injection water has a temperature of 52° Fahr. (which is the average for our seas), though in tropical climates it will not be found too much. The average temperature of the Mediterranean is about 65°; at 20° of latitude, about 75°: and at the equator, about 82°, Fahrenheit. The supply may be regulated at will by the opening

given to the valve, as shown on an index plate. It is better in the case of large engines to have two injection cocks fitted between the sea and each condenser—one, the *sea cock*, close to the side of the vessel, as a security in case of injury to the internal pipe, and the other upon the condenser. Besides these, it is usual to have an injection pipe led from the bilge of the vessel, so that in case of unusual leakage the sea cock may be closed, and the engine supplied with injection from this source. The mouth of this pipe should be carefully guarded and kept clean, as when the emergency arrives for its use it has too often been found choked up and unserviceable.

Temperature of the Condenser.—The process of condensation will be the more complete in proportion to the coldness and quantity of the injection water, the manner in which it is brought into contact with the steam, and the temperature of the steam itself on entering the condenser. The resulting temperature which is usually aimed at by engineers for the condenser is from 90° to 110°. The limit to a more perfect degree of condensation is imposed by the increased size of the air pump required to withdraw the additional injection water, which diminishes the work and increases the cost of the engine. Hence the engineer is well satisfied if the temperature of the condenser be not above 110°, with which a vacuum of 27½ or 28 inches of mercury is obtained by a good engine.

Elasticity of Watery Vapour at different Temperatures.— According to Dr. Ure's experiments, uncondensed watery vapour at a temperature of 100° balances 1·86 inch of mercury; at 110°, 2·45 inches; at 120°, 3·3 inches; at 130°, 4·366 inches; at 140°, 5·77 inches; and at 150°, 7·53 inches of mercury, or exerts a pressure of 3¾ pounds per square inch.

Flow of the Injection Water.—The velocity at which injection water enters the condenser varies as the square

root of the pressure, and will be about 40 feet per second for the full pressure of the atmosphere against a pure vacuum. The sea injection should be taken from about mid-way between the surface of the water and the bottom of the vessel, so as neither to draw impurities from the surface, nor be liable to become choked with sand or mud from the bottom, when working in shallow water, or when the vessel is aground. In many of the latter cases, the engines have been rendered useless at the time when most needed, by sand being sucked in and destroying the action of the air pump.

Barometer Gauge.—A barometer gauge is attached to the condenser to show the vacuum. It is usually constructed like a common barometer, except that the top of the glass tube communicates through a small pipe and cock with the interior of the condenser, the partial vacuum of which then takes the place of the Torricellian vacuum of the ordinary barometer. The surface of the column of mercury in this case indicates the difference which exists between the pressure of the atmosphere and the pressure in the condenser, so that if we see a column of 27 inches of mercury supported in the tube, and the pressure of the atmosphere at that time be 30 inches of mercury, we know that there is a pressure of three inches of mercury, or $1\frac{1}{2}$ lb. on the square inch within the condenser.

Sources of Error.—As we find by the common barometer that the pressure of the atmosphere is constantly varying, a correction should be made for this in estimating the vacuum of the condenser. Another source of error arises from the varying level of the mercury in the open cup which supplies the gauge tube, according as the tube becomes more or less filled; since it is evident that only that portion of the column which rises above the surface of the mercury in the cup can be reckoned as the counterpoise to the atmosphere. The simplest manner of *alleviating* the last-mentioned source of error is to make the surface of mer-

cury in the cup very large in comparison with the bore of
the tube. As the barometer gauge is very often found to
show incorrect results (either through ignorance or design
on the part of the foreman who saw it fitted) it would be
well if every commander of a steam vessel satisfied him-
self of its accuracy, before giving credence to such wonders
about vacuum as are sometimes published to the world.

Improved Barometer for the Condenser.—Subjoined is a
sketch of an improved barometer for the condenser, which
has been tried and found useful. A glass syphon tube,
a a, 34 or 35 inches long, is half filled with mercury; one
end at *b* being left open to the atmosphere, which is ad-
mitted through a very small aperture to exclude the
dust. A sliding brass scale, graduated from 0 at the bottom
to 30 inches at the top, is fitted in
the space between the two legs of
the inverted syphon. When required
to show the vacuum, the zero point
of the scale must be shifted to where
the mercury falls in the leg open to
the atmosphere, and the height of
the mercury in the other leg being
then read off from the scale, the exact
difference of height between the two
columns is thus obtained. This baro-
meter posesses also the advantage
that the mercury cannot be blown
out by a slight pressure of steam in
the condenser (as is the case with
the common barometer), which ad-
mits of its being kept in constant
use as a guide to the engineers in
stopping and starting their engines
in any time of difficulty. The sy-
phon may be made, if preferred, by uniting two straight
glass tubes in a short piece of bent iron pipe.
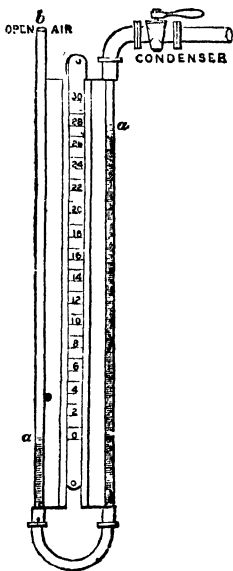
Evils arising from the Use of Sea Water for Condensation.
—The use of sea water for condensing the steam and sub-
sequently feeding the boilers, entails upon marine engines
the necessity for ejecting, or " blowing off" a portion of the
saturated water, at intervals, into the sea, to prevent the
deposition of scale and salt, and causes the loss of a con-
siderable quantity of caloric. The specific gravity of the salt
water in the boiler, taken at a medium degree of saturation,
is about one-tenth part greater than that of fresh water;
and as the capacity of the water spaces requires to be in-
creased to allow for cleaning, as well as for the more ready
escape of the steam through the denser fluid, we may add
about one fifth for the extra weight of salt water in the
boiler as compared with fresh, taking into account the
portion which is blown off. When we consider also the
very rapid wear of boilers using salt water, it is at once ap-
parent that an efficient means of supplying them with fresh
water at sea is one of the greatest desiderata in marine
engineering.

Surface Condensation attempted.—With this view, many
attempts have been made to condense the steam by con-
tact with cold metallic surfaces, instead of by the plan of
injecting amongst it a large body of salt water from the sea.
Could this be done effectively, the boiler might then be fed,
during the whole voyage, with the fresh water which it had
at starting; the same water, after circulating through the
cylinder as steam, being condensed without intermixture
with other water in the condenser, and then returned to the
boiler to be again formed into steam, being thus kept in a
continuous round of action.

Surface Condensation found to be Inefficient.—But, unfor-
tunately, the principle of surface condensation has hitherto
always proved inefficient. The difficulty has generally been
to present a sufficiently large cooling surface to the steam,
so as to produce a rapid condensation.

Hall's Condensers.—This cannot be urged against Hall's Condensers, however, in which the steam is passed through many miles of little copper pipes enclosed in a cistern of cold water, which is constantly renewed from the sea by means of a force pump worked by the engine, but in this case the small pipes through which the steam is passed are liable to become "furred" on the outside, or choked up altogether by deposits from the sea water. Besides this, the additional machinery required adds so much to the expense and intricacy of the engine, as well as to its weight and the space it occupies in the vessel, that this condensing apparatus has not been found applicable in practice. In such an arrangement the loss of steam arising from leakage, or from blowing off at the valves, is compensated to the boiler by the use of a small apparatus for distilling sea water. The air pump is then, of course, much reduced in size, as it has no injection water to remove.

Air Pump.—The capacity of the air pump is usually proportioned to the cylinder as 1 : 8, or thereabouts; and the delivery valve has an area of one third of the air pump, though the orifice through the ship side for the escape of water from the hot well need not be more than one sixth of the area of the air pump, when the latter is single-acting. In large engines, a sluice valve is usually fitted inside the vessel across the mouth of the discharge pipe at the ship side, which being closed by hand when the engines are not working prevents the wash of the sea from entering the hot well.

Feed Pumps.—The feed pumps supply to the boiler so much of the water which has been used in condensing the steam as will restore the waste from evaporation and blowing-off, and each of the two feed pumps which are usually fitted up is made sufficiently large to supply all the boilers in case of accident to the other pump, or to its feed pipes. The

necessary quantity to be admitted to the boiler is judged of
by observing the level in the glass water gauge, and is regu-
lated by hand by means of the feed cock on each boiler—
the surplus water, which is rejected by the boiler, being
expelled into the sea by the feed pump through a loaded
escape valve.

Bilge Pumps.—Bilge pumps are fitted to marine engines
as a security to the ship in case of extraordinary leakage, as
well as to save the work of the crew in pumping the hold
dry. The bilge pipes should be made of lead, which suffers
less corrosion than copper from the acidulous bilge water of
wooden ships, and care must be taken that they do not get
choked with filth.

Hand Pump connected with the Engines.—A hand pump
must also be fitted for the purpose of feeding the boilers
while the engines are at rest and the steam blowing off.
This is made capable of being connected to and driven by
the engines, so as either to assist in feeding the boilers, if
necessary; to act as a fire engine in case of need; or for the
every-day duty of washing decks. It should also be so ar-
ranged that it may draw either from the sea or the bilge.

Hand Pump driven by a Supplementary Engine.—In the
case of vessels with tubular boilers this pump usually receives
its motion from a small high-pressure engine (technically
known as "the donkey") which works by the pressure of
steam in the large boilers. Such a provision becomes ne-
cessary on account of the rapid evaporation of tubular
boilers in comparison with their confined area at the water
level; but in the case of flue boilers, where the water sur-
face is comparatively larger, and danger from the water
level falling too low during a temporary stoppage is there-
fore diminished, this pump is generally worked by hand
only.

CHAPTER III.

THE MARINE BOILER: ITS GENERAL PROPORTIONS, AND THE PRINCIPLES CONCERNED IN ITS OPERATION.

The Marine Boiler.—The Marine Boiler differs from one on shore in this essential particular, that, in the former, the fire and flues are wholly contained within the boiler itself, and are surrounded with water in every direction,—such an arrangement being rendered necessary as a precaution against fire. There are several varieties of this boiler in use, designated the Flue boiler, the Tubular boiler, the Sheet-water-space boiler, &c.

Flue Boiler.—In the Flue boiler, the flame and hot gases generated in the furnace are confined in narrow flues, which wind about amongst the water of the boiler until the heat of their contents has been nearly all absorbed; after which, the flues are gathered together into the "up-take," at the bottom of the chimney.

Form of the Flues.—They should be so roomy as to allow of a boy getting readily through them to clean out any deposit of soot or ashes; but their area must not be unduly increased in any one place, so as to check the velocity of the draft, as in that case a deposition of soot and ashes invariably takes place, by which the heating surface is not only impaired, but the plates are corroded and destroyed.

Arrangement of the Heating Surface.—It is a point of the utmost importance that no part of the heating surface of a boiler should be so situated that the steam may not readily

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rise from it, and escape to the surface of the water; since the plate, if left in contact with steam instead of water, becomes unduly heated and destroyed, and an explosion frequently ensues.

Horizontal Heating Surface the best.—It is found in practice that a perpendicular heating surface, such as the sides of rectangular flues, is by no means so efficient for raising steam as an equal area of horizontal surface, such as the tops of the same flues or of the furnaces. The reason of this is sufficiently apparent; for the steam in the first case, rising perpendicularly from every portion of the surface, forms a film or stratum of vapour in contact with the sides of the flue, which prevents the free access of the water to the hot metal; but, in the other case, the steam leaves the iron as soon as it is generated, and allows the water to be constantly in contact.

Bottom Heating Surface inefficient.—From the same cause of imperfect contact, the flat bottom of a metal flue is very inefficient as heating surface; and plates thus disposed are found to wear out much quicker than those forming the tops of flues or fire boxes. The plan of covering the bottom of the flues with a non-conducting material, as bricks or cement, has been found to cause hardly any diminution in the evaporative power of the boiler, and is by some thought to increase the durability of the bottom plates.

The objection to this plan is, that from the unequal degrees of expansion between the iron and the non-conducting lining, it is impossible to maintain an unbroken joint between their surfaces, so that a space is formed in which brine may collect in contact with the plates, and thus do more mischief than the original disease.

The flues generally increase a little in height as they recede from the furnaces, in order that the depth of water

over them may be less in proportion as the contained air is cooler.

Disadvantages of Flue Boilers. — Although flue boilers occupy at least one third more space in the vessel than tubular boilers of an equal evaporative power, and are nearly one third heavier, they are still preferred in some instances (as on board the West India mail packets), as being more economical both with regard to first cost, repairs, and durability. It is hardly believed, however, that these qualities, if really possessed, are not more than counterbalanced by the increased consumption of fuel necessarily attending any increase in the displacement of the vessel, as well as in the loss of so much valuable space for passengers, goods, or stores.

Tubular Boilers.—In tubular marine boilers, the flame and hot gases from the furnaces are led through a great number of small tubes (of iron or brass), completely surrounded with water, to the flue or "up-take" at the bottom of the chimney. By this arrangement we are enabled to condense a very large amount of "heating surface" within a comparatively small space; and in consequence of the extreme subdivision of the heated gases in passing through several hundreds of tubes not above three inches in diameter, every particle of them is brought into contact with the absorbent surface, and their caloric is thus extracted in the smallest possible time.

Furnaces.—The furnaces, or "fire boxes," should be so deep as to allow of a roomy ash-pit under the doors, the front of the grate bars being fixed at a height of about 30 inches above the firing stage, and sloping down with an inclination of about two inches to the foot towards the "bridge."

Fire Bars.—The bars are best made of wrought iron in several lengths of about 30 inches each, to suit the length of the furnace, which should not exceed 6½ to 7 feet. The bars may be made from five eighths to three quarters of an inch thick on the top edge, about three inches deep, and may have from three eighths to seven sixteenths of an inch of air space between each for Welsh coal, though these dimensions should be modified according to the nature of the fuel it is intended to burn. No open space should be left between the outer bars and the sides of the furnace, as it is expedient to check the formation of flame at that part, in order to protect the plates from being "burnt."

The direct Impact of Flame to be avoided.—It should be borne in mind that the direct impact of flame is very much hotter than radiant heat, and the plates of a boiler should be protected from it as much as possible. This forms a source of objection to many of the plans which have been proposed, or adopted, for burning the inflammable gases in the flues of a marine boiler by the admission of a jet of air, which too often acts like a blow-pipe by directing the flame thus generated against the plates.

The Bridge.—The "Bridge," to which we have alluded, crosses the back of the furnace to support the ends of the fire-bars, and prevent the fuel being carried into the flues, and also tends to cause the flame to reverberate upon the roof of the furnace, although the construction of the boiler sometimes does not require it at all. It is either formed of fire-brick, or else constitutes a part of the boiler by being made hollow, and containing water, in which case the top of the bridge inclines at a considerable angle to allow the escape of steam.

Water Spaces.—The furnaces should be covered with 14 or 15 inches of water, and the tubes or flues with 10 or

12 inches, in the case of sea-going steamers. The water spaces between the furnaces are usually five to six inches wide; and between the flues, four to five inches. The spaces between the crowns of the furnaces and the bottoms of the tubes should be not less than 10 inches, to allow of a "man-hole" between the arched tops. The bottom water spaces should be not less than eight inches, to allow room for "scaling" and cleaning. It is usual to allow a space of one inch between the tubes of a tubular boiler, these being arranged in perpendicular rows, one over the other, by which means the steam is supposed to escape more readily than when they are placed zig-zag.

Although many of the proportions here set down are beyond the control of the officers in charge of a steam vessel, still we think it expedient to state, in as few words as possible, what proportions of engine and boiler are considered by practical men to be most conducive to perfect efficiency. For unless a general knowledge of these proportions be acquired, it is plainly impossible to form a judgment as to whether any observed deficiency in the work of the engines is due to the fault of their original construction, or depends upon those details of *management* which it is more particularly our present object to explain. And although it is but just to the talented constructing engineers of this country to assume, that in the majority of cases the machinery of a steam vessel leaves their hands in a perfect state, it is nevertheless most satisfactory to be enabled to prove this for one's self.

Requisite Amount of Heating Surface.—Before we can obtain a good average result from the combustion of the fuel, it is necessary that the boiler should present about twelve square feet of effective heating surface per horse power; for if less surface than this be given, a wasteful quantity of heat escapes up the chimney, from not having been absorbed by the water. What is termed "effective"

heating surface, must be calculated independently of the bottoms of flues and fire-boxes, and of one fourth part of the whole tube surface. The grate-bar surface should be *at least* 80 square inches per horse power, and, where practicable, may be increased to 100 square inches with much advantage.

Areas of Flues and Tubes.—The area of the first flue, or the clear area through the tubes, should equal one sixth of the grate-bar surface led into them; and the area of the flues may be gradually diminished from the fires to the chimney by one fourth part.

A Roomy Furnace desirable.—As a large furnace is found by experience greatly to facilitate the admixture of the gases, and to ensure their more perfect combustion, as well as to afford the most effective kind of heating surface, it is of great importance that there should be plenty of room over the fires.

Combustion checked by the Carbonic Acid.—The carbonic-acid gas which results from the combustion of solid carbon, has a most injurious effect in checking combustion within the furnace, for we find by experiment that flame is barely supported in a mixture of one part of this gas with four of atmospheric air. Hence the necessity for admitting into the furnace at least twice the amount of air chemically required; and even then, if we analyze the contents of the chimney, we shall find from one fourth to one-half of the oxygen which entered the fire still free and uncombined, mixed up with the products of combustion.

Loss of Heat attending the Combustion of the Inflammable Gases.—Now, as the whole of the air thus supplied in excess must be heated to a very high temperature before the combustion of the inflammable gases in the furnace

can ensue, much heat is thus unavoidably wasted—so much, indeed, that it is now well ascertained that the evaporative value of a bituminous coal producing a large quantity of gaseous matter is very little, if at all, superior to the evaporative value of the same coal *after being coked;* the heat generated by the combustion of its volatile products proving, in practice, to be little more than that expended in volatilizing them, and in heating the surplus air required for their subsequent combustion.

Formation of Carbonic Oxide.—When a stinted supply of oxygen is furnished to the incandescent fuel on the bars, an imperfectly oxygenated carbonic-acid gas, named "carbonic oxide," is partly produced, accompanied by a corresponding loss in the heat generated during combustion. As this gas is inflammable, and that at a comparatively low temperature, it may be burnt in the furnace, or flues, by the admission of a further supply of atmospheric air—otherwise, it escapes unconsumed up the chimney, where it may be often seen burning at the top, having caught fire upon coming into contact with the oxygen of the air. Although it may be beneficial to consume this carbonic-oxide, when once formed, by admitting fresh air into the flues behind the bridge, it is certainly preferable to prevent its formation altogether by using a large grate surface, a thin fire, and plenty of air space between the bars.

Smoke-burning Apparatus.—Notwithstanding all that has been done and written with reference to the so-called "smoke-burning" apparatus, it is the opinion of those most capable of forming a correct judgment on this subject, that by a proper construction of the furnace, and a skilful management of the fire, the smoke and gases may be as effectually, and certainly more safely, consumed, by admitting the requisite quantity of air for this purpose at once through the grate bars.

Recapitulation.—It may be gathered from the preceding remarks, that some of the most important requisites to ensure efficiency in a steam boiler are the following:—1st. That the boiler should be designed with a sufficient amount of heating surface, so contrived that as little of it as possible may be rendered ineffective, either from the retention of steam in contact with it, from the formation of scale within, or from the deposition of soot and ashes in the bottoms of the flues and tubes. 2nd. That the fire-bar surface should be sufficiently large to admit of the necessary quantity of coal being consumed with thin and open fires. 3rd. That the proper area be maintained through the flues or tubes, and that the passage to the chimney be such that the draft may not be interrupted. 4th. That the furnace should be roomy; the bars thin, with plenty of air-space between them; and, that the fires should not be longer than can be conveniently stoked. And, 5th (which is, perhaps, the most important requisite of all, and the one most neglected), That experienced and careful fire-men be provided.

Clothing Marine Boilers, found to be sometimes prejudicial.—Although it must be admitted that the practice of "clothing" marine boilers with non-conducting materials, such as hair-felt, wood, &c., is in all cases highly beneficial for the production of steam; yet this is alleged to have induced, in some instances, a rapid wear in the plates of the boiler. This corrosion is most apparent in boilers which are frequently used and disused alternately, and takes place on the interior surface, attacking principally the top of the boiler and the steam chest. It is, probably, owing to the alternate wetting and drying of the plates, which causes the rust to scale off, and thus present a fresh surface for corrosion each time that the water is blown out of the boiler. In the case of an unclothed boiler, on the other hand, the internal surface is scarcely ever "quite dry,"

from the evaporation being checked by the low tempera-
ture, and the consequent saturation of the enclosed air.
Marine boilers which are constantly in use, or which make
long voyages only, do not experience this destructive cor-
rosion of the steam chests to the same extent.

Bedding of Marine Boilers.—The manner of *bedding* ma-
rine boilers is a point of some importance, as it materially
affects the durability of the bottom plates. The usual
method adopted by the Admiralty, is to form a close plat-
form of timber over the keelsons, upon which is spread a
plaster of cement, or mastic, about one inch thick, on
which the boiler is set. As this becomes quite hard, it
prevents the bilge-water (which in wooden ships is highly
acid) from washing up to and corroding the plates; and it
is also intended to stop any leaks which may break out in
the bottom of the boiler, as well as to strengthen it in the
event of an unusually rapid corrosion taking place from
the inside. Unfortunately, however, it is impossible to
preserve a close contact between the iron and the cement,
on account of their different degrees of expansion by heat,
so that when a leak does take place in the boiler, it extends
itself for a large space between the two surfaces, and the
corrosion is increased instead of diminished. Perhaps the
best practice is to rest the boiler on saddles of cast-iron
fixed on the boiler bearers, which leaves the bottom exposed
for examination and painting, and even for small repairs if
necessary. In this case the bottom of the vessel under
the boilers must be kept quite clean and dry by the bilge-
pumps.

Galvanic Action.—It is necessary, both in marine engines
and boilers, to guard against the destructive effects of gal-
vanic action, which ensue in all cases where two metals
of different degrees of solubility (or possessing different
degrees of affinity for oxygen) are placed in juxtaposition;

as, for instance, iron and brass, when the former metal suffers a rapid corrosion from being the more oxidable of the two, while the brass is quite protected.

Copper Boilers.—In cases where the frequent renewal of boilers is attended with great expense and inconvenience, they are sometimes made of copper, which lasts about four times as long as iron. Their first cost, however, is about five times greater for boilers of the same weight, and copper is only three fifths of the strength of iron when cold, or less than half its strength at 500° Fahrenheit. Iron, on the contrary, increases in strength from 32° to 550°, when its strength is believed to be at a *maximum*. It is evident, however, that although a copper boiler is not so strong as a *new* iron one of the same weight, it retains its original strength unimpaired for a long time, whilst the iron boiler is every day becoming weaker by corrosion. An iron boiler, when new, has thus a great superabundance of strength, to allow for the wearing of the plates by use; and it must on no account be forgotten, that a boiler which may show no symptoms of weakness on being first used under a pressure of 20 pounds on the square inch, may be very unfit to work at this pressure after a couple of years' service. As copper conducts heat more readily than iron, in the ratio of 2·4 : 1, a copper boiler does not require so much heating surface as an iron one. Also, after the copper boiler is worn out, the old material is still valuable, whereas the price obtained for the scrap iron is little more than what it costs to break up an old iron boiler.

CHAPTER IV.

THE MARINE BOILER: MANAGEMENT OF THE FIRES.

The skilful Management of the Machinery necessary for its Efficiency.—Having endeavoured to show in a few words what the machinery of a steam vessel ought to be, we proceed to consider, in the next place, how it may best be used: for, notwithstanding all the talent and perfection of workmanship which may be displayed by the constructor, it still rests mainly with those to whose care it has been entrusted whether this costly machinery shall give satisfaction or not.

Economy of Steam is the main Question.—The economical working of an engine evidently depends upon the quantity of steam which is required to do a given quantity of work, so that the whole question resolves itself into this, how can we best save steam ? This question, again, naturally divides itself into two heads, which are really quite distinct, though too often associated together; namely, the production of steam in the boiler, and its subsequent use in the engine—and we shall therefore consider those separately.

The Generation of Heat in the Furnaces.—The economy of a steam boiler is again sub-divided into the *generation* of heat by the combustion of the fuel in the furnace, and the subsequent *absorption* of this heat by the water, as has been already commented upon.   As the latter is beyond the control of those in charge of the machinery, (except in keeping the surface of the flues and tubes as clean as possible,) we shall not further advert to it, but will pass on to the management of the furnace.

Management of the Fires.—The management of the fires on board a steam vessel affects the question of economy in the consumption of coal to so great an extent, that the importance of skilful firemen cannot be too much insisted upon. It is a great mistake to suppose, as too many captains and owners of steam vessels do, that any able-bodied man who can throw coals on a fire is fit for a stoker: and under this false impression, *sailors* are frequently engaged, instead of regular firemen, " to stoke when required." The only cases in which this should be allowed are, perhaps, in auxiliary-screw vessels, and in such vessels as may be expected to make a considerable portion of their voyage under canvas; but even in such cases there should always be one well-trained fireman for each watch to have the charge of the other stokers. This man should be kept constantly at his post, and must not be liable to be called away while the vessel is under steam, except in cases of emergency; and he should receive a higher rate of pay than the other stokers, if it were only for the purpose of giving him the necessary authority over them.

Effects of Mismanagement.—Thus, many instances of steamers are to be found at the present day in which the same quantity of coal is regularly burnt per hour, whether the engines are going fast or slow; whether forty cylinders full of steam are used per minute, or only thirty. In such a case, one quarter of the fuel is thrown away through ignorance of the despised art of stoking; for the firemen may have either allowed the surplus steam generated to blow off at the waste-steam pipe; or they may have thrown open the fire doors, by which means the steam is only prevented from being generated by the rush of cold air which takes place through the flues, while the same quantity of coal is burnt as before.

Feeding the Furnaces.—Boilers of the proportions most

usually adopted by constructing engineers are suited for the combustion of from 15 to 18 pounds of coal upon each foot of grate surface per hour. In applying this fuel, it is found most advantageous to throw on at one time a supply to last for about 12 minutes, the furnace door being opened in about eight minutes after the fire has been fed, to see how the coal is burning; and if any part of the grate has burnt bare, a little coal must then be quickly and skilfully thrown over that place; or should the coal appear to lie too thickly at any part, it must be levelled with the "rake."

Clearing the Bars.—In the case of a very bituminous coal it is often found necessary to open or break up the fire at this time, owing to the tendency of such a coal to cake on the bars, and thus prevent the passage of air through them; but this may be obviated to a certain extent by keeping the fires thinner with bituminous coal than would otherwise be desirable.

Keeping the Fire Doors shut.—As it is of the utmost importance that the fire door should not be open longer than necessary, since the cold air which then rushes in acts most prejudicially and by absorbing heat from the flues, the experienced fireman will study to dress his fire, in the first instance, so as to demand as little interference as possible between the times for throwing on fresh fuel, or "firing-up," as it is termed.

Levelling the Fuel.—The fires should be kept of a moderate and equal thickness throughout, and as the firemen are very apt to heap up coals at the far end of the bars, it is a good practice to make each set of men, before leaving their watch, lay the rake or pricker along the surface of each fire quite back to the end of the furnace, in order to find whether the thickness of the fuel is uniform or not. Should any of the fires then want dressing, the firemen under

whose charge they are should be forced to remain until those fires have been brought to a regular and proper thickness.

Each Watch to leave their Fires clean.—It is the general practice for each set of men on first beginning their watch to clean their fires and clear the bars of all clinkers or vitreous matter, according as each fire burns down for the first time after taking charge. By this means the men are made responsible for the condition and efficiency of their own fires during their watch; and before leaving, they should clear out the ashes from the ash pits, collect the cinders to be re-burnt, and throw the refuse overboard.

Forcing the Fires is expensive of Fuel.—If it is found that the boilers do not generate the requisite supply of steam, it will then be requisite to urge the fires to a greater extent by the frequent use of the " slice," which is inserted from underneath between the bars, in such a manner that the coal is raised and broken up, and a larger supply of air is permitted to pass through. It is evident, however, that in this case a considerable waste must ensue from cinders falling through the bars into the ash pit before they are thoroughly consumed, and these cinders cannot now be again thrown on the fire, because it is necessary that the combustion should be as bright and active as possible, in order to "keep the steam."

The Cinders to be re-burnt when practicable.—Hence this valuable fuel is thrown overboard; but in well-constructed boilers of sufficient capacity for the easy supply of the engines, a considerable economy will result from carefully separating the cinders from the ash and re-burning them. When using Welsh or other coals that are easily broken, it becomes of special importance that the fires should be allowed to burn regularly, without being frequently broke up or disturbed, for as these coals contain a large propor-

tion of *small* and dust, this would be entirely lost by falling through the bars were the fires much worked. When, on the contrary, this small coal is thrown over the fire and allowed to cake, it then becomes available; but as it deadens the fire when first thrown on, this cannot be done unless the boilers are large enough to generate a sufficient supply of steam with "dead" or slow-burning fires.

Superior Economy of Large Boilers.—Hence arises a principal source of economy from the use of boilers of ample capacity to generate the steam without the fires being unduly disturbed, and it is believed that on this ground alone can the alleged superiority of slow over rapid combustion be maintained, in cases where the flue surface is supposed sufficient to absorb all the heat generated.

The Boiler Power is usually subdivided into Sections.—In large steam vessels the boiler power is usually subdivided into three or four sections, each independent of the other, and capable of being connected together, or disconnected, at pleasure. In such vessels it frequently happens that the full steam power is not required, so that a fourth part, or even a half of the steam which the boilers are capable of generating, may be dispensed with. When this is the case it is the usual practice for the engineer to disuse either one or two of the boilers altogether, urging the remaining sections so as to make them generate the full quantity of steam of which they are capable.

How to manage the Boilers when full Steam is not wanted. —It is now recommended, however, that instead of disusing one of the three or four boilers, they should all be kept in use, the fuel being burnt slowly and equally upon the fires. By this means not only will the fuel be used more economically in the furnace, but an additional advantage will be derived from the flue or tube surface (in a marine boiler always more or less insufficient), which will now be enabled

to absorb more of the heat generated. In like manner, where one half of the steam power is sufficient, one only of the four sections should be disused. This is considered preferable to using all the four in such a case, as it is difficult in practice to carry out the system of slow combustion to its extreme limits; because, when small quantities of coal are spread over the fires at long intervals between, they are apt to burn into holes and admit the entrance of jets of cold air, which rob the flues of their heat. If, however, the engineer in charge can surmount this difficulty either by skill in managing the fires, or by bricking over a portion of the grate surface in each fire (which is perhaps the best mode of proceeding), he might then continue to use all the four boilers with decided advantage.

Lord Dundonald's Experiments on Slow Combustion in Marine Boilers.—The beneficial results which may be obtained from slow combustion, combined with large absorbing surface, in a marine boiler, have been clearly proved in a series of experiments conducted by Lord Dundonald, to whose inventive genius in mechanics, and steady perseverance in carrying out his projects, every engineer who has been brought into contact with him must bear evidence. The weight of water evaporated by one pound of coal in marine boilers of the usual proportions varies from eight to ten pounds, whereas in those constructed by Lord Dundonald for the "Janus," 12·9 lbs. were evaporated. This high result was attributed by his lordship to the more effectual burning of the coal by "slow combustion," combined with a peculiar arrangement of the flues and tubes constituting the absorbing surface of the boiler, which, it must be kept in mind, was nearly double the size usually allowed for the supply of the same quantity of steam.

Experiments with a Tubular Boiler in Woolwich Dockyard.—To form a comparison with these results, therefore, the furnaces of a common tubular boiler, such as are used in

the Royal Navy, and which was at the time lying in Wool-
wich dockyard, were partially bricked up—the absorbing
surface remaining the same as before. The result now ob-
tained was quite equal to that from the boilers of the
"Janus," although the rate of combustion per square foot
of grate-bar surface was more rapid in the case of the Wool-
wich boiler. It is evident, therefore, that this boiler, when
altered, was in precisely the condition into which marine
boilers, not required to generate their full quantity of steam,
may and should be brought by the engineer in charge,
whenever the occasion presents itself. In the above in-
stance, a saving of about one third of the fuel was thereby
effected, although, as a necessary consequence, the quantity
of steam which the boiler was capable of producing in a
given time was diminished to nearly one half.

The experiments above referred to are of considerable
value, as indicating the economy of slow combustion on the
bars of a marine boiler (when this is practicable), as well as
the relative effect on the evaporative power of the boiler
produced by a progressive diminution of the grate-bar sur-
face, as will be seen from the subjoined table.

Dimensions and Description of the Experimental Boiler.—
The boiler experimented upon was an eighty-horse tubular
marine boiler of the ordinary construction, with horizontal
tubes over the furnaces. Its extreme measurements were
9 ft. long by 8ft. 6 in. wide, covering an area of 76½ sq. ft.
in the vessel, or ·956 sq. ft. per horse power. It had 3 fires,
each 8 ft. by 2 ft. 2 in., affording 93·6 sq. in. grate surface
per horse. The total " effective" heating surface, after de-
ducting one third for the bottoms of tubes, was estimated
at 13 sq. ft. per horse power. There were 176 iron tubes,
each 3 in. outside diameter and 6 ft. long. The boiler was
12 ft. 2 in. high, and the furnaces 2 ft. 10 in. high. Capacity
for steam was 167 cub. ft. Total space occupied by the
boiler, 761 cub. ft. Total evaporating surface in the boiler
estimated at 1057 sq. ft.

D

Dimensions of the Boilers of the "Janus."—There were four boilers originally in the "Janus," each measuring 12 ft. 2 in. by 8 ft. 4 in. and covering an area of 406¼ sq. ft. in the vessel, and three fires in each boiler, each 6 ft. by 2 ft. 1¼ in. The boilers are 14 ft. high to top of steam chests; the total space occupied 4738 cubic feet. The total evaporating surface, measuring the outside of the tubes, as in the Woolwich boiler, is 5137·4 sq. ft. The North-country and Welsh coals having been mixed in the stores at Chatham dockyard, where the trials were ordered to be made, it was necessary to select by hand, lumps of Welsh coal for the trials; and, to render the comparison fair, this was done in the latter trials of the Woolwich boiler also. From this cause the results in both cases are beyond the average.

TABLE OF EXPERIMENTS WITH A TUBULAR MARINE BOILER OF EIGHTY-HORSE POWER, MADE IN H.M. DOCKYARD, WOOLWICH.

	No. 1	2	3	4	5	6	7	8	9	10
Evaporating Surface per cub. ft. of Water evaporated per hour. (sq. ft.)	10·06	9·54	—	16·22	19·57	13·56	14·99	19·19	19·20	
Temp. of the Water supplied to the Boiler. (Deg.)	56	54	54	53	54	63	50	47	47	41
Coals burnt per sq. ft. of Bars per hour. (lbs.)	13·75	15·51	9·04	11·81	8·81	11·79	17·11	17·58	10·34	10·62
Coals burnt per sq. ft. of Bars, during the Experiment. (lbs.)	89·38	90·46	73·23	34·46	55·77	75·49	101·23	45·23	43·08	64·61
Ratio of Effect in Proportion to Bar Surface.	8·83 : 1	8·38 : 1	14·14 : 1	9·36 : 1	11·28 : 1	8·55 : 1	6·02 : 1	13·25 : 1	8·49 : 1	8·49 : 1
Evaporation in hour in cub. ft. with the Feed at 100°. (cub. ft.)	105·06	110·76	65·09	65·21	54·01	71·32	77·35	70·49	55·06	56·96
Ratio of Effect with Feed at 100°.	9·18	8·58	8·73	10·11	11·23	11·07	10·87	11·18	12·90	12·88
Ratio of Effect at Temperature of Feed.	8·83	8·24	8·38	9·69	10·78	10·62	10·39	10·66	12·21	12·21
Quantity of Water evaporated. (lbs.)	41,040	38,760	31,920	11,400	20,520	27,360	27,360	25,080	13,680	20,520
Quantity of Coal used. (lbs.)	4648	4704	3808	1176	1904	2576	2632	2352	1120	1680
Kinds of Coal used in the Experiments.	Welsh Coal.	Lewis' Merthyr	Wood's do.	" "	" "	Lewis' Merthyr	Handpicked.	" "	" "	" "
Bar Surface, per cub. ft. evaporated per hour. (sq. ft.)	·515	·489	·825	·546	·658	·499	·351	·773	·495	·482
Total Surface of Grate Bars. (sq. ft.)	52	"	34·125	"	"	"	26	52	26	26
Dimensions of the Furnaces. (ft. in. ft. in.)	8 0×2 2	" "	5 " 3×2 2	" "	" "	4 " 0×2 2	8 0×2 2	4 4 0×2 2		
Duration of Experiment. (h.m.)	6 30	2 55	8 20	2 24	5 58	5 58	4 10	4 6		
No. of Experiment.	1	2	3	4	5	6	7	8	9	10

EXPERIMENTS MADE WITH TWO OF LORD DUNDONALD'S BOILERS AS MADE FOR THE "JANUS."

	No. 1	2	3	4
Evaporating Surface per cub. ft. of Water evaporated per hour. (sq. ft.)	16·87	16·77	17·13	22·06
Temp. of the Water supplied to the Boiler. (Deg.)	50	50	50	50
Coals burnt per sq. ft. of Bars per hour. (lbs.)	10·13	10·22	12·53	13·1
Coals burnt per sq. ft. of Bars, during the Experiment. (lbs.)	60·77	61·33	75·2	78·55
Ratio of Effect in Proportion to Bar Surface.	12·34 : 1	12·597 : 1	10·769 : 1	10·14 : 1
Evaporation in hour in cub. ft. with the Feed at 100°. (cub. ft.)	156·9	153·1	149·9	116·4
Ratio of Effect with Feed at 100°.	12·901	12·483	11·96	12·127
Ratio of Effect at Temperature of Feed.	12·34	11·94	11·44	11·6
Quantity of Water evaporated. (lbs.)	56,277	54,920	53,770	41,784
Quantity of Coal used. (lbs.)	4558	4600	4700	3600
Kinds of Coal used in the Experiments.	Handpicked and Llangennock			
Bar Surface, per cub. ft. evaporated per hour. (sq. ft.)	·5	·51	·437	·41
Total Surface of Grate Bars. (sq. ft.)	75	75	62·5	45·83
Dimensions of the Furnaces. (ft. in. ft. in.)	6 0×2 2	6 0×2 2	6 0×2 2	6 0×2 2
Duration of Experiment. (h.m.)	6 0	6 0	6 0	6 0
No. of Experiment.	1	2	3	4

Slow Combustion generally impracticable in Marine Boilers. —In order to carry out this principle in the case of steam vessels constantly using their full power, the boilers would have to be made nearly double their present size, which of course in most vessels is wholly impracticable, and is certainly not to be recommended in cases where the full supply of steam is rarely wanted. From a pamphlet of Captain Ramsay's we find that the "Terrible" steam frigate used her full steam, and lighted all her fires, on one occasion only—and that for a trial of speed.

Regulation of the Draft.—Where it is not convenient to lessen the grate-bar surface by bricking up the bars at the further end, the same object may be effected, though certainly not so economically, by checking the draft. With this object in view, every boiler should be provided with damper doors upon the mouths of the ash pits, accurately fitted, and furnished with the means of regulating with nicety the amount of air entering beneath the bars, or, if necessary, of excluding it altogether. Dampers are besides fitted at the foot of the chimney, but these are not so completely under control, nor do they admit of the draft of each fire being regulated separately.

Banking up the Fires.—Cases frequently occur in which it becomes an object to check the rapid formation of steam for a longer or shorter period, but at the same time to retain the power of getting up full steam and starting the engines again on the shortest notice. This is done by pushing the burning fuel back against the bridge, and covering it with wetted small coal and ashes, by which means the fires will be kept in a smouldering state, ready to be broken up and spread over the bars when the order is given to get up the steam. But as this process requires at least twenty minutes before the fires can be brought to their proper state of efficiency, it is better, when such no-

tice cannot be reckoned upon, merely to push back the fires and heap them up against the bridge, raking them forward again when required.

To get the Steam up rapidly.—It is of great importance when wishing to get up the steam rapidly, to take care that the fire bars are so covered by coal, that a current of cold air is not allowed to pass through the flues, mixing with the small quantity of smoke or products of combustion at first formed. Every thing should be done to facilitate, or if possible cause a draught of air into the ash pits.

No Water to be thrown in the Ash Pits.—It is a most reprehensible custom amongst firemen, and one which should not on any account be permitted, to throw water upon the ashes in the ash pit. They should be drawn out and the best of them, roughly separated by the shovel, be thrown again upon the fire, while the remainder should be drawn well away from the boiler and gradually quenched with a stream of water from a hose, so as not to fill the engine-room with steam and dust, nor keep the front of the boilers constantly wet, so as to corrode and destroy them at this spot.

CHAPTER V.

THE MARINE BOILER: MANAGEMENT OF THE WATER AND STEAM.

Supply of Water to the Boilers.—The keeping up a due supply of water in the boilers demands the utmost care and watchfulness on the part of the engineer, for should the iron in any place be allowed to become red-hot from want of water, an explosion is almost inevitable. The immediate effect of the heat upon the unprotected plates is to warp and distort them, causing them either to separate at the joints by the giving way of the rivets, or to be torn asunder by the elasticity of the steam acting upon the distorted and softened surface. Explosions have also frequently taken place from water having been too suddenly admitted to the hot plates in the eagerness of the engineer to make up for his previous neglect, when steam is generated so rapidly that the safety valves are insufficient for its escape. It is said that in such cases a portion of the water, becoming decomposed into its elements by contact with the red-hot iron, may form an explosive compound of oxygen and hydrogen gases, which, on ignition, causes the explosion. But whatever the theory, the fact itself is indisputable that explosions do frequently occur in this way, and should the engineer ever find himself in such a predicament he must instantly draw his fires, and *then* add water very sparingly and cautiously until the plates be again cool.

The Water Level must not rise too high.—Danger of another kind is to be apprehended if the water level is allowed to rise too high in the boilers, for the water may then boil over into the steam-pipe, or if the steam space be already somewhat contracted, it may increase the "priming" of the

boilers to a dangerous degree, for nothing is found to tend more to this most troublesome evil, than too limited steam room.

Water Gauges.—To guard against such accidents as these, every boiler is fitted with two different sets of apparatus for indicating the water level, and thereby guiding the engineer in the admission of the feed. These are called the "glass water gauge," and the "water-gauge cocks."

Glass Water Gauge.—The first apparatus consists of a glass tube about 18 inches long, fitting into brass sockets at top and bottom, by which it is connected vertically to the front of the boiler, in such a position that when the boiler is filled to the proper height, the water level may coincide with the centre of the tube. This tube is furnished with three stop-cocks, one at *r*, leading from the top into the boiler *above* the water level, another at *r* from the bottom into the boiler *below* the water level, and the third at *s*, leading from the tube itself into the stokehole through a small pipe. When a communication is opened therefore, at *a a*, between each end of the tube and the boiler, the water being subjected to the same pressure of steam as within the boiler, will stand in the tube at the same height, thus accurately showing the water level. As the tube, if left to itself, is apt to become choked with salt or deposit (especially if the water be dirty), the third cock is provided, and by occasionally opening this the rush of steam and water through it clears away all obstructions. Should there be much ebullition at the part of the boiler where the gauge is fixed, the level of the water in
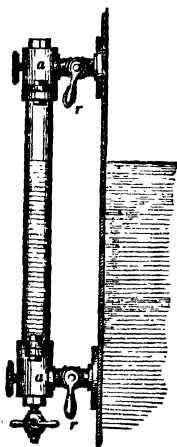
the glass will be very unsteady, and this must be remedied
if possible by leading a small pipe from the top of the tube
into the crown of the boiler, where the steam is dryer, and
at the same time sinking another small pipe from the
bottom of the tube into some place where the water is less
agitated.   It is also of importance that the gauge be fixed
nearly in the centre of the front of the boiler, so as to be
as little affected as possible by the rolling motion of the
vessel.   The last two remarks apply equally to the brass
gauge cocks.

Brass Gauge Cocks.—In case of accident to the glass
water gauge three gauge cocks are fitted besides, one above
the other, at six or eight inches distance between, the mid-
dle one being placed at the average water level of the boiler.
Upon opening these therefore, successively, steam ought to
issue from the upper one, water and steam from the middle
one, and water alone from the bottom cock, and any varia-
tion from this will clearly indicate that the water is either
too high or too low in the boiler.   These cocks should be
frequently opened, as they are also liable to become choked
up with salt or deposit.   As the surface of the water in the
boiler is generally at a higher level than can be conveni-
ently reached from the firing stage, the gauge cocks may
be fixed at any convenient height to the front of the boiler,
and pipes led up inside to the respective heights.

Only One Feed Pump to be worked.—Although each of
the feed pumps is made capable of supplying the full quan-
tity of water required by the boilers, it is nevertheless the
practice in many steam vessels to keep both the pumps
constantly at work, the surplus water which is rejected by
the boilers being returned to the hot well, or thrown over-
board.   This practice, arising from an over-anxiety for an
abundant supply of feed water, is much to be deprecated, as
when the pumps are both kept working, a partial failure in

either of them may escape detection until one meets with an accident, and is rendered useless, when it is probably found that the other pump is also out of order, and is insufficient to do the full duty alone. In such a case recourse must be had to the supplementary pumps, which are always fitted for the purpose of feeding the boilers when the engines are not at work.

Amount of the Brine abstracted.—We have already adverted to the necessity which exists for abstracting from the boiler a certain proportion of the super-salted water, in order to prevent the deposition of scale or salt upon the plates. The amount thus abstracted, or "blown off," as it is technically called, varies with the quantity of the salt and other impurities contained in the water, but this may be stated to be on an average about one-fourth part of the whole feed water admitted.

Proportions of Salt in Sea Water from different Localities.—According to Dr. Ure's experiment, the largest proportion of salt held in solution in the open sea is 38 parts in 1000 (by weight), and the smallest 32. In a specimen brought from the Red Sea, 43 parts were found, the specific gravity of the water being 1·035. The Mediterranean contains about 38 parts, the British Channel, 35·5; the Arctic Ocean, 28·5; the Black Sea about 21; and the Baltic only 6·6.

Analysis of Deep Sea Water.—The same authority states that deep sea water, from the ocean, from whatever locality, holds nearly the same constituents in solution, containing, on an average, in 1000 parts,

> 25 of Chloride of Sodium (common Salt).
> 5·3 Sulphate of Magnesia.
> 3·5 Chloride of Magnesium.
> 0·2 Carbonates of Lime and Magnesia.
> 0·1 Sulphate of Lime.
> ———
> 34·1 ;

besides a little sulphate and muriate of potash, iodide of sodium, and bromide of magnesium.

Blowing-off.—The operation of "Blowing-off" is performed sometimes by hand at regular intervals of half-an-hour or more; but a preferable system has been for some time introduced by which the brine is constantly and uniformly abstracted, in a fixed and determinate proportion to the feed water, by means of a set of "brine-pumps," worked by the engine.

Brine Pumps.—This arrangement, introduced by Messrs. Maudslay and Field, has been further improved by Messrs. Seaward, who connect the valve for the exit of the brine with that for the admission of the feed in such a manner that the two open and shut simultaneously; and, as their areas are proportioned to each other in the proper ratio, no more brine escapes than is demanded by the evaporation of the water. The brine-pipe is further fitted with a stop-cock for its better regulation, or in case it may be wished to shut it off altogether when using fresh water in the boilers.

Kingston's Valve applied as Blow-off Cock.

Lamb's Blow-off Apparatus.—Another mode of blowing-off has been successfully introduced into the boilers of the Peninsular and Oriental Steam Navigation Company, by Mr. Lamb, their resident Engineer. This consists in blowing off partly from the surface, in addition to the usual method from the bottom, by which means many of the particles of insoluble matter, of which the scale is formed, which are ballooned up to the surface on bubbles of steam,

are caught and removed from the boiler before they have an opportunity of aggregating and falling to the bottom. This apparatus, represented in the subjoined cut, may be

INSIDE   OF THE BOILER

a

e

TO THE REFRIGERATOR
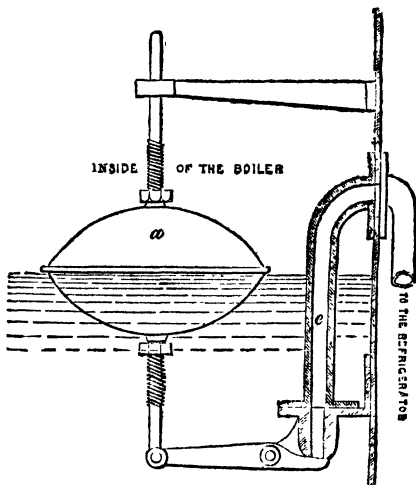
Lamb's Surface Blow-off Apparatus.

made self-acting by means of a float, *a*, which, rising or falling in proportion to the amount of feed water admitted, opens or closes the blow-off pipe, *e*.

The Refrigerator.—The hot brine, ejected by the brine pumps at a temperature of perhaps 218° is generally made to pass through a cylindrical vessel, called the "refrigerator," containing a number of copper tubes through which the feed water, at a temperature of about 100°, circulates on its way from the hot well to the boiler. A considerable portion of the heat of the brine being by this means transferred to the feed is again returned to the boiler, and a proportionate saving in fuel is effected.

Attempts made to Supersede Blowing off.—It has been attempted in various ways to modify the usual manner of

blowing off, with the view of saving a portion of the fuel consumed in bringing the ejected brine to the boiling point.

By Mechanical Means.—These have been either mechanical contrivances for collecting the insoluble particles at the surface of the water, and preventing their solidification at the bottom by agitation with foreign substances introduced for that purpose ; or else

By Chemical Means.—A chemical solvent has been added to the water of the boiler, which it is intended shall act upon its mineral impurities without injuriously affecting the iron plates. The utmost that can be done, however, by even the most successful of these schemes, is to prevent the formation of a hard crystalline scale ; the impurities being now deposited in the shape of a loose powder from a state of mechanical suspension in the water. This powder, then, must still equally be removed by partial blowing off, if we would preserve the water from loss of heat by imperfect conduction, or the plates from danger of being burnt. For, since pure water alone can leave the boiler in the form of steam, it follows that all the foreign constituents must remain behind, however they may be disguised by solution in an acid ; and, unless this mineral solution be removed too, it must of necessity reach a limit at which the bases will be deposited, the point of saturation being deferred in proportion to the solvent power of the acid employed. It is also the case, as we shall presently see, that the greater the degree of saturation the more heat is required to bring the water to the boiling point, and the hotter, therefore, is that portion of brine which must, under any circumstances, be got rid of. There is also danger to be apprehended from the chance of an improper or too powerful solvent being employed, which may act injuriously upon the materials of the boiler.

The Brine Pumps are found to be perfectly efficient at a trifling Expenditure of Fuel (see p. 69).—Hence it arises that the regular and constant blowing off by the brine pumps is in every respect the best that can be adopted, and when this operation is properly performed, the boilers may be kept perfectly free from scale at a comparatively trifling expenditure of fuel—not exceeding 4 or 5 per cent. of the whole fuel burnt. For it must be kept in mind that the brine blown off has had its temperature raised by about 120° only (from 100° to 220°), a considerable part of which is given back to the feed water during its exit through the refrigerators.   Had this water been converted into steam (it is true), and absorbed heat in a latent form, the case would have been very different.

Salinometers.—Since the freedom of the boiler from scale or deposit depends, as we have seen, upon the greater or less degree of saturation of the water, it is an object of much importance to be able to test the saltness of the water with ease and certainty. This may be done in two ways, each of which the engineer should have the means of trying from time to time; namely, by ascertaining the true boiling point of the water at a given pressure, and by finding its specific gravity at a given temperature—the strength of the solution maintaining a fixed and known relation to its boiling point, and specific gravity. The instruments to be used are therefore the *Thermometer* and the *Hydrometer.*

The Thermometer used as a Salinometer.—In using the thermometer for this purpose an instrument must be selected in which the scale is graduated in large degrees, capable of being subdivided into quarters, at least; but the scale need not extend beyond twenty degrees above and below the boiling point of water. Such thermometers are in use for ascertaining the heights of mountains, by observing the temperature at which water boils at the top.   This fact, of itself, plainly de-

* Mr. Dinnen's Paper on Boilers, &c., in Vol. III., new edition, of Tredgold on the Steam Engine.

monstrates the dependence of the boiling point of liquids upon the pressure, and it is therefore necessary always to take the pressure of the atmosphere into account. When we say that water boils at 212°, it is understood to mean when subjected to the *usual* pressure of the atmosphere, indicated by a column of 30 inches of mercury in the weather barometer at the level of the sea.

The following Table shows the boiling point and specific gravity of sea-water (at 60° Fahr.) of different degrees of saturation expressed in parts of salt contained therein, the barometer indicating 30 inches of mercury.

	Saltness.	Boils.	Sp. gr.
Pure Water . . .	0	212°	1·
Common Sea Water .	1/32	213·2°	1·029
	2/32	214·4°	1·058
	3/32	215·5°	1·087
Up to this point no deposit will be formed .	4/32	216·7°	1·116
	5/32	217·9°	1·145
	6/32	219·1°	1·174
	7/32	220·3°	1·203
	8/32	221·5°	1·232
	9/32	222·7°	1·261
	10/32	223·8°	1·290
	11/32	225·0°	1·319
	12/32	226·1°	1·348 saturated solution.

As a general rule, the atmospheric boiling point of the water should never be allowed to exceed 216°. The temperature must be ascertained, by drawing off a small quantity of the brine, and boiling it in a deep copper vessel in the engine room, a correction being made, if necessary, for the state of the barometer.

The following Table shows the height of the boiling point in Fahrenheit's scale at different heights of the barometer.

Barometer. Inches.	Boiling Point.	Barometer. Inches.	Boiling Point.
27	206·96°	28	208·69°
27½	207·84°	28½	209·55°

Barometer. Inches.	Boiling Point.	Barometer. Inches.	Boiling Point.
29	210·38°	30½	212·79°
29½	211·20°	31	213·57°
30	212°		

It will be seen that if we would preserve the water of the boiler at a degree of saturation indicated by $\frac{1}{32}$ of salt; we must blow off one half of the feed water; if at $\frac{1}{24}$, then one third must be blown off; at $\frac{1}{32}$, one fourth, and so one. We have said that $\frac{1}{32}$ is the highest degree of saturation that should be permitted.

The Hydrometer used as a Salinometer.—The hydrometer employed for measuring the density of water, or other liquids, consists of a hollow ball of glass or metal from which there rises a tall stem graduated with degrees, and ballasted so as to swim upright, the graduated stem being more or less immersed in proportion to the density or specific gravity of the liquid. The brine, therefore, increasing uniformly in density according to the salt it contains, may by this means be very conveniently tested ; but as the densities of fluids vary also in proportion to their temperature, care must be taken that the portions of brine experimented upon have the particular temperature for which the scale of the salino-meter has been calculated.

Annexed is a table of specific gravities of sea water at 60° Fahrenheit, in various parts of the globe, as ascertained by Dr. Marcet.

	Spec. gravity.		Spec. gravity.
Arctic Ocean . .	1·02664	Sea of Marmora .	1·01915
Northern Hemisphere	1·02829	Black Sea . . .	1·01418
Equator	1·02777	White Sea . . .	1·01901
Southern Hemisphere	1·02882	Baltic	1·01523
Yellow Sea . . .	1·02291	Ice Sea Waters . .	1·00057
Mediterranean . .	1·02930	Dead Sea	1·21100

The specific gravities corresponding to various degrees of saturation of the sea water have been already given.

Seaward's Salinometer.—To obviate the inconvenience of withdrawing the water from the boiler, in order to test its specific gravity, Messrs. Seaward have invented a salinometer of which the following is the description. It consists of a strong glass tube of about three-quarters inch bore, and fourteen inches long, firmly fixed at each end in a brass frame, to which are attached four cocks, one at each end and two at the side. By the two latter cocks the instrument is attached to the front of the boiler, being fixed at such a height that the water line in the boiler may show its level in the glass tube. Now, upon opening the two cocks which are attached to the boiler, the water will rise up from the bottom of the boiler, by a pipe attached to the lower cock, to the same level as in the boiler. These cocks are then closed and the upper one opened, and two metallic or glass balls are dropt into the tube. The ball first dropt in has been graduated to swim when the water of the boiler is one degree salter and denser than the proper degree of saturation; and the second ball to sink when the water has become one degree more diluted and lighter.

The upper cock is then closed, and the two cocks communicating with the boiler remain open. It is evident, therefore, that when the water in the boiler is at the degree of saturation intended to be maintained, the lighter ball will float at the water level, and the heavier ball remain at the bottom; and further, that any change of density will alter the position of the balls, the lower ball rising as the water becomes more saturated, and the upper one sinking upon the water becoming more diluted. The upper and lower cocks are for the purpose of changing and cleaning the balls when required, the bore of each cock being equal to the diameter of the balls.

Cases in which the Amount of Blow-off may be diminished.—
In the case of a vessel going at half speed, when the full
quantity of steam is not evaporated, the quantity of water
blown off may of course be proportionally diminished, un-
less it be wished to take advantage of this circumstance
and freshen the water in the boiler, while it may be done
without checking the power of the engines. For it is
apparent, that the less water is blown off so much less feed
need be admitted to cool the boiler, and so much the more
steam is generated. This renders it sometimes expedient,
under critical circumstances, to stop the supply of feed
altogether for a while, in order to ensure an abundant
supply of steam to the engines, and it is the duty of an
intelligent engineer to provide for such emergencies, if pos-
sible, by having a good supply of water in the boilers before-
hand. In making "trials of speed" of steamers this is a
usual jockeying trick.

In case the Blow-off Cock sets fast.—In the case of the
blow-off cocks or any of the apparatus on board for with-
drawing the brine from the boilers becoming choked or
getting out of order, water must either be let out of the
boiler by some means into the bilges, or it may sometimes
happen that one of the systems of feed-pipes may be made
available to allow the escape of water into the sea.

Safety Valve, its Area.—The area of the safety valve
should obviously be proportioned to the evaporative power
of the boiler; but is usually made in the proportion of half
a square inch to each horse power of the engines, which in
the generality of cases is ample enough.

Manner of loading.—It is loaded by the manufacturer to
the extent best adapted for the machinery, and this per-
manent load should not be augmented without his express

sanction. The steam power of the vessel being subdivided amongst two or more boilers, each separate boiler must have its own safety valve; and as the different sections communicate with each other by means of stop valves, this constitutes an additional source of safety in case of one being out of order.

Occasional Defects.—A properly constructed safety valve is not liable to get out of order, although, if suffered to lie long in contact with its seat without being raised, it will sometimes stick so fast as to defy all ordinary means of moving it. It should therefore be frequently tested by the engineer, to see that it moves freely.

With this view, and also as a ready means of relieving the pressure of steam without mounting to the top of the boiler, a set of jointed rods lead from the firing stage to the bottom of the valve spindle; being so contrived that the engineer may push the valve up off its seat, but at the same time offering no obstruction to the free rising of the valve by the steam pressure. It more frequently happens that the valve fits its seat so badly as to allow of the escape of steam. This should be guarded against by making the valve itself as solid and stiff as possible, and fixing the seating in a strong cast-iron valve box, which will not spring by the pressure of steam upon it.

In case the Safety Valve sticks fast.—Should it happen that the safety valve of any one boiler becomes inoperative, the surplus steam will still have a free passage through the stop valve into the adjoining boiler, whose valve, it may be presumed, is in good order; but should this means of escape either not exist, or prove inadequate to relieve the pressure, then the blow-through valves of the engines must instantly be opened, so that the steam may find an exit through the valve casing and condenser. The fire doors should at the

same time be thrown open and the ash pit dampers closed, to check the fires as much as possible, before they are quenched with water, and drawn. The first indication of an excessive pressure is usually given by the mercury being blown out of the mercurial steam gauge, where such is fitted, this acting to the best of its capacity as a safety valve also.

Steam Gauge.—The steam gauge usually fitted to marine boilers is a bent iron tube, like a syphon tube reversed, attached vertically to the front of the boiler, one of the orifices opening into the steam chest, and the other open to the external air. The tube is partially filled with mercury, which of course stands at an equal level in both legs of the gauge, so long as there is no pressure of steam in the boiler. But as the pressure upon the surface of the mercury in the two legs becomes unequal, it is forced down the one leg and up the other, until the equilibrium is restored. Hence, a depression of one inch of mercury in the leg communicating with the boiler is followed by a corresponding rise of one inch in the other leg, but the difference of level between the surfaces of the mercury in the two legs is manifestly *two* inches. Thus, a rise of one inch indicates an additional pressure of one pound in the boiler, and not half a pound, as might at first sight be supposed. On the surface of the mercury in the open end of the tube there floats a light rod of wood, and this rising or falling with the level of the mercury indicates the pressure upon a fixed scale of inches or pounds.

Vacuum, or Reverse Valve.—In addition to the safety valve each boiler should be provided with a vacuum valve, (of small dimensions,) to prevent the possibility of the boiler collapsing, when the pressure of steam inside falls below the pressure of the atmosphere. This is frequently ex-

perienced in boilers whose supply of steam is insufficient
for the engines, (as it is apparent that the latter may con-
tinue to work with a negative pressure in the boilers, pro-
vided there be a good vacuum in the condensers,) and it
may happen to any boiler, by a sea breaking over the decks
and suddenly condensing the steam. The action of this
valve is sufficiently obvious, as it is only a reversed safety
valve, slightly loaded; and the only attention it requires is
to try it occasionally, and see that the spindle moves
freely.

Supply of Air to the Fires.—The amount of air that is
required to keep up combustion in steam-engine boilers is
much greater than is generally supposed. For 1lb. of coal,
of average quality, 150 cubic feet of air are required for
exact chemical combination alone, and as this can never be
perfect, from a variety of disturbing causes, a supply of
about 300 cubic feet is found in practice to be beneficial.
If 8 lbs. of coal be consumed for one-horse power per hour,
an engine of 100-horse power will require a supply of 2400
cubic feet of air per hour, or 40 cubic feet per minute.
Every facility therefore, by means of hatchways, wind pipes
and windsails, should be provided and carefully attended to
for this large supply.

Staying Boilers.—It is usual to stay the flat portions of
tubular boilers with rods of about one inch square, or one
inch diameter, from sixteen to eighteen inches apart each
way, and flue boilers (which are not so well adapted to bear
a high pressure of steam as tubular boilers) not quite so
heavily. It must be borne in mind, that it is highly inju-
rious to stay weak plates at long distances, however strong
the stay rod may be, as the alternate distension and con-
traction of the plate between the stays causes it to *buckle*
round each stay every time that the pressure of steam is
added or removed.

This action, in time, wears a furrow round the fastening of the stay, by throwing off the scale from the surface of the plate, and opening the fibre of the iron, the circular piece of plate to which the stay rod is attached remaining at the same time quite sound.
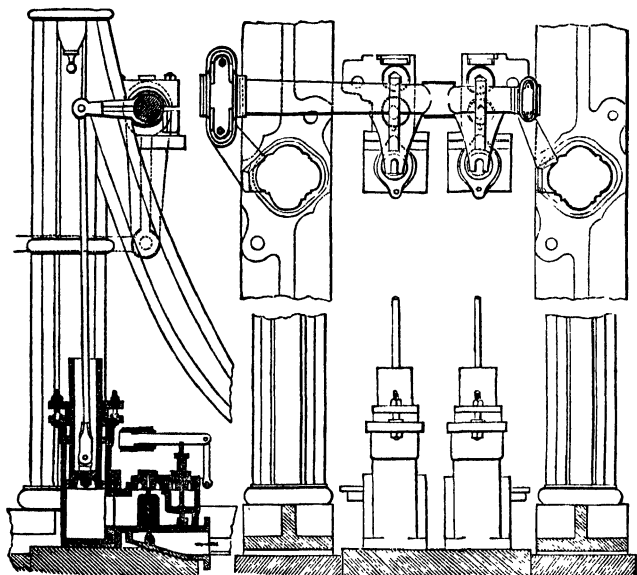
Brine-pumps, as fitted on board H. M. S. Medea, 220 *Horse-power,* MAUDSLAY, SON & FIELD.

CHAPTER VI.

MANAGEMENT OF THE ENGINES.

The Bearings require Attention.—In the management of the engines, the points to be most attended to are the following. The bearings of all the working parts must be constantly attended to, and regularly lubricated with oil or melted tallow. If the brasses are screwed or driven up too tight, the bearing will heat; if, on the other hand, they be too slack, a jar is produced at every revolution, destructive, if not positively dangerous, to the engine. As the brasses wear by the friction, therefore, they must be driven up to a moderate tightness by the cutters. As these are apt to work loose unless properly secured, it is now the practice to make the main cutters with a screw and nut at the point to prevent this. When any of the main bearings heat, they must be slackened and bathed with melted tallow and sulphur; or, if the heating has proceeded to a great extent, a stream of cold water from the hose of the hand pump should be directed upon them. The bearings most liable to heat are those of the crank pin and crank shaft; but care must be taken whilst cooling the latter, that the cold water does not crack the cast-iron plummer blocks. To avoid this, it must be thrown on very cautiously at first. The larger the surface of the bearing is in proportion to the friction to which it is subjected, the more easily it is kept cool and in good order, and the less oil is consumed in lubricating it.

To test the Tightness of the Engine before starting.—The following method of ascertaining the tightness of the dif-

ferent parts of the engine subjected to steam pressure is recommended to be used in every case after the engine has been fresh packed, or has been out of use for some time. After getting up steam, and while the vessel is still at her moorings, blow through, and then, after obtaining a partial vacuum in the condenser by the admission of a little water, watch the barometer to see how long the engine holds her vacuum. If the condenser gradually becomes hot, while the cylinder ports remain closed, we know that steam is passing the packing of the valves; or, if the valves are made without packing, the steam must be passing their faces. The tightness of the faces of D and other valves may be tested by shutting both ports to steam, and opening the cocks for taking indicator diagrams above and below the piston, the grease cocks, or any others communicating with the cylinder. If no steam passes through these cocks when the throttle valve is full open, the valve faces are then, of course, tight. The tightness of the piston may be proved in the same way, by admitting steam above or below it, and opening the indicator cock on the opposite side. The injection cock may be slightly opened for an instant, to withdraw any steam that may have collected on the opposite side of the piston, so that the passage of any steam may be the more readily perceived. The tightness of most parts of the engine may be tested in this way without moving it beyond half a stroke.

To discover a Leakage of Air into the Engines.—The engineer must watch strictly for leaks of air into the engines, by which the vacuum may be vitiated; as well as for every leakage of steam into the engine room. If the engine draws air on the " steam side," this may be discovered before it is set to work during the process of blowing through, when a jet of steam will be seen to escape; but if the leakage be suspected after the engines are at work, the engineer must endeavour to discover it, either by the

whistling sound of the rush of air, or, taking a lighted candle in his hand, pass the flame along all the joints till he finds it sucked in by the vacuum. Leakage in a horizontal joint may be readily discovered by laying water along it. An air leak may also be discovered by closing the snifting valve and the discharge valve at the ship's side, and filling the engines with steam. When the leak is found out, it must be stopped temporarily by driving in spun-yarn, or gasket steeped in red lead and oil, or other means.

A Cure for Leaky Condensers.—If the leakage be into the condenser, it is sometimes convenient to allow water to be injected through the orifice, by which means little harm is done. In several cases where, during a long voyage, the bottom of the condenser has become leaky by corrosion, (often induced by galvanic action with the copper bolts of the ship's bottom, as well as the brass foot valve, &c.), a water-tight tank has been constructed at sea between the side keelsons. By this means the condenser and air pump are placed in a kind of well constantly replenished with cold water from the sea, which, forcing its way through the leaks by the pressure of the atmosphere, shares with the proper injection water the duty of condensing the steam—the injection-cock orifice being partially closed in proportion to the extent of leakage through the bottom.

Injection to be diminished when the Ship labours much.—When the vessel is labouring in a heavy sea, it is recommended that the supply of injection water should be diminished; for in such a case, where the speed of the engines is subject to great and constant fluctuations, depending upon the greater or less submersion of the wheels or screw-propeller, the condenser is liable to become choked with water, thereby causing the engines to stop. The effect of working the engines with a stinted supply of condensing water is, of course, that the condensers will become hot,

and the vacuum will be diminished; but this is a minor evil in comparison with endangering the machinery by subjecting it to too severe a strain.

When the Injection Cock leaks.—Care must be taken, when the engines make a temporary stoppage, that the injection cock, or air pump, does not leak, and allow the condenser to fill with water, which causes much trouble and delay in starting the engines again ; so, should this be apprehended, the sea cock must also be closed at the same time with the injection cock. It is also advisable to blow through at short intervals, to keep the condenser free of water, and admit a little injection water to keep up a vacuum, so as to be able to start upon the shortest notice.

Advantage to be derived from the Bilge Injection Pipes.—It is calculated that an engine requires about one ton of condensing water per horse power per hour ; and it is apparent that the abstraction of this large body of water from *the bilge,* in case of the vessel springing a leak, constitutes a very valuable property in the machinery, and one which has ere now saved many steamers from foundering. It is essential, however, that the orifice of the bilge injection pipe be most carefully guarded against the entrance of chips of wood or oakum, which, by getting into the condenser, may gag the valves of the air pump, &c., and stop the engines. The bilge injection pipe should have no rose upon the orifice opening into the condenser, as such is liable to become choked ; but the water should be spread by striking against a flat surface, or otherwise.

Injecting through the Snifting Valves.—Where no bilge-injection has been fitted, a considerable body of water may be admitted into the condenser through the snifting valves, in case of a leak in the vessel. Should there be no means provided for lifting them, by stopping the injection and then

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blowing through, they will rise from the pressure of steam
in the condenser, when they must be prevented from closing
again; or, should they be inaccessible, the cover of the foot
valve, or the man-hole door of the condenser (if the water
rise above it), should be slackened to allow the water to enter.

To make Steam-tight Joints.—The usual mode of making
air or steam-tight joints between two surfaces, is to inter-
pose hemp packing, or *gasket*, soaked in red or white lead
and linseed oil, the joint being made when the steam is
down, and screwed well up when the engine gets hot.   If
the joints have been accurately chipped and filed, then
sheet lead, thick paper, wire gauze, &c., are usually em-
ployed, well smeared on both sides with red lead; or, if the
joint has been planed and made perfectly true, then a little
thin red lead is all that is necessary between the surfaces
to make them steam-tight.   Cement joints are now almost
wholly discarded from marine engines, and should never be
made where there is a chance of the surfaces requiring to
be again separated.

How to act in case of Accident to the Engines.—The various
accidents to which steam engines are liable are so nume-
rous, that any directions to meet particular cases are likely
to be fruitless.   Any engineer who expects a list of re-
medies for every evil that may occur, whether it be to
smother a leak in a pipe with a stoker's fearnought dress
and lap it with spun yarn, or to fish an intermediate shaft,
must be disappointed.   He must rely on his own judgment
when a flaw has shown itself, or a fracture taken place, and
consider carefully the direction of the strain, and take steps
to provide for this; and also to guard against further injury
if the weak part should give way.   Wood and wrought iron
are the materials with which all repairs at sea must be
effected, and care should therefore be taken to have efficient
means for adapting them to use when required.   No hesita-

tion must be felt regarding the unseemliness of a massive
piece of timber to strengthen the frame of an engine; and
the principle of the expansion of wrought-iron straps or
bolts by heat, so as to effectually tighten them, must not
be forgotten.   A clear perception of the principles of truss-
ing, of leverage, and of the resolution of forces, is most
important; and it is by such knowledge that a good and
thorough mechanic will show his superiority in difficulties
over the mere engine driver.

Test Cocks.—Small cocks should always be fitted to the
top and bottom of the cylinders for clearing them of any
water.   They are generally constructed with a ball or reverse
valve at their mouth, so as to allow of their being kept open
without the entrance of air, when there is a vacuum on the
side of the piston with which they communicate, which
would injure the action of the engines.

Grease Cocks.—The grease cocks, for lubricating the pis-
tons, must, of course, be opened only during the ascent of
the piston, when the vacuum will suck in the melted tallow;
otherwise it would be forced out by the pressure of steam.
Those grease cocks on the slides, where there is a constant
pressure of steam opposed to them, may generally be made
to act by one man suddenly closing the throttle valve of the
engine which it is wished to lubricate, while another opens
the grease cock at the same instant; the throttle valve be-
ing reopened, and the whole operation performed as quickly
as possible, so as not to stop the speed of the engine more
than is absolutely necessary.

Turning the Engines by Hand.—One of the principal
duties of the engineer, whilst in harbour, is regularly to
move the engines round by hand through a portion of a
revolution, in order to change the relative positions of all
the touching surfaces.   It is found, that when the iron

piston rod, for example, remains for even a day or two in contact with the brass gland, a slight, though perceptible, furrow is eaten in the rod by the oxidation of the metal, induced by the galvanic action which results from the contact of the brass and the iron.

Galvanic Action.—The same destructive effect is produced in all the other parts of the machinery where copper or brass remains in contact with iron; but this proceeds more rapidly when sea water or moisture of any kind is present, and according as the temperature is greater. In the case of paddle engines, the wheels present a convenient leverage for moving the engines by hand; but, with screw steamers, much difficulty is sometimes experienced in effecting this, and it has generally been found requisite to fit some mechanical contrivance for the purpose.

Essential to have square Regulating Lines marked on Marine Engines.—As spirit levels and plumb rules cannot be used on board ship, every thing must be done by straight edges and squares. Every engineer, therefore, on taking charge of a pair of engines, on their coming out of the hands of the manufacturing engineers, should see that centre lines are scored well into the framing, at a sufficient number of parts, to facilitate any future examinations as to whether the engines have altered their position in any way, as well as to facilitate his putting the engines very correctly, when so required, at half stroke, and many other operations. Athwartship lines should certainly be scored in on the cylinder flanges, across the centres of the two cylinders, and on the base plates in beam engines, under the centre of the crank shafts. A fore and aft line in the centre line of each engine should also be scored in along as much of the base plate as possible. It is also usual in well-constructed engines to have four horizontal points in an athwartship line on the framing, dressed off so that four points in a true line

on the face of a straight edge may lie upon the whole of them, and thus prove at any time whether the engines have fallen in towards each other, or fallen away towards the sides of the vessel.

To adjust the Paddle Shaft.—If the eye of the crank of the paddle shaft be perceived to bear hard upon the connecting rod brasses at one part of its revolution, and to separate from them at another part, the engineer may know that the centre of the paddle shaft is out of line with the centre of the intermediate shaft. To rectify this defect, place the engines on the top stroke and measure the distance accurately between the faces of the two cranks at the side of the crank pin, then put the engines on the bottom stroke and measure the distance at the same place. If the distance at the bottom be less, the outer end of the paddle shaft must be too low and require to be raised. Subtract the one distance from the other, and take one half of the remainder, and say, as the length of the crank is to the length of the paddle shaft, from the face of the crank to the centre of the outer bearing, so is this half-remainder to the amount that the outer bearing requires to be raised. Other examinations as to whether the crank and paddle shafts are true to each other, in other respects, can be made in a similar manner.

To replace the Levers on the Valve Shaft if carried away.— The length of the valve lever is the distance from the centre of the valve shaft to the centre line of the valve spindle, with the addition of half of the versed sine of the arc through which it vibrates. The length of the gab lever must bear such proportion to the length of the valve lever that the traverse given to it by the excentric shall produce the requisite amount of motion in the valves. The throw of the excentric, multiplied by the length of the valve lever,

must always be equal to the travel of the valves, multiplied
by the length of the gab lever.

To fix the Gab Lever on the Valve Shaft.—The valve lever
or levers being fixed upon the shaft, it must then be put in
place on the engine, and turned round till the centre line of
the valve lever is at right angles with the centre line of the
valve spindle. The shaft being fixed in this position, the
gab lever is now to be put upon it in such a position that
its centre line will be at right angles to a line stretched from
the centre of the intermediate shaft to the centre of the gab
pin on the end of the lever.

To find the Length of the Excentric Rod if carried away.—
Place the valve shafts with the valve lever at right angles
to the centre line of the valve spindle, and then measure
the distance from the centre of the intermediate shaft to
the centre of the pin of the gab lever, and this is the length
from the centre of the ring of the excentric rod to the centre
of the gab at the other end of it.

*To replace the Stops on the Intermediate Shaft for driving
the Excentric.*—The excentric rod being out of gear, place
the engines at top stroke, and place the valves in the posi-
tion in which they ought then to be, that is, with the requi-
site amount of lead open to the steam. Now move the ex-
centric, which is loose upon the shaft, in the direction in
which it would revolve, if the engine was going a-head, until
the excentric rod drops into gear; the position of the stop
for going a-head may now be marked upon the shaft, to
meet the face of the stop upon the excentric block. The
gab of the excentric rod being taken out of gear again
without the engines or the valves having been moved, the
excentric block is now to be turned back, in the direction in
which it would be revolving if the engines were going

astern, and the excentric rod will again drop into gear as it comes round, and this, in the same manner, gives the position of the stop upon the shaft for going astern.

Essential to know the Position of the Steam Valves from External Marks.—The valve rod being generally so fitted that its length can be varied with facility for the sake of adjustment, it is essential that there should be a ready means of testing the correctness of its length at any time. This can only be done by a mark upon the rod, above the gland of the valve bonnet or cover, this mark being made when the valve is at its mid-stroke, at a certain known distance above a mark on the flange of the valve casing or some other fixed portion of the engine framing. These marks are generally made by a centre punch well struck in, and a record of the required distance is made by another mark on the valve casing or framing at the required distance. If the valve be placed at mid-stroke, the valve lever may now be connected with it, the only care requisite being that the centre line of the valve lever shall be at right angles to the centre line of the valve rod, when the valve is in this position. If any doubt is entertained of the correctness with which the parts in question have been originally constructed, due examination of the steam ports and valve faces must be made, and the length of the valve rod and the marks tested. It is sometimes convenient to have a mark made on the framing, or some other ready means, by which it may be known when the valve lever is at right angles as stated.

CHAPTER VII.

USE OF THE EXPANSION VALVE, INDICATOR, AND DYNAMOMETER.

Principle of Expansion.—If steam be supplied to the cylinder of an engine at a uniform density during the whole length of the stroke, the resistance being at the same time uniform, the piston will move with a continually increasing velocity, until its momentum is suddenly and entirely destroyed upon commencing the next change of direction; thus causing a destructive jar to the parts of the machine. To obviate this, therefore, the steam is "cut off" before the end of the stroke, which is then completed under a diminished pressure. By this means the piston comes gently to rest at the top and bottom of the cylinder; but this is neither the only nor the chief advantage which results from cutting off the steam, since it is found that *the force actually exerted upon the piston by the isolated steam, during its expansion into the increased volume as the piston descends in the cylinder, is considerably greater than that due to the simple pressure of the same weight of steam acting at a uniform density.*

To render this intelligible, let us suppose a cylinder of one square foot area, and 20 inches long, to which steam at about the atmospheric pressure has been supplied during half the stroke. We may then suppose the pressure on the piston to equal one ton at the moment the steam valve is closed, the space under the piston being open to the condenser. As the piston descends farther, the steam above it will become diffused through an increased volume, and will consequently acquire a diminished pressure. We may assume that this diminution of pressure follows the law of elastic fluids in general, and that it decreases in the same propor-

tion as the volume of steam is augmented. While the
piston, therefore, moves downwards from the centre of the
cylinder (at 10 inches), it will be urged by a continually
decreasing force, until it arrives, we will suppose, at 15
inches, when the space occupied by the steam will be in-
creased in the proportion of two to three. The pressure
on the piston will also be diminished in the inverse ratio
of three to two; and will now equal two thirds of a ton at
15 inches from the top. In like manner, when the piston
arrives at the bottom, the space occupied by the steam will
be double that which it occupied at half-stroke, and the
pressure will be diminished one half—being now, conse-
quently, half a ton. By calculating in this way the pres-
sure on the piston at the termination of each inch of the
space through which the steam has been expanding, we find
the pressure at the 11th inch expressed by $\frac{10}{11}$ of a ton; at
the 12th inch $\frac{10}{12}$ of a ton; and so on to the 20th inch, where
the pressure is $\frac{10}{20}$, or half a ton.

Now, if the pressure of the steam through each of these
ten divisions be supposed to continue uniform, and, instead
of diminishing gradually, to suffer a sudden change in
passing from one division to the other, the mechanical
effect will be obtained simply by taking the average of the
ten pressures. Thus, it has been supposed, in the present
case, that the pressure on the piston at the beginning of
the first division is 2240 lbs.; and to obtain the pressures
corresponding to each of the other divisions, it will only be
necessary to multiply 2240 by 10, and divide successively
by 11, 12, 13, &c. The pressures in pounds, at each inch
below the half-stroke, will then be as follow, viz.:—

At end of 1st inch 2036·3 lbs.	At end of 6th inch 1400·0 lbs.
2nd „ 1866 6 „	7th „ 1317·6 „
3rd „ 1723·1 „	8th „ 1244·4 „
4th „ 1600·0 „	9th „ 1179·0 „
5th „ 1493·3 „	10th „ 1120·0 „

Benefit of Expansion.—If the mean be now taken by
adding these numbers together and dividing by 10, it will

be found to be 1498 lbs. as the mean pressure of steam during the expanding half of the stroke, which is nearly three fourths of the mechanical effect produced by the full steam during the first half of the stroke. In this calculation we have assumed, for the sake of simplicity, that the pressure is uniform throughout each of the ten divisions: which of course it is not, owing to the expansive action which takes place within each division; so, the more accurate calculation (which is a complicated one) makes the average pressure for the expanding half of the stroke equal to about 1545 lbs. It is evident that this principle is equally applicable at whatever part of the stroke the steam be cut off, a higher mechanical effect being obtained from a given weight of steam in proportion to the extent to which the expansive working is carried, and in proportion to the original density of the steam. Thus, in the Cornish engines, it is found to be most advantageous to use steam of from 30 to 40 lbs. pressure, and to cut it off in the cylinder at one sixth, or even one eighth part of the stroke, the remaining seven eighths being performed wholly by expansion. The limit to this principle is imposed, in practice, by the increased size required for the cylinder, and the inequality in the speed of the piston during the stroke.

It is found, by calculation, that if the steam be cut off at half-stroke its mechanical effect is multiplied by 1·7 nearly; if at one third, by 2·1; if at one fourth, by 2·4 nearly; &c.

The following rule will be found useful for calculating approximately the mean pressure of steam on the piston during the stroke, while working expansively.

Rule.—Divide the length of stroke by the distance the piston moves before the steam is cut off, and the quotient will express the relative expansion it undergoes. Take from the annexed table the multiplier corresponding to this number, and multiply it by the full pressure of steam per square inch on entering the cylinder. The product will be the mean pressure per square inch, nearly.

TABLE OF MULTIPLIERS.

Relative Expansion.	Multiplier.	Relative Expansion.	Multiplier.	Relative Expansion.	Multiplier.	Relative Expansion.	Multiplier.	Relative Expansion.	Multiplier.
1	1·0000	2	·8466	3	·6995	4	·5966		
1·1	·9957	2·1	·8295	3·1	·6875	4·1	·5880		
1·2	·9853	2·2	·8129	3·2	·6760	4·2	·5798		
1·3	·9710	2·3	·7969	3·3	·6648	4·3	·5718		
1·4	·9546	2·4	·7814	3·4	·6540	4·4	·5640		
1·5	·9370	2·5	·7665	3·5	·6436	4·5	·5564		
1·6	·9188	2·6	·7521	3·6	·6336	4·6	·5491		
1·7	·9001	2·7	·7382	3·7	·6239	4·7	·5420		
1·8	·8821	2·8	·7249	3·8	·6145	4·8	·5351		
1·9	·8641	2·9	·7120	3·9	·6054	4·9	·5284		
2·	·8466	3	·6995	4	·5966	5	·5219		

The Indicator.—In practice, a much simpler, and more accurate method is employed for finding the power exerted within the cylinder of a steam engine, namely, by the use of the indicator.

The Indicator, its Construction and Principles.—This little instrument, which ought to be familiar to every one intrusted with the care of machinery, consists of a small cylinder placed in connection with the cylinder of the engine, either above or below the piston. This cylinder is open at top, and is fitted with a piston which presses against a spiral spring. The cock which connects the indicator with the cylinder of the engine being opened, steam is admitted under the piston of the indicator during the one stroke, and vacuum during the other, precisely as in the large cylinders; thus causing the little piston to *push* or *pull* alternately against the spiral spring. If the pressure were uniform throughout the stroke, the indicator piston would start at once from the top to the bottom, and *vice versâ*, remaining stationary until acted upon by the opposite pressure. In such a case, the pressure exerted

would be simply proportional to the flexure of the spiral
spring, and might be measured accordingly; but, as we
have seen that the pressure on the piston is continually
varying during each stroke, it follows that the pressure on
the spring must also be a variable pressure corresponding
to the movements of the indicator piston, either up or
down. Now, if a pencil be fixed to the piston rod of the
instrument, it will register the fluctuations of pressure
upon a piece of paper held close to it; but, unless some
provision be made for allowing the pencil a clear space on
the paper at each successive instant of time, it will only
move up and down in the same vertical line, and the mark-
ings due to fluctuation of pressure will be undistinguish-
able. To obviate this, the paper receives a circular motion
in one direction during the down stroke of the piston, and
a reversed motion during the return stroke, the result
being that, as the pencil moves vertically up and down, a
continuous curved line is traced upon the paper. By this
line an oblong space is enclosed, called indifferently the
Indicator Figure. Card, or Diagram, the vertical ordinates
of which will then represent the effective pressure at the
corresponding portions of the stroke, and whose area will
represent the whole pressure exerted during the stroke.

Before the instrument is connected with the steam
cylinder, the roller, with the paper attached, is set in mo-
tion, and the pencil then describes a straight line (called
the *neutral* or *atmospheric line*), which represents the pres-
sure of the atmosphere, the space enclosed above this line
being the measure of the pressure above the atmospheric
pressure, and below this line measuring the pressure below
the atmosphere. If the junction between the indicator
and the cylinder be now formed while steam is entering
the cylinder, the indicator piston will evidently rise; and
if steam be escaping from the cylinder it will fall,—the ex-
tent of the rise and fall depending upon the strength of
the spiral spring. The alternating circular motion of the
roller is given by connecting it with any reciprocating part

of the engine, by means of a cord attached to a pully fixed on the same axis with the paper-roller. This cord gives motion in one direction only, the return movement being communicated by a coiled spring attached to the instrument.

Scale.—The scale of the indicator in general use is divided into tenths of an inch, each division representing one pound pressure on the square inch of the piston. When the instrument is not in use, the index stands at 0; but when communication is opened with the engine the pressure of steam is exhibited above zero, and the vacuum below.

How to use the Indicator.*—To use the indicator, its cock must be made to fit the grease cock of the cylinder cover, or any other fitted for the purpose in a convenient place at the top or bottom of the cylinder, or both. The line may then be attached to the radius bar of the parallel motion at six or seven inches from the joint, and connected by a running loop to the hook on the small line at the bottom of the instrument. By means of the running loop the line must be lengthened or shortened, till it is of the proper length to allow the roller to traverse as far it can without coming into contact with the stop or the springs. This is easily effected by shifting the line upon the radius bar; and when the proper length has been found, the running loop may be fixed permanently, to be ready for future trials. Having stretched the paper upon the roller, and fastened it by means of the clasp, a sharp-pointed pencil is put into the socket, and allowed to press lightly (by means of a little spring) upon the surface of the paper. When all is ready, the instrument is first made to work a few strokes with the cock shut, in order to form the "atmospheric line," after which, the cock is opened when the piston is at the top of the stroke, and the registration proceeds as described.

* See p. 288, Marine Engines, new edition of Tredgold on the Steam Engine.

How to make the Calculation.—When the figure is made, the pressure of the steam is calculated by drawing any number of lines across it at right angles to the atmospheric line, and taking their mean length as measured on the scale attached to the instrument. In practice, it is usual to divide the figure into ten spaces by equi-distant ordinates, measure each of those spaces in the middle, find their sum, and cut off a decimal figure for the division by 10, the result being the average force of the steam in pounds on the square inch. To find the power that the engine is actually exerting, therefore, we have only to take the area of the cylinder in square inches, multiply by the average pressure as found above, and again by the number of feet which the piston travels in a minute, when the product divided by 33,000 is the indicator or gross horse power of the engine.

To find the Nominal Horse Power of an Engine.—The horse power of an engine, as found in this way (which is the most accurate method with which engineers are acquainted), must not be confounded with what is called the *Nominal* or *Commercial* Horse Power. The latter is obtained by the following formula, viz. :—

$$\frac{\text{Area of cylinder} \times \text{effective pressure} \times \text{speed of piston}}{} = \text{H. P.}$$

The area of the cylinder must be taken in square inches, the " effective pressure"•assumed at 7 or $7\frac{1}{2}$ lbs. per square inch of piston, and the speed is to be reckoned in the number of feet through which the piston travels, or *is expected* to travel, per minute. The divisor is 33,000 lbs. as before; this weight when raised one foot high in a minute being the standard of a commercial horse's power adopted by James Watt, and subsequently retained for convenience sake. In tendering for engines for the Government service, the " effective pressure " is assumed at seven pounds

only, and the speed of the piston is presumed to vary with the length of stroke, according to the following table :—

Stroke.		Speed of piston.	Stroke.		Speed of piston.
Ft.	In.	Ft. per min.	Ft.	Jn.	Ft. per min.
4	0	196	6	6	226
4	6	204	7	0	231
5	0	210	7	6	236
5	6	216	8	0	240
6	0	228			

We may observe, that on the Thames the effective pressure is usually taken at 7 lbs., and on the Clyde at 7½ lbs., which tends to make the nominal horse power of the Glasgow and Greenock engines of somewhat less commercial value than those built in London.

Distinction between Nominal and Real Horses' Power.— It will be seen that the horse power thus calculated is irrespective either of the actual pressure of the steam used, of the perfection of the vacuum in the condenser, or the amount of friction arising from good or bad workmanship; hence this rule, however useful in comparing the size of different engines, is a very imperfect guide to their actual power. We have thus two distinct values of horse power, which no one conversant with the steam engine ever confounds; the one, fixed and nominal, by which engines are bought and sold; the other fluctuating, though real, as shown by the indicator. To discover, however, *the effective power*, or the power actually available for the purpose for which the engine is used, a deduction would require to be made for friction of the moving parts and for the power required to work the pumps and valves, but as this would be nearly alike for well-constructed engines of equal power, and no ready means exists of testing it, the total or indicator horse power is taken as the measure of the power in all ordinary cases.

Use of the Indicator for showing the Internal State of the Engine.—The indicator, moreover, tells us not merely the power exerted by the engine, but the nature of the faults (where those occur) by which the power is impaired. Thus, one form of the indicator figure, or "diagram," may show that the cylinder ports are too small, or that there is condensation in the steam pipes; another, that the engine is drawing air; or a third may show that the valves are improperly set. Let us take, for example, the accompanying imaginary diagram —
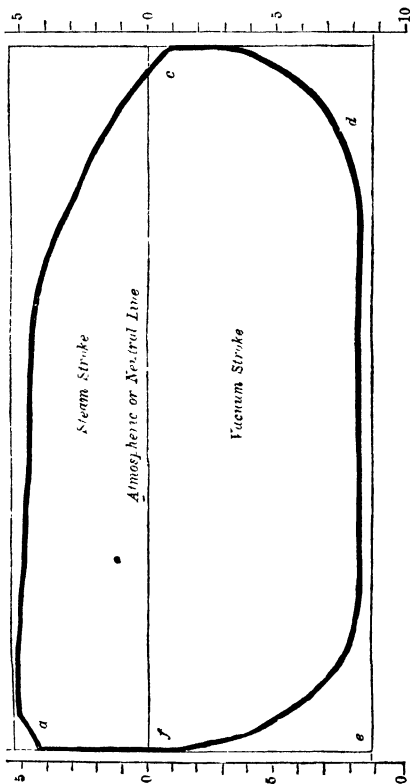
When the pencil is at the point marked *a*, the piston is at the commencement of its stroke, and the paper being made to move, the line is traced from *a* to *b* and thence to *c*, at which point the stroke in one direction is finished. At the point *b* the valve is being shut to prevent the further admission of steam; and while the line from *b* to *c* is being traced the steam is expanding, and its pressure consequently decreasing as indicated by the falling of the line. The line from *b* to *c*, instead of being convex, should be concave, as in the double diagrams, page 93; and it is thus discovered that the slide is in bad order from steam being admitted after it is shut. If the engine had been working expansively, and the valve been shut before the pencil had reached the point *b*, the steam would have begun to expand at that point, and the line have begun to fall so as to indicate the degree of expansion in the most precise and definite manner. On the pencil approaching the point *c*, the valve is opened to the condenser, the steam escapes, is condensed, the pressure falls, and the pencil descends towards *d*. The action as here indicated is not very good, as the corner should be more nearly square. The piston now commences its return stroke, and the paper is made to move simultaneously also in the opposite direction, and the line towards *e* is traced. It is here seen to rise again towards the atmospheric line, thus indicating that there is some pressure increasing in the cylinder. From the form of the diagram at this point, it is gathered that the vapour remaining inclosed in the cylinder, after the communication with the condenser has been closed, is compressed, and exerts a pressure against the piston to an injurious extent. As the pencil approaches *f*, the valve is opened for the admission of steam, and the pencil rises towards *a*, ready again to trace another diagram of what takes place on one side of the piston during another stroke.

To compare the Efficiency of different Engines by means of the Indicator.—The following method has been successfully

adopted in comparing the relative economy of performance of different steam engines by means of their Indicator Diagrams.

First, calculate the gross indicator horse power of the engine in the usual way, as already described. Then draw on the diagram a pure vacuum line at 15 lbs. below the atmospheric line; and if, as is generally the case, the eduction begins before the end of the stroke, continue upon the diagram the sloping line of the expansion as if it had been uniform to the end of the stroke, as represented, for instance, at *a, a,* Fig. p. 93.* The pressure of steam thus found at the end of the stroke (being the pressure above a pure vacuum) may be called the "Terminal" pressure.

Now find the cubic contents of the cylinder in feet, by multiplying the area into the length of stroke, and adding the "clearance" of piston at top or bottom, and the steam space in one port between the valve-face and the inside of the cylinder. The contents of the cylinder *at the terminal pressure* must now be reduced into the corresponding number of cubic feet of steam *at the atmospheric pressure.* This is easily done by reference to the table of relative volumes of steam pressure given at page 208. If our cylinder, for example, have 185 feet of cubic contents, and the terminal pressure be 8 lbs. above a vacuum, we must employ the following proportion :—

2983 (vol. corresponding to 8 lbs. pressure) : 185 :: 1669 (vol. corresponding to steam at atmospheric pressure) : 103·5 cub. ft. of steam at atmospheric pressure.

* There is in general no difficulty in continuing this line with certainty, but if there be a doubt as to where the eduction begins, take the diagram at any definite point, say at nine tenths of the stroke (after the valve has been certainly closed to all further admission of steam), and complete the figure by calculating, from the pressure of steam at this point, what would be its pressure if expanded into the increased space at the end of the stroke. This will be readily done by consulting the table of relative volumes of steam to pressure, given in the end of the book.

This amount being multiplied by the number of cylinders filled with steam in one minute, and the product being divided by the gross indicator horse power as previously calculated from the diagram, we thus obtain the number of cubic feet of atmospheric steam required by this engine to produce one horse power. It must not be forgotten that the cylinder of each engine is filled twice with steam for each revolution of the crank shaft.

The same simple process being gone through with the other engines under trial, or with the same engine under different circumstances of speed or expansion, affords a tolerably accurate method of comparing, in a general way, their relative efficiency.

Example of Calculation.—The following is the calculation made from the diagrams of *Penelope*, 650 nominal horse power (Figs. p. 93.).

The Diameter of cylinder is $91\frac{6}{8}$ in.

       Area of   ditto   6593·5 sq. in. = 45·8 sq. ft.

       Length of stroke 6 ft. 8 in., or with clearance 6·75 ft.

       No. of strokes per minute, 14.

       Gross indicator horse power for both engines, as per diagrams, 1333 H. P.

Then, 45·8 area of cyl. in feet × 6·75 ft. length of stroke = 309·150 cub. ft. + 3·85 cub. ft. for steam space of port = 313 cub. ft. of steam required to fill the cylinder once : or 313 × 14 = 4382 cub. ft. of steam used above or below each piston in each cylinder during one minute.

Taking now from the diagrams the four terminal pres-
sures corresponding to the top and bottom of each cylinder,
we have,—

    4382 cub. ft. at 12 lbs. press. = 3567 cub. ft. at atmospheric press.
      Do.   ,,   13 ,,   ,, = 3841 do.   ,,   ,,
      Do.   ,,   15 ,,   ,. = 4382 do.   ,,   ,,
      Do.   ,,   15 ,,   ,, = 4382 do.   ,,   ,,
                              ─────
                              16172 cubic feet of steam at atmo-
spheric pressure used per minute by the two engines—or 16172 ÷ 1333
gross indicator horse power = 12·13 cubic feet of atmospheric steam per
horse power per minute.

*Difference of Effect between throttling the Steam and cut-
ting it off by the Expansion Valve.*—An experiment made in
this manner to determine the difference of effect between
expanding the steam in the cylinder by a proper system of
expansion, and merely shutting it off by the throttle valve
when it is wished to work the engines to a low power, gave
the following result :—An engine of the nominal power of
400 horses was selected, and was first worked on the lowest
grade of expansion, the steam in the boiler having its full
pressure of 8 lbs.   Under these circumstances, it was found
that 10·87 cubic feet of steam at atmospheric pressure were
consumed per horse power per minute.

The expansion valves were then thrown out of gear, and
the engines reduced by the throttle valve to exactly the
same number of revolutions.   It was now found that al-
though the gross horse power, as shown by the indicator,
was almost identical in both cases; in the latter case the
power exerted was obtained at an expenditure of 14·72
cubic feet of atmospheric steam per minute, in place of
10·87 cubic feet, as formerly; 3·85 cubic feet of steam per
indicated horse power per minute being thus saved by the
principle of expansion.

It is apparent that this calculation will not give us the
cause of any loss of effect by the steam escaping, or being

INDICATOR DIAGRAM FROM PENELOPE'S ENGINES.

FULL STEAM, 14 REVOLUTIONS, 650 NOMINAL H.P.

Top

Port Engine

6·39

Atmospheric Line 7·26

a

Bottom

Barometer 26⅜

$\frac{10·96}{17·35}$ $\frac{11·57}{18·80}$

a

T p

Starboard Engine

6 06

Atmospheric L   7·24

a

Bottom

Barometer 26¼

$\frac{10·86}{16·92}$ $\frac{11·33}{18·60}$

a
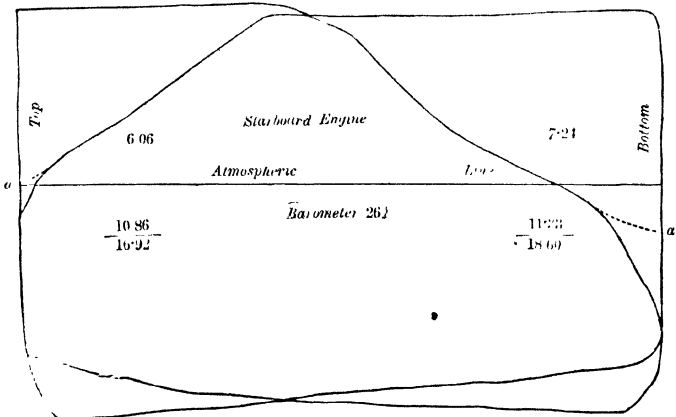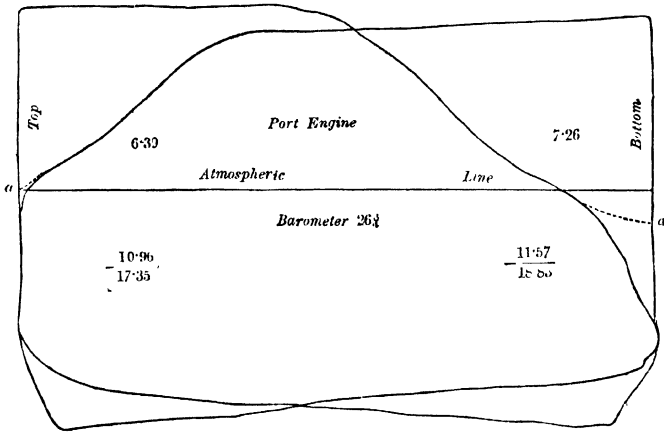
Starboard Cyl. Top 16·92 ⎫ Mean 17·76 ⎫
,,   Bott. 18·60 ⎬   ⎬ Mean 17·92
Port Cyl. . . Top. 17·35 ⎫ Mean 18·09 ⎭
,,   Bott. 18·83 ⎬

$$\frac{6593·5 \times 186·2 \times 17·92}{33,000} = 666·6 \times 2 = 1333 \text{ H.P.}$$

exerted by both engines.

condensed in the pipes, &c., which must be sought for
when suspected, either in the form of the indicator dia-
gram, or by testing the engine for leakage of steam or air,
as already explained.

Dynamometer.—A DYNAMOMETER is an instrument by
which it is attempted to measure the force actually exerted
in propelling a vessel.   An excellent one, designed by Mr.
Colladon of Geneva, has been erected in Woolwich Dock
Yard, by which the pull of any vessel made fast to it can be
accurately measured. An instrument of this kind, but subject
to many disturbing influences, can be fitted on board screw
steamers to show the thrust of the propeller shaft through
a series of levers on a spring balance. The lever is sometimes
made to take the pressure from the end of the shaft; at
other times, from a revolving frame with a number of fric-
tion rollers in it, which works against a collar on the shaft
at any part that may be most convenient.   The lever or
levers should have knife-edge centres, so as to work with
as little friction as possible; and the rod connecting the
lever with the spring balance has a small sliding rod at-
tached to it carrying a pencil.   By the side of this rod is a
small cylinder, round which a piece of paper is coiled, as in
the indicator.   This cylinder receives a continuous rotatory
motion by means of a small band from the screw shaft, the
motion being so regulated that the speed of the cylinder
(round which the paper is coiled) may be considerably less
than that of the screw shaft.   The pencil is now brought
into contact with the paper on the cylinder, and a zero
line traced before the pressure of the shaft is allowed to
act upon the lever.   The pencil should now be disengaged
from the paper, and the connecting rod of the lever screwed
up until it is ascertained that the whole forward pressure
of the shaft acts upon the lever, and that the shaft is quite
clear of every other part of the machinery which might re-
ceive a portion of the pressure.   Upon the pencil being

again brought into contact with the paper, an undulating line is described upon it, showing the variable thrust of the engines upon the propeller during the period of each revolution. After the diagram is traced, the paper is taken off, and equidistant lines drawn at right angles to the zero line, the lengths of these ordinates from the curve to the zero line, measured upon the scale of pounds of the spring balance, giving the action of the lever upon the balance at these places. The numbers being then marked upon the diagram, their sum taken, and divided by the number of ordinates for a mean, we shall have the force exerted on the lever, which, being multiplied by the leverage, will give the average forward pressure exerted by the propeller shaft upon the vessel. If it be only a single lever that is used for the dynamometer, the leverage is of course found by dividing the length from the fulcrum to the point where the rod of the spring balance is attached, by the length between the fulcrum and the point which receives the pressure of the shaft; but if it is a compound lever that is used, multiply together all the long arms of the levers, and divide the product by the product of all the short arms (measuring the length from the fulcrum of each lever), and the quotient is the leverage. When the forward pull or pressure in pounds has been found, the number of horses' power may be calculated for paddle-wheel vessels attached to Mr. Colladon's machine, by multiplying the velocity of the centre of effort of the paddle-board in feet per minute, by the total pull in pounds, and dividing the product by 33,000. The centre of effort of a paddle-board may be taken at $\frac{1}{3}$ of its depth from the outer edge. In screw vessels, the speed of the screw must be taken for the velocity. Experiments with this instrument when worked out in this way, have generally shown the effective to be about one half the gross indicator horse-power.

Counter.—The COUNTER is an instrument so contrived

by the aid of wheelwork that an index hand is moved for-
ward a certain distance for every stroke of the engine, thus
registering or " counting " the number of strokes an engine
makes during a day, a month, or any given period. The
construction of the counter varies much ; in most cases,
however, the wheels are moved round by a pendulum at-
tached to some vibrating part of the engine, the wheel
being carried forward one tooth for every vibration, and an
extreme slowness being obtained by a differential motion.

   Extract from p. 291, *Tredgold on the Steam Engine, vol.
ii. new edition.*—" THE COUNTER.—To estimate the saving
of fuel by the application of Watt's engines, an apparatus
was attached to the beam to ascertain the number of strokes
the engines made in a given time : it is called the Counter,
and consists of a train of wheel-work resembling that of a
clock, so arranged that every stroke made by the engine
moves one tooth, and the index shows how many strokes
have been made between the times of examination. The
counter is enclosed in a box, and locked, to prevent its
being altered during the absence of the observer. If the
box be attached to the axis of the beam, the inclination of
the beam causes its pendulum to vibrate every time the
engine makes a stroke, and this moves the counter round
one tooth for every stroke. The box may also be fixed to
the supports of the beam, and then at every stroke a small
detent is moved one tooth."

CHAPTER VIII.

ON THE QUALITIES OF FUEL, WITH HINTS FOR ITS SELECTION.

On the Qualities and Value of Different Coals.—The following observations upon the qualities and economic values of coal from different localities, are condensed chiefly from the Parliamentary "Report on Coals suited to the Royal Navy," drawn up in the years 1848-49, by Sir Henry de la Beche and Dr. Lyon Playfair.

Much depends on the Construction of the Boiler.—In estimating the evaporative power of coals, much must of course depend upon the construction of the boiler, and the manner in which the fuel is burnt on the grate. Thus, in Cornwall, where every attainable advantage is given to the fuel by large heating surface, slow combustion, and prevention of loss of heat by radiation, the average evaporative value of 1 lb. of coals may be taken at 10 to 11 lbs. of water, while in marine tubular boilers it rarely exceeds 8 to $8\frac{1}{2}$ lbs. An evaporative power of 14 lbs. of water is the highest result *theoretically* possible for a good average sample of coal.

Mr. Wicksteed's Experiments.—Mr. Wicksteed's experiments on this subject give the following results in pounds of water evaporated by one pound of coal, in land boilers of good construction, viz. :—

	lbs.		lbs.
Best Welsh coal	9·5	Average small Newcastle	8·07
Anthracite	9·01	Average Welsh	8·04
Best small Newcastle	8·52	Average large Newcastle	7·66

M. Cavé's Experiments. — Some recent experiments on the evaporating power of cylindrical boilers ashore, made by M. Cavé, of Paris, give a mean result of 8·2 lbs. water for 1 lb. coal.

Description of the Boiler used in the Parliamentary Experiments.—The boiler employed for the Parliamentary Experiments was made on the Cornish principle, being cylindrical with flat ends, and an internal flue, within which the grate was placed at one end. The hot air and gases, after leaving the furnace, passed through the central flue to the other end of the boiler, where they divided into two streams, and returned to the front of the boiler, along the outside, by a flue on each side; these two were then united again under the front of the boiler, and returned along a flue under the bottom of the boiler, finally entering the chimney after a course of about 36 feet. The grate surface was five square feet, and the total heating surface of the boiler 197·6 square feet. The boiler was worked under a pressure of from 1 to 3 lbs. on the square inch.

Management of the Fire.—In the management of the fire, care was taken to supply the coals in pieces not exceeding 1 lb. weight, and in quantities of not more than one or two shovelsful at a time spread evenly over the fire, except in the case of anthracite, and of highly bituminous coal. With anthracite, it was found that the sudden application of heat caused the pieces to split and fall through the bars; hence a gradual heating on the dead plate in front of the furnace (which in the experimental boiler was 10 inches wide) was found to be beneficial. With the highly bituminous coals, also, a partial coking on the dead plate prevented their caking together on the fire, which would have impeded the passage of air through the bars.

On Patent Fuels, their Advantages and Defects.—The Re-

port states that as the varieties of patent fuel are generally made up in the shape of bricks, they are well adapted for stowage, so that though the specific gravity of patent fuels is lower than that of ordinary coals, yet, from their shape and mechanical structure, there are very few coals that could be stowed in a smaller space per ton. While we look to the different varieties of patent fuel as of the highest importance, and from their facility of stowage as being peculiarly adapted for naval purposes, and perhaps even destined to supersede ordinary coal; at the same time, the greater part do not appear to be manufactured with a proper regard to the conditions required for war steamers. It is usual to mix bituminous or tarry matter with bituminous coal, and from this compound to make the fuel. An assimilation to the best steam coals would indicate, however, the very reverse process, and point to the mixture of a more anthracite coal with the bituminous cement. As the greater part is at present made, it is almost impossible to prevent the emission of dense opaque smoke, a circumstance extremely inconvenient to ships of war, as betraying their position at a distance at times when it is desirable to conceal it. Besides this and other inconveniences, the very bituminous varieties are not well suited to hot climates, and are as liable to spontaneous combustion as certain kinds of coal. To avoid these inconveniences some kinds of patent fuel have been subjected to a sort of coking, and thus in a great measure obtain the desired conditions. There is little doubt, however, that notwithstanding the large number of patents in operation for the manufacture of fuel, its value for the purposes of war steamers might be much enhanced by its preparation being specially directed to this object. It will be seen by reference to the table, that the three patent fuels examined rank amongst the highest results obtained.

Rapid Corrosion of Iron Coal Bunkers.—The retention of

coal in iron bunkers, if these are likely to be influenced by
moisture, and especially when by any accident wetted with
sea-water, will cause a speedy corrosion of the iron, with a
rapidity proportionate to its more or less efficient protec-
tion from corroding influences. This corrosion seems due
to the action of carbon, or coal, forming with the iron a vol-
taic couple, and thus promoting oxidation. The action is
similar to that of the tubercular concretions which appear
on the inside of iron water pipes when a piece of carbon,
not chemically combined with the metal, and in contact
with saline waters, produces a speedy corrosion. Where
the "make" of iron shows it liable to be thus corroded, a
mechanical protection is generally found sufficient. This is
sometimes given by Roman cement, by a lining of wood, or
by a drying oil driven into the pores of the iron under great
pressure.

*Gases evolved from Coal during Exposure to the Atmo-
sphere.*—Recent researches on the gases evolved from coal,
prove that carbonic acid and nitrogen are constantly mixed
with the inflammable portion, showing that the coal must
still be uniting with the oxygen of the atmosphere, and
entering into further decay. Instances have frequently
occurred of men who had descended into the coal boxes
having been rendered insensible by the carbonic acid col-
lected there.

Natural Decay in Coal.—Decay is merely a combustion
proceeding without flame, and is always attended with the
production of heat. The gas evolved during the progress
of decay in free air consists principally of carbonic acid, a
gas very injurious to animal life. It is well known that this
change in coal proceeds more rapidly at an elevated tempe-
rature, and therefore is liable to take place in hot climates.
Dryness is unfavourable to the change, while moisture
causes it to proceed with rapidity. When sulphur or iron

pyrites (a compound of sulphur and iron) is present in con-
siderable quantity in a coal still changing under the action
of the atmosphere, a second powerful heating cause is in-
troduced, and both acting together may produce what is
called *spontaneous combustion*. The latter cause is in itself
sufficient, if there be an unusual proportion of sulphur or
iron pyrites present.

Spontaneous Combustion.—The best method of prevention
in all such cases is to ensure perfect dryness in the coals
when they are stowed away, and to select a variety of fuel
not liable to the progressive decomposition to which allusion
has been made.

Advice in the Selection of Fuel.—It may be desirable to
sum up in a few words some of the principal points alluded
to in this Report. It has been shown that the true practical
value of coals for steam purposes, depends upon a com-
bination of qualities which could only be elicited by care-
fully and properly continued experiments. Their qualities,
so far as regards steam ships of war, may be stated as
follows :—

1. The fuel should burn so that steam may be raised in a
short period, if this be desired ; in other words, it should
be able to produce a quick action.

2. It should possess high evaporative power, that is, be
capable of converting much water into steam with a small
consumption of coal.

3. It should not be bituminous, lest so much smoke be
generated as to betray the position of ships of war, when
it is desirable that this should be concealed.

4. It should possess considerable cohesion of its particles,
so that it may not be broken into too small fragments by
the constant attrition which it may experience in the vessel.

5. It should combine a considerable density with such
mechanical structure, that it may easily be stowed away in

small space; a condition which, in coals of equal evaporative
values, often involves a difference of more than 20 per
cent.

6. It should be free from any considerable quantity of
sulphur, and should not progressively decay, both of which
circumstances render it liable to spontaneous combustion.

All the Good Qualities are never united in one Coal.—It
never happens that all these conditions are united in one
coal. To take an instance, anthracite has very high evapo-
rative power, but not being easily ignited, is not suited for
quick action; it has great cohesion in its particles, and is
not easily broken up by attrition, but it is not a caking
coal, and therefore would not cohere in the furnace when
the ship rolled in a gale of wind; it emits no smoke, but
from the intensity of its combustion it causes the iron of
the bars and boilers to oxidate, or waste rapidly away.
Thus, then, with some pre-eminent advantages it has dis-
advantages, which under ordinary circumstances preclude
its use.

By a due attention to these practical hints the com-
mander of a steam vessel will be enabled to strike a balance
between the good and bad qualities of the fuel offered him
for sale, and to select that which appears likely to fulfil
most of the conditions which his peculiar service may
demand.

Tables of the "Economic values of different coals and
patent fuels;" of the "Mean composition of average samples
of the coals;" and of the "Substances produced by the
destructive distillation of certain coals," will be found at
the end of the book.

Wood used as Fuel in Steam Vessels.—When wood is used
for fuel in steam vessels, it requires from $2\frac{1}{3}$ to 3 lbs. (ac-
cording to the degree of dryness) to equal one pound of
coal, Wood tolerably well dried contains one fifth of its

own weight of water, in evaporating which about one quarter of the whole heat generated is absorbed; peat, on the contrary, contains only from 1 to 3 per cent. of "hygroscopic" water.

Turf used as Fuel in Steam Vessels.—Turf has been occasionally used for fuel in steam boats, though not hitherto with much success. Its calorific value depends wholly upon the degree of dryness to which it has been brought, and when kiln-dried it is found to have a strong tendency to re-absorb moisture ; so it should be used as soon after this process as possible. When burnt in a tubular marine boiler with $6\frac{1}{2}$ square feet of grate bar and 280 square feet of total heating surface, it required 51 lbs. of good peat to evaporate one cubit foot of water, being about one sixth of the duty of coal.

CHAPTER IX.

CONSIDERATIONS AFFECTING THE RATE OF CONSUMPTION OF THE FUEL IN A STEAM VESSEL.

Rate of Consumption of the Fuel in a Steam Vessel.—The rate of consumption of the fuel in a sea-going steamer is a consideration of the first importance, not merely as it regards the question of expense, but also as it affects the capability of the vessel for increasing the length of her voyage under steam, as well as her safety in case of unusual detention from adverse weather. It is proved alike by theory and experience, that under ordinary circumstances of weather, a vessel will steam further with a given quantity of coals, by using only a fraction of her steam power, than she would if going at full speed. Theoretically speaking, the slower the vessel's speed, the greater the economy of fuel, provided always that no steam escape from the safety valve, or is otherwise wasted; but if her progress be opposed by contrary winds and currents, the engines should of course exert sufficient power, not merely to preserve her position, but to give forward motion if possible.

Steaming against the Stream.—In this case it is found that the power is applied most economically when the vessel steams half as fast again as the velocity of the opposing stream or current. Thus, if the vessel be steaming up a river, or in a tide way where the current runs at four knots an hour, her speed should then not be less than six knots.

Natural Law regulating the Speed of a Steamer.—These results chiefly depend upon the natural law that *the power*

expended in propelling a steam ship through the water varies as the cube of the velocity. This law is modified by the retarding effect of the increased resisting surface, conse-quent upon the weight of the engines and fuel, so that the horse power increases in a somewhat higher ratio than that named.

Limit imposed to the Possible Speed.—This consideration imposes a limit to the possible speed of a steamer, depend-ing upon the weight of the machinery and fuel which it can carry, relatively to its dimensions and tonnage. It is apparent also that this limit is extended according as the proportions of the engines and vessel are increased, for the larger the engines the less is their weight per horse power, and the greater is the effect of the steam in the cylinders; while the larger the vessel, the less is the resisting surface increased by the displacement of each additional ton of machinery and fuel.

To find the Speed corresponding to a Diminished Consump-tion of Fuel.—Hence, if a vessel of 500 horses power, we shall suppose, have a speed of 12 knots, with a consump-tion of 40 tons of coal per diem, if we wish to find the speed corresponding to a diminished consumption of 30 tons per diem, the following simple calculation is re-quired, viz. :—

$$40 : 30 :: 12^3 : V^3 \text{ (cube of the required velocity)},$$
$$\text{Or, reduced, } 4 : 3 :: 1728 : V^3,$$
$$\text{As an equation, } 3 \times 1728 = 5184 = 4 \ V^3,$$
$$\text{Or, } \frac{5184}{4} =$$
$$\sqrt[3]{1296} = 10 \cdot 902 \text{ knots} = V, \text{ required velocity.}$$

Thus, by diminishing the horses power, or the consump-tion of fuel, of this vessel by one fourth, we lose only a little more than one knot per hour in the resulting speed.

The same calculation may be applied for comparing the effects of engines of different power in the same vessel, or of the same engines when worked at reduced power.

The results thus obtained are of course independent of the additional advantage gained by expanding the steam in the cylinders, which in the case of large engines working at low powers, is very considerable.

To find the Consumption of Fuel corresponding to an Increased Speed.—Again, if we find that the speed of our vessel has advanced from eight knots (we will suppose) to nine knots, in consequence perhaps of her having received new boilers, and using more steam in the cylinders, and we wish to find the corresponding increase in the consumption of fuel, the following calculation will be necessary, viz. :—

$$8^3 : 9^3 :: \text{former consumption} : \text{present consumption},$$
$$512 : 729 :: \qquad ,, \qquad : \qquad ,,$$
$$\text{Or, in the ratio of 1 to } 1\cdot424.$$

Relation between the Consumption of Fuel, and the Length and Velocity of the Voyage.—Again, the consumption of fuel during two or more voyages of known lengths will vary in the proportion of the square of the velocity multiplied by the distance traversed.

Thus, if we find that during a voyage of 1200 miles, performed at the average speed of ten knots, the total consumption of fuel is 150 tons, and if we now wish to ascertain the consumption for a longer voyage of 1800 miles (we will suppose), at a reduced speed of eight knots, the calculation will be as follows :—

$$150 \text{ tons} : \text{C required consumption} :: 10^2 \text{ knots} \times 1200 \text{ miles} : 8^2$$
$$\text{knots} \times 1800 \text{ miles}.$$
$$\text{Then, C} \times 100 \times 1200 = 150 \times 64 \times 1800,^*$$
$$\text{Or, C} \times 120,000 = 17,280,000$$
$$\text{Reduced to C} = \frac{1728}{12} = 144 \text{ tons consumption.}$$

If, on the other hand, we require to know at what rate the vessel must steam in order that her consumption during the longer voyage of 1800 miles may not exceed her previous consumption of 150 tons during a voyage of 1200 miles at ten knots an hour, the calculation will be as follows:—

If we substitute 150 tons (our supposed consumption) for C in the equation above, marked thus*, and V^2 (the square of the required velocity) for 64, we shall then have,

$$150 \times 100 \times 1200 = 150 \times V^2 \times 1800,$$
$$\text{Or, } 120,000 = 1800 \ V^2,$$
$$\text{Reduced, } \frac{1200}{18} = V^2,$$
$$\text{And } V = \sqrt{66 \cdot 66} = 8 \cdot 15 \text{ knots.}$$

Economy attending a diminished Speed in the Vessel.—These examples all show the great economy which attends a diminution of speed in the vessel; and although in the case of merchant steamers, the loss of time is generally too serious a disadvantage to admit of any permanent reduction of speed, much benefit has resulted to ships in the Royal Navy from the judicious husbanding of the fuel in this manner, whether it be to meet the requirements of an unusually long run, or merely to save coal when the vessel is employed on a service not demanding extraordinary despatch.

Use of Sails of a Steamer.—The steamer's sails, also, form a most important addition to her capabilities, as for each knot that the vessel is propelled by their aid, as much fuel is saved as may afterwards propel her the same number of knots in a calm. The sails should therefore be set upon every occasion of a fair wind, and according as it is more or less favourable, so should the steam be more or less cut off and expanded in the cylinders. By this means we avoid the unnecessary consumption of dense steam, which would

otherwise be used at a disadvantage, for it is evident that however little the engines may assist in propelling the ship, they must nevertheless work very fast in order to overtake the vessel's speed generated by the sails alone, and two cylinders full of steam must always be used for each revolution.

Disconnecting the Engines.—Hence, when a moderate speed is attained by the sails alone, it is more economical (though otherwise not always to be recommended) to stop the engines entirely, and disconnect the wheels or screw when practicable, suffering them to revolve freely in their journals by the re-action of the water.   When, on the other hand, the wind and sea are adverse, the full power of the engines must be applied, every knot gained being now of double value.

CHAPTER X.

Varieties of the Paddle Wheel.—With regard to PADDLE WHEELS, it is believed that the common wheel, if properly proportioned and allowed the proper degree of immersion, is preferable, under ordinary circumstances, to any of the "improved" varieties which have from time to time appeared. Of these, the only one which can be recommended, and that only under peculiar circumstances, is Morgan's feathering wheel, by the use of which the boards may be made deeper, and therefore narrower than in the common wheel, and the diameter may be somewhat diminished; but it is objectionable from its weight (which is nearly twice that of the common wheel), from its complexity and consequent liability to derangement, and from its considerable additional expense. Mr. Field's " Cycloidal " wheel, in which the paddle board is divided into steps with an open space between, can hardly claim any superiority over the undivided board, but the simple modification of this plan, formed by dividing the board into two breadths, and placing one on either side of the paddle arm, is probably the best form of wheel that can be adopted for large steamers.

Variable Immersion the Grand Objection to the Paddle Wheel.—We have already hinted that the grand objection to the paddle wheel is the unequal " dip " or immersion of the boards, consequent on the varying draught of water, as the coals and stores continue to be consumed on the voyage. A vessel, for instance, with a displacement of 12 tons per

inch at the load line, burning perhaps 460 tons of coals during a long run, will swim 3 feet 6 inches lighter, from the consumption of the fuel alone, at the end than at the beginning, so that it is only in the middle of her voyage that the wheels can have the dip best calculated for them.

The most advantageous Dip.—The most advantageous dip varies with the diameter of the wheel, the speed of the vessel, and the service in which she is employed, as for sea or river navigation. Sea-going steamers of the first class are usually allowed 18 to 21 inches of water over the vertical float at the mean draught; and smaller vessels may have 12 to 15 inches. It is usual in the case of fast river boats to allow only an inch or two over the boards, when the wheels are large. When the wheels are too deeply immersed, they may sometimes be " reefed " by disconnecting the boards, and securing them nearer the centre.

The " Slip " of the Paddle Wheel.—The " slip " of the paddle wheel, by which is meant the excess of its velocity above that of the vessel, is usually reckoned at one fifth (or 20 per cent.) of the vessel's speed, the wheel being supposed to be well-proportioned, and the water lines of the vessel tolerably good for speed.

Explanation of Table of Velocities of Paddle Wheels.— As it is of considerable importance to observe and compare the slip of the wheel under different circumstances, or in different vessels, we have prepared a table of velocities of paddle wheels of varying diameters and speeds, in feet per minute, and miles per hour. The " effective diameter " of the wheel may be reckoned by subtracting one third of the breadth of the boards from each end of the extreme diameter. This subtraction should therefore be made before referring to the Table given in the Appendix. The rule for finding the velocity of a paddle wheel, when its effective

diameter and number of revolutions are given, is the following:—

Multiply the diameter by 3·1416, multiply the product by the number of revolutions per minute, multiply the last product by 60, and divide by 5280 for the velocity in statute miles, or by 6082·66 for knots per hour.

The Table referred to will be found at the end of the book.

Area of the Paddle Boards.—In proportioning the area of the paddle boards we must take into consideration the estimated dip of the wheels. By taking an average of the practice with regard to large sea-going steamers, we find that the whole paddle-board surface for the two wheels is between 2½ and 3 square feet per horse power; but for steamers with a lighter dip, from 4 to 5 square feet are allowed. The surface of each board, for large vessels, rarely exceeds one twenty-fifth of the total horse power, in square feet; but increases as the dip and diameter of the wheel diminishes, to about one fifteenth: while for river steamers one tenth of the total horse power is a usual proportion. A long narrow board is more effective than a short and deep one, but is inconvenient, especially in sea-going vessels, from the increased breadth of the paddle box. Thus, in large steamers, the proportion of depth to length varies from one fourth to one fifth, but in river steamers the board is generally about seven times as long as it is broad.

Disconnecting the Paddle Wheels.—As it is frequently desirable to disconnect the paddle wheels from the engines, and permit them to revolve in their bearings while the ship is under canvas, several kinds of disconnecting apparatus have been employed for this purpose.

Description of Braithwaite's Disconnecting Apparatus.—
Braithwaite's apparatus is represented in the subjoined

.......t, and it may be thus described. A cast-iron disc, a, is keyed on the end of the paddle shaft, b, and a strong wrought-iron hoop, c c, lined with brass to diminish the friction, surrounds and slides over the periphery of the cast-iron disc. At one side of this hoop, at d, a projection
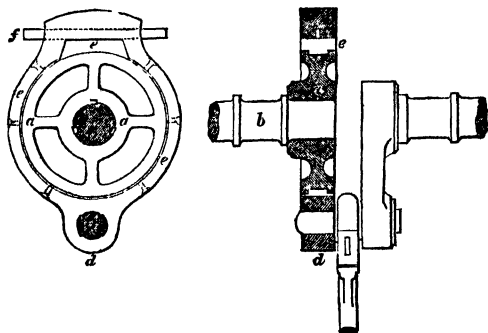
Braithwaite's Disconnecting Apparatus.

is forged, in which the eye is bored for the crank pin, and at the other side the hoop is swelled out to receive a brass cushion, e, inserted between the hoop and the cast-iron disc. Now, when this cushion is driven hard and tight against the periphery of the disc, by means of a strong key, f, the friction between the hoop (in which the crank pin is fixed) and the disc on the paddle shaft becomes so great that the former drags round the latter, and thus communicates motion to the wheels. These are again disconnected by driving back the key, and by this means loosening the friction cushion, when the hoop and the disc revolve each independently of the other.

This apparatus is by no means perfect, and gives much trouble at sea by the slipping of the hoop, notwithstanding that the key may have been driven as tight as possible. The hoop has also itself frequently given way, as the forging is a difficult one to make perfectly sound.

Maudslay's.—Messrs. Maudslay and Field adopt the plan of sliding the paddle shaft, with the outer crank upon it, out of the crank pin, using for this purpose a worm wheel and cogged collar on the shaft, worked from the deck.

Seaward's Plan.—Messrs. Seaward form the pin end of their outer crank with a slot cut out of the thickness of the boss on the inside, the breadth of the slot being equal to the diameter of the pin, which is held fast by square keys in the boss while the engines are working. When it is wished to disconnect the wheels, the engines are stopped, and the keys withdrawn, when the boss of the outer crank clears and passes the pin by means of the slot, as the wheels revolve in their bearings from the resistance of the water.

The Screw Propeller.—An idea of a screw may be given

by supposing a line or thread wound round a cylinder, and advancing along it in the direction of its length by a gradual and equal rate of progression. This thread may be of any shape, either triangular, as in many cases, or it may be in the form of a thin plate of metal kept upon its edge, and wound round a cylinder of so small a diameter that it would no longer be called a cylinder, but would become a mere rod or spindle in the centre. This will probably be best understood by reference to the annexed diagram, which represents one thread of this kind wound
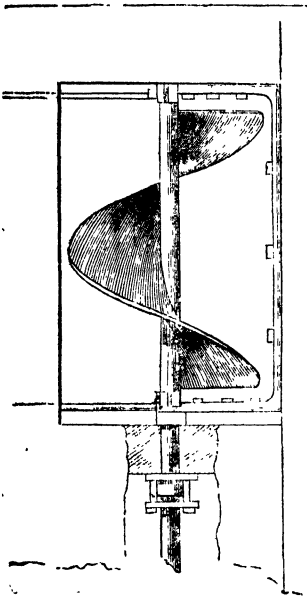
round a spindle, and this is called a single-threaded screw. It will be at once evident that two, three, or more threads, if kept uniformly parallel to each other, may in the same manner be wound round the cylinder, and there is then produced a two-threaded or three-threaded screw accordingly. The properties of a screw of this kind were first investigated and made known by Archimedes.

The Pitch of a Screw.—Supposing that a line is drawn along the surface of a cylinder in the direction of its length, and that a line or thread as before is wound round it, the distances between the points where the thread crosses the longitudinal line, and which are always the same, is called the pitch of the screw.

The Slip of a Screw.—If a screw be made to revolve in a solid, as a carpenter's screw in wood, it is evident that it will progress in the direction of its axis the distance of its pitch for each revolution, the latter portions following exactly in the course cut by the preceding or first entered portions of the thread. If, however, it be made to revolve in water, which is a yielding medium, the water will to some extent give way, and the screw will not progress the full amount of its pitch, this deficiency in its progress being denominated the slip of the screw.

Anomaly in the Performance of the Screw, called " Negative Slip."—There is an anomaly in the performance of the screw, namely, the well-authenticated presence of "negative slip," as it has been termed, or the fact of the vessel actually going faster than the rate at which the screw which propels it would advance if revolving in a solid. The explanation offered is, that the vessels in which this occurs have their after lines so badly formed for closing the water, that instead of the hull passing through the fluid with so little disturbance as scarcely to affect its condition of relative rest, a large body

of " dead water " is created, which follows the vessel, being
towed (as it were) in her wake. An opposing current, and
therefore an increased resistance, is thus offered to the ac-
tion of the screw. This seems to have the effect of anni-
hilating the slip, the vessel appearing to outstrip the
propeller by virtue of its advancing through still water
(relatively to its own motion), while the screw revolves
against an opposing stream. It cannot be supposed that in
such a case the power of the engines is economically ap-
plied, as a much larger portion of the power is expended in
towing the dead water against which the screw re-acts, than
is afterwards recovered by the increased effect of the screw.
Thus, if the rate of progression of the screw be 10 knots
through a solid, and if a current flows against it at the rate
of three knots, this will be equal to a real progression of 13
knots for the screw, and we need not be much surprised
if the speed of the vessel, under these circumstances, ex-
ceeds the apparent speed of the screw by perhaps one
knot per hour. Anomalies of this kind most frequently
occur in auxiliary-screw steamers, where the vessel, after
attaining a high velocity by sails alone, still continues to
derive additional assistance from the screw, although its
speed may not equal that of the vessel.

Dragging of the Screw.—In such vessels, therefore, it
does not always follow that the engines are no longer use-
ful after the speed attained by the sails is equal to the
progression of the screw, but the engineer should under
these circumstances watch the thrust of his propeller shaft
very narrowly, as there must be a limit to this in all vessels
carrying a large spread of canvas. If he find the thrust to
cease, he will then know that the screw is " dragging," and
will recommend his commander to discontinue the use of
the engines as being no longer serviceable. Direct evi-
dence of the screw " dragging " has been obtained by the

fact of a propeller having been carried away by the strain brought upon it from the velocity of the ship due to the sails exceeding the velocity of the screw. The rupture in this case clearly showed that the blade, which was of iron plate riveted upon a wrought-iron arm, was torn off *backwards* by the drag brought upon it.

Disconnecting the Screw.—It is usual in the Government service to provide means for withdrawing the driving shaft out of a socket in the screw shaft, for the purpose of disconnecting the screw and raising it entirely out of the water when the ship is under canvas. This is effected by having a hollow trunk constructed over it in the stern of the vessel, into which the screw is lifted by proper machinery, the outer screw shaft fitting into a vertical frame of gun metal which rises along with it. This will be best understood by reference to the frontispiece, which is a section of the stern of a vessel so fitted. In some vessels, the screw is only capable of being disconnected from the engines, and left free to revolve by the action of the water upon it, from the motion of the vessel. Contrivances have also been introduced to place the blades in a fore and aft direction, so that they may lie within the dead wood of the vessel, and present no projecting surface to impede her progress, or affect her steering.

The Propelling Power of the Screw.—If the spindle of the screw (see fig. in page 113) be supposed to be passed through the side of a box filled with water, and made to revolve there without the power of moving in the direction of its axis, it will send the water away from it with a certain amount of force, and hence, as action and reaction are always equal, the screw is pushed forward with this amount of force; and, if it were attached to a ship, the ship would thus be propelled. The reverse of this action would take place, and the ship would

be pulled backwards, if the screw were made to revolve in
the opposite direction. From the number of revolutions
which a screw propeller of a known pitch makes in a minute,
the progress which it would make in an hour is calculated;
and, if the speed of the ship be found by observation to be
less than this, the difference is the slip.

Explanation of the Term "*Screw Blade.*"—If the screw
(see fig. in page 113) be cut into any number of portions by
planes passing across it at right angles to the axis, which would
be represented in the figure by lines, any one of the portions
would have the appearance of the vane of a windmill; and,
if the screw were two-threaded, the vanes or blades would
be exactly opposite each other. If a sixth part of the length
of the screw be marked off in the plate, it will be seen that
the part will then resemble one of the blades of the screw
propeller represented in its place in the vessel in the fron-
tispiece, the latter screw however being two-bladed.

To find the Pitch of a Screw Blade.—This operation pro-
ceeds upon the fact that if a line representing the circum-
ference of the screw's disc at its extreme diameter, and
another representing the pitch of the screw, be drawn at
right angles to each other, to a scale of parts, the hypo-
thenuse of this right-angled triangle will represent the length
of the winding thread. After measuring the diameter in
order to find the circumference from it, the length of the
blade along its periphery is to be measured, this being a
portion of the hypothenuse of the triangle whose sides we
wish to determine; then measure the distance that one
corner of the blade is before the other in the line of the
axis, and this being a portion of the pitch is a part of
another side of the triangle. Now two sides of a right-
angled triangle being known, the third can be found in this
case by subtracting the square of the side from the square

of the hypothenuse and finding the square root of the re-
mainder, and the dimension so found will represent a por-
tion of the circumference. And now, as this portion of the
circumference is to the whole circumference, so is the por-
tion of the pitch as measured to the whole pitch.

Introduction and Progress of the Screw Propeller.—Having
thus endeavoured in a popular manner to give an outline
of what a screw propeller is, it may not be uninteresting
or out of place to trace shortly the introduction and pro-
gress of screw propulsion. Dr. Shorter, a practical me-
chanic of this country, succeeded in propelling a vessel by
a screw in 1802 ; but, as no power was at that time known
capable of driving his propeller with proper effect, it fell
into oblivion. The first introducers of Watt's steam engine
for marine purposes adopted the paddle wheel ; and its
success, with such an agent to drive it, seems for a time to
have drawn off the current of invention entirely from sub-
merged propellers. Though other patents had been taken
out, it was not till Captain Ericsson and Mr. F. P. Smith
brought out their experimental vessels in 1837 that any real
progress was made. Captain Ericsson's small vessel of 45
feet in length and 8 feet beam, and drawing only 2 feet 3
inches of water, towed the American ship Toronto, of 630
tons burthen, on the Thames, on 25th of May, 1837, at the
rate of 4½ knots per hour against tide, as authenticated by
the pilot : and also towed the Admiralty barge, with their
Lordships, from Somerset House to Blackwall and back at
the rate of about 19 miles an hour. To Captain Ericsson's
anxious application, and after his pointing out the many
advantages of a submerged propeller for vessels of war, he
received the discouraging reply that their Lordships de-
clined to entertain the project. Later in the same year
Mr. Smith made some very successful trips with his small
boat and screw propeller between Margate and Ramsgate.

The next screw vessel was the Robert Stockton, in 1839, built for an American gentleman who had witnessed Captain Ericsson's experiments and taken a favourable and correct view of them. This vessel was eminently successful; but the designer, finding himself still unable to move the Board of Admiralty, left this country for America, whither this vessel had proceeded, determined to prosecute his invention there. In the mean time some influential mercantile men had connected themselves with Mr. Smith with the view of purchasing his patent; and the Archimedes, a vessel of 232 tons and 80-horse power, was brought out in 1840.* The success of this vessel was complete, and the publicity given to her performances by her spirited owners, who took her round Great Britain and showed her powers in every port, rendered the capabilities of the screw no longer a matter of doubt. The Board of Admiralty having received most favourable reports of the performances of this vessel from Captain Chappel, who had accompanied her on this voyage, and from Mr. Lloyd who had witnessed her performances in making several trips between Dover and Calais in competition with the mail steamers then running, now ordered the Rattler to be built on the same lines as the paddle-wheel steamer the Alecto, and with engines of the same nominal horse power. The next screw vessel to be noticed whose performances influenced the progress of the screw as a propeller is the Dove, constructed at Liverpool, of iron, under Mr. Smith's direction. The speed realized, however, was not equal to what was expected if she had been fitted with paddle-wheels: the owners were in consequence dissatisfied, and ordered her to be altered as quickly as possible to paddle-wheels. She was built with very fine lines abaft; and, most unfortunately, from this circumstance, and from some experiments in the Archimedes which had proved the possibility of negative slip,

* See Appendix D. to Tredgold on the Steam Engine, 4to.

Mr. Smith, and those with him on whose judgment as men of science he relied, took up the idea that full stern lines were the most advantageous for the screw. The Rattler was now tried; and, after her trials had fully satisfied the Board of Admiralty, they ordered the construction of several additional screw vessels, and Mr. Smith inculcated his views in favour of full sterns upon their different constructors. This was finally proved to be erroneous, and that a fine run with a ready access for the water to the screw, and as clear an escape for it abaft as possible, was absolutely necessary, and the whole of these vessels had to be altered at great cost. In the mean time the screw had risen most rapidly in favour with the public, and fast vessels had been constructed by Mr. Slaughter, of Bristol, with Woodcroft's patent screw, and by other parties, as well as several auxiliary screw vessels.

Varieties of the Screw Propeller.—A great variety of patents for screw propellers were taken out, not only before, but also largely since the success of Captain Ericsson and Mr. Smith; but it is proposed here to refer only to those which have been found successful on trial, and which seem to promise to be of any practical utility. The propellers formed of portions of a true screw, have been already described, and of these Smith and Lowe claim to be the patentees; the latter party having taken out a patent in September, 1838, for the use of one or more screw blades, similar to what are now generally employed.

Woodcroft's Screw.—Professor Woodcroft, in his patent of 1832, prior to Captain Ericsson and Mr. Smith, proposed a screw of such construction that the pitch or distance between the revolutions of the thread should continually increase through its whole length, with the view that the after part might act with greater efficiency on the water that had been previously acted upon by the foremost part.

He fell into the error, into which Mr. F. P. Smith also subsequently fell, of supposing that one full turn or more of the thread was requisite to make an efficient propeller ; and no practical progress was made with his invention, till the first experimental vessels already referred to had been tried and found to be successful. Woodcroft then reduced the length of his screw to that of Lowe's blades, and a trial was made with it in the *Rattler*, when the following results were obtained, in comparison with a propeller of similar proportions, but whose blades were portions of a true screw :—

	True Screw.	Woodcroft's Screw.
	18th of March, 1844.	13th of April, 1844.
Number of Blades	4	4
Diameter of Propeller	9 ft. 0 in.	9 ft. 0 in.
Length of ditto.....................	1 ft. 7 in.	1 ft. 7 in.
Pitch of ditto	11 ft. 0 in.	11 ft. 0 in. to 11·55 ft.
Strokes of the Engine per minute	26·28	24·152
Mean pressure of Steam, by indicator ..	14·38	14·57
Horse Power, by indicator	459	428·76
Speed of Ship	8·180	8·159

To compare these results, we know that if both propellers were equally efficient, the speed should be as the cube roots of the powers exerted;—now if 459-horse power gave a speed of 8·180, to find what speed 428·76 ought to give, we must use the following proportion, $\sqrt[3]{459} : \sqrt[3]{428\cdot76} :: 8\cdot180 : 7\cdot9962$. But instead of 7·9962 knots, Woodcroft's screw with this power gave a speed of 8·159, or nearly ¼ knot more, thus proving its superiority to this extent in this case.

Ericsson's Propeller.—Captain Ericsson's propeller consists of a number of blades fixed at a distance from the axis upon the periphery of a short cylinder, or ring of metal, the ring being united to the axis by two or more
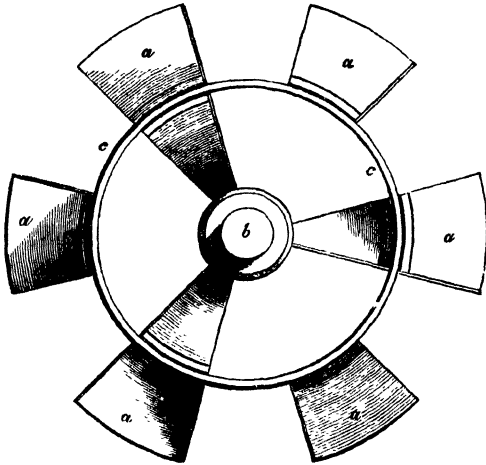
arms. It is here represented. Both M. Carlsund and M.
Sorenson of the Swedish navy are using a
similar screw, but with the ring on the
periphery or exterior of the blades. The
blades and arms are segments of a screw,
and there is nothing to prevent this being
a most efficient propeller. It seems to con-
tinue in favour in America and in France;
but the great objection to it in this country
is the difficulty of removing it, or preventing
it from retarding the vessel when she is
placed under canvas. Captain Ericsson at
first used two of his propellers acting in
combination, but he soon found that one
was sufficient.
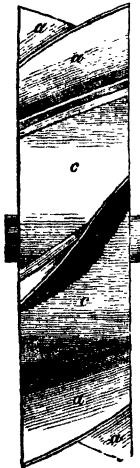
Maudslay's Feathering Screw.—This screw
is represented in the opposite page. The
object sought to be attained is, that the blades, whenever
the vessel is put under canvas and the screw not required,

MAUDSLAY'S FEATHERING SCREW,

1st. *In position for use as a Propeller.*
2nd. *In position for sailing under canvas alone.*
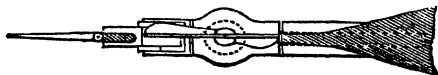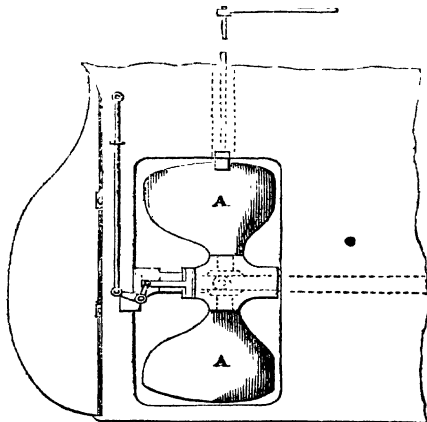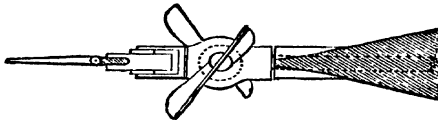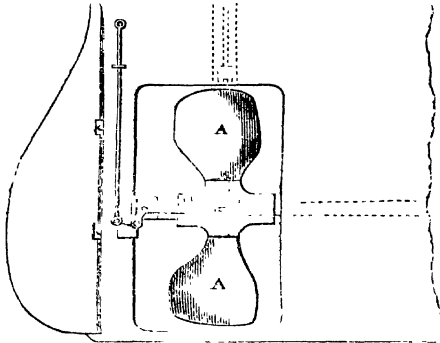
should be placed in a direction parallel with the line of the keel, and so form as it were a portion of the dead-wood, as they cause considerable obstruction if permitted to remain fixed in their position, or even though they be disconnected from the engine and allowed to revolve. In auxiliary sailing vessels not fitted with a trunk or aperture for the purpose of raising the screw out of the water, this is particularly valuable; but it will also be found useful in men of war, by lessening the width of the trunk through which it has to rise, if this be desired; and also by the facility which it gives in emergencies, for placing a vessel quickly under canvas, or under steam, without requiring the aid of the crew; and also for placing the vessel under canvas when it may not be possible to keep the engines at work, from their having been injured by shot or any other cause, and when it may at the same time be imperative to keep the screw down in its place to permit the stern guns to be used over the aperture of the trunk.

Hodgson's Parabolic Propeller.—This propeller is constructed with two blades, placed at an angle to the centre line of the axis, but differing essentially from the blades of a true screw, or of Woodcroft's screw, in their being hollow on the face, and being bent backwards in such a form as to be portions of a parabola. It is now much adopted in Holland. The peculiar principle of this propeller lies in this, that whereas the line of the action of other propellers upon the water is parallel to their axes, and the particles of water when driven off assume the form of a cone diverging as they recede; the water acted upon by the parabolic propeller, when driven off from each blade, is projected by the nature of the parabolic curve to its focus in the line of its axis. The water is therefore forced towards the centre, and exerts a greater amount of resistance, from its not being so readily thrown up to the surface in the line of least resistance, where it escapes in the form of broken water.

Macintosh's Elastic Propeller.—This propeller is con-
structed with flexible blades of steel, in such a manner that,
when made to revolve, the action of the water in pressing
against them to propel the vessel bends or springs their
faces back, so as to make them approach nearer to a
disc at right angles to its axis; and it is understood that
Mr. Macintosh, if he could construct his blades to be so
very flexible, would desire that they should be so bent as to
assume this form when revolving at their highest velocity.
In this case the propulsion of the vessel, instead of being
obtained on the principle of the screw, may be looked upon
as being obtained by the elastic spring or tendency of the
blades to recover their form, thus keeping up a constant
pressure upon the water behind them, and forcing the vessel
forward.   The higher the velocity of revolution is, the
more the blades will be bent back, and the greater will be
their propelling force, until they assume the form of a disc,
when any further velocity would cease to produce additional
effect.

*Comparison of the Flexible Propeller with the Action of a
Fish.*—The tails of three fishes—salmon, mackerel, and her-

ring—that swim at high velocities are here represented; and, if the mode of their action be considered, it is conceived that it will be seen to resemble that of Macintosh's propeller more than that of the Archimedean screw. When
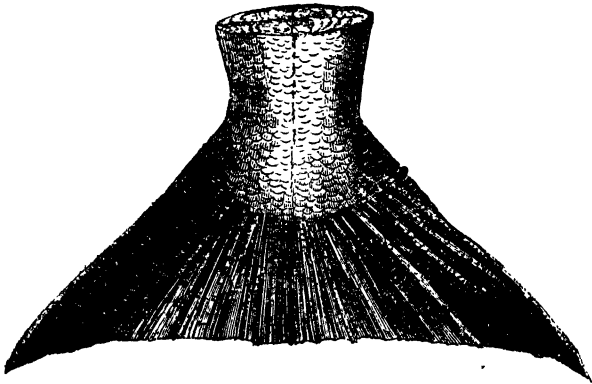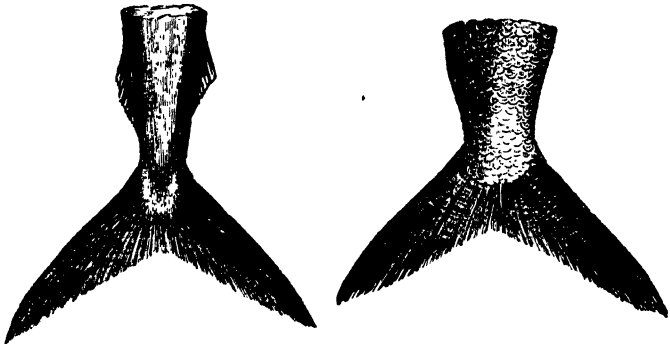
the tail of the fish is moved to the right, the web, or thin finny part, is bent to the left on account of its weakness in comparison with the stronger parts near the body; and it is conceived that it is from the water pressing upon this oblique portion, while it keeps it bent back in opposition to the force exerted by the fish to send it to the right, that the motion is obtained.

In the Application of the Screw, fine After-lines are indispensable.—With regard to the application of the Screw propeller, it is now well understood that the after-lines of the vessel must be kept as fine as practicable just before the screw, the body of ᴛthe vessel terminating, if possible, at the inner stern post, so as to avoid the flat surface, or "square tuck," which occasioned so much disquietude to our dockyard engineers upon the first introduction of this principle. It was then shown by experiment with the *Dwarf* that the filling out of the lines immediately before the screw produced a most injurious effect upon the speed of the vessel, and those of the Admiralty screw

steamers which have had their lines fined away there, have since advanced in speed by several knots an hour. In wooden vessels, the edges of the screw aperture are strengthened with gun-metal castings, by means of which a sharper finish can be given to them. And it is chiefly in this point of view that iron vessels have shown themselves better adapted for the screw propeller than wooden ones, in consequence of the extreme fineness to which they may be tapered at the stern-post, with a due regard to strength.

Diameter of Screw.—The diameter of the screw should, in most cases, be made as great as the draught of water will admit, and for running in smooth water its upper edge need not be more than a few inches beneath the surface. In the case of sea-going vessels, it is preferable to keep it 18 inches or 2 feet below the mean surface of the water.

Area of the Screw.—By the *area* of the disc of the screw is understood the area of the circle described by its extreme diameter. When the area of the blades is spoken of, their actual oblique surface should always be specially distinguished from the plane projection of the resisting surface. This latter measurement, as representing the actual amount of surface directly employed in the propulsion of the vessel, is probably the most important of these areas. The *Dwarf's* experiments show that the speed of this vessel gradually increased a little as the length of her screw was diminished from 2 feet 6 inches to 1 foot, the area corresponding to each length being 22·2 and 8·96 square feet respectively. It appears at first sight remarkable that so great a variation in the resisting surface should cause so little disturbance in the speed of the engines or of the vessel, thus showing very plainly how small a segment of the whole "pitch" is required to absorb all the power which the reaction of the water is capable of imparting. The fact seems to be that the water in which the screw revolves ac-

quires very soon the same rotatory motion with the screw, and as its resisting power is thus destroyed by the action of the *leading* part of the thread only, any additional length of screw, after the power has been absorbed, only retards by friction. The *Rattler's* experiments, conducted by the Engineering Department of H. M. Dockyard at Woolwich, were commenced with a screw 5 ft. 9 in. long, which was gradually shortened, followed always by an improvement in the speed of the vessel, until it reached its present length of only 15 inches. The result of numerous experiments has led to the now very generally received opinion that the length of the screw should be about one sixth of its pitch.

Relative Value of Coarsely or Fine pitched Screws.—The question between the relative values of fine and coarsely pitched screws appears to be as yet quite undecided. The equally good results that have been obtained (more especially in the merchant service) by the use of coarsely pitched screws running at a comparatively low speed, and very finely pitched screws running at a great velocity, tend to the conclusion that a variation in pitch is not of much practical importance within certain limits.

Extent of Slip of the Screw.—The diameter of the screw and the speed at which it is driven modify, in a great measure, the amount of slip, which is usually found to diminish in proportion as the diameter and velocity increase. Thus, the diameter of the *Rattler's* screw during her experiments was 10 feet, and the average slip 15 per cent., while the *Dwarf* and *Fairy*, with screws of between five and six feet diameter, showed an average slip of about 35 per cent. The slip is also affected by the form of the vessel's run, and the manner in which the water closes in upon the screw, so that it is necessarily very uncertain, and will probably vary in every ship.

CHAPTER XI.

COMPARATIVE MERITS OF DIFFERENT STEAM VESSELS AND OF SCREW AND PADDLE-WHEEL VESSELS.

To compare the General Efficiency of different Vessels.—It will be apparent from what has been already said that it is very difficult, if not wholly impracticable, to institute a just comparison between the degrees of efficiency of different steam vessels. In the first place, the performance of the machinery has to be separated from the question of the form of the vessel, if we would enter minutely into the subject, and the performance of the machinery itself should again be subdivided into the relative efficiency of the *engines* and *boilers*.

But as it cannot be expected that mercantile men should enter into these details, a simple method of drawing a general and approximate comparison between different vessels taken as a whole may be found useful.

For Commercial Purposes.—It is at once apparent that the mere statement of the number of miles run for one ton of coals, can be a just criterion only between vessels of the same or nearly equal size, making the same voyage, at nearly equal speeds, and that it is by no means applicable as a general standard, since a ton of coals will, as a matter of course, carry a small vessel further than it will a larger one. As we have seen, too, that an increase of speed is obtained only at the expenditure of a very great increase of power, a proper allowance must also be made for this. Hence to draw even the most superficial comparison between the " efficiency " of two steam vessels, their speeds must first be reduced to a common standard, and the relation must then be found between the consumption of the fuel at this speed and the size or tonnage of the vessel, the *maximum speed* of each being considered as a separate question. The signification of the term *efficiency*, varies so materially in different

classes of vessels, that steamers of the same class only can
be justly compared together; the speed required by any
particular service, or in other words, the estimation of *time*
in each service, being a totally distinct consideration, as re-
gards consumption of fuel and general efficiency. Thus,
one vessel may make a voyage at a slow rate, and with a
small consumption of fuel, while another vessel of the same
power and tonnage, although it may be of very decidedly
superior " efficiency," may consume a much greater quantity
of fuel, by performing the same voyage in a much shorter
time. In the Government service, the time occupied by a
voyage is usually not so much considered as a low consump-
tion of fuel, and the vessel is therefore limited to a slow and
economical speed. In the case of merchant steamers, on
the other hand, this system would be the reverse of economy.

It is believed, that if the number of Register tons carried
by one ton of coals, at the rate of 10 knots an hour, be
taken as a common standard of comparison for estimating
the duty of sea-going steamers, it will be found sufficiently
accurate for mercantile purposes, the maximum speed of the
vessel being treated as a separate consideration.

Example No. 1.—Suppose, for example, that a vessel of
1300 tons, and 500 horse power is found, by experiment,
when at her medium draught of water, to make 10·5 knots
an hour, with a consumption of three tons of coal per hour.

To reduce her performance to the proposed standard,
therefore, the following calculation must be made:—

$$\text{10·5 knots : 10 knots} :: \sqrt[3]{\text{3 tons, present consumption} :}$$
$$\sqrt[3]{\text{required consumption.}}$$

Cubing these quantities, and working out the proportion,
we have

$$\text{1157·625 : 1000 :: 3 : 2·59 tons, required consumption.}$$

We have thus found that 1300 tons (tonnage) are carried
10 knots in an hour, by a consumption of 2·59 tons of
coals: Therefore,

$$\frac{1300}{2·59} = \text{501·9 tons (tonnage) carried by this steamer a distance of 10}$$
$$\text{knots in an hour, by one ton of coals.}$$

Example No. 2.—Again, a vessel of 1072 tons and 400 horse power, is propelled at the rate of 10·4 knots, with a consumption of 48¼ cwt. of coals per hour:

Then, as before, 10·4 : 10 :: $\sqrt{48·5}$: $\sqrt{\text{required consumption}}$.

Or, 1124·8 : 1000 :: 48·5 : 43·1.

And now, 43·1 : 1072 :: 20 : 497·4 tons (tonnage) carried by this steamer a distance of 10 knots in an hour, by one ton of coals.

The comparison between those two steamers, therefore, shows that their performance is nearly equal, being in the proportion of 501·9 to 497·4.

To compare Efficiency of Different Vessels for Scientific Purposes.—If it be wished to form a more scientific and accurate comparison, the separate question of the efficiency of the boiler being ascertained by an experiment as to weight of water evaporated by 1 lb. of coal, and the efficiency of the engine by finding the quantity of steam used in it to produce an indicator horse power, it will be necessary to substitute the *indicator horse power* for the *consumption of fuel,* and the actual *displacement* of the vessel for the *nominal tonnage.* With regard to the latter point, it is much to be regretted that a certain petty jealousy still existing amongst ship builders, though now happily exploded amongst engineers, frequently steps in to obstruct the investigation of all questions relating to the form and displacement of a vessel's body, by withholding the design from which it was built. As the lines of the vessel cannot be deduced from the scale of displacement,* however, we think that every owner of a steamer may insist upon this being supplied to the captain of his ship, without taxing too far the communicativeness of the designer, who, it would appear, is apt to forget that only quacks and charlatans work in secret, while with the true scientific practitioner all is open and above-board, and publicity courted with a view to criticism and discussion, and consequently progressive improvement.

* For an example of a scale of displacement, see Rudimentary Treatise on Shipbuilding, Vol. I., in this series, Plate C.

The number of tons of displacement, therefore, that 100 gross or indicator horse power will propel at the rate of 10 knots an hour, is proposed as a standard of comparison for enabling us to judge of the relative values of different forms of vessels.

Example No. 1.—A vessel, upon trial, is found to have a speed of 10·5 knots an hour, the engines exerting an indicator power of 1440 horses, and the displacement being at the same time 2380 tons, as taken from the scale of displacement.

Then, as 10·5 knots : 10 knots :: $\sqrt{1440 \text{ H.P.}}$

$\sqrt{\text{indicator power required}}$;

Or, 1157·625 : 1000 :: 1440 : 1243·9.

And 1243·9 : 2380 :: 100 : 191·3 = tons of displacement propelled, in this vessel, by 100 indicator horse power at the rate of 10 knots an hour.

Example No. 2.—Another vessel, on trial, is found to have a speed of 10·4 knots; her engines exerting an indicator power of 919·6 horses, and her displacement at the same time being 1323 tons.

Then, as 10·4 knots : 10 knots :: $\sqrt{919 \cdot 6 \text{ H.P.}}$: $\sqrt{\text{required H.P.}}$

Or, 1124 8 : 1000 :: 919·6 : 817·5,

And 817·5 : 1323 :: 100 : 161·8 = tons of displacement propelled, in this vessel, by 100 indicator horse power, at the rate of 10 knots an hour.

Comparison between the Screw and the Paddle as a Means of Propulsion.—This leads us to consider the broad question of the relative merits of the two great rival modes of propulsion, by *screw* or by *paddle wheel.*

General View of their respective Efficiency for full-powered Passenger Steamers.—Although the screw certainly possesses many advantages over its rival, which are at once apparent, these must, nevertheless, be considered of minor importance, in the case of passenger steamers, if it fail to ensure the same amount of regularity and speed which we are accustomed to obtain from the paddle wheel, with engines of the same power. That this deficiency actually exists *at present* is incontrovertible, and this has hitherto prevented the adoption of the screw in steamers designed for quick

passenger traffic, both for ocean and river navigation: the general impression amongst practical men of the present day being, that it is inapplicable in the first case from its observed deficiency of power when the vessel is pitching while steaming head to wind; and, in the second case, that a considerable draught of water is requisite for its efficient action. Although experience certainly favours these views, the staunch advocates for the screw will not willingly admit their truth; and if its very recent introduction be considered, as well as the rapid advances which have really been made in improving it, it is, perhaps, natural that they should withhold their assent.. The slow progress that was made in bringing the paddle wheel to its present state of efficiency must not be forgotten, especially as the shipbuilders of the present day have shown as much desire to box up the screw in its position, as their predecessors did to keep the paddle wheel buried in sponsons.

Efficiency of the Screw for full-powered Steamers of War.— The value of the screw in vessels of war, not only as an auxiliary, but also in full-powered steamers, seems to admit of but little doubt.—A clear broadside for the guns; the comparative safety of the machinery from shot owing to its low position; the increased stability of the ship from the same cause, enabling her to carry heavier armament on the upper decks; and the freedom of these decks from the machinery; and finally, the power of arranging the masts, sails, and rigging, so as to make her an efficient sailing vessel, are advantages of such moment, that even if a considerably higher power were required to realize the same speed as would be obtained from paddle-wheels, the adoption of the screw would appear to be justified.

Efficiency of the Screw as an Auxiliary in Sailing Vessels.— The screw, as an auxiliary propeller, to be used either in a calm, or in conjunction with sails in light or contrary winds, stands unrivalled. Several attempts have been made to adapt the paddle wheel and other propellers to this purpose; but

they have signally failed to meet the varying circumstances of the ship deeply laden, sailing light, or heeling over under a press of canvas. The efficiency of the screw, however, remains comparatively unimpaired under any of these circumstances.

The Success of the Screw as an Auxiliary in Men of War.—In the Royal Navy, the best test of its success in this respect is, that the screw vessels employed in cruizing for slavers have been pre-eminently serviceable. It has been also perfectly successful in the various classes of vessels in which it has been fitted as an auxiliary, from the *Plumper* of 9 guns, up to the Frigate *Arrogant* of 46 guns, and the old 72-gun ships converted into guard ships, and it is anticipated that the largest ships of war will have this additional service.

The Effect that Auxiliary Screw Vessels may have on the Shipping Interests of the Country.—The success of auxiliary-screw merchantmen has already been such, that it appears probable that the whole commerce of the country will be carried on by them at so reduced a cost as to beat out of the field all sailing vessels, not only of this but of other countries; the value of speed and regularity being now so greatly and so truly appreciated by merchants. If there be any truth in this view of the case, the results to the country will be most important; but they must be carried out with energy by the combined efforts of ship-owners, ship-builders, engine-makers, sailors, and engine-workers, and this will not be done without a struggle on the part of some of those in favour of their old-established habits.

The *City of Paris,* built by Messrs. William Joyce & Co., is an iron steam ship built for the Commercial Steam Navigation Company, and plying with passengers and goods between London and Boulogne. Her principal dimensions are—

					ft.	in.
Length between perpendiculars	.	.	.	.	165	0
Breadth of beam	.	.	.	.	23	0
Depth of hold	.	.	.	.	14	0
Draught of water	.	.	.	.	6	6
Burthen	.	.	.	.	.	425 tons.

Speed per hour in still water, 15·75 statute miles.

The vessel and engines were constructed by Messrs. William Joyce & Co., of the Greenwich Iron Works; and, as a matter of interest, it may be mentioned that this is the first iron steam ship ever built at Greenwich.

Her engines are of the collective power of 140 horses, and are of the direct action kind. Each piston has two rods, between which there is a recess in the piston, which allows of a corresponding recess in the cylinder covers, and thereby permits the connecting rods to descend considerably lower than is practicable in the single-rod direct action engine. The arrangement is most compact and simple; and it is manifest that the cylinders being fixed a most important advantage is secured.

These engines occupy less space than any other description of marine engine yet known; and both the engines and boilers may be taken as a fair specimen of the great reduction of space and weight effected by modern arrangements over the earlier examples of steam machinery as applied to naval purposes.
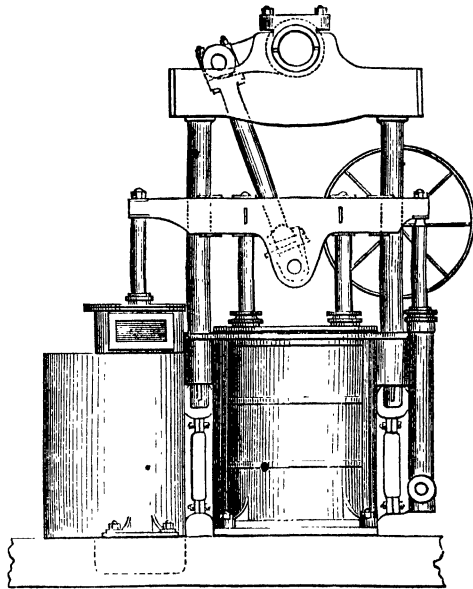
Pacha of Egypt Steam Yacht Kassed Kheir, is a fine schooner-rigged steam screw yacht, constructed of iron. Her dimensions are—

				ft.	in.
Length between perpendiculars	.	.	.	150	0
Breadth of beam	.	.	.	18	0
Depth of hold	.	.	.	11	0
Mean draught of water	.	.	.	6	6
Burthen, O. M.	.	.	.	240 tons.	

Built by Messrs. William Joyce & Co., Greenwich Ircn Works, and fitted by them with a pair of vibrating engines of collective

Horses' power, nominal	.	.	.	80
Horses' power, by indicator	.	.	.	311
Diameter of cylinder	.	.	. ft.	0 38 in.
Length of stroke	.	.	.	0 30
Strokes per minute, 42.				
Multiple of gear, 5 to 1.				
Screw propeller diameter	.	.	.	6 6
,, pitch	.	.	.	7 3
,, length	.	.	.	1 3
,, number of blades, 2.				
Revolution of screw, 210.				
Speed of vessel, 14 miles.				

Of the Spiral Propeller or Water-Screw.—The acting portion is a spiral surface projecting from a cylindrical axis * and, in order that it may be at all effective, each point in the surface must revolve so rapidly, that the motion of that point in the direction of the axis must be greater than that of the vessel. Also, if the angle of the spiral to the axis be constant, it is obvious, that by having more than one revolution, the rest add little to the effect, perhaps not equivalent to the additional friction.

Let B A C · *a* be the angle which the screw forms with

a line A B perpendicular to its axis; then, during the time

* See Tredgold's Work on the Steam Engine, Division B, Marine, new edition.

the boat would move from C to B, a point in the surface must move from B to A, otherwise it would retard the boat; and, in order that it may be effective, it must move at some greater velocity. But the velocity of the boat, v, is to that of a point in the surface, when no effect is produced, as

$$BC : AB :: v : \frac{AB.v}{BC} = \frac{v}{\tan. a}.$$ Hence the actual effective

velocity must be

$$V - \frac{v}{\tan. a} = \frac{V \tan. a - v}{\tan. a}.$$

Let x be the variable radius of the cylinder, then $\frac{2 \pi x}{\cos. a} =$ the length of the spiral, and $\frac{2 \pi x\, d x}{\cos. a} =$ the differential of its area. Its resistance is therefore

$$\frac{\pi (V \tan. a - v)^2 (2 \sin. a^3 + \sin. a^2) x\, d x}{\cos. a \tan.^2 a},$$

when the vessel is at rest; and when it is in motion, it increases in the ratio of $\frac{V \tan. a - v}{\tan. a} : v$; hence

$\pi v (V \tan. a - v) (2 \sin.^2 a + \sin. a) x\, d x =$ the differential of the resistance.

The integral gives

$\frac{1}{2} \pi v x^2 (V \tan. a - v) (2 \sin.^2 a + \sin. a) =$ the resistance.

This resistance is to the effect to impel the boat as the radius is to tan. a; hence

$\frac{1}{2} \pi x^2 v (V \tan. a - v)^2 (2 \sin. a^2 + \sin. a) \tan. a =$ the force,

and $\frac{1}{2} \pi x^2 v^2 (V \tan. a - v) (2 \sin.^2 a + \sin. a) \tan. a =$ the effect,

which should be equal to the resistance of the vessel.

CHAPTER XII.

SCREW STEAMERS IN THE ROYAL NAVY AND MERCHANT SERVICE.

Full-powered Vessels: The Rattler.—The *Rattler* is a vessel of 888 tons burthen, and has engines of 200 horse power collectively. The area of her submerged midship section (at 10 ft. 6 in. draught) is 330 square feet. Her most favourable experiments were made with the common or Smith's two-threaded screw, 10 feet diameter, 15 inches long, and 11 feet pitch, the effective surface being about 23 square feet. With this screw the engines made 26·19 revolutions per minute, and the screw 103·67 ; the speed of the vessel being 10·074 knots an hour, and the slip of the screw 10·72 per cent.

Dimensions and Speed of the Fairy.—The following are the dimensions of H. M. steam yacht *Fairy,* also a favourable specimen of screw propulsion.

Length between the perpendiculars	.	. 144 ft. 8 in.
Breadth of beam for tonnage . . .	. 21 ,, 1½ ,,
Depth in hold , ...	. 9 ,, 10 ,,
Burthen in tons, builder's old measurement	. 312 ,,
Horses power	. 128 ,,
Draught of water	. 6 ,,
Diameter of screw	. 5 ,, 4 ,,
Length of screw	. 16 ,,
Revolution of engines per minute . .	48 ,,
Ditto screw, per minute . . .	240 ,,

Maximum speed of the vessel, 13¼ knots.

Dimensions and Particulars of Termagant.—*Termagant,*
steam frigate, 24, propelled by the screw. Designed by
White of Cowes, engines by Seaward.

            Length between perpendiculars   .   210 ft. 1 in.
            Length of keel for tonnage .   .   . 181 ,, 0 ,,
            Breadth extreme   .   .   .   .   .   40 ,, 6 ,,
            Breadth for tonnage   .   .   .   .   40 ,, 0 ,,
            Breadth moulded   .   .   .   .   39 ,, 4 ,,
            Depth in hold   .   .   .   .   .   25 ,, 9 ,,
            Burthen in tons   .   .   .   . . 1547 ,, 0 ,,
            Horses power   .   .   .   .   . 620 ,, 0 ,,
            Length of space for machinery, placed under
                the water line   .   .   .   .   .   85 ,, 0 ,,

  The stores—280 tons of coals in boxes, 6 weeks' provisions for 320
men, and 53 tons of water. She mounts four 10-inch guns, and two
8-inch guns, on the upper deck; and eighteen 32-pounders on the main
deck.

During her trial of speed in Stoke's Bay, her draught of
water was 16 feet forward and 18 feet aft, with 260 tons
of coal in boxes. The pitch of her screw (14 ft. 6 inch.
diameter), was 17 ft. 3 inch. The vacuum in the conden-
sers $27\frac{1}{2}$ inches; revolutions of screw 36 to 37 per minute.
Steam in boilers 14 lbs. Under these circumstances she
attained an average speed of $9\frac{1}{2}$ knots an hour.*

  Dimensions and Particulars of Encounter.— Screw steam
sloop, 14 guns, designed by Fincham; engines by Penn.

            Length between perpendiculars   . ;   190 ft. 0 in.
            Breadth extreme   .   .   .   .   32 ,, 2 ,,
            Depth in hold .   .   .   .   20 ,, 10 ,,

  * Although this trial is allowed to have been of the most favourable
nature, the *Termagant's* speed falls short, by at least 2 knots an hour,
of what similar vessels with the same high proportion of horse power to
tonnage, and *fitted with paddle-wheel engines by the same makers,* have
attained.

Tonnage, builder's old measurement .	953
Horses power, nominal . . .	360
Horses power, by indicator . .	646
Displacements at 12 ft. 6 in. mean draught	1290 tons.

This vessel has been one of the most successful of the full-powered screw steam vessels yet constructed. At her load draught of 12 ft. 10 in. aft and 12 ft. 2 in. forward, she realised a speed of 9½ knots under steam alone, and when light she has steamed at 10¼ and 10½ knots. Her sailing powers are also good, as she has kept her place under canvas when in company with a squadron. On a trial in going before the wind, when the frigates of the experimental squadron were making 10 knots, the *Encounter* was found to lose ground, but on her getting up her steam she over-hauled them, attaining a speed of 13 knots, with full canvas and full power of steam combined. The engines on this occasion made 74 strokes per minute, and as the pitch of the screw is 15 feet, and it is driven direct from the engine, the vessel over-ran her screw and gave a negative slip, and realized a higher velocity than could be obtained from her under any other circumstances.

Dimensions and Particulars of the Arrogant.—Screw frigate, 48 guns; designed by Fincham; engines by Penn.

Length between perpendiculars .	200 ft. 0 in.
Breadth extreme	45 ,, 9 ,,
Depth in hold	29 ,, 6 ,,
Tonnage, builder's old measurement .	1872
Horses power, nominal . .	360
Horses power, by indicator . .	623
Displacements at 18 ft. 11 in. mean draught	2444

Trials of Arrogant *(Auxiliary)*.—During the *Arrogant's* trial in the estuary of the Thames, she had on board her full complement of men, viz. 450; provisions for 140 days, stores for 12 months, and water for 80 days. Under these

circumstances the engines made 63 revolutions per minute (working full power), and the speed of the vessel was 8·6 knots: consumption of fuel at the rate of 32 tons of coal in 24 hours: with a slight head swell, no sails being set.

Trials of Arrogant.—Subsequently, upon the occasion of her steaming round to Portsmouth to be put into commission, this fine frigate (which is one of the most successful of our auxiliary steam fleet) made an average speed of seven and a quarter knots an hour, at the measured mile in Long Reach, under the following circumstances: She had on board 246 tons of coal, 187 tons of water in tanks and 13 tons in casks; also her full armament, viz. two 68 pounders of 95 cwt. each, mounted on traversing platforms and pivots, and sixteen 32-pounder guns of 32 cwt. each, on the upper deck; twelve 8-inch guns for 56-pounder hollow shot, or 68-pounder solid shot, and sixteen 32-pounder guns of 56 cwts. each, for the main deck. Her draught of water on starting was 18 ft. 9 inch. aft. and 16 ft. 10 inch. forward. Average number of revolutions of screw, 62 per minute. The engines are 6 feet under the water line, and the top of the steam chest three feet. By trial on this occasion between the Nore and Mouse Lights (where there is deep water), she is said to have made 8·3 knots by the log, the engines making 57 to 59 revolutions against the wind, and 61 to 62 revolutions with the wind. The engine room is ventilated by a fan driven by the supplementary engine.

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La Hogue.—*La Hogue*, steam guard ship, old 74-gun ship, 1750 tons of burthen, and fitted with engines by Seaward of 450 horses' power, has a speed of 7·2 knots, the engines making 49 revolutions per minute, and consuming 28 tons of coal in 24 hours.

Ajax.—*Ajax*, steam guard ship, old line-of-battle ship of

60 guns, 1761 tons, with auxiliary steam power of 450 horses, propelled by the screw. Mean speed at the measured mile in Stoke's Bay, with all her weights aboard and lower masts in, 7·147 knots per hour. Draught of water forward 21 ft. 11½ in.; aft, 23 ft. 1½ inch. Height of lower deck midship portsill, above the water, 5 ft. 5⅓ in. The engines are horizontal, by Messrs. Maudslay, with 4 cylinders, each 55 inches diameter and 2 ft. 6 in. stroke. Smith's screw 16 ft. diameter, and 20 ft. pitch. The engines are applied direct to the screw shaft, and make 48 revolutions per minute.

The use of Screw Vessels as Tugs.—Many experiments have been made with screw vessels in towing, and the results have generally been most favourable. With a paddle-wheel steam vessel not expressly designed for towing, the revolutions of the engines are much reduced on taking a heavy vessel in tow, and she is consequently unable to work up to her full power, while the screw vessel is comparatively little affected in this respect, and continues to work with comparatively little loss of power. In assisting a vessel that may have got on shore this difference becomes particularly apparent, because the engines of the paddle-wheel steamer when she is held fast are reduced to about one half their number of strokes, and consequently to nearly one half their power; the engines of the screw vessel not being reduced under the same circumstances more than about 10 per cent. Auxiliary screw vessels also of moderate speed have been found to be wonderfully efficient as tugs, arising no doubt mainly from the foregoing cause. The screw vessel can also be brought alongside or be communicated with more readily than the other.

The Screw in the Merchant Service.—The machinery for screw vessels in the merchant service is not confined by the same requirements as in the Royal Navy, and consequently

the screw has generally been made larger in diameter in proportion to the vessel, and in many instances engines of the same form as those used for paddle-wheel steamers have been continued and toothed wheels introduced to obtain the requisite number of revolutions for the screw shaft. The first results obtained from this course are good, on account of the less liability to derangement in engines of tried and good construction, but in all vessels of large power it is to be feared that the wear upon the teeth of the wheels will be such as to give much trouble and cause constant renewal necessary. If the amount of surface of the teeth in action and the intensity of the power passing through them be compared with the proportions in general use in wheel-work in the manufacturing districts, it will be evident that it would be impossible on board ship to continue the same proportions without rendering the wheels much too heavy and cumbersome. In auxiliary vessels, there is no difficulty in obtaining a sufficient velocity for the screw with direct-acting engines and a somewhat coarse pitch, but in full-powered vessels the question becomes more difficult, though, it is believed, not insurmountably so, when it is considered that locomotive engines are running at 200 strokes per minute with ease and certainty. The difficulty of driving the air pump at the high velocity required has been the main difficulty in the way, but the introduction of canvas or vulcanized india rubber valves appears to be one way of getting over it, while the introduction of a pair of wheels to reduce the speed of the air pump, or of a totally different engine fitted on board for the express purpose of working the air pump, have also been proposed. By the latter proposal the engines for propelling the vessel are placed in all respects on a perfect equality with the common locomotive engine, or they may indeed be made even more simple than these by attaching the feed pumps to the supplementary engine, which would be driven at the ordinary speed.

Performance of the Screw in Vessels of General Screw Steam Shipping Company.—The following statement by the managing director of the " *General Screw Steam Shipping Company,*" presents a highly favourable view of the performance of the screw as an auxiliary propelling power in the vessels of that company, from the 1st of January to the 31st of December, 1849. It is remarked, that the seven vessels specified have made altogether during the year 170 voyages, out and home, with cargoes, performing a distance of 110,849 knots, at an average speed of 8 to 8½ knots per hour. Only one casualty is stated to have happened during the year to any of the Company's vessels, and that in the Thames.

Performance of the Screw on Canals.—An able report, made by Sir John Macneill, C. E., is inserted in the Appendix, p. 225.*

City of Rotterdam, 272 tons, 33 horse power, has made during the year 42 voyages to French and Dutch ports, performing 15,450 miles, at an average speed of 8 knots.

City of London, 272 tons, 30 horse power, has made 44 voyages to Dutch ports; total distance 13,327 miles; average speed 8 knots.

Lord John Russell, 320 tons, 40 horse power, has made 50 voyages to Dutch ports; total distance 25,379 miles, at an average speed of 8½ knots.

Sir Robert Peel, 320 tons, 40 horse power, has made 3 voyages from Liverpool to Constantinople, and 21 voyages to ports of France and Holland; total 24 voyages, 28,206 miles, at an average speed of 8½ knots.

Earl of Auckland, 450 tons, 60 horse power, has made 4 voyages to Constantinople, and 6 to ports of Holland, Portugal, and France; total 10 voyages, 28,487 miles.

* Kindly communicated by John M'Mullen, Esq., of Dublin.

Bosphorus, 536 tons, 80 horse power. Laden with 360 tons of merchandise, and 120 tons of coal: took 16 days 15¼ hours on her first voyage from Liverpool to Constantinople. Sailed 15th September, 1849; average speed 8·02 knots. Left Constantinople October 10; time on passage 15 days 11½ hours; average speed 8·50 knots.

Hellespont, 536 tons, 80 horse power. Laden with 360 tons of merchandise, and 120 tons of coal. Sailed from Liverpool for Smyrna October 15th; time on the passage 16 days 20½ hours; average speed 7·93 knots. Sailed from Smyrna November 14; time on the passage 18 days 6 hours 30 minutes; average speed 7·20 knots. Average speed of four passages 7·91 knots.

Speed at the trial of *Bosphorus* at the measured mile in Long Reach, 9·68 knots.

Speed at the trial of *Hellespont* at the measured mile in Long Reach, 9·65 knots.

Dimensions and Particulars of Bosphorus.—*Bosphorus* is 175 feet long ; 25 feet beam ; 536 tons burthen ; and 80 horses' power. Diameter of cylinders, 36 inches; stroke, 24 inches; diameter of screw, 10 feet, 6 inches; pitch, 18 feet, 6 inches; mean number of revolutions, 62 2; length of the engine-room, 30 feet, which includes space for the stowage of 150 tons of coal; draught of water on trial, forward, 6 feet, 8 inches; aft, 9 feet, 6 inches, the screw being 14 inches out of the water. Mean speed as above, 9·679 knots; speed of screw, 11·348 knots; slip of screw, 1·669 knots, or 14·7 per cent. Builders of vessel (iron), Messrs. Mare and Co., of Blackwall. Engineers, Messrs. Maudslay, Sons, and Field.

Voyage of Bosphorus *under Steam from the Cape of Good Hope to Plymouth.*—The *Bosphorus* made the following

quick run from the Cape of Good Hope to Plymouth in
the months of June and July, 1851. She left Table Bay
at half-past two o'clock in the afternoon of May 31, passed
St. Helena near midnight of the 8th of June. At daylight
of the 17th anchored off Sierra Leone, where she stopped
17 hours to coal. Was off the Island of St. Vincent (of
the Cape de Verde group) on the morning of the 23rd.
Left again at noon of the 24th, and arrived at Plymouth on
the evening of July 7th. She consumed in her outward
and homeward voyages, 787 tons of coal, and had an average
speed of 7¾ to 8 knots.

Epitome of Rattler's *Experiments.*—Before quitting the
subject of screw-propelled vessels, I shall give a brief epi-
tome of the results obtained from the extensive and valuable
series of experiments made with the *Rattler*, in the year
1844.

Dimensions of the Vessel.—This vessel has the following
dimensions, viz :—

	FT.	IN.
Length between the perpendiculars . . .	176	6
Length on keel	157	9½
Breadth of beam	32	8¼
Depth in hold	18	7⅛
Burthen in tons, builder's old meas. . . .	888	0$\frac{54}{94}$
Mean draught of water during trials . .	11	3
Horses' power, 200; Maudslay, Sons, and Field, engineers.		
Speed of the engines is multiplied by gearing 4 times, nearly.		
The weight of ballast carried during the trials was .	132 tons.	
Ditto of coals	122 ,,	

Experiments.—Feb. 3, 1844. With a two-threaded com-
mon screw, 9 feet diameter, 3 feet long, and 11 feet pitch,
the vessel made 9·25 knots, the engines making 26·8 revo-
lutions per minute, and the screw 106; slip, 19.5 per cent.

Feb. 9. With a three-threaded common screw of the same dimensions as the last, the speed of the vessel was reduced to 8·23 knots, the engines making 24·2 revolutions, and the screw 94·3; slip, 19·66 per cent.

Feb. 23. When the last screw was shortened to 1 foot, 7½ inches, the vessel's speed increased to 8·57 knots, the engines making 24·8 revolutions, and the screw 98·4; slip, 19·7.

Feb. 28. With a two-threaded common screw, 10 feet diameter, 3 feet long, 11 feet pitch, the vessel made 8·958 knots, the engines making 24 revolutions, and the screw 95; slip, 13·8 per cent.

March 11. When the same screw was shortened to 2 feet, the vessel's speed increased to 9·448 knots, the engines making 25·5 revolutions, and the screw 107; slip, 13·5 per cent.

March 18. With a four-threaded common screw, 9 feet diameter, 1 foot 7 inches long, and 11 feet pitch, the vessel's speed was 9·18 knots, the engines making 26·3 revolutions, and the screw 104·4; slip, 27·7 per cent.

April 13. With a four-threaded Woodcroft's increasing pitch screw, of the same dimensions as the last, the pitch varying from 11 feet forward to 11 feet 6 inches aft, mean, 11·275, the speed of the vessel was 8·159 knots, the engines making 24·15 revolutions, and the screw 96; slip, 23·5 per cent.

April 18. With the same screw as the last, but with two of the blades cut off, the vessel's speed advanced to 8·63 knots, the engines making 27·07 revolutions, and the screw, 107·5; slip, 25·97 per cent.

April 23. With Smith's or common screw (of cast brass), 9 feet diameter, 1 feet 2 inches long, and 11 feet pitch, three-

threaded, the vessel's speed was 9·88 knots, the engines making 27·39 revolutions, and the screw 108·4 ; slip, 15·97 per cent. Air quite calm.

June 13. With a common two-threaded screw, 10 feet diameter, 1 foot 6 inches long, and 11 feet pitch, the speed of the vessel was 9·811 knots; the engines making 27·92 revolutions per minute, and the screw 110·7 ; slip, 18·3 per cent.

June 27. The same screw as last, reduced in length to 1 foot 3 inches, gave a speed of 10·074 knots for the vessel ; the engines making 26·19 revolutions, and the screw 103·97 ; slip, 10.42 per cent.

   Note.—This is the most favourable result obtained during the experiments.

October 10. With Mr. Sunderland's propeller, 8 feet in diameter, the vessel's speed was 8·38 knots; the engines making 17·49 revolutions, and the screw-shaft 69·97.

October 12. With Mr. Steinman's propeller, 10 feet 1 inch diameter, the vessel's speed was 9·538 knots ; the engines making 25·06 revolutions, and the propeller 104·24 ; the pitch 11 feet 6 inches ; slip, 29·32 per cent.

October 17. With the common screw, 10 feet diameter, 11 feet pitch, 1 foot 3 inches long, the speed of the vessel was 9·893 knots; the engines making 27·03 revolutions, and the screw 108·12 ;—slip 15·65 per cent.

The experiments show, therefore, that the *common* screw, of the dimensions last quoted, gave a higher result than either Mr. Woodcroft's, Mr. Sunderland's, or Mr. Stein-man's.

Thrust on the Dynamometer.—Experiments were made during the last three trials to ascertain the actual thrust of

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33) 1070 (32·42 *mean*

Dynamometrical Figure taken from the Screw Shaft of the Rattler.

the screw in propelling the ship, by observing the pressure on the spring of the dynamometer fitted to the end of the shaft. The results were as follow :—

October 15. With Sunderland's screw, the speed of the vessel being 8·346 knots, the pressure on the end of the shaft was 2·88 tons; the horse-power calculated by the dynamometer being 164·9, and by the indicator 320 horses : the ratio of the two powers being as : 1·94. When the speed of the vessel was reduced to 6·698 knots, the pressure on the end of the shaft was 1·86 tons, equal to 85·85 horse-power by the dynamometer, the indicator showing 173·2 H.P.

October 12. With Steinman's screw, the speed of the vessel being 9·537 knots, the pressure on the end of the screw shaft was 3·35 tons; the horse power calculated by dynamometer being 219, and by indicator 452—the ratio of the two powers being as 1 : 2·7.

October 17. With the common screw, the speed of the vessel being 9·893 knots, the pressure on the end of the screw-shaft was 3·61 tons; the horse-power cal-

culated by dynamometer being 245, and by indicator 465·6
—the ratio of the two powers being as 1 : 1·9.

Loss of Speed by Expansion Gear.—Experiments were
likewise made with the expansion-gear of the *Rattler's* en-
gines, to ascertain the loss of speed in the engines, caused
by applying successively each of the expansion cams. The
stroke of the engines is 4 feet, and the slide valve was set
to cut off one-quarter of the stroke, or one foot. The ex-
pansion cam has six steps, each cutting off four inches of
the stroke ; so that when the last step is working, the steam
is expanded for three feet, or three-quarters of the stroke.

With the
1st step of the cam, the engine made	25·2 double strokes per minute.
2nd	,,	,,	25·1	,,	,,
3rd	,,	,,	23·9	,,	,,
4th	,,	,,	23·4	,,	,,
5th	,,	,,	22·4	,,	,,
6th	,,	,,	21·3	,,	,,

Each of these experiments lasted five minutes, the mean
being then taken.

Power consumed in driving her Machinery, per Indicator.—
Another set of experiments were made with the indicator,
to ascertain the amount of power consumed in driving the
Rattler's machinery. The results were as follow:—

I. Without any gearing attached, the mean working
   pressure on the piston (taking the mean of both en-
   gines) was 1·1 lb. per square inch, the engines making
   26 revolutions per minute, and the vacuum in the con-
   denser being 28 inches.

II. With the gearing and screw-shaft attached, but with
   the straps slack, the mean pressure was 1·67 lb., the
   engines making 25 revolutions, and vacuum in the con-
   denser 28¼ in.

III. With gearing and screw-shaft attached and straps tightened (but the screw not in gear), the main pressure was 2·24 lbs., the engines making 25 revolutions, and the vacuum in the condenser 28½ in.

IV. With Woodcroft's four-threaded screw in gear, the mean working pressure indicated was 14·57 lbs., the engines making 24·85 revolutions.

V. With the three-threaded screw in gear, the mean working pressure indicated was 14·38 lbs., the engines making 26·2 revolutions.

Dwarf's *Experiments.*—In connexion with this subject there will be found at the end of the book a Table of Experiments with Her Majesty's Steam Tender *Dwarf* (of 164 tons and 98 horses' power), undertaken at Woolwich in the year 1845, to determine the best relative proportions for the screw-propeller, with regard to *pitch, length,* and *area.* The whole of the screws used in these trials were true Archimedean screws. From this Table it appears that the most favourable results were obtained from a double-threaded screw of 5 feet 8 inches diameter, with a pitch of 8 feet, the length of segment being 18 inches, and the area 13·3 square feet; and it is remarkable that in the experiment following this, when the length of the screw has been reduced to 12 inches and its area to 8·9 square feet, there is scarcely any appreciable variation in the resulting speed of the vessel or screw.

The possible effect of Screw Steamers on future Mail Contracts.—The large sums paid by this country at the present time for the conveyance of the foreign mails by steam vessels, cause this question to be one of great importance. The increasing number of superior screw vessels between Liverpool and New York, which will undoubtedly make their passages within a short time of the regular mail

packets, necessarily attract public attention to the question
of the amount to be paid for the receipt of the American
or West Indian correspondence, perhaps not more than one
day earlier, and also whether a different principle is to be
adopted with these than with the mails carried on the rail-
ways. The latter are not carried by the fastest possible
express trains running at great cost; and if this principle
be once admitted, there is no doubt but that great economy
would result, and, perhaps, ultimately without any loss of
speed whatever. It is believed that the mails might be car-
ried by steamers on all the great lines at an almost nominal
cost, and the necessity of a large and wealthy company be
obviated, if the Government were to make contracts to suit
parties who are the owners of, perhaps, only one or two
such vessels as are required. If fortnightly voyages, for
instance, are desired, there appears to be no difficulty, be-
yond a little extra trouble to the Government authorities,
in taking the contracts with two or three, or any number
of separate parties, to sail consecutively—one party under-
taking to send their vessel on the 1st of every alternate
month, or at such intervals as will suit the length of the
trips to be made. Such an arrangement would ensure suffi-
cient competition on taking the contracts to lessen the
amount demanded, as parties owning competing vessels
on the station would be ready to subject themselves to the
necessary restrictions for almost no other consideration
than the being able to advertise their "Royal Mail Steam-
ers," on account of the additional favour that they would
thus obtain with the public. A competition would also be
created between the different contractors, tending to in-
crease the speed of the vessels beyond that required by the
Government, with the view of getting the greater number
of passengers—a competition of this kind having been
already felt to be very much wanted. This principle would
also enable the Government to make contracts for new

lines where regular communication may be very much wanted by the country, but not of sufficient importance to induce the formation of a company with sufficient capital to undertake the whole line, though one or two different parties might each undertake to despatch a vessel at certain intervals.

Tables of Screw Steamers and their Machinery.—Amongst the Tables at the end there will also be found a

Table of the Dimensions of Screw Steamers and their Machinery, in the Royal Navy.

Table of the Principal Dimensions of 28 Merchant Screw Steamers.

Government Formula of Specification for Marine Steam Engines with Screw Propellers.

Tender to the Admiralty for Marine Engines, with Screw Propellers, of 450 horses power.

Admiralty List of Tools and Spare Gear required with those Engines.

CHAPTER XIII.

THE PADDLE WHEEL AND PADDLE-WHEEL STEAMERS IN THE ROYAL NAVY AND MERCHANT SERVICE.

Paddle-wheel Steamers in the Royal Navy.—WE shall now note a few particulars of our most successful PADDLE-WHEEL STEAMERS, both in the Royal Navy and Merchant Service, beginning with the *Terrible*.

Dimensions and Particulars of Terrible.—This fine steam frigate, built from the designs of Mr. Oliver Lang, of Woolwich, was commissioned in the year 1846. She is built of Honduras mahogany, East Indian teak, and English oak.
Her principal dimensions are as follow :—

Terrible Steam Frigate of 1847 Tons and 800 Horse-power.

	ft.	in.
Length between the perpendiculars	226	0
Ditto keel for tonnage	196	10
Breadth extreme	42	6
,, for tonnage	42	0
,, moulded	41	2
Depth in hold	27	0
Burthen in tons, builder's old measurement 1847		
Length from the figure-head to taffrail	253	9
Depth from under side of keel to crown of figure-head	37	7
Length of the engine room	78	7
Width of ditto, in the clear	38	0
Depth of ditto	27	4
Launching draught of water, forward	8	10
Ditto ditto aft	11	6
Load ditto mean	17	6

Terrible's Machinery.—The engines, of 800 horses power collectively, are by Messrs. Maudslay and Field; double-

cylinder direct action, with tubular boilers divided into sections, placed two before and two abaft the engines. Diameter of cylinders each 72 inches; stroke, 8 feet. Paddle wheels, 34 feet diameter × 13 feet.

The contract weight of the engines was			.	212 tons.
,,	,,	boilers .	.	150 ,,
,,	,,	water in boilers	.	138 ,,
,,	,,	paddle wheels	.	44 ,,
,,	,,	coal boxes	.	16 ,,
	Total estimated weight of machinery			560

The coal boxes were estimated to contain 800 tons of coal, although Sir Charles Napier affirms that 500 tons only are carried.

The contract price of the machinery was £41·250.

Speed.—The *Terrible's* speed at the measured mile, with sea-stores and guns on board, was found to be 11·78 miles, or 10 knots an hour, the engines making 13 strokes per minute. By Massey's log the speed was found to be 10·9 knots, the engines making 14¼ strokes per minute.

Armament.—Her armament consists of 21 guns, viz. two 8-inch and two 56-pounder long guns of 98 cwt. each, on traversing platforms, on her upper deck, with two 12-pounder carronades, and one 6-pound brass gun, forward, and two 8-inch and two 56-pounder guns aft. The lower deck has the same armament, with the exception of the carronades and the brass gun.

Terrible's *Daily Expenses.*—The expense of this costly steamer has been recently brought to light by the Report of the "Select Committee on Navy Estimates," where it is stated that the *Terrible*, with a complement of 320 men, costs per day in pay and provisions, £44 5s. 2d.; and in wear and tear of hull, masts, yards, &c., £25—together,

£69 5s. 2d. per day. The wear and tear of machinery, and consumption of oil, tallow, &c., is estimated at £19 11s. 2d. per diem — making the total expenses, exclusive of fuel, £88 16s. 4d. per diem. When the ship is under steam, an additional expense of £4 5s. 6d. *per hour* is incurred, equal to £102 per diem for coals alone; or at 100 days steaming, to £10,200 per annum. The vessel and machinery thus cost £32,418 1s. 8d. per annum, exclusive of coals; or £42,618 1s. 8d. when the steam power is used for 100 days of 24 hours each. She proved herself, however, to be a very efficient steamer, good speed having been obtained from a very reduced power.

Sidon.—*Sidon* steam frigate, of 1328 tons, and 560 horse power. This vessel is constructed by Mr. Fincham, the machinery by Seaward under Sir Charles Napier's superintendence.

The following are her principal dimensions, viz.—

		ft.	in.
Length between the perpendiculars	.	210	9
„ of keel for tonnage	. .	185	9¾
Breadth, extreme . . .	.	37	0
„ for tonnage	. .	36	6
„ moulded	. .	35	10
Depth in hold	. . .	27	0

The *Sidon* carries about 700 tons of coal, with her main deck portsills 6 feet 6 inches above the water; the coal boxes being so fitted that when the coals are expended, water ballast may be taken in, to prevent too great a variation in the dip of the wheels. Her armament is, we believe, twenty-four 68 pounders, on two decks. The speed of the *Sidon* with her coals, guns, and sea stores on board, equals 10 knots.

Odin.—*Odin* steam frigate of 1326 tons, and 560 horses power, has the same dimensions as *Sidon,* except being two

feet shorter and three feet less depth in hold. The vessel is constructed by Mr. Fincham, the engines by Fairbairn.

The principal dimensions of the machinery are as follow:—

	ft.	in.
Diameter of cylinders	0	87½
Length of stroke	5	9
Stroke per minute	19	0
Diameter of paddle-wheels, extreme	27	0
Breadth of ditto	9	6
Diameter of necks of paddle-wheel shaft .	0	16

Coals stowed in boxes, 445 tons, or 12½ days' consumption at 6 lb. per horse power per hour.

The engines are upon Messrs Fairbairn's direct-action principle.

		tons.
Weight of the engines and paddle shafts	.	180
,,	boilers and their apparatus	.	60
,,	water in boilers . .	.	48
,,	coal boxes . . .	.	16
,,	paddle wheels . . .	.	30
,,	spare gear, floor plates, &c.	.	25
	Total weight of machinery .	359

Cost of engines, boilers (with iron tubes), and coal boxes	.	£21,480
,, paddle wheels	.	950
,, duplicates and spare articles, as per admiralty list	.	1650
	Total cost of machinery .	. £24,080

Length of the engine room, 52 feet; of coal hold, 8 feet—together, 60 feet.

Breadth of the engine room in the clear, 34 feet 4 inches; depth, 20 feet; centre of shaft, 8 feet 6 inches above the load water-line.

Odin's *Machinery.*—The boilers are tubular, with iron tubes 3¼ inches internal diameter, divided into four sections, placed two at each end of the engine room. Fire surface in boilers, 80 square inches per horse power. Effective heat-

ing surface (after deducting one third of tube surface as non-effective), 13 square feet per horse.

Diameter of steam pipes, for each engine   .   .   19 in., bore.
    ,,   injection pipes   ,,   .   .   .   6   ,,
    ,,   feed pipes, and bilge pipes   .   .   5¼   ,,

Speed.—The speed of the *Odin* with coals, sea-stores, and armament on board, averaging 11½ knots. Both *Sidon* and *Odin* are excellent sea boats, and sail well under canvas. Sir Charles Napier admits that the *Odin* beats *Sidon* a mile an hour, when each has her full complement of coals on board; and still passes her when each is loaded with coals in proportion to the horse power, which may be chiefly attributed to the increased height and weight of the *Sidon's* hull. *Odin* carries main-deck guns.

Performance of Steamers in the Royal Navy—with and without Steam.—In evidence before the Committee of the House of Commons,* on the subject of arming the Mercantile Steam Marine, CAPT. HENDERSON, of the *Sidon*, declares his ship to be " the best steam vessel he ever saw; she could take 700 tons of coals, which would last 20 days at full speed. She is rigged as a barque, and spreads as much canvas as a 32-gun frigate—more than any other steamer he ever saw. In cruising without steam, she kept company with the *Canopus* line-of-battle ship. Has never tried the *Sidon* with merchant steamers, but has had 12½ knots with 300 tons of coals. The *Odin* is about equal to the *Sidon*. Merchant steamers with their present masts and yards would be unable to keep up with a fleet without steaming. The masts of vessels in the navy prevent them steaming so well; but there is a great economy resulting from it, because they frequently sail for months without steaming at all. If a

* This evidence in these and subsequent pages is given in a condensed form as published in the Artizan Journal for 1849.

merchant steamer could perform 10 knots with sail alone, she would be able to accompany a fleet on ordinary occasions. Whilst commanding the *Gorgon*, found that in steaming head to wind, with all the masts and yards up, it might make two to three knots difference if they were struck."

CAPT. HENRY CHADS " has tested the capabilities of the *Blenheim*, auxiliary screw, of 1747 tons and 450 horse-power. She is a most useful vessel for every kind of service, her maximum speed, under steam alone, good 6 knots. Towed the *Bellerophon* (2000 tons) at 4¼ knots. Opinion that merchant steamers could not keep company under sail with a fleet. From their rig they could not keep way without steaming, and consequently they would soon run short of coals. The *Blenheim* can sail with a fleet without steam. We attach too much importance to speed, and forget the guns. The French steamers carry 14 to 16 guns, but give up speed. Few of our steamers of war are equal to go alongside a French steamer. They have broadside armament, whereas many of ours are only armed at bow and stern. Our steam sloops carry two heavy guns; a 95-cwt. 68-pounder, and an 86-cwt. 10-inch gun, and four broadside guns, 32 pounders of 40 or 42 cwt. We have only three real steam frigates (carrying guns on the main deck), namely, the *Odin, Sidon,* and *Terrible*—and the screw vessels."

A high Speed in the Navy attainable only by an Extravagant Proportion of Horse Power to Tonnage.—The three vessels last named (which we have already particularized) are probably the fastest war steamers, properly so called, in the Royal Navy ; but it is apparent that their comparatively high speed has been obtained only by the use of an extravagant proportion of power to tonnage, such as is very rarely found in ocean steamers in the merchant service. The average speed of government steamers, when using their full power, not exceeding 8 to 8¼ knots.

Comparisons between the Performance of Government and Merchant Steamers are generally imperfect.—This comparatively low result has given rise to many unjust comparisons between the performances of government and merchant steamers ; for when we consider the peculiar qualifications demanded by a vessel of war, it will be seen that the comparison cannot be made on equal terms. War steamers are built not only to steam but to sail well ; and moreover they must be able to carry a great weight of armament on the upper deck without prejudice to their stability, and since the only effectual way of doing this is by giving them a greater relative breadth than merchant steamers are limited to, the consequence is that the hull opposes an increased resistance to the water, and the speed is diminished. Then the weight of hull and equipment of a war steamer is usually much greater than in the merchant service, causing a corresponding increase of displacement : the masts, yards, and rigging, being of greater dimensions, oppose a greater resisting surface to the air : and owing to the weight of the large guns at the extremities of the vessel demanding support from the upward pressure of the water, the lines at the bow and stern cannot be made so fine as might otherwise be desirable. Hence it follows, that the speed of the contract mail steamers, for instance, averages from one to one and a half knots above that of vessels in the navy, with a similar proportion of power to tonnage ; but if the proportion of horse power to *displacement* be taken, the comparison will generally become more favourable to the war steamer.

Economy of Steam Power the best Criterion of Efficiency in the Navy.—In estimating the performance of a government steam vessel, therefore, we should look rather to the direct distance run by the combined action of steam and sails, at a moderate but uninterrupted speed, and with a low rate of consumption of steam and fuel, than to the attainment of a high velocity, which is seldom wanted in war

steamers. The best exposition we can offer of the practical working of this combined system of steaming and sailing in the navy, has been supplied by Capt. Hoseason, in his account of the performance of the steam sloop *Inflexible*.

Performance of the Inflexible *in a Steam Voyage round the World.*—This vessel, designed by Sir W. Symonds, is of 1122 tons burthen, and 378 horses power. The engines are direct-action, by Fawcett, and the boilers are loaded to 8 lbs. on the square inch. The whole distance run (without counting going in and out of harbour) during the time she was in commission, from the 9th of August 1846, to the 28th of September 1849, was as follows :—

Steamed	64,477	nautical miles.
Sailed	4,392	,,
	68,869	
Number of days under steam . . .	345½	
,, ,, under sail alone . .	27¼	
	372¾	
Average daily steaming	186·62	knots.
Average daily sailing	161·18	,,
For the whole period	57·44	,,
Time under one boiler	76¾	hours.
,, two boilers . . .	4047	,,
,, three ,, ...	3324¼	,,
,, four ,, ...	844	,,
Total	8,292	,,

Her fires have been lighted 483 days. Total consumption of coals while under steam, 8121 tons 12¾ cwt.; coals expended in raising steam and banking the fires, 576 tons 16¾ cwt.; average distance steamed per ton of coals, 7938 knots. Consumption of coals per hour, 19,588 cwt.; ditto per day, 23 tons, 10 cwt., 12½ lbs.; average consumption of coals per nominal horse power per hour, 5·85 lbs.

It is stated that the above-mentioned distances were ob-

tained by the patent log, towed about 50 fathoms astern, out of the influence of the backwater from the wheels; the error arising from this cause, while throwing the common or hand-log, having been found on board the *Inflexible* to vary from one to four knots. It is recommended, therefore, that the patent log only should be used by a steam vessel, its results being verified by the bearings of the land, when the distances are known.

The expenditure of coal was taken by measuring every tenth bag in the ship, and every tenth bag as used by the fires, a mean being taken every four hours for the hourly expenditure.

Performance of the Inflexible.—The distance accomplished by the *Inflexible* is stated to have been reckoned only from the time the patent log was thrown overboard, and when the final departure from the land was taken.

It is further stated that she was employed for 15 months on the coast of New Zealand, during which time about 4000 tons of the Newcastle Australian coal were consumed, the best quality of which, delivered at the mines, is about ten per cent. inferior to good English coal, but rendered fully 25 per cent. inferior by being exposed on the open beach at New Zealand. A deduction should, therefore, be made for this circumstance in considering the expenditure of fuel.

On the outward voyage of the *Inflexible* to the Cape of Good Hope, in the months of August and September 1846, a run of 5502 nautical miles was accomplished on a single coaling, at a mean average speed of 7·31 knots per hour, and an average daily expenditure of 12 tons, 19 cwt. 3 qrs. 14 lb. This run was accomplished in 32 days.

On the voyage from the Cape of Good Hope to Port Jackson, Sydney, 5356 nautical miles were accomplished at one coaling, with an expenditure of 458 tons 10 cwt., being at the rate of 15 tons, 3 cwt. 2 qrs. per diem, and with a

mean average speed of 7·87 knots per hour. Time taken,
30½ days.

In calculating the consumption of coal as above, an allow-
ance of 5 per cent for "*wastage*" has been added to the
actual weight burnt in the fires—such allowance being made
in order that the captain may judge of the quantity of
coals remaining in the boxes at any time. This per-centage
was determined by experiment during the *Inflexible's* first
two voyages, when the difference of weight was accurately
noted between the coals burnt, and those received on board
in England.   It is thence argued that 5 per cent should be
subtracted from the gross quantity, if the true duty in
miles per ton of coals is sought.   We confess we are at a
loss to account for so large a wastage.

It is further stated that on one occasion, when the full
power of the engines was exerted, the *Inflexible* towed
the barque *Claudine*, and succeeded in transporting 1500
soldiers, tent equipage, and baggage, 1400 nautical miles in
12 days, four of which were occupied in the landing of one
regiment and the embarkation of another.

After service on the coasts of India and China, the *In-
flexible* returned to England by Cape Horn, thus making the
circuit of the globe, and fulfilling her comprehensive mission
in a manner most creditable to her able commander, Captain
Hoseason.

*Economy of a Moderate Proportion of Horse-power in com-
bination with the Sails.*—These results show, in a most favour-
able light, the economy of a moderate proportion of horse-
power in combination with the judicious use of the sails ; and
it is a question of much interest to the navy whether a better
average result might not be expected and obtained from
such a system, than from the present expensive fashion of
loading the vessel with very large engines whose full power
is but seldom wanted, and which monopolize so much weight

and space that sufficient coals cannot be carried for the proper development of the steam power. It is true, that by the use of a high proportion of power to tonnage the vessel has the advantage of having always a high speed at her command, *so long as the coals last;* while, by expanding the steam in her large cylinders, she may burn the fuel, on ordinary occasions, most economically, still we must remember the increased first cost of the machinery, and the increase of displacement consequent upon the great extra weight to be constantly carried (whether it be used or not), by which the speed of the vessel is permanently diminished.

A high Proportion of Horse Power requisite in the Merchant Service.—Although we thus advocate the employment of a moderate proportion of power to tonnage for the Royal Navy, say, one-horse power to three tons, this question has a different aspect when considered with reference to the merchant service. For though, as is well understood, any increase of speed requires an increased power in the duplicate ratio of the increased speed; and, therefore, a great economy would seem to result from the low proportion of power to tonnage; still, if *time* be calculated as an element (and, in reality, a very important one) in the economy of mercantile conveyance, it will be generally found that a high speed at any expense of fuel will compensate for the additional expense. As regularity of arrival, also, is of the utmost importance in passenger traffic, this can be ensured only by the employment of a high ratio of power; for it is apparent that, should the contrary forces of adverse winds and waves, of tides and currents, equal or exceed the power of the engines, the vessel may burn an indefinite quantity of fuel without making any progress. We believe that the proportion of one-horse power to $2\frac{1}{2}$ tons (builders' old measurement) will be generally found the most advantageous for merchant steamers, of from 500 to 1000 tons.

Considerations to be attended to in proportioning the Horse Power to the Tonnage.—In proportioning the horse power of a vessel, the fact is seldom borne in mind that the effective power of the engines increases in a higher ratio than simply as the tonnage, the resistance of the water to the hull of the vessel varying as the square of the cube root of the tonnage. Thus, if a vessel of 1000 tons and 500 horses power have a speed of 12 knots, a vessel of 1600 tons and 800 horse power ought, *ceteris paribus*, to have a considerably greater speed, since the square of the cube root of 1600 ($\sqrt[3]{1600^2}$, or $11\cdot7^2$) is 684 horses power only. This law is somewhat neutralized in practice, by the fact of the *displacement* usually increasing in a higher ratio than the *nominal tonnage*. If it be desired to design a vessel of a proposed size and speed, the safest mode of proceeding is to take the vessel nearest in tonnage and general description to that which it is intended to construct as a groundwork. If greater speed is required, the natural law as given in page 104, will be the guide as to the amount of additional power that will be necessary; thus if a vessel of 1000 tons and 400 horses power now running, is found to have an average speed of 10 knots, and it be desired to have a vessel of the same tonnage, with a speed of 11 knots, the proportion becomes

$$10^3 \ : \ 11^3 \ :: \ 400 : \text{horse power required.}$$

By means of this proportion 532 horses power is found to be necessary, supposing the new vessel to be of no better form, and the engines to work to the same amount of excess of indicator over nominal horse power. Much may undoubtedly be done by an improvement in form, but too much ought not to be expected from it, and though some faults may be very apparent in the original and be capable of remedy, yet it ought not to be assumed that the new vessel will be entirely free from all retarding causes.

Dimensions and Particulars of Banshee.—As a favourable example of what may be accomplished by Government builders when they are not trammelled by considerations of armament or displacement, we give the following particulars of the Holyhead Mail Packet, *Banshee :*—

Banshee, designed by Mr. O. Lang, jun., engines by Penn, is a wooden vessel. Her principal dimensions are as follows :—

Length between the perpendiculars	. . .	189 ft. 0 in.
from figure head to taffrail	. . .	209 ft. 0 in.
Breadth extreme	.	27 ft. 2 in.
" over paddle boxes	. . .	49 ft. 6 in.
Depth in hold	.	14 ft. 9 in.
Draught of water, forward	. . .	8 ft. 10 in.
" aft	. .	9 ft. 2 in.
Burthen in tons, builders' old measurement .	No. 670	
Horse power	No. 350	
Diameter of paddle wheels . . .	.	25 ft. 0 in.
Breadth of "	.	9 ft. 0 in.
Area of "	.	33·9 square feet
Dip of "	.	5 ft. 6 in.
Area of midship section . . .	.	190 square feet.
Diameter of cylinders . . .	.	72 in.
Length of stroke	.	5 ft. 6 in.
Strokes per minute	No. 30	
Speed at the measured mile, with the tide	.	21·5 stat. miles.
" " against the tide	.	15·75 stat. miles.
Mean speed	.	18·62 stat. miles.

The *Banshee* has proved the fastest of the Holyhead packets, performing the trip from Holyhead to Kingston in a little under four hours on the average. Her shortest passage is about 3⅓ hours, her longest 4½. The distance from Holyhead to Kingston is 55 nautical miles. She has, however been taken off this station and been sent to Malta, but it has been found necessary to remove one half of her boiler power to enable her to carry sufficient coals for the

longer voyages there.   Her speed has thus been reduced to
12 knots, or 13·82 statute miles.

Paddle-wheel Steamers in the Merchant Service: Asia.—
As an example of a first-class merchant steamer, we subjoin
the dimensions of the British and North American Royal
Steam-Navigation Company's new vessel, the *Asia.*

		FT.	IN.
Length of keel and fore rake	. .	·2C7	0
Breadth of beam	. . . .	40	6
Ditto over the paddle boxes	. .	63	6
Depth of hold, amid ships	. . .	27	6
Length of the engine space	. . .	92	6
Tonnage, builders' old meas.	. .	2130	$\frac{87}{94}$
Horses power	. . . . .	No. 800	

Speed, per hour (between Glasgow and Liverpool) 15 miles,
or 12½ knots.
Load draught of water, forward 19 feet, aft 19 20 feet.

Asia has a pair of side-lever engines, diameter of cylin-
ders 96 in.: length of stroke, 9 ft.; diameter of paddle
wheels, extreme, 37 ft. 6 in.; floats 9 ft. 2 in. long, × 3 ft.
2 in. broad, divided into two breadths; number of floats in
the water at one time, eight.   The boilers are four in
number, measuring together 20 feet in length, and 16 feet
in breadth; they have 20 furnaces, five in each section, each
furnace 8 ft. long, 2 ft. 9 in. broad, and 5 ft. 9 in. deep.
The coal bunkers hold about 900 tons.   The engine-room
staff comprehends 38 men, viz., eight engineers, 18 firemen,
and 12 coal trimmers.   o
   The vessel is of timber, round sterned, carvel built, three
masts schooner rigged, three decks all flush, and carries
six boats.   Builders, Messrs. Robert Steele and Co. of
Greenock; engine maker, Mr. Robert Napier, of Glasgow;
completed in the year 1850.

Dimensions and Particulars of the Orinoco.—Royal West Indian Mail Steam Packet; designed by Pitcher; engines by Maudslay.

Length between perpendiculars	. .	270 ft. 0 in.
Breadth over paddle boxes	. .	. 71 ,, 10 ,,
Breadth of vessel, extreme .	. .	41 ,, 10 ,,
Depth of hold . . .	.	. 26 ,, 0 ,,
Tonnage, builder's old measurement	.	2245$\frac{51}{94}$
Horse power, double-cylinder engines	.	800

This vessel on her first experimental trip at her medium draught of water attained a speed of 12 knots, as ascertained by careful trial at the measured knot in Stokes Bay off Portsmouth, with the engines making 13¾ revolutions per minute. She is fitted with feathering wheels, with all the latest improvements and a greatly increased length of bear·ing for the centres, on which the paddle boards vibrate. Some of the older vessels belonging to the same company have also lately had their paddle wheels altered and made to feather, with decidedly good results, arising chiefly from the circumstances that these wheels are not so much affected as common wheels by heavy seas, and by the variation in dip, to which these vessels, from their long voyage, are necessarily subject. The vessels on the North American station have hitherto been prevented from adopting these wheels by the fear of injury from ice, but it is a matter of doubt whether the advantage on those voyages on which no ice is encountered would not be so great as to compensate for the risk, especially as any partial injury, though it might prevent the feathering of the boards for the remainder of the voyage, would by no means render the wheel totally inoperative as a common paddle wheel with fixed boards. The engines of the *Orinoco* are fitted with double-beat equilibrium valves, opened by cams instead of the common slide valves or piston valves hitherto usually adopted, and in this case, as well as in the steam frigate *Penelope,* they seem to have been thoroughly successful. In the *Orinoco* the cams, which are

placed on a vertical shaft driven by wheels from the inter-
mediate shaft, drive levers which act upon a bell-crank
shaft and lift the spindles of the valves. In the *Penelope*
the cams are placed on a horizontal shaft driven by an in-
clined shaft from the intermediate shaft, and running
through an eye in an upright rod, attached by a projecting
arm to the spindle of each valve. The steam cams are made
movable on the shaft, so as to give any required degree of
expansion, while the eduction cams are stationary. The
horizontal shaft on which the cams are placed, is driven, in
the same manner as in many machines with a reversing
motion, by a clutch between two bevil wheels, running loose
on it, so that it may revolve always in one direction, accord-
ing to the motion of the wheel into which the clutch may
be geared, while the intermediate shaft revolves either way
for going ahead or going astern.

*Summary of the Peninsular and Oriental Company's Fleet
of Steamers.*—The Peninsular and Oriental Steam Navi-
gation Company have 29 steamers, amounting in round
numbers to 30,000 tons and 11,000 horses power. They
navigate annually about 600,000 miles, with 29 vessels.
Of their 29 vessels 10 are of wood and 19 of iron. The
average speed of their Mediterranean packets is 10 to 11
knots: that of Cunard's line of Transatlantic packets,
nearly 12 knots. At the present moment the new iron
steamer, the *Himalaya*, of the following extraordinary di-
mensions, is estimated to run between Southampton and
Alexandria, a distance of 3100 geographical miles, in 9
days :—

Length between the Perpendiculars	325 ft.
Breadth of Beam	43 ,,
Depth in Hold	32 6
Burthen in Tons	No. 3000
Horses Power	1200
Estimated speed, 14 knots.	

Some Particulars of the Peninsular and Oriental Com-
pany's Fleet of Steamers.—Mr. Pitcher, of Northfleet,
states before the Committee of the House of Commons,
that he "has lately built two vessels for this company, of
1200 tons each. The scantling in the midship part of those
ships is rather larger than that of ships of the same size in
the Government service, but fore and aft it is rather lighter.
These vessels are constructed capable of carrying an 8-
inch pivot gun forward, and a 10-inch pivot gun aft, and
ten broadside guns—altogether 12 guns." The weight of
a 10-inch pivot gun, an 84 pounder, with carriage and fit-
tings, is stated to be about 10 tons; and an 8-inch gun, a
68 pounder, from 6 to 7 tons. These vessels by Mr.
Pitcher are "framed of English oak; outside planks of teak,
many of them 70 feet long, wales 7 inches thick; and the
general run of the interior parts, best Honduras mahogany."
He further remarks, "We build the floors of vessels accord-
ing to the station they are to go on. We cannot get so
much speed out of a flat floor without reducing the breadth
a little. We rather like to have a rising floor, they roll
easier. Steamers are always weatherly by reason of their
length, but a flat-floored vessel would not be so weatherly
as a vessel with a rising floor. With vessels of this size we
expect to get a displacement of $15\frac{1}{2}$ tons per inch, at a
draught of 15 feet. Opinion that the vessels he has built
for the Peninsular and Oriental Company are equal if not
superior to any in the navy. They would steam 11 knots,
and would sail better than most vessels in the navy because
they are longer in proportion to their breadth; their water
tanks give them sufficient stability to carry sail. Has found
the boilers in the West India Mail Packets last about six
years. We have found that by having two boilers at each
end of the engine room, and coal boxes right across the ship
instead of at the sides of the boilers, the heat is kept from
the cabins, the ship is kept in better trim, and fewer
coal trimmers are required, as the coals run nearer the
furnaces."

Mr. JOHN RONALD "is a ship builder, and has been captain of a steamer.   Builds vessels now which beat the Government vessels in speed.   A merchant steamer carries more weight than a ship of her class in the navy.   The mainmast of the Peninsular and Oriental Company's steamer *Bombay* is 81 feet, and the main yard 72 feet long.   No vessel of that class in the navy has larger spars.   Nor is there much difference in their rigging and area of sails.   It is a fancy of the Government to make their vessels sharp-floored and of a greater draught of water, but draught is not necessary to give stability.   Colliers sail as well in ballast as when loaded, even in going to windward, but that is a part of ship building they have not found out nor adopted yet in the navy."

Captain SAMUEL LEWIS, "has been at sea thirty-four years, and with the Peninsular and Oriental Company since its commencement.   Took the *Malta* out to Ceylon.   She is 1225 tons, and was under sail almost the whole of the passage.   Her greatest speed under sail alone, was 9·6 knots.   When the floats were taken off she did 10 knots.   She was uncommonly stiff and weatherly, and if she had ha 1 larger spars she would have done two knots more; th3 floats could be taken off in one hour forty minutes, and replaced in the same time.   She was three months and eight days from Southampton to Ceylon.   The *Bentinck* averaged 10 knots from Calcutta to Suez.   Opinion that there would be no difficulty in adapting these superior vessels to war purposes; that they would be very efficient in carrying troops and coals, and *that the engineers and crews would enter the service when required."

J. R. ENGLEDUE, Esq. " is superintendent of the Peninsular and Oriental Company at Southampton.   There would be no difficulty in giving merchant steamers the same masts, yards, and sails as similarly-sized vessels in the navy; they would be stiff enough with a little ballast or

cargo at the bottom. Their speed under canvas would not be less than vessels in the navy. I have run 13 knots an hour, for six or seven hours, down Channel with a steamer under canvas alone."

Government Mail Contracts with Merchant Steamers.—With reference to the Government mail contracts, we have the following evidence by Mr. ANDERSON, Managing Director of the Peninsular and Oriental Company. He says, " The postal communication can be done much cheaper by private-contract steamers than by Government boats, because of the merchandise and passengers carried. The steam communi-cation between Southampton and Alexandria, with vessels of 300 to 400 horses power, was done for 4s. 6d. per mile. From Suez to Ceylon, Calcutta, and Hong Kong, with vessels of 400 to 500 horses power, for 17s. 1d. per mile. The East India Company's line between Suez and Bombay, with vessels of only 250 to 300 horses power, cost 30s. per mile. Her Majesty's vessels in the Mediterannean cost about 21s. per mile. £189,000 a year is the gross sum paid for the three great contracts: Peninsular and East Indian, West Indian, and North American. Receipts from post-age £380,000. The advantages of the communication should not be estimated merely by the postage. After steam communication to Constantinople and the Levant was opened, our exports to those quarters increased by £1,200,000 a year. The actual value of goods exported from Southampton alone, last year (1848-49) by those steamers is nearly £1,000,000 sterling. Greek merchants state that the certainty and rapidity of communication enable them to turn their capital over so much quicker. Forty new Greek establishments have been formed in this country since steam communication was established. The imports in that trade, fine raw materials, silk, goats' hair, &c., came here to be manufactured. Supposing the trade to increase one million, and wages amount to £600,000, cal-

culating taxes at 20 per cent., an increase of revenue of £120,000 would result from steam communication."

Minerva.—We shall close our examples of steamers by giving some details of the Cork Steam Navigation Company's iron vessel *Minerva*, running between Cork and Glasgow. She was built by Messrs. Thomas Vernon and Co., in 1846-47, and fitted with side-lever engines by Messrs. Bury, Curtis, and Kennedy, of Liverpool.

		FT.	IN.
Length on deck	.	197	0
Length between the perpendiculars	.	190	0
Breadth of beam, extreme	.	26	0
Depth of engine room	.	16	6
Length of engine room	.	57	0
Burthen in tons, builders' old meas.	No. 655		$\frac{25}{54}$
Horses power	No. 384		

Diameter of cylinders, each 70 inches × 6 ft. 2 in. stroke; extreme diameter of paddle wheels 26 ft. 9 in.; floats 9 ft. 10 in. long × 2 ft. 1 in. deep, No. 22 ; revolutions 19 to 21 per minute ; two tubular boilers, together 19 ft. long, fixed from each end ; total number of furnaces, 12 ; each boiler has 526 tubes, 3 in. diam. × 7 ft. 1 in. long ; has an elliptical stern ; is clinker-built to the water line, and carvel-built above ; and is schooner rigged, with two masts, without top masts.

Maximum speed, 15 to 16 knots, or $17\frac{1}{2}$ to $18\frac{2}{3}$ statute miles.

Estimate of the Number of Merchant Steamers.—The number of merchant steamers belonging to the United Kingdom at present is about 1200, the registered tonnage of which, exclusive of the engine-room tonnage, is 165,000, equal to a gross tonnage of about 295,000 tons; propelled by engines of 100,000 horses power.

Estimate of the Number of Steamers in the Royal Navy.—The number of steam vessels of all kinds in the Royal Navy is at present about 190, representing a gross tonnage of perhaps 150,000; and propelled by engines of 51,000 horses power. The number of *armed* steamers in the Royal Navy

is about 125, carrying 800 guns (exclusive of the armaments of the guard and block ships fitted with auxiliary engines), and propelled by engines of about 41,000 horses power.

The French Steam Navy.—The French steam navy is believed to consist at present of 114 vessels propelled by engines of 26,000 horses power, irrespective of those not yet completed. The number of steam trading vessels in France during the year 1850 was returned at 279 ; having a tonnage of 40,098 tons, and a power of 22,893 horses.

Amonst the Tables at the end of the book will be found one of paddle-wheel steamers in the Royal Navy. Also, a Table giving the principal dimensions of 195 paddle-wheel steamers of all classes.

Registering Paper used in Trials of Government Steamers. —The following is the form of registering paper used by the Admiralty engineer officers in determining the maximum speed of a steam vessel at her trial :

Remarks.	Time occupied by Experiment.	Total Number of Revolutions of Screw.	Average number of revolutions per minute.	Total number of Revolution of Engine	Average number of Revolutions per minute.	Observed Rate of Ship.	Reduced Rate of Ship.	True Rate of Ship.

The "Observed Rate" is deduced from the time taken to run the measured knot or mile in each separate experiment ; the "Reduced Rate" is the mean of the two adjacent experiments, the one with and the other against the tide,

the mean of the first and second experiment giving the first reduced rate, and the mean of the second and third, the second reduced rate ; and so on, each experiment after the first being thus used twice in the calculations. The true rate is the mean of the first and second reduced rates, and of the second and third, and so on, thus using each reduced rate twice also as before; and the mean of the true rates is then taken as the speed of the vessel.

Speed of the Vessel.—Two posts are erected on the shore to mark the distance either of a knot or mile, and at about 200 yards or farther inland from these, two other posts are erected at right angles to the first. It is evident that a vessel running at any distance out at sea from these posts, if kept by the compass or by any leading marks parallel to the line of measurement, will run the exact distance as measured when she brings the inland posts into one with those on the shore as she passes them. It may be observed, that a mean of the times would not give a true result, as no compensation would in that case be given for the greater length of time that the tide would act against the vessel than it would in her favour. By the system adopted the influence of the tide is thrown out as far as possible ; and, if the tide should flow at the same rate, or should increase or diminish by regular gradations during the series of trials, the result would be mathematically correct. In making the experiments it is essential to avoid any change of the direction of the tide during the series, and also, if possible, to select a calm day. If the wind is in the direction of the course, the effect will be less detrimental to the mean speed of the vessel than if it be on her beam. In the latter case the vessel is driven to leeward while running both up and down the course, and thus subjected to a constant retarding force, while in the other case the wind is in favour of the vessel in one direction, though in the other it retards her in a somewhat greater degree.

To facilitate these calculations, the Table (No. XIV.) which will be found on p. 223 of the Appendix is used by the officers of the Admiralty.

With reference to the question of arming merchant steamers, the following also was given in evidence before the Committee of the House of Commons:

Mr. ANDERSON says, that, " according to the present con- tracts for carrying the mails, the vessels are to be so con- structed in respect of scantling and arrangements as to carry and fire four guns of the largest calibre then used in her Majesty's service.   Also the Government have the power to take the vessels at two months' notice, the indem- nification for the hire, purchase, or destruction of them, to be determined by arbitration. Thinks the same arrangement might be extended to all vessels capable of carrying heavy guns.   Has ascertained from competent parties that all the merchant steamers of 400 tons and upwards are capable of carrying pivot guns, with some strengthening.   Opinion, that in the greater number of cases exemption from the coast-light dues, and from the unjust law of being com- pelled to take a pilot whether he is wanted or not, would be sufficient compensation to owners for the additional expense incurred for strengthenings, &c.   There are about 170 vessels from 400 to 1000 tons which would carry guns. Opinion, that the exemptions proposed would not induce steam-boat owners to put the machinery under the water line, the expense being too heavy.   More than three times as much money is collected for the light dues than is ne- cessary to support them.   It is expected that a bill will be brought in to reduce the light dues to a fixed rate per annum." *

* The entire amount of dues at present collected is about £430,000. The maintenance of the light houses costs about £140,000 per annum.

JOHN RALPH ENGLEDUE, ESQ.—"Has had experience in the Navy as gunnery officer. Considers nearly all our sea-going vessels might be made to carry guns. No extra risk from engines and boilers being above the water line. (?) Has had much experience with heavy guns, and thinks a 68 pounder worked as easily as a heavy 32 pounder, and with little more concussion. Opinion, that vessels of 600 tons are quite capable of carrying two pivot guns. Opinion, that the engineers would require better pay than those in the Navy. On board the Oriental boats a first-class engineer receives £16 to £26 per month. It is true that in the Queen's service the chief first-class engineers get £17 a month and pensions, but we find our first engineer as good a table as you or I would sit down to—in fact, they live like princes. In the Navy they have to find their own table, except the common rations of the ship. As regards pensions, I have heard some of the engineers say, ' What is the use of a pension ? Very few of us will ever live to enjoy pensions ; if we go on a foreign station, perhaps there is not one of us that will return to receive it.' In India we have scarcely kept a complete crew of engineers for more than a year together ; we have entire changes year after year, principally from death, and from liver complaints arising from the intense heat of the engine room. Opinion, that the average speed of the mail steamers is about one or one and a half knots more than those in the Navy. Increased speed is a great element of superiority. The conversion of the mail steamers into war steamers would not necessarily diminish their speed. The armament would be of far less weight than the cargo is now. War steamers are built to sail well, which accounts for their inferior speed. There may be a few fast vessels in the Navy, but they have extravagant power and carry but few coals. Our Mediterranean vessels average 10 to 11 knots. Cunard's vessels make 280 to 300 miles a-day. One of these vessels carries more weight than a man-of-war of same

tonnage. The weight is all below; but if part were put on deck in the shape of guns, it would be counteracted by putting weight below. In a vessel of this size it would have no material effect, and she would go just as fast. Private builders are not fettered, and competition produces a good article; but in the Government yards there has been one surveyor and one system for a length of time. Second-class steamers of 500 to 800 tons would carry a 68 pounder in addition to the 32 pounder on the quarter-deck. Opinion, that the steam chest of the *Hindostan* would be well protected with 10 feet of coal on each side. Those vessels in the Navy which have their boilers below the water line would not be protected when the ship rolled. I have no doubt that the spar deck of the *Hindostan* could be strengthened to carry a 90-cwt. 10-inch gun. Would particularly draw the attention of the Committee to the *Bombay* steamer, which has been fitted to carry two 10-inch guns and 10 medium 32 pounders, and is in every way equal in fittings and efficiency to any vessel in H. M. service."

Mr. ANDREW LAMB.—" Is superintendent engineer to P. & O. Company. Opinion, that the engineers of the private companies would volunteer at a moment's notice, if the vessels were required for H. M. service. There would be no difficulty whatever if a provision were guaranteed, the same as the engineers in the Navy have.

" It would be quite practicable to place the boilers and steam chests in merchant steamers below the water line, and it would not interfere materially with the stowage. In our first-class vessels like the *Hindostan*, there is 10 feet of coal between the steam chest and the ship's side. In this vessel I should imagine the engineers to be safer than in any of H. M. steamers I have seen, because a body of coal is carried between the boilers and engines, against which the force of steam would spend itself in the event of an explo-

sion; the stokers would suffer most. The engineers and stokers would not be so safe from shot as if the engine room were below the water line. The coal that protects the boilers is left till the last, and by the time that is wanted it is time to look out for a coaling port. The Peninsular and Oriental Company do not do their own repairs either to ships or machinery. It is more economical to employ private individuals. The machinery made at Woolwich cannot be better than ours, and should not be worse. Has never found any obstacle in getting the repairs done efficiently and with readiness. The annual expenses on a vessel and machinery amount to seven per cent. on the total original cost."

CAPTAIN EDWARD CHAPPELL, R. N.—" Is Secretary and Joint Manager of West India Packets. Opinion, that all their vessels would carry even a 95-cwt. gun forward, but not in all cases abaft, as the sterns rake too much. Would put 32 pounders in the entrance ports for broadside guns. The average speed, including the intercolonial work, is 8 knots. On their trial trips, without cargo, they had a speed of 12 knots. Opinion, that they would surpass in speed all the men-of-war, with the exception of the five or six last new boats; men-of-war have heavier scantling, which gives them greater weight. The *Urgent* mail steamer was bought by the Admiralty, but proved a complete pick-pocket from the lightness of her scantling.

" Opinion, that the engineers would remain on board if compensated. Thinks they are not a class of men who like martial law. We pay our engineers £16 to £20 per month. We commenced with all good men at £20 per month, and have had few accidents in consequence. We use the beam engine in all our boats, except the *Conway;* she has direct-acting engines, and we very much regret it. We use all flue boilers on a peculiar plan of our own engineers."

CHARLES WYE WILLIAMS, ESQ.—" Is manager of the

City of Dublin Steam-Packet Company, which owns 24 ships of 10,837 gross tonnage. Our vessels often carry very heavy deck loads. One of the smallest has often carried on deck, in bad weather, two locomotives, weighing 17 tons each. We have carried troops, a thousand men, with heavy baggage, besides women and children. In our mail boats, where the work is severe, we give our first engineer £2 15s.; to the second, £1 17s. 6d; to the third, £1 8s. In the other vessels, to the first engineer, £2 10s.; to the second, £1 15s.; no third engineer."

LIEUTENANT JULIUS ROBERTS.—"Is a lieutenant of Royal Marine Artillery, and has been employed by the Admiralty to inspect contract steamers. Has surveyed a great many, and reported on thirteen for fittings. Ten have been equipped and completed for service. The others inefficient, and unable to carry armament on account of number and nature of fittings, windlasses, hatches, &c. Must have a clear deck, within sweep of bow and stern guns. Has found it necessary to strengthen knees and put in additional deck beams. Would put 32 pounders of 56 cwt. in merchant ships of 500 tons, as a pivot gun forward and aft. The four last vessels of Cunard's line would carry a 95-cwt. gun very well, and some others also. The United States Trans-atlantic steamers are larger than ours, but less capable of carrying guns for want of proper arrangements. Some of the contract steamers are and will be capable of carrying the heaviest shell guns. Would not call a steamer armed, if only with broadside guns and paddle wheels. Wants heavy pivot guns. Would undertake, with enough hands, to alter and turn out 100 merchant steamers in two months, to carry heavy guns forward."

CAPTAIN HENDERSON, R.N. "has been in action in a steamer with batteries, but not with another steamer. Against batteries they answer admirably, because you can fight with steam down. Opinion, that in a general war

large steamers would be available against line-of-battle ships, because the line-of-battle ship would be taken on her weak points by the larger guns of the steamer, which would keep at a distance, and could elevate her guns more than a sailing vessel could do. Opinion, that steamers might be brought into broadside action, and would not be so vulnerable as people generally fancy. That in half an hour a line-of-battle ship would be very much crippled by a steamer, if it were calm or a light wind. If the line-of-battle ship had an auxiliary screw she would be a more dangerous enemy, but the steamer of superior speed would still have the advantage. In case of a battle, each ship of the line would have a steamer to tow her into position. In the first of the war we ought to have a number of light fast steam vessels to protect our trade and act as privateers. Opinion, that there is an end of blockades, because men-of-war could always be towed out by steamers when the blockading fleet was blown off shore. Blockading would become an observation by steamers. With reference to arming large merchant steamers, it is a great mistake attempting to put large guns of 80 cwt. and upwards in vessels that are built of light material, without immense strengthening. I am quite sure that merchant steamers are not near so strong in the scantling as Government steamers generally."

CAPTAIN CHADS, R.N.—" If I were in a 120-gun ship, I should not care for the *Sidon*. She dare not come under my guns. Supposing the line-of-battle ship in a calm, not having heavy pivot guns on deck, I should endeavour to capture her if I were in the *Sidon ;* but I believe you might fire away the whole ammunition of the steamer without hardly striking the ship, if you kept out of range of her guns, say, 3000 yards. In a calm her boats would always keep her broadside on the steamer. Does not agree with Captain Henderson on this point. At 3000 yards, even under favourable circumstances, the steamer will not strike the

ship above eight or nine per cent. Pivot guns have little advantage over 32-pounders in the lower deck of a ship, as to precision. Opinion, that the merchant steamers would lose speed after they had taken in their armament and spars. Is not aware that vessels of a comparatively small class will carry 50 tons of cattle on their decks, and do very well with it."

Report of the Committee of the House of Commons.—The Report of the Committee of the House of Commons, with reference to the " practicability of providing, by means of the commercial steam marine of the country, a reserve steam navy available for the national defence when required," is as follows :—

"That mercantile steam ships of the size and strength necessary for the reception of such guns as are in use in the Royal Navy, would be a most useful auxiliary force for national defence ; and your Committee do not foresee any difficulty in carrying out such a measure.

" That the prompt development of the whole available maritime resources of the country, in the event of threatened hostilities, is most desirable as a means for the preservation of peace.

" That the steps necessary for rendering such mercantile steamers available for the purpose, and the remuneration to be given by the public for fitting them and holding them liable to be called into the public service, must be matters of arrangement between the owners and the Government, upon which your Committee do not deem it necessary to offer an opinion."

APPENDIX.

TABLE No. I.

ADMIRALTY FORMULA OF SPECIFICATION FOR MARINE ENGINES, WITH PADDLE WHEELS.

SPECIFICATION *of certain Particulars to be* strictly *observed in the construction of a pair of Marine Steam-Engines with Paddle Wheels, referred to in the Admiralty Letter on Her Majesty's Service.* 1845.

THE tenders are to be made (in triplicate) on the accompanying printed forms, *every particular in which is to be strictly and carefully filled up;* and all drawings, models, and boxes containing them are to be distinctly marked with the names of the parties transmitting them.

The whole weight of each pair of engines, including the boilers (with the water in them), the coal boxes, the paddle wheels, the spare gear, the floor plates, ladders, guard rails, and *all other articles* to be supplied under the contract, is not to exceed 190 tons.

The coal boxes (in the space of the engine room) are to contain eight-days' coal, computed at 8 lbs. per horse power per hour, and at 48 cubic feet to the ton. Sufficient details of the coal boxes are to be shown in the drawing, to enable a computation of their contents to be made. In this computation the space below the deck to the depth of six inches is to be excluded, to allow for the space occupied by the beams, and for the difficulty of completely filling the boxes with coals.

To avoid the possibility of mistake in the dimensions given in the drawings furnished to the respective parties, it is to be understood that—

> The length of the engine room, in the clear, is not
>   to exceed . . . . 48 ft. 0 in.
> Breadth of ditto . . . . . ⎫ As shown in
> Depth of ditto . . . . . ⎬ the drawing.
> The centre of the shaft above the water line ⎭

The situation of ditto, as per drawing, or as near as can be.

The holding-down bolts are to be secured by nuts let into the sleepers, so as not to require the bolts to pass through the vessel's bottom; and the bolts are to have, at the lower end of their points, wrought-iron washers about eight inches square, and one inch thick, placed between the nuts and the wood. Should this mode of security be inapplicable to the particular kind of engine proposed, the engineer is fully to describe any other secure mode which he may think the most advisable to adopt.

The pistons are to be fitted with metallic packings.

The blow-off pipes are to be not less than $3\frac{1}{4}$ inches in diameter, and their thickness not to be less than $\frac{1}{4}$ inch.

The thickness of the steam pipes is not to be less than $\frac{1}{4}$ inch; of the bilge pipes, not less than $\frac{1}{4}$ inch; of the feed pipes, not less than $\frac{1}{8}$ inch; of the waste-steam pipe, not less than $\frac{1}{8}$ inch; and of the waste-water pipes (if of copper), not less than $\frac{1}{4}$ inch.

The cylinders are to be fitted with discharge or escape valves at the top and at the bottom of each, for allowing of the escape of water therefrom; the valves to have suitable metallic cases to obviate the danger of persons being scalded by any escape of boiling water.   Reverse valves are to be fitted to the boilers.

Each cylinder is likewise to be fitted with a separate movement and valve, for the purpose of using the steam expansively in various degrees, as may from time to time be found eligible.

The air-pumps are to be lined with gun metal of half an inch in thickness, when finished.

The air-pump buckets are to be of gun metal, with packing rings.

The air-pump rods are to be of gun metal, of Muntz's metal, or of wrought iron cased with gun metal.

The threads of all screwed bolts, nuts, and pins used in engines and boilers, and in every other part of the work furnished by the contractor, are to agree with the threads used in the steam department at Woolwich.

A small engine is to be fitted, capable of working one of the pumps for feeding the boilers.

Pipes to be fitted for supplying, in the event of a leak in the vessel, the requisite quantity of water from the bilge to the condensers.

The hand pump to be made capable of being worked by the engine also, and to be arranged to pump into the boilers, on deck, or overboard; and to draw water from the boilers, from the bilge, or from the sea.

The feed apparatus to be complete, independently of any feed from a cistern above the deck, should such be fitted.

The steam pipes and *all* other pipes to be of copper, and their respective diameters to be specified in the tender.

A separate damper to be fitted to every boiler, and dampers to be fitted to the fronts of the ash pits.

Brine pumps, or some other equally efficient apparatus, with refrigerators, to be fitted to the boilers.

A small flat iron vessel to be fixed in one of the paddle boxes, with two pipes, one communicating with the stoke hole, and the other with the boiler, for obtaining a small supply of distilled water from the boiler. Air tubes to be fixed in the coal boxes, for ascertaining their temperature. Particulars will be furnished to the contractors, on application to the captain superintendent at Woolwich Dockyard.

The boilers are to be tubular, having iron tubes of 2½ or 3 inches outside diameter; and it is desirable that the upper part should not be a greater distance above the water line than circumstances render necessary. They are to be constructed in three or more separate parts, each of which may be used independently of the others. Sufficient details of the boilers are to be shown, to enable a calculation to be made of the area of fire grate, and of the fire and flue surface.

In the manufacture of tubular boilers, care is to be taken to leave sufficient room between the crowns and the lowest row of tubes, with mud-hole doors in the front of each boiler, to admit a person into these parts, both for the purpose of cleaning them and of repairing them, without taking out the tubes. All mud-hole doors to be placed on the *inside* of the boilers.

A space of 13 inches wide is to be left clear between the boilers and the coal boxes in every part. The boilers are to be placed on a bed of mastic.

The paddle wheels are to be of the common construction, and to be fitted with suitable brakes. Braithwaite's disconnecting apparatus is also to be applied.

The power of the engines is to be 260 horses, calculated at 7lbs. effective pressure on each square inch of the piston, and the speed of the piston

ft.	in.				
for 4	0	stroke not to exceed 196 feet per minute.			
4	6	ditto	.	.	. 204 ,,
5	0	ditto	.	.	. 210 ,,
5	6	ditto	.	.	. 216 ,,
6	0	ditto	.	.	. 222 ,,
6	6	ditto	.	.	. 226 • ,,
7	0	ditto	.	.	. 231 ,,
7	6	ditto	.	.	. 236 ,,
8	0	ditto	.	.	. 240 ,,

All the necessary ladders for the engine room, together with fenders, guard rails, and floor plates, are to be included in the tender, and likewise the expense of *trying and fitting* the spare gear.

The expense of clothing (in the following manner) the cylinders, steam pipes, and boilers is also to be included in the tender.

The cylinders are to be covered with hair felt to the thickness of two inches. The felt is to be covered with thoroughly dried wood, and bound together by iron or brass hoops.

The steam pipes are to be clothed with felt, which is to be woulded with spun yarn, and then to be covered with canvas; the whole to be of such thickness as to be even with the flanges.

After it has been ascertained by trial that every part of the boilers is perfectly tight, two good coats of red-lead paint are to be then put on them, and felt applied to the tops, sides, and ends, to the thickness of two inches, while the paint is moist. For the more convenient application of the felt, it is to be previously stitched to canvas for the purpose of holding it together. The canvas is then to be well painted and carefully covered with thoroughly dried one-inch deal boards, having rabbeted, or grooved and tongued joints, and bound up to the boilers by suitable iron straps.

The coating of felt and boards on the top of the boilers or steam chest is to be kept at least 18 inches from the funnel, and the circular space between the coating and the funnel is to be covered with a three-inch course of brick, set in cement, and surrounded and held together by an iron hoop, or this space may be filled up with mastic.

The boards and bricks on the upper parts of the boilers are to be covered with sheet lead, 4 pounds to the square foot, so as to prevent any leaks from the deck reaching the felt.

N.B. Parties contracting to supply machinery for her Majesty's ships and vessels are to be bound in a penalty of one thousand pounds to complete their contracts at the stipulated periods; and it is distinctly to be understood that it is their Lordships' intention to enforce the bond in all cases where the machinery is not fixed and ready for trial at the time specified in the contract.

The time required for completing the machinery so as to be ready to be put on board the vessel, is to be considered as commencing from the date of their Lordships' acceptance of the tender.

And the period stipulated for fixing the machinery on board the vessel is to be calculated from the date the vessel is placed in the hands of the parties for that purpose.

It is likewise to be understood that, if the weight specified in the tender be exceeded, the contractor is to forfeit one thousand pounds, or their Lordships are to be at liberty to reject the engines, the manufacturers paying one thousand pounds for the disappointment.

It is to be understood that the practice of fixing new engines on board her Majesty's vessels at Woolwich Dockyard is to be *entirely discontinued.* The ports to which their Lordships will, for the convenience of manufacturers, allow vessels to be taken,

are those of London, Liverpool, Greenock, Glasgow, and Dundee, provided *the places* at which the vessels are to lie in those ports shall be named in the tender, and approved of by their Lordships.

In all cases of vessels receiving their engines on board at any other port than that of London, a deduction of two per cent. will be made from the price of the engines named in the tender, as a compensation for the expense, wear and tear, and risk thereby incurred.

No charge will be allowed for transporting the vessel to the place where the engines are to be fixed on board; for coals in trying the engines *until they are complete;* for boats, anchors, men, lighters, pilotage, canal or dock dues, shipwrights' work, or for any other expense whatever. The "watching" of vessels is to be performed in future by officers and men in her Majesty's service.

TENDER *from*   *for a pair of Steam Engines with Paddle Wheels, pursuant to a Letter from the Admiralty, dated*   *, and the Specification accompanying the same.*

Collective power of the two engines . . .	260 horses.
Weight of the engines	80 tons.
,, Boilers and their apparatus . . .	45 ,,
,, Water in boilers	30 ,,
,, Coal boxes	10 ,,
,, Paddle wheels	13 ,,
,, Spare gear, and all fittings included in contract	12 ,,
Total weight	190 tons.

	ft. in.
Diameter of cylinders	0 61½
Length of stroke	4 6
Strokes per minute . . . No. 24	
Diameter of paddle wheels	21 0
Breadth of ditto	8 3
Diameter of necks of intermediate and paddle-wheel shafts	0 12½

Quantity of coals which can be stowed in } 185 tons, or 8½ days' con-
the coal boxes . . . . . } sumption.

Estimated consumption of coals per horse per hour . . 8lb.

Cost of engines, boilers, and coal boxes £11,090	} Including the erection
Ditto paddle wheels, common . . 800	} on board.
Cost of duplicate and spare articles, as	} Including the entire
per list 850	} fitting and trying of the
	} same wherever and
Total cost £12,740	} whenever required.

Including all the items of expense mentioned at the end of the specification.

Time required for completing the work ready to be put on board—for one pair, eight months; for two pairs, nine months.

Further time required for fixing the whole in the vessel, ready for service, two months. The engines to be fixed on board in the East India Docks, London.

The boilers will be constructed on the tubular principle, embodying all the latest improvements. The tubes will be of iron, 3 in. external diameter, and 6 feet long, and secured in the best manner in tube plates of the best charcoal iron, ¾ in. thick. The bottoms of the boilers will be composed of plates $\frac{7}{16}$ in. thick; the sides and tops of plates ⅜ in. thick; and the fire boxes of Lowmoor plates, ⅜ in. thick. The heating surfaces of the proposed boilers will be—grate-bar surface, 85 square inches per horse power; *total* tube and flue surface, 16 square feet per horse, and *effective* surface 13½ square feet. Sufficient room will be left between the crowns of the furnaces and the tubes for cleaning the former. Each boiler will be fitted with separate safety valve and stop valve, so that either may be worked distinct from the other if required. Brine pumps will be attached to the boilers; also a small feeding engine will be provided for working the supplementary feed pump.

The boilers will be clothed with felt, wood, and lead, as usual.

The blow-off pipes will be of copper, 3¼ in. diameter, and ¼ in. thick, having their cocks, conical pipes, and stop valves of gun metal.

The engines will be constructed on the direct-action principle, as shown by the drawings, and will embody all the latest improvements. The slide valves will be formed on the long D construction. The air pumps will be of solid gun metal; and the air-pump rod and bucket, foot valve, and delivery valve, will be all of gun metal.

There will be two feed and two bilge plunger pumps, each pump capable of supplying both the boilers.

The pistons to be of the most approved construction, with metallic packing. The steam pipes, feed pipes, and all other pipes usually constructed of copper will be of this material, of sufficient thickness. All the bearings will be of best brass. Expansive gear will be attached to the engines. The framings of the engines will be composed chiefly of wrought iron, and will be made as light as is consistent with the requisite strength.

The paddle wheels will be on the common construction; and the shaft will run through to an outside bearing on the spring beam.

The whole to be of the best material and workmanship.

List *of* Tools *and* Spare Articles *for Paddle-wheel*
Engines *of*   Horses Power.

ENGINEERS' TOOLS.

				No.
Brushes, for boiler tubes, to every 100 horse power	.	20
Drifts, short and long do. do.	. .	1 each.
Fire irons	.	12
Mandrils do. do. .	. .	1 each.
Scrapers, circular and forked do.	. . .	5 each.
Spanners and wrenches of sorts . . .	.	24
Stocks taps and dies, from ¼ inch to 1¼ .	. . .	1 set.

SPARE GEAR.

Air pump, side rods, with straps and brasses complete
  (if so fitted) 2
Air-pump rod 1
Air-pump cross head (if so fitted) 1
Arms for paddle wheels 4
Bars, furnace . . . . ½ set.
Bearers 3
(Beam, sway (if so fitted) . . . . . . 1)
Boiler plates . . . . 6 cwt.
Bolts and nuts for engines, properly assorted . . 120
Bolts and nuts for paddle wheels, or rivets instead (if
  so fitted) 100
Bolts and nuts hook for paddle boards . . . 100
Brasses for outer end of shaft 2
(Cylinder side rods, with straps and brasses complete
  (if so fitted) . . . . 2)
Cylinder lid 1
Cylinder cross head (if so fitted) 1
Ferrules for boiler tubes, to every 100-horse power . 50
(Fork head (if so fitted) . . . . . . 1)
(Side links to fork head, with straps and brasses com-
  plete (if so fitted) . . . . 2)
Paddle boards 12
Paddle plates . . . . . . ꝑ . . 18
Piston and rod 1
Rod connecting with strap and brasses, complete . 1
  „ Parallel motion, with brasses complete, for one
    engine . . . . 1 set.
  „ Feed pump (if so fitted) 1
  „ Bilge (if so fitted) 1
  „ Slide 1
Screws, packing, for slide, complete for one engine . 1 set.
Segments for paddle wheels, large 4
Segments for paddle wheels, small (if so fitted) . . 2

Springs for each piston (if so fitted)   .   .   . .   1 set.
Springs for other parts of engines, for 1 engine .   .   1 set.
Tubes, boiler, to every 100-horse power   .   . .   10
Tubes, glass, for barometers   2
Tubes, glass, for boilers   4
Valve, foot, without seat   1
Washers, iron   100

NOTE.—Such articles contained in this list as are not to be
found in the particular kind of engine tendered for, to be struck
out by the party tendering; and any articles may be added to it
which, from the construction of the engines, he may consider
ought to be supplied.

TABLE No. II.

ADMIRALTY FORMULA OF SPECIFICATION FOR MARINE ENGINES, WITH SCREW PROPELLERS.

SPECIFICATION *of certain Particulars to be* strictly *observed in
the construction of Marine Steam Engines (with Screw Pro-
pellers), referred to in the Admiralty Letter of the 9th of Sep-
tember,* 1845, *for Her Majesty's Steam Guardship of* 72 *Guns,
with Auxiliary Engines of* 450-*Horse Power.*

The tenders are to be made (in triplicate) on the accompanying
printed forms, *every particular in which is to be carefully and
strictly filled up;* and all drawings, models, and boxes contain-
ing them, are to be distinctly marked with the names of the parties
transmitting them.
   The coal boxes (in the space of the engine room) are to contain
as much room as possible. The arrangement, and quantity (com-
puted at 48 cubic feet to the ton) to be shown in the tender.
   The consumption of coal per horse power, and the *number of
days'* coals which the boxes will contain, are to be accurately stated
in the tender.
   The breadth and depth of the engine room are shown in the
drawing. If the length should be found insufficient, the *foremost*
bulkhead may be removed as much farther forward as is neces-
sary ; but the situation of the *after* bulkhead is not to be
altered.
   As the engines will not be so frequently worked as in an ordi-
nary steam vessel, especial care is to be taken in the arrangement
of the boilers and machinery, that every part may be easily ac-

cessible, so that no difficulty may be found in preserving them in an efficient state.

The situation of the centre of gravity of the whole machinery, coals, &c., to be shown in the drawing.

The pistons are to be fitted with metallic packings.

The blow-off pipes are to be at least 3½ inches in diameter, and their thickness not to be less than ¼ inch.

The thickness of the steam pipes is not to be less than ¼ inch; of the bilge pipes not less than ¼ inch; of the feed pipes not less than ⅛ inch; of the waste steam pipe not less than ⅛ inch; and of the waste-water pipes (if of copper) not less than ¼ inch.

The cylinders are to be fitted with discharge or escape valves at the top and at the bottom of each, for allowing of the escape of water therefrom; the valves to have suitable metallic cases to obviate the danger of persons being scalded by any escape of boiling water. Reverse valves are to be fitted to the boilers, and efficient stop valves at the ship's side to the waste-water pipes.

Each cylinder is likewise to be fitted with a separate movement and valve for the purpose of using the steam expansively in various degrees, as may from time to time be found eligible.

The air-pumps are to be lined with gun metal of half an inch in thickness, when finished.

The air-pump buckets are to be of gun metal, with packing rings.

The air pump rods are to be of gun metal, Muntz's metal, or of wrought iron cased with gun metal.

, The threads of all screwed bolts, nuts, and pins used in the engines and boilers, and in every other part of the work furnished by the contractor, are to agree with the threads used in the steam department at Woolwich.

A fan-blower with all the necessary apparatus is to be provided for blowing the fires in the event of injury to the funnel; and a small engine is to be fitted, capable of working the blower as well as one of the pumps for feeding the boilers.

Pipes to be fitted for supplying, in the event of a leak in the vessel, the requisite quantity of water from the bilge to the condensers.

The hand pump to be made capable of being worked by the engine also, and to be arranged to pump into the boilers, on deck, or overboard; and to draw water from the boilers, from the bilge, or from the sea.

The steam pipes and *all* other pipes to be of copper, and their respective diameters to be specified in the tender.

A separate damper to be fitted to every boiler, and dampers to be fitted to the fronts of the ash-pits.

Brine pumps or some other equally efficient apparatus, with refrigerators, to be fitted to the boilers, and blow-off pipes so arranged that any boiler may be blown off separately.

Air tubes to be fixed in the coal boxes, for ascertaining their temperature. Particulars of these and other small fittings, such as glass water gauges, &c., to which the contractors will be required to conform, will be furnished to the contractors on application to the captain superintendent at Woolwich Dockyard.

The boilers are to be of the tubular construction having tubes of 2½ or 3 inches diameter outside, the cost with iron and with brass tubes respectively is to be specified in the tender.

The boilers are to be constructed in three or more separate parts, each of which may be used independently of the others. Sufficient details of the boilers are to be shown, to enable a calculation to be made of the area of fire grate and of the fire and flue surface.

In the manufacture of tubular boilers care is to be taken to leave sufficient room between the crowns and the lowest row of tubes, with mud-hole doors in the front of each boiler, to admit a person into these parts, both for the purpose of cleaning them, and of repairing them, without taking out the tubes.

A space of thirteen inches wide is to be left clear between the boilers and the coal boxes in every part. The boilers are to be placed on a bed of mastic.

The power of the engines to be 450 horses; and the weight, if possible, not to exceed 300 tons; the power to be calculated at 7lbs. effective pressure on every square inch of the pistons; and at 45 strokes per minute.

The whole of the machinery and boilers to be below the lower or sleeping deck.

The speed of the propeller shaft to be at least 45 revolutions per minute, the shaft to be driven direct from the engines.

The screw propeller to be two-threaded and to be made of gun metal of about 15 ft. 6 in. in diameter, and of the form to be hereafter determined.

The screw to be hung upon a separate shaft, capable of being easily disengaged from the driving shaft, and suitable means are to be provided for shipping and unshipping it through a trunk extending from the upper part of the aperture for the screw to the upper deck.

It is to be understood that any plans in which the arrangements may differ from those above described will be taken into consideration, if they shall appear likely to answer.

All the necessary ladders for the engine room, together with fenders, guard rails, and floor plates, are to be included in the tender, and likewise the expense of *trying and fitting* the spare gear.

The expense of clothing (in the following manner) the cylinders, steam pipes, and boilers, is also to be included in the tender.

The cylinders are to be covered with hair felt to the thick-

ness of two inches; the felt is to be covered with thoroughly dried wood, well fitted, and bound together by iron or brass hoops.

The steam pipes are to be clothed with felt, which is to be woulded with spun yarn, and then to be covered with canvas; the whole to be of such thickness as to be even with the flanges.

After it has been ascertained by trial that every part of the boilers is perfectly tight, two good coats of red-lead paint are to be then put on them, and felt applied to the tops, sides, and ends, to the thickness of two inches, while the paint is moist. For the more convenient application of the felt, it is to be previously stitched to canvas for the purpose of holding it together. The canvas is then to be well painted and carefully covered with thoroughly dried one-inch deal boards, having rabbeted, or grooved and tongued joints, and bound up to the boilers by suitable iron straps.

The coating of felt and boards on the top of the boilers or steam chest is to be kept at least 18 inches from the funnel, and the circular space between the coating and the funnel is to be covered with a three-inch course of brick, set in cement, and surrounded and held together by an iron hoop, or this space may be filled up with mastic.

The boards and bricks on the upper parts of the boilers are to be covered with sheet lead, 4 pounds to the square foot, so as to prevent any leaks from the deck reaching the felt.

The engines to be fitted on board the ships, either in the Thames, at Portsmouth or Plymouth; the parties tendering to state the expense of fixing the machinery at each place respectively, it being understood that if fixed in the Thames, dock dues and all other expenses are to be borne by the contractors. But if at Portsmouth or Plymouth dock yards, the use of the government shears or cranes, with the necessary hands, will be allowed for lifting the heavy weights.

N.B. The time required for completing the machinery so as to be ready to be put on board the vessel, is to be considered as commencing from the date of their Lordships' acceptance of the tender.

And the period stipulated for fixing the machinery on board the vessel is to be calculated from the date the vessel is placed in the hands of the parties for that purpose.

Parties contracting to supply machinery for Her Majesty's ships and vessels are to be bound in a penalty of one thousand pounds to complete their contracts at the stipulated periods, and it is distinctly to be understood that it is their Lordships' intention to enforce the bond in all cases where the machinery is not fixed and ready for trial at the time specified in the contract.

It is likewise to be understood that, if the weight specified in the tender be exceeded, the contractor is to forfeit one thousand

pounds, or their Lordships are to be at liberty to reject the engines, the manufacturers paying one thousand pounds for the disappointment.

TENDER *from*   *for a pair of*
  Steam-Engines (with Screw Propellers), pursuant to a Letter from the Admiralty, dated the 9th of September, 1845, and the Specification accompanying the same. For a 72-Gun Steam Guard Ship (auxiliary).

N.B. All the following particulars are to be carefully stated in this paper, so far as may relate to the tender required by the Admiralty.

                    In words and figures.

Collective power of the two engines   four hundred and fifty horses 450.

The centre of gravity of these weights is to be clearly stated in the drawing.	Weight of engines . .	127 tons.	One hundred and twenty-seven.
	Do. Boilers and their apparatus }	55 ,,	Fifty-five.
	Do. Water in the boilers	45 ,,	Forty-five.
	Do. Coal-boxes . .	15 ,,	Fifteen.
	Do. Propeller, propeller shaft, and machinery for driving it }	30 ,,	Thirty.
	Do. Spare gear, and all fittings included in contract }	18 ,,	Eighteen.

              Total weight   290 tons.   Two hundred and ninety.

Diameter of cylinders   four, each   50 in.
Length of stroke . . . .   3 ft. 0 in.
Strokes per minute . . .   No., 45
Revolutions of propeller } No., 45
  shaft per minute   }
Diameter of the necks of }
  the engine shaft   }   13 in.
    Do. Propeller shaft   13 in.
The quantity of coal which }
  can be stowed in the   } 250 tons, being 9 days' consumption.
  coal boxes   }
Estimated consumption of }
  coals per horse power   }   6 lbs.
  per hour   }
Cost of engines, boilers and } £17,620   ⎫
  coal boxes   }   ⎪ Including the erection on
Do. Propeller, shafts, and }   ⎬   board.
  all machinery connected   } 3,650   ⎪
  with them   }   ⎭

Cost of Duplicate and spare articles as per inclosed list, and all fittings and other articles to be supplied under the contract	£1,450	Including the entire fitting and trying of the same wherever and whenever required; and all the other items of expense mentioned at the end of the specification.

Total cost . . . £22,720

Time required for completing the work ready to be put on board	12 months.
Further time required for fixing the whole in the vessel, so as to be fit for service	3 months.

At what place the engines are to be fixed on board.

The construction and dimension of the boilers to be here described, and the thickness of the plates of the various parts of them; and if the boilers be tubular, the diameter and length of the tubes to be specified, as well as the material of which they are to be composed.

Boilers to be tubular, over all 19 ft. 9 in. long, 24 ft. wide, and 12 ft. high, being kept (as well as the engine) entirely under the orlop deck. Heating surface to be 15 sq. ft. per horse power, and grate-bar surface, 80 sq. in. per horse.

Engines to have four horizontal cylinders driving the screw shaft direct.

The blow-off pipes to be 4 in. in diameter and ¼ inch thick, of *copper;* having their cocks, conical pipes, and stop valves of *gunmetal.*

The whole to be of the best materials and best workmanship.

N.B. The position of the engines, propeller, boilers and coalboxes to be distinctly shown in the accompanying drawings of the engine room.

LIST *of* TOOLS *and* SPARE ARTICLES *for Engines (with Screw Propellers) of* 450 *Horses' Power.*

ENGINEERS' TOOLS.

	No.	
Brushes, for boiler tubes, to every 100 horse power .	20	
Drifts, short and long do. do. . .	1	each.
Fire irons	12	
Mandrils do. do. . .	1	each.
Scrapers, circular and forked, do. do. . .	5	each.
Spanners and wrenchers of sorts	24	
Stocks taps and dies from ¼ inch to 1¼ . . .	1	set.

K 2

SPARE GEAR.

	No.
Air pump, side rods, with straps and brasses complete (if so fitted)	2
Air-pump rod	1
Air-pump cross head (if so fitted)	1
Bars, furnace	½ set.
Bearers	3
Boiler plates	6 cwt.
Bolts and nuts for engines properly assorted . . .	120
Cylinder lid	1
Cylinder cross head (if so fitted)	1
Ferules for boiler tubes, to every 100 horse power .	50
Piston and rod	1
Propeller and shaft complete	1
Rod, connecting, with strap and brasses complete . .	1
„ Feed pump (if so fitted)	1
„ Bilge pump (if so fitted)	1
„ Slide	1
Screws, packing, for slides, complete for one engine .	1 set.
Springs for each piston (if so fitted)	1 set.
Springs for other parts of engines, for 1 engine . .	1 set.
Tubes, boiler, to every 100 horse power . . .	10
Tubes, glass, for barometers	2
Valve, foot, without seat	1
Washers, iron	100

NOTE.—Such articles contained in this list as are not to be found in the particular kind of engine tendered for, are to be struck out by the party tendering, and any articles may be added to it which, from the construction of the engines and propeller machinery, he may consider ought to be supplied.

NOTE.—For Tables III. and IV. see also "Artizan Journal" for 1849 and 1850. This journal is the more specially devoted to steam navigation and machinery generally.

TABLE No. III.

TABLE OF THE PRINCIPAL DIMENSIONS OF 194 STEAMERS WITH PADDLE-WHEELS.

Name of the Vessel	Length on Deck	Breadth, Extreme	Depth in Engine-room	Tonnage—Builder's old Measurement	Horses' Power	Diameter of Wheels	Mean Load—Draught	Material	Builders of the Vessel	Makers of the Machinery.
	ft. in.	ft. in.	ft. in.	Tons.	Nominal.	ft. in.	ft. in.			
Acadia	206 0	34 0	22 6	1150	420	28 6	16 0	wood	Duncan	R. Napier
Africa	268 0	40 6	27 0	2130	814	37 7	17 0	„	R. Steele	Ditto
Agir	150 3	19 0	10 0	255	80	15 0	7 6	iron	Fairbairn	Fairbairn
Albert	145 0	24 5	13 9	400	150	18 7		„	Wilson	Maudslay
5 America	251 0	38 1	25 7	1756	674	33 1	18 0	wood	R. Steele	R. Napier
Asia	268 0	40 6	27 6	2130	814	37 0	18 6	„	Ditto	Ditto
Atlantic	280 0	45 0	31 0	2720	800	36 0	18 0	„	American	American
Aurora	153 0	22 9	13 1	435	161	22 7	7 6	„	Connell	Coates and Young
Baltic	282 0	45 0	32 0	2725	828	36 0	18 0	„	American	American
10 Banshee	190 0	27 2	14 9	670	350	25 0	9 0	„	Lang, Jun.	Penn
Baron Osy	190 0	24 9	14 0	620	220	19 0		iron	Robinsons & Russell	
Bentinck	235 0	39 0	31 6	2020	500			wood	Wilson	Fawcett
Berenice	170 0	28 8		646	250	23 0	13 0	„		R. Napier
Birkenhead, R.N.	215 0	37 6	23 0	1440	560	30 0	16 0	iron	Laird	Forrester
15 Black Eagle, R.N.	155 0	26 1	14 10	500	260	20 3		wood	Lang	Penn
Blackwall	150 0	19 1	9 10	258	90	15 6	5 0	iron	Ditchburn	Miller
Bolivia	200 0	27 0	15 3	705	262	23 0		„	R. Napier	R. Napier
Brian Boirorimhe	180 0	26 2	16 9	600	300	26 4	10 0	„	Ditto	Ditto
Britannia	206 0	34 0	22 6	1150	420	28 6	16 0	wood	Duncan	Ditto
20 Britannia	167 0	22 6	10 9	412	146	21 3	8 6	iron	Smith and Rodger	Smith and Rodger
Brit. Queen	245 0	40 6	27 0	1862	500	31 0	17 0	wood	Curling and Young	R. Napier
Briton	150 0	20 0	9 14	283	110	18 6	6 3	iron	Tod and M'Gregor	Tod and M'Gregor
Brunswick	150 0	19 1	9 0	258	90	15 6	5 0	„	Ditchburn	Seaward
Bull Dog, R.N.	194 0	30 0	21 0	1125	530	26 6	16 0	wood	Symonds	Rennie
25 Caledonia	206 0	34 0	22 6	1150	420	28 6	16 0	„	Duncan	R. Napier
Cambria	220 0	35 9	24 6	1350	500	30 6	17 0	„	R. Steele	Ditto
Camilla	190 0	23 1	14 8	530	180	23 6	8 0	iron	Caird	Grendon
Canada	251 0	38 1	25 6	1756	690	33 1	17 0	wood	R. Steele	R. Napier
Cardiff Castle	172 6	19 3	9 8	317	84	19 0	5 6	iron	Caird	Caird.
30 Celt	155 0	20 3	10 3	275	136	20 6		„	Denny	Wingate
City of London	215 0	32 0	20 0	1119	460	26 6	14 0	„	R. Napier	R. Napier
City of Paris	170 0	23 6	13 0	425	120		6 9	„	Joyce	Joyce
Clyde	215 0	36 6	30 6	1350	450	30 0	17 0	wood	Duncan	Caird
Colon	190 0	32 0	20 0	850	350			wood	Wigram	Penn
35 Cora	185 0	34 3	17 0	970	270	19 0		„	Patterson	Miller
Courier	176 3	22 7	12 6	429	150	21 8	6 6	iron	Wingate	Wingate
Craignish Castle	172 6	19 3	9 8	317	84	19 0	5 6	„	Caird	Caird
Cumberland	200 0	25 0	13 7	610	300	25 6	10 6	„	Tod and M'Gregor	Tod and M'Gregor
Cyclops R.N.	195 0	38 0	23 0	1300	320	26 0	15 6	wood	Symonds	Seaward

TABLE No. III.—*Continued.*

	Name of the Vessel	Length on Deck.	Breadth, extreme.	Depth in Engine-room.	Tonnage Builder's old Measurement.	Horses' Power.	Diameter of Wheels.	Mean Load—Draught.	Material.	Builders of the Vessel.	Makers of the Machinery.
		ft. in.	ft. in.	ft. in.	Tons.	Nominal.	ft. in.	ft. in.			
40	Danzig, Pruss.R.N.	230 0	34 4	20 3	1280	400	24 4	15 0	wood	J. Scott Russell	Robinsons & Russell
	Dee	215 0	35 9	30 3	1325	435	29 8	17 0	"	Scott	Scott and Sinclair
	Demerara	285 0	41 0	33 0	2318	750			"	Patterson	Caird & Co.
	Dundalk	173 0	26 1	15 6	556	270	24 9	10 6	iron	R. Napier	R. Napier
	Dundee	175 0	28 0	17 6	650	300	24 0	11 6	wood	J. Wood	Ditto
45	Duchess Argyll	147 0	14 6	6 6	100	70	14 0		iron	Denny	Penn
	Eagle	105 0	18 0	8 5	150	73	15 0		"	Tod and M'Gregor	Tod and M'Gregor
	Eblano	205 6	25 2	15 8	635	370	28 7	10 0	"	Ditto	Ditto
	Eclipse	150 0	16 0	7 0	200	62	16 6	3 6	"	Wingate	Wingate
	Eclipse	156 0	19 0	9 6	278	100	16 6	5 0	"	D. Napier	D. Napier
50	Elfin, R.N.	103 6	14 0	7 9	98	60		4	wood	Symonds	Rennie
	Emperor	240 0	32 0	20 0	1270	416		14 0	iron	R. Napier	R. Napier
	Engineer	162 0	18 1	8 2	295	104	18 0	5 3	"	J. & W. Napier	J. & W. Napier
	Equador	168 0	23 0	14 0	315	174	22 0		"	Tod and M'Gregor	Tod and M'Gregor
	Europa	251 6	38 2	25 8	1764	690	33 1	17 0	wood	J. Wood	R. Napier
55	Euxine	222 0	29 5	18 6	1200	450	28 6	15 0	iron	Caird	Caird
	Fairy	129 0	16 3	8 3	135	66	16 6		"	Tod and M'Gregor	Tod and M'Gregor
	Fairy	125 0	16 7	7 8	140	62	14 6	3 0	"	Vernon	Forrester
	Father Thames	145 0	19 0	10 0	247	90	18 6	4 0	"	Ditchburn	Penn
	Favorite	175 0	22 7	12 5	443	150	22 0	7 0	"	Wingate	Wingate
60	Finella	160 0	20 4	11 4	327	110	19 6	6 0	"	Vernon	Forrester
	Fire King	180 0	28 0	16 8	683	300			"	R. Napier	R. Napier
	Frederikshald	134 0	16 0	7 0	158	45	9 6		"	Robinsons & Russell	Robinsons & Russell
	Fitzroy Somerset	102 7	19 8	10 7	200	108	16 0		wood	J. Scott	Scott and Sinclair
	Foyle	196 0	25 0	16 0	761	372	26 6	8 6	"	American	American
65	Fury, R.N.	195 3	36 0	21 0	1123	515	25 6	16 0	"	Symonds	Rigby
	Ganges	236 0	30 4	18 7	1066	470	29 8	11 6	iron	Tod and M'Gregor	Tod and M'Gregor
	Georgia	265 0	46 0	33 0	2300	700	36 0		wood	American	American
	Gorgon,R.N	180 0	37 6	20 0	1100	320	26 0	15 8	"	Symonds	Seaward
	Great Liverpool	225 0	30 10	19 8	1140	468	28 5	16 6	"	Patterson	Forrester
70	Great Western	215 0	35 4	23 8	1340	450	28 0	16 0	"		Maudslay
	Guadaloupe	185 0	30 0	18 0	800	360		9 0	iron	Laird	Forrester
	Guadalquiver	205 0	25 0	12 0	660	220	27 0	7 0	"	Vernon	Fawcett
	Hamburg	215 0	25 8	16 0	680	270		9 6	"	R. Napier	R. Napier
	Helen M'Gregor	180 0	26 0	16 0	591	250			"	Laird	Forrester
75	Helwellyn	132 6	17 0	8 6	18?	70	15 6	4 0	"	Craig & Co.	Craig & Co.
	Her Majesty	125 0	14 0	7 0	120	40	11 0	4 0	"	Robinsons & Russell	Robinsons & Russell
	Herne	160 0	21 6	10 0	355	120	18 6	6 2	"	Ditchburn	Boulton and Watt
	Hibernia	218 0	36 0	24 0	1350	500	30 4		wood	R. Steele	R. Napier
	Hindostan	235 0	39 0	30 0	1800	550		17 0	"	Wilson	Fawcett

TABLE No. III.—*Continued.*

	Name of the Vessel.	Length on Deck.	Breadth, extreme.	Depth in Engine-room.	Tonnage—Builder's old Measurement.	Horses' Power.	Diameter of Wheels.	Mean Load—Draught.	Material.	Builders of the Vessel.	Makers of the Machinery.
		ft. in.	ft. in.	ft. in.	Tons.	Nomi-nal.	ft. in.	ft. in.			
80	Inca .	166 0	27 0	14 0	628				wood	Patterson	Miller
	India .	195 0	32 0	28 0	1200	325	26 6	16 0	„	Scott .	Scott and Sinclair
	Inverary Castle	140 0	20 0	8 7	270	113	16 9	7 6	iron	Tod and M'Gregor	Tod and M'Gregor
	Isaac Newton .	345 0	40 6		2833	500			wood	American	American
	Islay .	167 0	21 6	11 0	385	152	22 0		iron	Tod and M'Gregor	Tod and M'Gregor
85	Jenny Lind	145 0	15 0	7 9	165	70	14 0		„	Denny	Penn
	Juverna	180 8	25 0	14 6	555	274	24 5	9 0	„	Lunell & Co.	Lunell & Co.
	Kamtschatka	215 0	36 0	24 6		600		16 0	wood	American	American
	Lapwing (Tow-boat)	82 8	14 6	10 0	115	45	14 0	7 3	iron	Reid and Co.	Murdoch
	Laurel	190 0	23 0	12 9	500	180	23 6		„	Caird .	Caird
90	Leinster Lass	200 6	27 0	16 2	720	370	26 6		„	R. Napier	R. Napier
	Lightning	90 0	11 0	6 0		24	10 4	2 0	„	Joyce .	
	Lady Kelburne	150 0	18 2	8 0	233	87	18 0	5 3	„	Barr and M'Nabb	Barr and M'Nabb
	Lion .	183 9	25 7	14 9	600	256	24 0	8 6	„	Smith and Rodger	Smith and Rodger
	Llewellyn	190 0	26 7	15 0	643	350		9 0	„	Miller .	Miller
95	Loch Lomond	126 0	16 9	6 11	175	56	15 5	3 0	„	Denny	Smith and Rodger
	Londonderry	160 8	25 3	15 11	488	240	21 5	10 9	wood	R. Steele	R. Napier
	Lyra .	218 6	25 6	12 10	600	275	25 4	10 3	iron	R. Napier	Ditto
	Magicienne, R. N.	200 0	30 0	21 0	1000	400	28 0	13 8	wood		Penn
	Maid of Lorn (Tow-boat)	85 0	14 3	9 0	80	60	15 0	7 6	iron		
100	Manchester	165 0	22 6	10 6	400	150	18 0		„	Robinsons & Russell	Robinsons & Russell
	Maria .	275 0	36 0	9 6	1747	h.pr.	30 0		wood	American	American
	Marquis of Stafford	103 0	23 0	12 1	365	154	22 0		iron	Reid & Co.	Thomson
	Medway	215 0	36 6	30 6	1350	450	30 0	17 0	wood	Pitcher	Maudslay
	Merlin	152 0	16 7	8 3	207	70	13 1	3 10	iron	Wingate	Wingate
105	Meteor	105 9	17 6	8 6	130	62	14 0	5 6	„	Caird .	Caird
	Mindello	160 0	28 0	17 6	604	220	23 0	11 3	wood	Green .	Blyths
	Minerva	197 0	26 0	16 6	652	384	16 9		iron	Vernon	Bury
	Mississipi	220 0	40 0	23 6	1600	600	28 9		wood	American	American
	Mongibello	160 0	26 0	18 0	500	200		10 6	„		Maudslay
110	Nemesis	170 0	29 0	11 0	600	120	17 6	5 0	iron	Laird .	Forrester
	Nevka .	150 0	18 0	9 6	230	70	15 6	4 0	„	Fairbairn	Fairbairn
	New Grenada	178 0	25 0	14 0	390	212	23 0		„	Smith and Rodger	Smith and Rodger
	New York	210 0	36 6	22 0	1700	420		16 0	wood		Fawcett
	Niagara	251 0	38 1	25 6	1757	674	33 1		„	R. Steele	R. Napier
115	Niagara	265 0	28 6	9 3			30 0	4 8		American	American
	Nile .	175 0	33 0	20 6	912	220	20 0	13 6	„		Boulton and Watt
	Nimrod	185 0	26 0	16 0	591	320	24 6	11 10	iron	Vernon	Bury.
	Nix, Pruss. R. N.	170 0	26 0	11 6	560	160	17 0	6 9	„	Robinsons & Russell	Robinsons & Russell

TABLE No. III.—*Continued.*

Name of the Vessel	Length on Deck.	Breadth, extreme.	Depth in Engine-room.	Tonnage—Builder's old Measurement	Horses' Power.	Diameter of Wheels.	Mean Load—Draught.	Material.	Builders of the Vessel.	Makers of the Machinery.
	ft. in.	ft. in.	ft. in.	Tons.	Nomi-nal.	ft. in	ft. in.			
Norah Criena	135 0	18 6	8 0	236	77	16 4	6 0	wood	At Water-ford	At Water-ford
120 Ocean	160 0	25 0	15 6	500	239	23 6	12 6	,,	Wilson	Scott and Sinclair
Odin, R. N.	212 0	37 0	24 2	1326	560	27 6	70 0	,,	Fincham	Fairbairn
Ohio	265 0	46 0	33 0	2300	700	36 0		,,	American	American
Oregon	325 0	35 0	11 0	2000	h.pr.	35 0		Ditto .	American	American
Orion	212 0	28 0	18 6	805	440	29 7		iron	Caird .	Caird
125 Peiki Tijaret	172 0	26 6	16 6	568	180		10 6	wood	Fletcher	Miller
Peloro	135 0	20 2	11 2	252	100	15 6		,,	Pitcher	Boulton and Watt
Peterhoff	190 0	21 6	9 0	412	150	16 3	4 0	iron	Mare .	Rennie
Petrel	166 6	17 10	7 11	248	100	19 1	5 0	,,	Barr and M'Nabb	Barr and M'Nab
Pharos	146 0	21 0	12 9	303	150	19 0	7 6	,,	Fairbairn	Penn
130 Philadelphia	300 0	33 0	18 3	1100	500	27 0		wood	American	American
Pioneer	161 0	18 2	9 0	252	95	19 0	5 0	iron	Barr and M'Nab	Barr and M'Nab
Pizarro	187 0	30 0	20 0	800	350			wood	Wigram	Miller
Pottinger	220 0	35 0	28 9	1250	450		16 0	iron	Fairbairn	Miller
Powhattan	251 6	45 0	26 6	2400	800	31 0	19 0	wood	American	American
135 Precursor	230 0	37 0	25 0	1480	520		17 0	,,	Hedderwick	R. Napier
President	238 0	41 0	30 0	1921	940	34 0	17 0	,,	Curling and Young	Fawcett
Premier	137 6	17 7	7 0	212	62	16 2		iron	Denny	Smith and Rodgers
Pride of Erin	195 0	27 2	16 0	715	368	25 6		,,	R. Napier	R. Napier
Prince	165 0	24 0	13 0	446	200	20 0	7 6	,,	Fairbairn	Penn
140 Pr. Albert	160 0	19 6	9 6	310	110	17 6	4 6	,,	Coutts .	Milner
Pr. of Wales	165 0	26 6	14 6	575	260	25 0	7 9	,,	Tod and M'Gregor	Tod and M'Gregor
Princess	166 0	24 6	16 0	637	298	23 10	12 2	wood	Wilson	Fawcett
Princess	135 0	18 0	8 5	210	8	15 11	4 3	iron	Tod and M'Gregor	Tod and M'Gregor
Prs. Alice	164 0	24 1	14 0	479	212	22 9	9 0	,,	Ditto .	Ditto.
145 Prs. Alice R. N.	125 0	20 0	10 6	270	120	17 0	6 6	,,	Ditchburn	Maudslay
Prs. Royal	200 0	28 0	17 0	800	380	29 0	10 0	,,	Tod and M'Gregor	Tod and M'Gregor
Queen	165 0	16 6	8 9	217	90	16 6	4 3	,,	Rennie	Rennie
Queen	162 0	24 4	13 7	460	175	20 8		,,	Vernon	Fawcett
Railway	150 0	19 1	9 10	258	90	15 6		,,	Ditchburn	Penn
150 Rainbow	195 0	25 0	13 0	581	180		5 6	,,	Laird .	Forrester
Red Rover	158 0	22 4	10 6	350	120	16 6	5 6	wood		Seaward
Retribution R. N.	220 0	40 0	26 4	1641	800	34 0	18 0	,,	Symonds	Maudslay
Roberto	195 0	34 0	19 0	1056	300			,,	Pitcher	Ditto
Rose	153 0	20 0	11 6	305	100	17 0	6 6	iron	Fairbairn	Fairbairn
155 Royal Alice	145 0	18 5	8 0	165	96	17 9		,,	Tod and M'Gregor	Tod and M'Gregor
Royal Consort	180 0	26 0	15 5	605	316	27 0		,,	Ditto .	Ditto
Salamander	170 0	26 0	11 6	560	160	17 0	6 9	,,	Robinsons & Russell	Robinsons & Russell
Sampson, R. N.	208 0	37 0	23 0	1297	467	27 6		wood	Symonds	Rennie
Sapphire	155 0	18 0	9 9		150	16 0	4 8	iron		Seaward

TABLE No. III.—*Continued.*

	Name of the Vessel.	Length on Deck.	Breadth, extreme.	Depth in the Engine-room.	Tonnage—Builder's old Measurement.	Horses' Power.	Diameter of Wheels.	Mean Load—Draught.	Material.	Builders of the Vessel.	Makers of the Machinery.
		ft. in.	ft. in.	ft. in.	Tons.	Nominal.	ft. in.	ft. in.			
160	Satellite	108 6	18 9	9 8	150	80	13 6		iron	R. Napier	R. Napier
	Sheffield	155 0	22 0	10 0	350	150	18 0		wood	Rennie	Rennie
	Sidon, R. N.	215 0	39 0	27 0	1440	560	27 6	17 0	,,	Sir C. Napier	Seaward
	Singapore	236 0	30 4	18 7	1066	470	29 8	11 6	iron	Tod and M'Gregor	Tod and M'Gregor
	S. America	250 0	27 0	9 0			29 0	5 0	wood	American	American
165	Sovereign	140 0	17 0	8 4	200	82	17 6	5 0	iron	Tod and M'Gregor	Tod and M'Gregor
	Sphynx R.N.	185 0	36 0	20 11	1065	500	28 0		wood	Symonds	Penn
	Star .	156 0	17 9	8 4	185	100	19 0		iron	Tod and M'Gregor	Tod and M'Gregor
	St. Columba	200 0	27 3	15 5	719	350	28 0	9 0	,,	Laird .	Forrester
	Stromboli, R. N.	185 0	34 4	21 0	970	280	25 0		wood	Symonds	R. Napier
170	Superb	164 0	17 2	9 6	200	74	15 2		iron	J. Reid	R. Napier
	Susquehanna	256 6	45 0	26 6	2436	800	31 0	19 0	wood	American	American
	Tagus .	188 0	28 1	17 4	700	260			,,	J. Scott	Scott and Sinclair
	Tay .	215 0	36 6	30 6	1350	450	30 0	17 0	,,	Duncan	Caird
	Temparador	155 0	24 0	14 0	418	140		9 9	,,	Fletcher	Miller
175	Terrible, R. N.	230 0	42 6	27 0	1800	800	34 0	17 0	,,	Lang .	Maudslay
	Teviot .	215 0	36 6	30 6	1350	450	30 0	17 0	,,	Duncan	Caird
	Thames	215 0	36 6	30 6	1350	450		17 0	,,	Pitcher	Maudslay
	Thetis .	190 6	22 5	11 6	345	160	22 7	7 6	iron	R. Napier	R. Napier
	Thistle	198 0	26 4	16 0	655	336	25 9	11 0	,,	Ditto .	Ditto
180	Thistle	153 0	20 6	11 6	305	100	17 0	6 6	,,	Fairbairn	Fairbairn
	Tiger, R. N.	210 0	36 0	24 6	1220			17 0	wood	J. Edye	Penn
	Trafalgar	192 0	28 1	16 11	750	346	26 7	10 6	iron	Tod and M'Gregor	Tod and M'Gregor
	Trent .	215 0	36 6	30 6	1350	450		17 0	wood		Miller
	Trident R.N.	185 0	31 6	18 0	800	350	22 0	10 9	iron	Ditchburn	Boulton and Watt
185	Urgent .	175 0	26 0	17 5	562	280	24 6		,,		Caird
	Vanguard	183 0	27 3	16 7	663	324	27 0	11 6	iron	R. Napier	R. Napier
	Vesper	155 0	18 0	9 8	250	70			wood	Fletcher	Miller
	Victoria	150 0	20 4	10 5	290	100	15 0	7 0	iron	Tod and M'Gregor	Tod and M'Gregor
	Victoria and Albert R.N.	198 0	33 0	22 0	1040	430	31 6		wood	Symonds	Maudslay
	Waterman 9.	100 0	15 0	7 3		35		2 9	iron	D. Napier	D. Napier
190	Whitehaven	182 0	25 5	13 10	575	300	25 10	10 0	,,	Vernon	Butterly and Co.
	Windsor	205 0	28 0	16 3	764	340	28 2	12 3	,,	Vernon	Bury ..
	Wizard (Tug)	75 0	14 2	9 0	82	40	12 9		,,	Scott and Sinclair	Scott and Sinclair
194	Ysabel la Catolica	235 0	38 0	24 6	1567	500		17 0	wood	Wigram .	Maudslay

TABLE No. IV.

TABLE OF THE PRINCIPAL DIMENSIONS OF TWENTY-EIGHT MERCHANT STEAMERS WITH SCREW PROPELLERS.

Name of the Vessel	Length on Deck	Breadth extreme	Depth in Engine-room	Tonnage Builder's old Measurement	Horses' Power	Diameter of Screw	Mean Load-Draught	Material	Builders of the Vessel	Makers of the Machinery
	ft. in.	ft. in.	ft. in.	Tons.	No-minal.	ft. in.	ft. in.			
Albatross .	197 0	30 0	16 0	853	124	10 6		iron	Smith and Rodger	Smith and Rodger
Antelope .	175 0	26 4	17 0	600	100			„	Hodgson	
Apollo .	185 0	30 2	14 0	820	100	8 10		„	Smith and Rodger	Smith and Rodger
Archimedes .	180 0	44 0	24 0	1587	330	15 0	18 0	wood		Rennie
5 Archimedes	115 0	22 6	13 0	237	90	8 0.	9 4	„	Wyun	Ditto
Arno .	190 0	27 6	16 6	636	136	12 4		iron	Reid & Co. .	Thomson
Astrologer .	186 0	25 0	15 0	553	124	19 8		„	Smith and Rodger	Smith and Rodger
Ayrshire Lass	88 3	19 0	7 4	94	16	6 0		„	Denny .	Wingate
Bosphorus .	180 0	25 0	16 0	530	80	10 6	8 6	„	Mare .	Maudslay
10 Brit. Queen	190 0	29 0	18 0	800	130			„	Denny .	Caird
City of Glasgow	228 0	34 0	24 6	1200	380	13 0		„	Tod and M'Gregor	Tod and M'Gregor
Erin'sQueen	135 0	21 0	12 9	283	20	7 0	10 6	„	Denny .	Caird
European .	172 0	25 0	14 4	415	98	9 2	9 0	„	Smith and Rodger	Smith and Rodger
Fawn .	135 0	20 6	10 6	275	110		6 6	„	Penn .	Penn
15 Gr. Britain	300 0	51 0	31 4	3500	1000		16 0	„	Gt. Western Co. .	Acraman
Gr. Northern .	225 0	37 0	26 0	1750	370	12 0		wood	At Derry	At Derry
Humming Bird	132 4	18 0	9 3	135	80	5 3	7 6	iron	R. Napier .	R. Napier
Lady Seale	122 6	22 0	13 3	305	40	7 0		wood	Follet & Co.	Marshall
Livorno .	160 0	25 6	15 0	508	100	10 6	9 0	iron	Denny .	Thomson
20 Loch Fine .	76 0	18 6	7 7	120	15	5 0		„	Ditto .	Wingate
Marie .	145 0	20 0	14 6	375	80	10 0		„	Reid & Co. .	Thomson
Mars .	185 0	30 6	16 0	806	100	9 0	9 0	„	At Waterford	Smith and Rodgers
Mermaid .	135 0	16 6	9 0	164	90	5 8		„	Rennie	Rennie
Monumental City .	185 0	30 0	24 0		120	12 0	13 0	wood	American	American
25 Pomone .	170 7	42 7	17' 3		260			„	Boucher .	Count Rosen
Propontis .	175 0	25 6	17 6	532	80			iron	Mare .	Maudslay.
Sarah Sands	200 0	32 0	19 6	1000	200	14 6	14 6	„	Grantham	
28 Vesta .	114 0	20 4	12 2	180	38	8 0	8 0	„		

TABLE No. V,

PADDLE WHEEL STEAMERS IN HER MAJESTY'S NAVY AND POST OFFICE SERVICE.

Name of Ship.	Designer.	Maker of Engine.	Tonnage—Builders' Old Measurement.	Horse Power.	Kind of Engine.	Diameter of Cylinder.	Length of Stroke.	Kind of Boiler.	Pressure in Boiler.	Diameter of Wheels.	Medium Speed under Steam only.
						in.	f. i.		lbs.	f. i.	knots
Acheron	Sir W. Symonds	Seaward	722	160	Side-lever	49	4 9	Flue	6	20 0	8
Adder	Old P. O. Packets	Boulton & Watt	241	100	Side-lever	39½	3 6	Flue	4	14 0	7½
Advice	Lang	Boulton & Watt	197	100	Side-lever	39½	3 6	Flue	4	14 0	7½
African	Lang	Maudslay	295	90	Side-lever	38	3 6	Flue	4	14 0	7
Alban	Lang	Boulton & Watt	295	100	Side-lever	39½	3 6	Flue	4	14 0	7½
Alecto	Sir W. Symonds	Seaward	800	200	Direct	53½	4 6	Flue	5	23 0	8½
Antelope (Iron)	Ditchburn	Penn	620	260	Oscillat.	64	4 6	Tubular	8	20 0	8¼
Ardent	Sir W. Symonds	Seaward	800	200	Direct	53½	4 6	Tubular	6	21 0	8½
Argus	Lang	Penn	975	303	Oscillat.	64	6 0	Tubular	14	23 5	9¼
Avon	Old P. O. Packets	Boulton & Watt	361	170	Side-lever	48¼	4 6	Tubular	8	14 0	8
Banshee	Lang, jun.	Penn	650	365	Oscillat.	72½	5 0	Tubular	14	25 0	12
Basilisk	Lang	Miller	1000	405	Oscillat.	74	6 0	Tubular	10	24 0	9¼
Bee	Sir W. Symonds	Maudslay	42	10	Side-lever	20	2 0	Tubular	10	9 0	7
Birkenhead	Laird	Forrester	1400	556	Side-lever	85	7 0	Tubular	6	30 0	10½
Black Eagle	Lang, jun.	Penn	540	261	Oscillat.	62	4 6	Tubular	10	22 0	11¼
Blazer	Sir W. Symonds	Miller	527	136	Side-lever	43	3 6	Tubular	8	14 8	7½
Bloodhound (iron)	Napier	Napier	878	150	Side-lever	48	4 0	Tubular	10	18 6	8
Bull-dog	Sir W. Symonds	Rennie	1124	500	Direct	82	5 8	Tubular	7½	26 0	9½
Buzzard	Edye	Miller	997	303	Oscillat.	64	6 0	Tubular	14	23 4	9½
Caradoc (iron)	Sir W. Symonds	Seaward	650	350	Direct	75	4 4	Tubular	12	25 6	12
Centaur	Sir W. Symonds	Boulton & Watt	1270	540	Direct	85½	6 0	Tubular	8	27 6	8½
Cherokee	Sir W. Symonds	Maudslay	750	200	Side-lever	54	5 0	Flue	4	20 0	7
Colombia	Lang	Boulton & Watt	361	100	Side-lever	39½	3 6	Flue	4	14 0	8
Comet	Lang	Boulton & Watt	338	80	Side-lever	35½	3 6	Flue	4	14 0	8½
Confidance	Lang	Maudslay	294	100	Side-lever	40	4 0	Flue	4	16 0	8
Cormorant	Sir W. Symonds	Fairbairn	1057	300	Direct	65½	5 3	Flue	7	24 0	10
Cuckoo	Lang	Boulton & Watt	234	100	Side-lever	39½	3 6	Tubular	1	14 6	9½
Cyclops	Sir W. Symonds	Seaward	1195	320	Direct	64	5 6	Flue	5	26 0	8¼
Dasher	Sir W. Symonds	Seaward	260	101	Side-lever	40½	3 6	Tubular	8	16 0	9
Dee	Lang	Maudslay	704	200	Side-lever	54	5 0	Tubular	8	20 0	8
Devastation	Sir W. Symonds	Maudslay	1058	420	4 cylinders	54	6 0	Tubular	6	25 4	10
Dover (iron)	Laird	Forrester	224	90	Side-lever	38	3 0	Tubular	8	13 6	10
Dragon	Sir W. Symonds	Fairbairn	1296	560	Direct	88	5 9	Tubular	8	27 0	10
Driver	Sir W. Symonds	Seaward	1056	280	Direct	62	5 3	Tubular	8	27 0	9½
Echo	Lang	Butterley Co.	295	140	Side-lever	44½	4 6	Flue	5	17 0	8½
Elfin	Lang, jun.	Rennie	111	40	Oscillat.	27	2 6	Tubular	16	11 4	12¼
Fearless	Old P. O. Packets	Boulton & Watt	165	76	Side-lever	35½	3 2	Flue	4	12 0	8
Firebrand	Sir W. Symonds	Seaward	1190	410	Direct	75	5 9	Tubular	8	26 8	8½
Fire-fly	Lang, jun.	Maudslay	550	218	Side-lever	55½	5 0	Tubular	5	20 0	8
Fire-queen	Napier	Napier	312	115	Staple	46	3 0	Tubular	16	16 0	13½
Furious	Fincham	Miller	1286	399	Oscillat.	72	7 0	Tubular	14	27 4	
Fury	Sir W. Symonds	Rigby	1124	515	Direct	84	5 9	Tubular	10	25 6	9½
Garland	Lang, jun.	Penn	300	124	Oscillat.	43½	4 0	Tubular	16	18 0	12½
Geyser	Sir W. Symonds	Seaward	1060	273	Direct	62	5 3	Tubular	6	25 7	8½
Gladiator	Sir W. Symonds	Miller	1210	455	Direct	79	5 0	Tubular	7	25 2	9½
Gorgon	Sir W. Symonds	Seaward	1108	320	Direct	64	5 9	Tubular	8	26 0	8½
Growler	Sir W. Symonds	Seaward	1059	280	Direct	62	5 3	Tubular	8	25 3	8½
Harpy (iron)	Ditchburn	Penn	345	150	Oscillat.	49	4 0	Tubular	8	16 0	8
Hecate	Sir W. Symonds	Scott & Sinclair	817	240	Side-lever	60	5 0	Tubular	8	24 6	8½
Hecla	Sir W. Symonds	Scott & Sinclair	817	240	Side-lever	60	5 0	Tubular	8	24 6	8½
Hermes	Sir W. Symonds	Maudslay	830	218	4 cylinders	40½	4 6	Tubular	8	20 0	8½
Hydra	Sir W. Symonds	Boulton & Watt	817	220	Side-lever	56	5 0	Tubular	8	23 6	8½
Inflexible	Sir W. Symonds	Fawcett	1122	379	Direct	72	5 9	Tubular	14	28 6	9
Jackal (iron)	Napier	Napier	340	150	Side-lever	48	4 0	Tubular	10	18 0	8
Janus	Lord Dundonald	American	763	220	Side-lever	56	5 0	Tubular	8	16 6	9½
Jaspar	Old P. O. Packets	Fawcett	233	100	Side-lever	39½	3 8	Flue	4	14 0	7½
Kite	Old P. O. Packets	Fawcett	800	150	Side-lever	47½	4 3	Flue	4	18 0	8½
Leopard	Fincham	Seaward	1435	560	Direct	86½	6	Tubular	14	30 0	
Lightning	Lang	Maudslay	296	100	Side-lever	40½	4 0	Flue	6	16 6	8°
Lizard											

TABLE No. V.—*Continued.*

Name of Ship.	Designer.	Maker of Engine.	Tonnage—Builders' Old Measurement.	Horses' Power.	Kind of Engine.	Diameter of Cylinder. (in.)	Length of Stroke. (f. i.)	Kind of Boiler.	Pressure in Boiler. (lbs.)	Diameter of Wheels. (f. i.)	Medium Speed under Steam only. (knots)
Locust	Sir W. Symonds	Maudslay	284	101	Side-lever	40½	3 6	Tubular	8	15 7	7
Magicienne	Edye	Penn	1220	399	Oscillat.	72	7 0	Tubular	14	27 4	10
Medea	Lang	Maudslay	335	850	4 cylinders	50	5 3	Tubular	10	23 2	9
Medina	Sir W. Symonds	Fawcett	886	30	Side-lever	64	6 0	Tubular	8	24 6	8¼
Medusa	Sir W. Symonds	Fawcett	880	300	Side-lever	64	6 0	Tubular	8	24 6	8¼
Merlin	Sir W. Symonds	Fawcett	880	300	Side-lever	64	6 0	Tubular	8	24 6	8¼
Minos	Canada	Ward & Co.	406	90	Side-lever		4 6	Flue	4		
Mohawk (iron)	Fairbairn	Maudslay	174	60	Side-lever	34	3 2	Flue	4	11 6	8½
Monkey	Old P. O. Packets	Boulton & Watt	212	130	Side-lever	45½	3 6	Tubular	8	14 0	8¼
Myrmidon (iron)	Ditchburn	Penn	370	150	Oscillat.	48	4 0	Tubular	10	17 0	8
Myrtle	Old P. O. Packets	Boulton & Watt	116	50	Side-lever	30	2 6	Flue	4	10 9	7½
Oberon (iron)	Sir W. Symonds	Rennie	650	260	Oscillat.	61½	5 0	Tubular	10	21 0	9
Odin	Fincham	Fairbairn	1326	560	Direct	88	5 3	Tubular	10	27 6	9
Onyx (iron)	Ditchburn	Penn	300	124	Oscillat.	43½	4 0	Tubular	16	18 6	13
Otter	Old P. O. Packets	Boulton & Watt	237	120	Side-lever	44½	3 6	Flue	5	14 0	7½
Penelope	Edye	Seaward	1616	625	Direct	91½	6 8	Tubular	10	31 0	9½
Pigmy	Old P. O. Packets	Fawcett	227	80	Side-lever	35	3 6	Flue	4	12 6	8
Pike	Old P. O. Packets	Fawcett	111	50	Side-lever	30½	2 6	Flue	4	10 9	8
Pluto	Lang	Boulton & Watt	365	100	Side-lever	39½	3 6	Flue	4	14 0	8
Polyphemus	Sir W. Symonds	Seaward	800	200	Direct	53½	4 6	Tubular	8	23 5	8½
Porcupine	Lang	Maudslay	380	132	Side-lever	44	4 0	Tubular	8	15 6	8½
Princess Alice (iron)	Ditchburn	Maudslay	270	117	Annular	43	3 6	Tubular	16	18 0	12½
Prometheus	Sir W. Symonds	Seaward	796	192	Direct	53½	4 6	Tubular	10	23 5	8½
Prospero	Old P. O. Packets	Coates & Young	249	144	Side-lever	46	4 0	Flue	4	14 9	9
Retribution	Sir W. Symonds	Penn	1640	399	Oscillat.	72	7 0	Tubular	14	24 4	10
Rhadamanthus	Roberts	Maudslay	813	220	Side-lever	55½	5 0	Flue	5	20 0	8
Rosamond	Sir W. Symonds	Miller	1059	298	Direct	65½	5 0	Tubular	10	25 0	9½
Salamander	Sir W. Symonds	Maudslay	818	220	Side-lever	55½	5 0	Flue	4	21 0	8
Sampson	Sir W. Symonds	Rennie	1299	470	Direct	81	5 8	Tubular	6	26 4	9
Scourge	Sir W. Symonds	Maudslay	1124	420	4 cylinders	54	6 0	Tubular	8	26 6	11
Shearwater	Graham	Boulton & Watt	343	160	Side-lever	48½	4 6	Flue	4	17 0	8
Sidon	Sir C. Napier	Seaward	1328	560	Direct	86¾	4	Tubular	10	22 6	10
Sphinx	Sir W. Symonds	Penn	1058	500	Oscillat.	82½	6 0	Tubular	8	28 0	9½
Spiteful	Sir W. Symonds	Scott & Sinclair	1060	280	Side-lever	62	6 0	Tubular	8	26 0	9
Spitfire	Lang	Butterley & Co.	430	140	Side-lever	44½	4 6	Tubular	8	17 6	8½
Sprightly	Old P. O. Packets	Boulton & Watt	234	100	Side-lever	39½	3 6	Flue	5	13 0	8
Stromboli	Sir W. Symonds	Napier	970	280	Side-lever	63	6 0	Tubular	8	25 0	8½
Styx	Sir W. Symonds	Seaward	1057	273	Direct	62	5 3	Tubular	8	25 7	9½
Tartarus	Sir W. Symonds	Miller	523	136	Side-lever	46	3 6	Tubular	8	15 6	8½
Terrible	Lang	Maudslay	1850	829	4 cylinders	72	8 0	Tubular	7	34 4	11
Tiger	Edye	Penn	1220	399	Oscillat.	72	7 0	Tubular	14	27 0	10
Torch (iron)	Sir W. Symonds	Seaward	345	150	Side-lever	49	3 9	Tubular	10	17 0	8
Trident (iron)	Sir W. Symonds	Boulton & Watt	850	350	Oscillat.	71	5 0	Tubular	10	23 0	8
Triton (iron)	Sir W. Symonds	Miller	653	260	Oscillat.	64	4 6	Tubular	10	21 0	9
Undine	Pasco	Miller	200	106	Oscillat.	42	3 0	Tubular	25	17 0	12½
Vesuvius	Sir W. Symonds	Napier	970	295	Side-lever	63½	6 0	Flue	5	26 4	8
Victoria & Albert	Sir W. Symonds	Maudslay	1034	420	4 cylinders	54	6 0	Tubular	10	29 8	11½
Violet	Ditchburn	Penn	300	124	Oscillat.	43½	4 0	Tubular	16	18 0	13
Virago	Sir W. Symonds	Boulton & Watt	1060	300	Direct	66½	5 0	Tubular	8	24 9	9½
Vivid	Lang, jun.	Penn	352	160	Oscillat.	49½	4 0	Tubular	16	18 6	13
Vixen	Sir W. Symonds	Seaward	1059	280	Direct	62	5 3	Tubular	8	25 8	9½
Volcano	Sir W. Symonds	Seaward	720	132	Side-lever	45	4 3	Flue	5	20 3	7½
Vulture	Sir W. Symonds	Fairbairn	1190	470	Direct	80½	5 9½	Tubular	10	25 0	10
Widgeon	Sir W. Symonds	Seaward	164	90	Side-lever	38	3 1	Tubular	8	13 9	9
Wildfire	Old P. O. Packets	Boulton & Watt	186	75	Side-lever	35½	3 0	Tubular	8	13 0	8
Zephyr	Old P. O. Packets	Boulton & Watt	237	100	Side-lever	39½	3 6	Flue	4	14 0	8

TABLE No. VI

TABLE OF EXPERIMENTS WITH H. M. SCREW STEAM-TENDER, "DWARF."

Burthen in tons, 163 $\frac{44}{94}$. Nominal horse power, 90. Draught of water, 7 feet aft; 5 feet 10 inches forward. Fitted with a common two-threaded screw, 5 feet 1 inch in diameter, with common pitch.

No. of Experiments.	Pitch of the Screw.	Length of the Screw.	Area of the Screw.	Average revolutions of the engines per min.	Average revolutions of the screw per min.	Proportion of revolutions of screw to engine.	Average pressure at the end of shafts, indicated by the Dynamometer.	Speed of the screw per hour.	Slip of the screw per hour.	Speed of the Vessel per hour.	Gross average power exerted in the cylinders.	Speed of the Vessel computed as if the power exerted had been (90 horses).	Average power expended in propelling, by Dynanometer.	Ratio of gross indicator to Dynanometer power.
	feet	ft. in.	sq. f.				tons.	knots		knts.	horses.	knots.	horses.	
1	8 0	2	22·2	28·3	146·2	5 16 1	1·36	11·53	25·0	8·65	130·7	9·25	81·0	1·62
2	,,	2	17·8	29·6	152·7	,,	1·49	12·05	25·7	8·95	151·5	9·12	92·1	1·65
3	,,	2	13·3	30·1	155·4	,,	1·42	12·26	27·1	8·94	137·0	9·41	87·3	1·57
4	,,	1 0	8·9	32·2	166·0	,,	1·51	13·09	30·4	9·11	168·8	8·95	95·1	1·78
5	10.32	1 8 7/16	13·3	31·8	127·1	4 1	1·07	12·93	33·4	8·60	148·7	8·82	63·5	2·33
6	,,	2 3 1/4	17·8	30·8	123·3	,,	·96	12·55	30·8	8·74	136·3	9·22	57·6	2·34
7	,,	1 1 3/4	8·9	34·9	139·7	,,	1·00	14·22	36·4	9·05	154·0	9·16	62·6	2·44
8	,,	2 1 7/16	22·2	30·9	123·6	,,	·91	12·57	29 3	8·89	143·8	9·21	55·9	2·57
9	13·33	1 10 0 9/16	13·3	36·6	114·2	3 13 1	1·17	14·90	40·4	8·88	161·7	8·85	71·8	2·25
10	,,	3 0 3/4	22·2	34·0	106·6	,,	1·35	13·90	38·7	8·52	149·5	8·72	79·4	1·9
11	,,	1 1 1/16	8·9	40·2	125·9	,,	1·74	16·42	44·7	9·07	176·9	8·77	108·5	1·62
12	,,	2	17·8	35·7	111·8	,,	1·74	14·54	39·5	8 83	166·4	8·71	105·9	1·57
13	,,	3	17·8	26·2	105·7	4 1	1·78	13·79	33·9	8·29	151·9	8·43	101·6	1·49
14	,,	3	22·2	25·4	101·6	,,	1·73	13·52	39·5	8·01	139·6	8·52	95·4	1·47
15	,,	1 10 7/8	13 3	26·0	104·1	,,	1·69	13·58	41·7	7·92	117·2	8·79	92·0	1·27
16	,,	1 3 7/16	9·9	29·8	119·3	,,	1·93	15·57	46·1	8·38	147·4	8·61	110·6	1·32
17	,,	1 3 7/16	8·9	21·6	111·7	5 16 1	1·64	14·58	46·1	7·85	116·6	8·73	88·8	1·31
18	,,	1 10 7/8	13·3	19·9	102·6	,,	1·62	13·39	42·9	7·64	114·2	8·55	85·4	1·34
19	,,	2 6 1/16	17·2	19·0	97·9	,,	1·73	12·78	41·1	7·52	111·5	8·48	89·6	1·23
20	,,	3 1	22·2	18·5	95·4	,,	1·71	12·45	39·5	7·52	108·8	8·56	88·5	1·22
21	10 32	2 10 7/16	2·2	22·5	116·2	,,	1·99	11·82	30·0	8·28	127·3	8 94	113·4	1·12
22	,,	1 8 7/16	13·3	24·9	128·4	,,	1·91	13·06	36·4	8·39	134·0	8·81	109·3	1·23
23	,,	1 1 3/4	8 9	26·6	137·5	,,	1·99	14 0	38·5	8·61	138·5	9·03	113·1	1·17
24	,,	2 3 1/4	17·8	23·9	123·1	,,	1·94	12·53	32·9	8·40	126·6	9·08	112·3	1·13

These experiments were made at Woolwich during the months of June, July, August, 1845. The following are the dimension of "Dwarf," viz.:—

	ft.	in.
Length between the Perpendiculars	130	0
Breadth extreme	16	6
Depth in Engine-room	15	9
Diameter of Cylinders	3	4
Length of Stroke	2	8

NOTE.—For Tables VI. and VII. see the very valuable Table in the new edition of "Tredgold on the Steam Engine," Vol. III. John Weale.

	Name of the Vessel.	Length between the Perpendiculars.	Breadth, extreme.	Mean draught at the time of trial.	Area of immersed midship section.	Displacement at time of trial.	Tonnage—Builder's old measurement.	Horses' power, Nominal.	Horses' power Indicated at trial.
		ft. in.	ft. in.	ft. in.	sq. ft.	Tons.	Tons.	H. P.	H. P.
1	Ajax . . .	176 0	48 6¼	22 6½	807	3090	1761	450	846
2	Amphion .	177 0	43 2	19 0	546	2025	1474	300	592
3	Archer . .	180 0	33 0	14 1	372	1238	970	200	345
4	Arrogant .	200 0	45 18¾	18 10½	580	2444	1872	360	623
5	Bee . . .	63 0	12 2	3 5½	28·2	33·2	43	10	
6	Blenheim .	181 2⅞	48 6	21 1½	738	2790	1832	450	938
7	Brisk . .	193 7	35 0	13 9	373	1474	1074	250	
8	Conflict .	192 6	34 4	14 6	402	1443	1038	400	777
9	Dauntless .	210 0	39 9	16 4	522	2240	1497	580	811
10	Ditto, lengthened at the stern	218 1				2251	1569	,,	1218
11	Desperate .	192 6	34 4	15 9	443	1628	1037	400	
12	Dwarf (iron) .	130 0	16 6	5 6	44	98	164	90	216
13	Encounter .	190 0	33 2	{11 9½ / 12 6}	{318 / 341}	{1192 / 1290}	953	360	{672 / 646}
14	Erebus . .	105 0	28 10	14 1	328	715	372	30	
15	Euphrates .	215 7	40 6	16 7½	570	2402		620	
16	Fairy (iron) .	144 8	21 1½	{4 10 / 5 10}	{71·5 / 82}	{168 / 196}	312	128	{364 / 321}
17	Greenock (iron)	213 0	37 4⅖	15 0	450	1980	1418	338	
18	Highflyer . .	192 0	36 4	15 9	465	1737	1153	250	
19	Hogue . .	184 0	48 4½	22 10	820	3155	1846	450	
20	Horatio . .	154 3	40 2½	19 1½	537	1707	1090	250	
21	Megæra (iron) .	207 0	37 10	16 0	487	2048	1395	350	780
22	Minx (iron) .	131 0	22 1	5 2½	82	203	303	100	234
23	Ditto, horse power diminished	,,	,,	,,	,,	,,	,,	10	32
24	Miranda . .	196 0	34 0	13 6	374	1522	1039	250	
25	Niger . .	194 4	34 8	{14 10 / 14 6½}	{403 / 392}	{1362 / 1323}	1072	400	{828 / 919}
26	Phœnix . .	174 7	31 10	{13 9½ / 13 1½}	{347 / 327}	{1225 / 1140}	809	260	{382 / 489}
27	Plumper . .	140 0	27 6	{10 11 / 12 3}	{204 / 241}	{539 / 652}	490	60	{148 / 149}
28	Rattler . .	179 6	32 8½	{11 8 / 13 6}	{274 / 330}	{870 / 1078}	888	200	{428 / 486}
29	Reynard . .	147 8	27 10	{9 6 / 10 11}	{184 / 222}	{478 / 604}	516	60	{165 / 158}
30	Rifleman . .	150 0	26 7	{9 3 / 9 3}	{173 / 173}	{484 / 484}	486	200	{348 / 366}
31	Ditto, horse power diminished	,,	,,	{9 3½ / 10 2½}	{175 / 199}	{487 / 565}	,,	100	{188 / 190}
32	Sanspareil .	200 6	52 1	22 9	920	3484	2334	350	408
33	Sharpshooter (iron)	150 0	26 7½	{9 1½ / 9 3}	{192 / 196}	{505 / 518}	489	200	{365 / 175}
34	Simoom (iron) .	246 0	41 0	17 0	567	2789	1980	250	
35	Teazer (iron) .	130 0	21 9½	5 3	82·9	205	296	100	
36	Ditto, horse power diminished	,,	,,	,,	,,	,,	,,	40	128
37	Termagant .	210 1	40 6	17 1	587	2408	1547	620	1351
38	Vulcan (iron) .	220 0	41 5	15 6	465	2076	1764	350	793
39	Wasp . .	180 0	33 10	14 9	395	1337	970	100	

N. B.—The Experiments made on each Vessel are continued, and

No. VII.

IN HER MAJESTY'S NAVY.

Vessel.

Speed per hour.	When completed and tried.	Constructor of Vessel.	Remarks, and state of the Vessel at her trial trip.
Knots.	Year.		
7·147	1848	Old 74 . . .	Not rigged, but ballasted.
6·75	1847	Old Frigate .	Rigged and fully equipped for sea.
7·818	1849	Deptford Dockyard .	Not rigged, but ballasted.
8·295	1849	Fincham . .	Rigged and fully equipped.
{ 6·822 / 7·501 / screw / paddles }	1842	Symonds . . {	Fitted also with · paddles, speed 7·501 knots.
5·816	1849	Old 74 . . .	Rigged and partially equipped.
	1851	Woolwich Dockyard .	Not completed.
9·289	1848		Rigged and partially equipped.
7·366	1848	Fincham . .	Jury rigged, ballasted to trim.
10·293	1850	„ . . . {	Altered at stern, rigged and fully equipped.
	1851	Pembroke Dockyard .	Not completed.
10·537	1843	Rennie . .	Not rigged.
{ 10·254 / 9·375 }	1848	Fincham . .	Not rigged, but ballasted to trim.
{ esti- mated at 3·5 }	1845	Old 28 . . .	Rigged and fully equipped.
	1851	Deptford Dockyard	Not completed.
{ 13·324 / 11·891 }	1845	Ditchburn . {	Not rigged, light. / Rigged and fully equipped.
	not com- plete	Scott and Sinclair	Not completed.
	„	Woolwich Dockyard	Not completed.
by log 7·5	1848	Old 74 . . .	Rigged and fully equipped.
	1851	„ . . .	Not completed.
9·75	1850	Fairbairn . .	Not rigged, but ballasted to trim.
9·137	1848	Symonds . .	Ditto.
4·515	1849	„	Ditto.
	not com- plete	Sheerness Dockyard .	Not completed.
{ 9·494 / 10·427 }	1849	Lang . . .	Rigged and fully equipped.
{ 7·106 / 8·74 }	1848 / 1849 }	Seppings . {	Not rigged, but ballasted. / Rigged.
{ 7·418 / 6·497 }	1848	Fincham . . {	Rigged and partially equipped. / Rigged and fully equipped for sea.
{ 10·074 / 9·639 }	1844 / 1845 }	Symonds . . {	Not rigged, but ballasted. / Rigged and fully equipped for sea.
{ 8·238 / 7·3 }	1848 / 1849 }	Symonds . . {	Not rigged, light. / Rigged and fully equipped.
{ 3·096 / 9·499 }	1847	Fincham . . {	Before stern made finer, &rigg.&ball / Subsequently to ditto ditto.
{ 8·011 / 7·977 }	1848	„	Horse power diminished.
	not com.		Not completed.
{ 9·782 / 9·189 }	1847 {	Fincham, same lines } as Rifleman . }	Not rigged, but ballasted. / Rigged and partially equipped.
	1851	Robert Napier .	Not completed. Troop ship.
{ 6·315 / 7·685 }	1847 / 1848	Symonds . / „	Not rigged. Before stern made finer. / Ditto. Subsequently to do.
9·51	1849	White, of Cowes	Rigged and equipped for sea.
9·605	1849	Ditchburn . .	Not rigged, but ballasted.
	1851	Deptford Dockyard	Not completed.

TABLE No.

TABLE OF SCREW STEAMERS

2.—*Propeller, and*

Name of the Vessel.	Tonnage—Builder's old Measurement.	Horses' Power, Nominal	Diameter of Screw.	Pitch of Screw	Length of Screw.	Revolutions.	
						Intended.	Actual at Trial.
	Tons.	H. P.	ft. in.	ft. in.	ft. in.	No.	No.
1 Ajax . . .	1761	450	16 0	17 11	3 2	45	48
2 Amphion . .	1474	300	15 0	21 0	2 6	48	45
3 Archer . . .	970	200	9 0	7 9	1 4	144	108·4
4 Arrogant . .	1872	360	15 6	15 0	2 6	60	55·5
5 Bee . . .	43	10	3 1	3 9			240
6 Blenheim . .	1832	450	16 0	20 0	3 4	45	43
7 Brisk . . .	1074	250				90	
8 Conflict . .	1038	400	13 6	16 6	2 9	75	68
9 Dauntless . .	1497	580	14 8	18 0	3 0	70	55·3
10 Do. lengthened and stern altered }	1569	,,	,,	,,	,,	,,	68·26
11 Desperate . .	1037	400	13 0	14 0	2 4	87·28	
12 Dwarf . . .	164	90	5 8	8 0	1 0	180	182·8
13 Encounter . .	953	360	12 0	15 0	2 6	80	{ 78 { 72
14 Erebus . .	372	30				70	
15 Euphrates . .		620					
16 Fairy . .	312	128	{ 5 4 { 6 2	8 0 8 0	1 0 1 4		{ 258 { 220
17 Greenock . .	1418	338	14 0	13 0	2 2	98	
18 Highflyer . .	1153	250				85	
19 Hogue . . .	1846	450	16 0	20 0	3 4	45	50
20 Horatio . .	1090	250				55	
21 Megæra . .	1395	350				55	
22 Minx . . .	303	100	4 6	5 0	1 0	220	254
23 Do. H. P. diminished.	,,	10	5 0	3 8			140
24 Miranda . .	1039	250				77·72	
25 Niger . . .	1072	400	12 6	17 0	2 10	75	{ 68·8 { 74·32
26 Phœnix . .	809	260	{ 12 0 { 11 10½	12 8 9 8	2 1 1 7 }	92	{ 68 { 96
27 Plumper . .	490	60	9 0	5 7	1 0	155	{ 115 { 112
28 Rattler . .	888	200	10 0	11 0	1 3	100	{ 104 { 107·92
29 Reynard . .	516	60	{ 8 9 { 8 11	8 0 7 3	1 4½ 1 4½ }	120	{ 108·86 { 112
30 Rifleman . .	486	200	8 0	9 0	1 6	144	{ 119·25 { 129
31 Do. H. P. diminished .	,,	100	{ 8 0 { 9 0	9 0 9 0	1 6 1 6 }	144	{ 110 { 98·75
32 Sanspareil . .	2334	350				55	
33 Sharpshooter .	489	200	{ 8 0 { 9 0	9 0 9 0	1 6 1 6 }	144	{ 140·7 { 124·5
34 Simoom . .	1980	350				55	
35 Teazer . . .	296	100	4 6	5 10	1 0	220	200
36 Do. H. P. diminished .	,,	40	5 0	7 0	1 2		192·09
37 Termagant . .	1547	620	{ 15 6 { 15 6	18 0 17 2½	3 0 2 10 }	70	{ 66 { 73
38 Vulcan . .	1764	350	14 0	16 6	2 9	65	66·5
39 Wasp . . .	970	100				121	

. B.—The Experiments made on each Vessel are continued and cor-

VII.—*Continued*.

IN HER MAJESTY'S NAVY.

Proportional Numbers.

Rate of Screw.	Rate of Ship.	Slip of the Screw.		Ratio of				
				Vessel's length to breadth.	Screw's Pitch to Diameter.	Immersed ⊕ Section to Screw's disc.	Nominal H. Power to ⊕ Section.	Indicated H. Power to ⊕ Section.
Knots.	Knots.	Knots.	p. Cent.					
8·482	7·147	1·335	15·74	3·625	1·12	4·01	0·56	1·05
·321	6·75	2·571	27·58	4·1	1·4	3·09	0 55	1·08
8·293	7·818	0·475	5·73	5·32	0 86	5·84	0·54	0·93
8 211	8·295	{nega-tive 0·084}	{nega-tive 1·02}	4·37	0·96	3·07	0·62	1·07
8·877	6·822	2·055	23·15	5·17	1·21	3·76	0·35	
8·483	5·816	2·667	31·4	3·73 5·53	1·25	3·67	0·61	1·27
11 667	9·289	1·778	16·06	5·6	1·22	2·81	0·99	1·93
9 818	7·366	2·452	24·97	5·28	1·22	3·99	1·11	1·55
12·123	10·293	1·83	15·09	5·48 5·6	,, 1·08	,,	,,	2·33
14·427	10·537	3 89·	26·96	7·87	1·41	1·74	2·04	4·91
11 541	10·254	1·287	11 15	5·73	1·25	{ 2·81 3·01	1·13 1·06	2·11 1·89
10·653	9·375	1·278	11·99 }	3·64 5·32				
20·359	13·324	7·035	34·55	6·84	{ 1·5 1·29	3·2 2·74	1·79 1·56	5·08 3·91
17·36	11·891	5·469	31·5	5 69 5·28				
9·864	{by log. 7·5}	2·364	23·96	3·8 3·83 5·47	1·25	4·03	0·55	
12·533	9·137	3·396	27 09	5·93	1·11	5·15	1·22	2·86
5·062	4·515	0·547	10·8	,, ·76	0·73	4·17	0·12	0·38
11·537	9·494	2·043	17·7 }	5·6	1·36	{ 3·28 3·19	2·05 1·02	2·05 2·34
12·462	10·427	2·035	16·33					
8·496	7·106	1·39	16·36	5·43	{ 1·05 0·81	3·16 2·97	0·75 0·79	1·1 1·49
9·153	8·74	0·413	4·51 }					
6·333	7·418	{nega-tive 1·085 0 329}	{nega-tive 17 13 5 33}	5·09	0·62	{ 3·2 3·78	0·29 0·25	0·72 0·62
6·168	6·497							
112	10·074	1 21	10·72 }	5·39	1·1	{ 3·49 4·2	0 73 0 6	1·56 1·32
11·709	9·639	2·07	17·67					
8·59	8·258	0·352	4·09 }	5·3	{ 0·94 0·81	3·06 3·55	0·32 0·27	0·89 0·69
8·009	7·3	0·709	8·85					
10·536	8·096	1·49	23·52	5·64	1·12	3·44	1·15	{ 2·01 2·12
11·452	9·499	1·953	17·95					
9·765	8·011	1·754	17 06 }	5·64	{ 1·12 1·0	3·48 3·12	0·57 0·5	1·07 0·95
8·766	7·977	0·789	9·	3·84				
12·49	9·782	2·708	21·68 }	5·63	{ 1·12 1·0	3·81 3·08	1·04 1·02	2·12 1·86
11·052	9·189	1·863	16·85	6·0				
11·507	6·315	5·192	45·12	5·96	1·29	5·21	1·2	2·11
13·263	7·685	5·578	42·05	5·96	1·4	4·22	0·48	1·54
11·718	9·16	2·552	21 77 }	5·19	{ 1·16 1·11	2·74 3·11	1·2 1·05	2·4 2·3
12·391	9·51	2·881	23·25					
10·823	9·605	1·218	11·25	5·31 5·32	1·18	3·02	0·75	1·7

TABLE OF SCREW STEAMERS IN HER MAJESTY'S NAVY.

3.—*Engines.*

Name of the Vessel.	Manufacturers of the Machinery.	Description of Engines.	Diameter of Cylinders.	Length of Stroke.	Revolutions per min. Intended.	Revolutions per min. Actual at Trial.	Indicator pressure on piston per sq.in.	Load on the Safety Valve.	Height of Engine Barometer.	Horses' power Nominal.	Horses' power Indicated.	Multiple of Gearing, when used.
		Cyls.	inches	f. i.	No.	No.	lb	lb	In.	H P	H P	
1 Ajax	Maudslay & Field	Horizontal 4	55	2 6	45	48	12·24	6	24½	450	846	Direct.
2 Amphion	Miller & Ravenhill	Ditto . . 2	48	4 0	48	45	15	10	25	300	592	,,
3 Archer	Ditto .	Ditto . . 2	46	3 0	48	36·16	15·8	10	26	200	345	3 to 1
4 Arrogant	Penn & Son	Horizont. Trunk }2 {60—24 / —55}		3 0	60	55·5	13	5	27	360	623	Direct.
5 Bee	Maudslay & Field	Beam . . 1	20	2 0	..	48	..	..	27½	10	..	5 to 1
6 Blenheim	Seaward & Capel	Horizontal 4	52	3 0	45	48	14·13	10	27	450	938	Direct.
7 Brisk	Scott, Sinclair & Co.	Ditto . . 2	52	3 6	40	..	..	..	..	250	..	2·25 to 1
8 Conflict	Seaward & Capel	Ditto . . 4	46	2 0	75	68	14·19	16	25	400	777	Direct.
9 Dauntless	Rob. Napier	Ditto . . 2	84	4 0	36	24·3	12·42	8	25½	580	811	2·276to1
10 Do. length-end &stern altered	Ditto .	Ditto . . 2	,,	,, ,,		30	15·11	,,	26½	,,	1218	,,
11 Desperate	Maudslay & Field	Ditto . . 4	55	2 6	40	..	..	..	..	400	..	2·182to1
12 Dwarf	C. J. Rennie	Vertical . 2	40	2 8	35	35·5	15	8	27	90	216	5·15 to 1
13 Encounter	Penn & Son	Horizont. Trunk }2 {60—24 / —55}		3 0	80	78	13·31	..	26	360	672	Direct.
14 Erebus	Maudslay & Field	Locom. H. Pres. 2	.	..	..	..	..	..	..	30	..	,,
15 Euphrates	Seaward & Capel	Horizontal 4	62	3 6	35	..	..	..	..	620	..	2 to 1
16 Fairy	Penn & Son	Vert.Oscil. 2	42	3 0	36·5	51·6	14	..	..	128	364	5 to 1
17 Greenock	Scott, Sinclair & Co.	Horizontal 2	71	4 0	42	..	..	..	..	338	..	2·33 to 1
18 Highflyer	Maudslay & Field	Ditto . . 2	55	4 0	31·5	..	..	..	..	250	..	2·7 to 1
19 Hogue	Seaward & Capel	Ditto . . 4	51½	3 0	45	50	..	..	26½	450	..	Direct.
20 Horatio	Ditto .	Ditto . . 2	54	3 0	45	..	..	..	..	250	..	2 to 1
21 Megæra	G & J.Rennie	Ditto . . 4	49½	2 0	55	..	..	..	..	350	..	Direct.
22 Minx	Miller & Ravenhill	Vert.Oscil. 2	34	2 9	55	63·5	12·19	10	26	100	234	4 to 1
23 Ditto, H.P. diminished	Seaward & Capel	H. Press. horizont. 2	..	.. ..	..	140	39	60	..	10	32	Direct.
24 Miranda	Rob. Napier	Horizontal 2	56	3 9	32	.	..	..	..	250	..	2·43 to 1
25 Niger	Maudslay & Field	Ditto . . 4	47⅝	1 10	75	74·3	15·63	8	24½	400	919	Direct.
26 Phœnix	Penn & Son	Vert.Oscil. 2	62	4 6	23	24	12·37	6	26½	260	480	4 to 1
27 Plumper	Miller & Ravenhill	Ditto , . 2	27	2 0	62	46	23·2	14	26½	60	148	2·5 to 1
28 Rattler	Maudslay & Field	Vertical . 4	40¼	4 0	25	26	13·42	5	..	200	428	4 to 1
29 Reynard	G.& J.Rennie	Horizontal 2	28	2 0	60	54·4	20·27	14	..	60	165	2 to 1
30 Rifleman	Miller & Ravenhill	Ditto . . 2	46	3 0	48	43	14·12	10	25½	200	366	3 to 1
31 Ditto, H.P. diminished	Ditto .	Vert.Oscil. 2	34	2 9	48	44	14·12	10	26½	100	188	2·5 to 1
32 Sans-pareil	Boulton & Watt	Horizont. Oscil. }4	44	2 6	55	..	..	..	..	350	..	Direct.
33 Sharpshooter	Miller & Ravenhill	Horizontal 2	46	3 0	48	46·9	14·4	10	26	200	408	3 to 1
34 Simoom	Boulton & Watt	Horizont. Oscil. }4	44	2 6	55	..	..	..	..	350	..	Direct.
35 Teazer	Miller & Ravenhill	Vert.Oscil. 2	34	2 9	55	50	11·6	10	..	100	175	4 to 1
36 Ditto, H.P. diminished	Penn & Son	Ditto . . 2	27	2 6	.	51·5	14·35	9	26½	40	128	3·73 to 1
37 Termagant	Seaward & Capel	Horizontal 4	62	3 6	35	36·5	14·45	14	27	620	1351	2 to 1
38 Vulcan	G.& J.Rennie	Ditto . . 4	49½	2 0	55	66·5	12·78	8	27	350	798	Direct.
38 Wasp	Miller & Ravenhill	Vert.Oscil. 2	34	2 0								

TABLE No. VIII.

Numbers for nufacturers.	Description of the proposed Engines.	Horses' Power, Admiralty estimate.	Horses' Power, Contractors' estimate.	Estimated weight of Engines.	Estimated weight of Boilers and their Apparatus.	Estimated weight of Water in Boilers.	Estimated weight of Coal-boxes.	Estimated weight of Paddle Wheels.	Estimated weight of Duplicates and spare Gear.	Estimated total weight.	Diameter of Cylinders.	Length of Stroke.	No. of Strokes per minute.	Diameter of Paddle Wheels.	Breadth of Paddles.	Diameter of necks of Paddle shaft.	Weight of Coals in Boxes.	Number of days' consumption.	Estimated consumption per horse per hour.	Cost of Engines, Boilers, and Coal-boxes.	Cost of the Paddle Wheels.	Cost of Duplicates and spare Gear.	Total cost, with iron tubes.	Cost per Horse Power, Admiralty estimate.	Extra cost for Brass tubes.	Cost per Horse Power, Contractor's estimate.	Cost per Horse, exclusive of spare Gear, Admiralty estimate.	Weight of total Machinery, per Admiralty Horse Power.
1	Oscillating	544	544	105	78	48	16	36	27	300	85	6	17½	25	0 10	16⅜	250	9	5	22,400	1490	2240	26,100	48	420	48	43 17	11 03
2	Direct	515	527	127	73	35	17	33	15	300	84	6	17½	24	0 9	16	345	9¾	6	19,820	1400	450	21,700	42	800	41	41 4	11 81
3		509	508	135	65	52	20	38	8	300	84	5	20	26	0 4	16	345	9¾	6	23,300	580	450	24,050	47		46	48 8	11 81
4	Oscillating	501	501	148	70	32	20	32	28	300	63½	6	19½	26	0 1	16	392	9¾	7	20,350	1650	1450	23,450	48	500	48	39 16	11 85
5	Direct	501	500	123	72	46	15	35	13	300	83	8	19½	26	0 0	16⅜	344	9	7	23,000	1070	1070	24,070	48		48	48 18	11 97
6	Oscillating	496	500	99	73	53	20	40	12	300	81	6 9	17	25	0 9	17	301		6¾	16,200	1740	720	18,720	37	680	37	38 0	12 09
7	Direct	450	450	150	50	50	20	20	5	300	83	5 6	variable	25 6	9 6	17	340 13			16,000	1000	720	17,000	34	670	34	32 0	12 09
8	Direct	464	484	140	71	31	11	39	12	300	83	5 4½	90	28	9 9	14	400 15		5¾	21,550	1250	22,800	47	500	47	44 10	12 39
9		465	470	130	62	47	15	43	20	300	81	5 4½	92	26	9 8	14¼	325 12		6	18,827	1525	325	22,000	46	560	46	43 16	12 73
10		460	460	148	48	41	17	29	20	300	78¾	7	20	26	9 6	14¼	330 104		6	17,250	750	400	19,400	47		47	38 18	12 86
11	Oscillating	460	460	110	69	40	15	38	5	300	78¾	6	10	25	8 0	17¼	360 122		6	19,640	850	1450	21,940	47		47	38 11	13 94
12	Double Cyl.	456	456	148	72	41	8	26	5	300	{ 45½ 27¾ }	6 0	18½	26	9 0	14¾	320 10		7	18,900	810	720	21,850	46 18	470	47 11	45	13 16
13	Direct	444	444	105	70	58	16	57	19	300	73	6	19	26	0 0	15¼	960 113		6	16,060	1680	1490	19,250	43	590	43	40	18 51
14		427	426	140	73	50	12	24	20	300	75	6	18	25	9 6	14	304 124		6	17,700	680	680	19,440	45	530	45	43	18 96
15		423	423	135	68	51	18	23	13	297	77	5 4	20	25	0 8	14	349 124		7	18,360	1100	1000	16,460	85	730	35	35	18 64
16		348	348	342	61	33	13	18	12	259	77	5 4	18	25	9 8	18	348 144		7	11,440	1160	1340	13,260	39	750	39	33	18 10
17	Beam	312	312	140	50	40	13	18	13	259	66	6	18	25	9 8	13	343 144		7	11,450	800	1000	13,350	42	550	42	39	17 63
18	Oscillating	312	312	312	50	40	13	18	13	258	68	6	18	25	8 0	13	345 144		7	11,430	800	1000	13,230	42	550	42	39	16 55

TABLE No. IX.—Continued.

FORM OF LOG FOR A SEA-GOING STEAMER.

—Observations, and Reductions, from No. 1, to be made every 12 hours by the First Engineer, and submitted to the Captain of the Vessel.

			June 12 6 p.m.	13 6 a.m.
Rate of the (Wheels or) Screw and Ship, in Knots per hour.	(Wheels) or Screw.	knots.	10·2	
	Average during preceding 12 hours. Ship, per Patent Log.	knots.	9·1	
	Distance run in preceding 12 Hours.	knots.	109·2	
Number of hours in which Sails were set.		hours.	8	
Number of Hours under Steam.		hours.	12	
Distance run from beginning of Voyage.		knots.	1086	
Draught of Water.	Forward.	ft. in.	14 9	
	Aft.	ft. in.	15 7	
	Dip of the (Wheels or) Screw.	ft. in.	2 10	
Pressure by Indicator.	Top.—Starboard.	lbs.	16·2	
	Bottom.—Starboard.	lbs.	at 11 a.m. {expans. aft. §}	
	Top.—Larboard.	lbs.		
	Bottom.—Larboard.	lbs.		
	Horse Power of one Engine.	H. P.	346	
Pressure on Dynamometer.		tons.	6·35	
Stores Consumed.	Coals. Burnt in the preceding 12 Hours.	tons. cwt. qrs. lbs.	12 19 0 1	
	Coals. Remaining in Ship.	tons.	217 6	
	Tallow. Used in preceding 12 Hours.	lbs.	4¾	
	Oil. Used in preceding 12 Hours.	pints.	5¼	
Remarks.				

TABLE OF THE VELOCITIES OF PADDLE WHEELS OF DIFFERENT DIAMETERS IN FEET PER MINUTE AND BRITISH STATUTE MILES PER HOUR.

Diam.—	10 ft.		10ft. 6in.		11 ft.		11ft. 6in.		12 ft.		12ft. 6in.		13 ft.		13ft. 6in.		14 ft.		14ft. 6in.		15 ft.		15ft. 6in.		16 ft.		16ft. 6in.		17 ft.		17ft. 6in.	
Revolutions per min.	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour
10	942																															

DIAM.—	18 ft.		18 ft. 6 in.		19 ft.		19 ft. 6 in.		20 ft.		20 ft. 6 in.		21 ft.		21 ft. 6 in.		22 ft.		22 ft. 6 in.		23 ft.		23 ft. 6 in.		24 ft.		24 ft. 6 in.		25 ft.		25 ft. 6 in.	
Revolutions per min.	Ft. per min	Mis. per hour	Ft. per min	Mis. per hour	Ft. per min	Mis. per hour	Ft. per min	Mis. per hour	Ft. per min	Mis. per hour	Ft. per min	Mis. per hour	Ft. per min	Mis. per hour	Ft. per min	Mis. per hour	Ft. per min	Mis. per hour	Ft. per min	Mis. per hour	Ft. per min	Mis. per hour	Ft. per min	Mis. per hour	Ft. per min	Mis. per hour	Ft. per min	Mis. per hour	Ft. per min	Mis. per hour

TABLE OF THE VELOCITIES OF PADDLE WHEELS, ETC.—*Continued.*

DIAM.	26 ft.		26 ft. 6 in.		27 ft.		27 ft. 6 in.		28 ft.		29 ft.		30 ft.		31 ft.		32 ft.		33 ft.		34 ft.		35 ft.		40 ft.	
Revolu-tions per minute.	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour	Ft. per min	Mls. per hour
5	408	4·64	416	4·73	424	4·82	432	4·91	440	4·99	455	5·18	471	5·35	487	5·52	508	5·71	518	5·89	529	6·01	550	6·25	628	7·14
6	490	5·57	499	5·67	509	5·78	518	5·89	527	5·99	547	6·21	565	6·42	584	6·63	608	6·85	622	7·07	635	7·12	660	7·50	751	8·57
7	571	6·49	582	6·62	593	6·74	604	6·87	615	6·99	638	7·25	660	7·49	682	7·73	704	8·09	726	8·25	741	8·41	770	8·75	880	9·99
8	653	7·42	666	7·57	678	7·71	691	7·85	703	7·99	729	8·28	754	8·56	779	8·84	804	9·23	829	9·42	846	9·62	880	9·99	1005	11·42
9	735	8·35	749	8·51	763	8·67	777	8·88	791	8·99	820	9·32	848	9·63	876	9·94	905	10·00	933	10·00	952	10·82	990	11·24	1131	12·85
10	817	9·28	832	9·46	848	9·64	864	9·81	879	9·98	911	10·36	942	10·71	974	11·06	1005	11·42	1037	11·78	1058	12·02	1099	12·49	1257	14·28
11	899	10·21	915	10·40	933	10·60	950	10·80	967	10·98	1002	11·39	1037	11·78	1071	12·16	1106	12·56	1140	12·96	1164	13·22	1209	13·74	1382	15·71
12	980	11·13	999	11·35	1018	11·56	1036	11·78	1055	11·98	1093	12·43	1131	12·85	1169	13·27	1206	13·70	1244	14·14	1270	14·42	1319	14·99	1508	17·16
13	1062	12·06	1082	12·30	1102	12·53	1123	12·76	1143	12·98	1184	13·47	1225	13·92	1266	14·37	1307	14·84	1348	15·31	1376	15·63	1429	16·24	1634	18·56
14	1143	12·99	1165	13·24	1188	13·49	1209	13·74	1231	13·98	1275	14·50	1319	14·99	1363	15·48	1407	15·98	1451	16·49	1481	16·83	1539	17·49	1759	19·99
15	1225	13·92	1248	14·19	1272	14·46	1295	14·72	1319	14·97	1367	15·54	1414	16·06	1461	16·58	1508	17·13	1555	17·67	1587	18·03	1649	18·74	1885	21·42
16	1307	14·84	1332	15·13	1357	15·42	1382	15·71	1407	15·97	1458	16·58	1508	16·36	1558	17·68	1606	18·27	1659	18·86	1693	19·23	1759	19·99	2011	22·85
17	1388	15·77	1382	15·71	1442	16·06	1468	16·69	1495	16·97	1542	17·62	1602	18·20	1656	18·79	1709	19·41	1762	20·03	1799	20·43	1869	21·24	2136	24·27
18	1470	16·70	1496	17·03	1527	17·35	1553	17·67	1583	17·97	1640	18·66	1686	19·17	1753	19·90	1810	20·55	1866	21·20	1905	21·64	1979	22·49	2262	25·70
19	1552	17·63	1581	17·97	1611	18·30	1643	18·67	1675	18·96	1731	19·66	1791	20·34	1850	21·03	1910	21·69	1970	22·38	2010	22·84	2089	23·74	2388	27·13
20	1633	18·56	1665	18·92	1696	19·28	1728	19·63	1759	19·96	1822	20·70	1885	21·42	1948	22·12	2011	22·84	2073	23·56	2116	24·04	2199	24·99	2513	28·56
21	1715	19·49	1748	19·86	1781	20·24	1815	20·61	1847	20·96	1913	21·72	1979	22·49	2043	23·22	2111	23·98	2177	24·74	2222	25·24	2309	26·24	2639	29·99
22	1797	20·41	1882	20·81	1866	21·20	1900	21·60	1935	21·96	2004	22·78	2073	23·56	2145	24·33	2212	25·13	2281	25·93	2328	26·44	2419	27·49	2765	31·41
23	1878	21·34	1914	21·76	1951	22·17	1987	22·58	2023	22·96	2095	23·81	2168	24·63	2240	25·43	2312	26·28	2384	27·09	2434	27·65	2529	28·74	2890	32·84
24	1960	22·27	1998	22·70	2035	23·13	2073	23·76	2111	23·96	2186	24·84	2262	25·70	2337	26·54	2413	27·40	2488	28·27	2539	28·86	2639	29·99	3016	34·27

NOTE. The British statute mile contains 5280 feet, and the geographical or nautical mile (commonly called knot) contains 6082·66 feet, being in the relative proportion of 60 to 69 nearly. Hence, to reduce the above velocities into *knots*, we must multiply by 60 and divide by 69, or multiply by ·868. If the result be required in *knots*, *in place of statute miles*, for a comparison of the velocities of the same paddle wheel at different speeds of the engine, it will then be most convenient to reduce the effective diameter of the wheel into nautical feet by multi- plying it by ·868, and then reading off the velocities corresponding to this reduced diameter in the table as *knots*.

TABLE No. XII.

1.—SHOWING THE ECONOMIC VALUES OF DIFFERENT COALS.

Names of the Coals experimented upon.	Economic evaporating power, or number of lbs. of water evaporated from 212° by 1 lb. coal.	Weight of 1 cubic foot of the coal as used for fuel.	Weight of 1 cubic foot as calculated from the density.	Ratio of B to C, or of the economical to the theoretical weight.	Difference per cent. between theoretical and economical weights.	Space occupied by 1 ton, in cubic feet (economic weight).	Results of experiments on cohesive power of coals, percentage of large coals.	Evaporating power of the coal, after deducting for the combustible matter in the residue.	Weight of water evaporated from 212° by 1 cubic foot of coal.	Rate of evaporation, or number of lbs. water evaporated per hour.
	A.	B.	C.	D.	E.	F.	G.	H.	I.	K.
										mean.
WELSH COALS.										
Craigola . . .	9·35	60·166	81·107	·742	34·8	37·23	49·3	9·66	581·20	441·48
Anthracite (Jones & Co.) . . .	9·46	58·25	85·786	·679	47·26	38·45	68.5	9·7	565·02	409·37
Oldcastle Fiery Vein	8·94	50·916	80·42	·633	57·946	43·99	57·7	..	455·18	464·30
Ward's Fiery Vein	9·40	57·433	83·85	·685	46·0	39·0	46·5	10·6	508·78	529·90
Binea Coal . .	9·94	57·08	81·357	·702	42·53	39·24	51·2	10·3	587·92	486·95
Llangennech . .	8·86	56·93	81·85	·695	43·76	39·34	53·5	4·2	523·75	376·22
Pentrepoth . .	8·72	57·72	81·73	·705	40·17	38·80	46·5	8·98	518·32	381·50
Pentrefellin . .	6·36	66·166	84·726	·781	28·051	33·85	52·7	7·4	489·02	247·24
Duffryn . . .	10·14	53·22	82·72	·643	58·43	42·09	56·2	11·80	540·12	409·32
Mynydd Newydd .	9·52	50·33	81·73	·089	45·09	39·76	53·7	10·59	536·26	470·69
Three-quarter Rock Vein . .	8·84	56·388	83·60	·674	48·26	39·72	52·7	..	498·46	486·86
Cwm Frood Rock Vein . .	8·70	55·277	78·299	·706	41·648	40·52	72·5	9·35	480·90	379·80
Cwm Nanty-gros	8·42	56·0	79·859	·701	42·60	40·0	55·7	8·82	471·52	404·16
Resolven . .	9·53	58·66	82·354	·713	40·39	38·19	35·0	10·44	559·02	390·25
Pontypool . .	7·47	55·7	82·35	·676	47·845	40·216	57·5	8·04	460·07	250·40
Bedwas . .	9·79	50·5	82·6	·611	63·565	44·32	54·0	9·99	494·39	476·96
Ebbw Vale . .	10·21	53·3	78·81	·676	45·98	42·26	45·0	10·64	544·19	460·22
Porthmawr . .	7·53	53·0	86·722	·614	62·7	42·02	60·0	7·75	401·34	347·44
Coleshill . .	8·00	53·0	80·483	·658	51·85	42·26	62·0	8·34	424·0	406·41
Thomas's Merthyr .	10·16	53·0	82·29	·644	55·26	42·26	55·5	10·72	538·48	520·8
Nixon's Merthyr .	9·96	51·7	82·29	·628	59·16	43·32	64·5	10·70	514·93	511·4
Hill's Plymouth Work . .	9·75	51·2	84·78	·603	65·68	43·74	64·0	10·18	599·20	531·6
Aberdare Co.'s Merthyr .	9·73	49·3	81·73	·603	65·78	45·43	74·5	10·27	479·68	489·5
Gadley nine-feet Seam . .	9·56	54·8	83·16	·658	51·75	40·87	76·0	10·46	523·88	517·3
Neath Abbey . .	9·38	59·3	83·57	·709	40·92	37·77	50·0	9·65	556·23	546·1
Gadley four-feet Seam . .	9·29	51·6	82·79	·623	60·44	43·41	68.5	10·73	479·36	400·0
Llynvi . .	9·19	53·3	80·35	·663	50·56	42·02	..	9·58	429·82	399·5
Rock Vawz .	7·68	55·0	80·21	·685	45·83	40·72	65·5	7·88	422·40	397·5
LANCASHIRE COALS.										
Balcarras Arley	8·83	50·5	78·17	·646	54·79	44·35	76·0	9·09	445·91	454·1
Blackley Hurst	8·81	48·0	78·90	·608	64·37	46·60	65·0	9·00	422·88	500·8
Blackbrook Little Delf . .	8·29	51·0	78·16	·652	53·25	43·92	61·5	8·58	422·79	440·4
Rushy Park Mine .	8·08	47·0	80·04	·587	70·31	47·65	67·0	8·35	379·76	419·1
Blackbrook Rushy Park . .	8·02	55·6	80·15	·689	44·93	40·50	80·5	8·26	443·50	481·2
Johnson&Wirthington's Rushy Park	8·01	50·0	80·10	·624	60·20	44·80	69·0	8·16	400·50	454·5
Laffak Rushy Park	7·98	52·6	84·07	·625	59·82	42·85	75·5	8·16	419·74	435·0
Balcarres Haigh Yard . .	7·90	50·8	80·10	·634	57·37	44·13	80·0	8·23	401·32	398·3
Cannel (Wigan) .	7·70	48·3	76·80	·628	59·00	46·37	95·3	8·06	371·91	381·1
Balcarras Lindsay .	7·44	51·1	78·61	·650	53·83	43·83	70·0	7·58	380·18	431·5

TABLE No. XII.—*continued.*

Names of the Coals experimented upon.	Economic evaporating power, or number of lbs. of water evaporated from 212° by 1 lb. coal	Weight of 1 cubic foot of the coal as used for fuel.	Weight of 1 cubic foot as calculated from the density.	Ratio of B to C, or of the economical to the theoretical weights.	Difference per cent. between theoretical and economical weights.	Space occupied by 1 ton, in cubic feet (economic weight).	Results of experiments on cohesive power of coals, percentage of large coals.	Evaporating power of the coal, after deducting for the combustible matter in the residue.	Weight of water evaporated from 212° by 1 cubic foot of coal.	Rate of evaporation, or number of lbs. water evaporated per hour. mean.
	A.	B.	C.	D.	E.	F.	G.	H.	I.	K.
LANCASHIRE COALS.										
Balcarras five-feet .	7·21	49·0	79·11	·619	61·44	45·71	44·5	7·35	353·29	487 5
Johnson&Wirthlington's, Sir John .	6 32	51·6	81·73	·631	58·39	43·13	82·0	6·62	326.11	362·7
NEWCASTLE COALS.										
Andrew's House (Tanfield) .	9·39	52·1	78·86	·360	51·36	42·99	..	9·80	489·21	351·2
Newcastle Hartley	8·23	50·5	80 27	·629	58·95	44·35	78·5	8·65	415·61	308·0
Hedley's Hurtley .	8·16	52·0	81·79	·635	57·28	43·07	85 5	8 71	424·52	300·8
Bute's West Hartley	8 04	50·8	78·17	·649	53·87	44·13	69·5	8·26	408·43	406.8
Buddle's West Hartley .	7·82	50·6	77·11	·656	52·39	40·09	80·0	8·01	395·49	413 3
Husting's Hartley .	7·77	48 5	78·04	·621	60·90	46·18	75·5	7·93	376·84	404 5
Carr's Hartley .	7·71	47·8	78 23	·611	63·66	46·86	77·5	8·13	368·53	344·3
Davison's West Hartley .	7·61	47·7	78 36	·608	64·27	46·96	76·5	7·83	362·99	402·9
North Percy Hartley	7·57	49·1	78 29	·627	56·45	45·62	60·0	7·72	371·68	423·5
Haswells Coal Co 's Steamboat Wall's-end .	7·48	49·5	79 36	·623	60 32	45·25	79·5	7 85	373·66	291·8
Derwentwater's Hartley .	7·42	50·4	78 79	·639	56·32	44·44	63·5	7·66	373·93	451·1
Original Hartley .	6·82	49·1	77 98	·629	58·81	45 62	80·0	6·98	334·86	428·4
Cowpen & Sidney Hartley .	6·79	47·9	78·67	·608	64·23	46·76	74·0	7·02	325·24	350·4
Lydney, Forest of Dean .	8·52	54·4	80·04	·680	47·02	41·14	55·0	8 98	4/3·86	487·19
Staveley,Derbyshire	7·26	49·9	79 79	·625	52·90	44·88	88·5	7 46	362·27	466·2
Broomhill .	7·30	52·5	79 79	·673	45·55	42·67	65·7	7·33	383·25	397·8
Slievardagh (Irish Anthracite).	9·85	62·8	99·57	·630	58·55	35·66	74·0	10·49	618·58	473·2
SCOTCH COALS.										
Dalkeith Jewel Seam	7·08	49·8	79·67	·625	5 98	40·98	85·7	7·10	352·58	355·2
Dalkeith Coronation Seam .	7·71	51·6	78·61	·657	52·17	43·16	88·2	7·86	398·29	370·1
Wallsend Elgin .	8·46	54·6	78·61	·694	43·78	41·02	64·0	8·67	460·82	435·7
Fordel Splint .	7·56	55·0	78·61	·699	42·92	40·92	63·0	7·69	415·80	464 9
Grangemouth . .	7·40	54·25	80·48	·674	48·35	40·33	69·7	7·91	401·45	390·40
Wellewood . .	8·24	52·6	79·78	·659	53·57	42·58	80·0	8·39	433·42	438·5
Eglinton . .	7·37	52·0	79·84	·651	51·48	43·07	79·5	7·48	383·24	406.2
Conception Bay, Chili . .	5·72	..	80·54	..	..	..	..	5·96	..	425·0
PATENT FUELS.										
Warlich's Patent Fuel .	10·36	69·05	72·25	·955	4·49	32·44	..	10·60	715·13	457·8
Lyon's Patent Fuel	9·58	61·1	74·73	·817	22·30	36·66	..	9·77	585·33	409·1
Wylam'sPatentFuel	8·92	65·08	68·63	·948	5·45	34·41	..	9·74	580·51	418·9
Bell's Patent Fuel .	8·53	65·3	71·12	·918	8·91	34·30	..	8·65	567·0	549·1

TABLE No. XII.—*continued.*

2.— SHOWING THE COMPOSITION OF AVERAGE SAMPLES OF THE COALS.

Locality or Name of Coal.	Specific gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphr.	Oxygen	Ash.	Per-centage of Coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
WELSH COALS.								
Craigola	1·30	84·87	3·84	0·41	0·45	7·19	3·24	85·5
Anthracite	1·375	91·44	3·46	0·21	0·79	2·58	1·52	92·9
Oldcastle Fiery vein	1·289	87·68	4·89	1·31	0·09	3·39	2·64	79·8
Ward's Fiery vein	1·344	87·87	3·93	2·02	0·88	{ included in ash.	7·04	
Binea coal	1·304	88·66	4·63	1·43	0·33	1·03	3·96	81·10
Llangennech	1·312	85·46	4·20	1·0·	0·29	2·44	6·54	83·69
Pentrepoth	1·31	88·72	4·50	0·18		3·24	3·06	82·5
Pentrefellin	1·356	85·52	3·72	Trace	0·12	4·55	6·09	85·0
Duffryn	1·326	88·26	4·66	1·45	1·77	0·60	3·26	84·3
Mynydd Newydd	1·31	84·71	5·76	1·56	1·21	3·52	8·24	74·8
Three-quarter Rockvein	1·34	75·15	4·33	1·07	2·85	5·04	10·96	62·5
Cwm Frood Rock vein	1·255	82·25	5·84	1·11	1·22	58	6·00	68·8
Cwm Nanty-Gros	1·28	78·36	5·59	1·86	3·01	5·58	5·60	65·6
Resolven	1·32	79·33	4·75	1·38	5·07	{ included in ash.	9·41	83·9
Pontypool	1·32	80·70	5·06	1·35	2·39	4·38	5·52	64·8
Bedwas	1·33	80·61	6·01	1·44	3·50	1·50	6·94	71·7
Ebbw Vale	1·275	89·78	5·15	2·16	1·02	0·39	1·50	77·5
Porthmawr Rock vein	1·30	74·70	4·79	1·25	0·91	3·60	14·72	63·1
Coleshill	1·29	73·84	5·14	1·47	2·34	8·29	8·92	56·0
Thomas's Merthyr	1·30	90·12	4·33	1·00	0·85	2·62	1·68	86·53
Nixon's Merthyr	1·31	90·27	4·12	0·63	1·20	2·53	1·25	79·11
Hill's, Plymouth Works	1·35	88·40	4·00	0·46	0·84	3·82	2·39	82·25
Aberdare Co.'s Merthyr	1·31	88·28	4·24	1·66	0·91	1·65	3·26	85·83
Gadley nine-feet seam	1·33	86·18	4·31	1·09	0·87	2·21	5·34	86·54
Neath Abbey	1·31	89·04	5·05	1·07	1·60		3·55	61·42
Gadley Four-feet seam	1·32	88·56	4·79	0·88	1·21		4·88	88·23
Llynvi	1·28	87·1·	5·06	0·86	1·33	2·53	3·04	72·94
Rock Vawz	1·29	77·98	4·39	0·57	0·96	8·55	7·55	62·50
LANCASHIRE COALS.								
Alcarras Arley	1·26	83·54	5·24	0·98	1·05	5·87	3·32	62·59
Hackley Hurst	1·26	82·01	5·55	1·68	1·43	5·28	4·05	57·84
Blackbrook Little Delf.	1·26	82·70	5·55	1·48	1·07	4·80	4·31	55·48
Ashy Park Mine	1·28	77·76	5·23	1·32	1·01	8·99	5·69	56·66
Blackbrook, Rushy Park	1·27	81·16	5·99	1·35	1·62	7·20	2·68	58·10
Hinson and Wirthington's, Rushy Park	1·28	79·50	5·15	1·21	2·71	9·24	2·19	57·52
Flak, Rushy Park	1·35	80·47	5·72	1·27	1·39	8·33	2·82	56·26
Alcarras Haigh Yard	1·28	82·26	5·47	1·25	1·48	5·64	3·90	66·09
Annel (Wigan)	1·23	79·23	6·08	1·18	1·43	7·24	4·84	60·33
Alcarras Lindsay	1·26	83·90	5·66	1·40	1·51	5·53	2·00	57·84
Alcarras Five-feet	1·26	74·21	5·03	0·77	2·09	8·69	9·21	55·90
Hinson and Wirthington's (Sir John)	1·31	72·86	4·98	1·07	1·54	8·15	11·40	56·15
NEWCASTLE COALS								
Drew's House (anfield)	1·26	85·58	5·31	1·26	1·32	4·39	2·14	65·13
Newcastle Hartley	1·29	81·81	5·50	1·28	1·69	2·58	7·14	64·61
Illey's Hartley	1·31	80·26	5·28	1·16	1·78	2·40	9·12	72·31
·s West Hartley	1·25	80·61	5·26	1·52	1·85	6·51	4·25	
dle's West Hartley	1·23	80·75	5·04	1·46	1·04	7··6	3·85	
tinga Hartley	1·25	82·24	5·42	1·61	1·35	6·44	2·04	35·00
's Hartley	1·25	79·83	5·11	1·17	0·82	7·86	5·21	60·63
son's West Hartley	1·25	83·26	5·31	1·72	1·38	2·50	5·84	59·49
h Percy Hartley	1·25	80·03	5·06	0·98	0·78	9·91	3·22	57·18
vell Coal Co.'s								
sambout Wallsend.	1·27	83·71	5·30	1·06	1·21	2·79	5·93	61·38
entwater's Hartley	1··6	78·01	4·74	1·84	1·37	10·31	3·73	54·83
nal Hartley	·/·\	··,·l·18		0·72	1·44	8·03	3·07	55·22
en and Sydney	7·44	51·1						
·y			5·10	1·60	0·71	77·9	2·99	58·59

TABLE No. XII.—continued.

Locality or Name of Coal	Specific gravity of Coal.	Carbon.	Hydrogen.	Nitrogen.	Sulphr.	Oxygen.	Ash.	Per-centage of coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
NEWCASTLE COALS.								
Park End, Sydney	1·28	73·52	5·69	2·04	2·27	6·48	10·00	57·80
Staveley (Derbyshire)	1·27	79·85	4·84	1·23	0·72	10·96	2·40	57·86
Broom-hill	1·25	81·70	6·17	1·84	2·85	4·37	3·07	59·20
Slievardagh, Irish Anthracite	1·59	80·03	2·30	0·23	6·76 {included in ash.}		10·86	90·10
SCOTCH COALS.								
Dalkeith Jewel Seam	1·27	74·55	5·14	0·10	0·33	15·51	4·37	49·80
Dalkeith Coronation Seam	1 31	76·94	5·20	Trace	0·38	14·37	3·10	53·50
Wallsend Elgin	1·30	76·09	5·22	1·41	1·53	·5·05	10·70	58·45
Fordel Splint	1·25	79·58	5·50	1·13	1·46	8·33	4·00	52·03
Grangemouth	1·29	79·85	5·28	1·35	1·42	8·58	3·52	56·60
Wellewood	1·27	81·36	6·28	1·53	1·57	6·37	2·89	59·15
Eglinton	1·25	80·08	6·50	1·55	1·38	8·05	2·44	54·94
FOREIGN COALS.								
Formosa Island	1·24	78·26	5·70	0·64	0·49	10·95	3·96	
Borneo (Labuan kind)	1·28	64·52	5·74	0·80	1·45	20·75	7·74	
Borneo, 3-feet seam	1·37	54·31	5·03	0·98	1·14	24·22	14·32	
Borneo, 11-feet seam	1·21	70·33	5·41	0·67	1·17	19·19	3·23	
Conception Bay, Chili	1·29	70·55	5·76	0·95	1·98	13·24	7·52	43·63
Sydney, N. S. Wales		82·39	5·32	1·23	0·70	8·32	2·04	
Port Famine		64·18	5·83	0·50	1·03	22·75	6·21	
Chirique		38·98	4·01	0·58	6·14	18·38	36·91	
Laredo Bay		58·67	5·52	0 71	1·14	17·33	16·63	
Sandy Bay, Patagonia, No. 1.		62·25	5·05	0·63	1·13	17·54	13·40	
Ditto ditto, No. 2.		59·63	5·68	0·64	0·96	17·45	15·64	
Talcahnano Bay		70·71	6·44	1·08	0·94	13·95	6·92	
Vancouver's Island		66·93	5·32	1·02	2·20	8·70	15·83	
Colcurra Bay, Chili		78·30	5·50	1·09	1·06	8·37	5·68	
PATENT FUELS.								
Warlich's Patent Fuel	1·15	90·02	5·56	Trace	1·62	{included in ash.}	2·91	85 10
Lyons ditto ditto	1·13	86·36	4·56	1·06	1·29	2·07	4·66	
Wylam's ditto ditto	1·10	79·91	5·69	1·68	1·25	6·63	4··	·80
Well's ditto ditto	1·14	87·88	5·22	0·81	0·71	0·42	·	·70

3.—SHOWING THE AMOUNT OF VARIOUS ... DUCED BY THE DESTRUCTIVE DISTILLATI... ....RTAIN COALS.

Name of the Coal.	Coke.	Tar.	Water.	Ammonia.	Carbon. Acid.	Sulph. Hydrogen.	Olefiant Gas and Hydro-Carbon.	Other Gases inflammable.
Graigola	85·50	1·20	3·10	0·17	2·79	Traces	0·28	7·01
Anthracite, from Jones, Aubrey and Co.	92·90	none	2·87	0·20	0·06	0·04	(?)	3·93
Oldcastle Fiery vein	79·80	5·86	3·39	0·85	0·44	0·12	0·27	9·77
Ward's Fiery Vein		1·80	3·01	0·24	1·80	0·21	0·21	
Binca Coal	88·10	2·08	3·58	0·08	1·68	0·09	0·31	4·08
Liangennech	83·69	1·22	4·07	0·08	3·21	0·02	0 43	7·28

TABLE No. XIII.

TABLE OF THE TEMPERATURES AND RELATIVE VOLUMES OF STEAM OF DIFFERENT DENSITIES.

Pressure in pounds per square inch.	Corresponding tempera- ture, Fahren- heit.	Relative Volume of the Steam.	Pressure in pounds per square inch.	Corresponding tempera- ture, Fahren- heit.	Relative Volume of the Steam.
lbs.	degrees.	volume.	lbs.	degrees.	volume.
1	102·9	20868	31	253·6	857
2	126·1	10874	32	255·5	833
3	141·0	7437	33	257·3	810
4	152·3	5685	34	259·1	788
5	161·4	4617	35	260·9	767
6	169·2	3897	36	262·6	748
7	175·9	3376	37	264·3	729
8	182·0	2983	38	265·9	712
9	187·4	2674	39	267·5	695
10	192·4	2426	40	269·1	679
11	197·0	2221	41	270·6	664
12	201·3	2050	42	272·1	649
13	205·3	1904	43	273·6	635
14	209·1	1778	44	275·0	622
15	212·8	1669	45	276·4	610
16	216·3	1573	46	277·8	598
17	219·6	1488	47	279·2	586
18	222·7	1411	48	280·5	575
19	225·6	1343	49	281·9	564
20	228·5	1281	50	283·2	554
21	231·2	1225	51	284·4	544
22	233·8	1174	52	285·7	534
23	236·3	1127	53	286·9	525
24	238·7	1084	54	288·1	516
25	241·0	•1044	55	289·3	508
26	243·3	1007	56	290·5	500
27	245·5	973	57	291·7	492
28	247·6	941	58	292·9	484
29	249·6	911	59	294·2	477
30	251·6	883	60	295·6	470

TABLE No. XIV.

SECONDS.

MILES PER HOUR.

Min.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
3	20·000	19·890	19·780	19·672	19·564	19·460	19·355	19·251	19·150	19·047	18·947	18·848	18·750	18·652	18·556
4	15·000	14·938	14·876	14·810	14·745	14·694	14·634	14·566	14·516	14·457	14·400	14·342	14·285	14·220	14·173
5	12·000	11·960	11·920	11·880	11·841	11·803	11·764	11·726	11·688	11·650	11·613	11·575	11·538	11·501	11·465
6	10·000	9·972	9·944	9·917	9·890	9·863	9·830	9·809	9·785	9·756	9·729	9·703	9·677	9·651	9·625
7	8·571	8·551	8·530	8·510	8·490	8·470	8·450	8·430	8·413	8·391	8·372	8·352	8·333	8·314	8·295
8	7·500	7·482	7·468	7·453	7·438	7·422	7·407	7·392	7·377	7·362	7·346	7·331	7·317	7·302	7·287
9	6·666	6·654	6·642	6·629	6·617	6·605	6·589	6·581	6·559	6·555	6·545	6·533	6·521	6·509	6·489
10	6·000	5·990	5·980	5·970	5·960	5·950	5·940	5·930	5·921	5·911	5·901	5·891	5·882	5·872	5·863
11	5·454	5·446	5·438	5·429	5·421	5·413	5·405	5·397	5·389	5·381	5·371	5·365	5·357	5·349	5·341
12	5·000	4·993	4·986	4·979	4·972	4·965	4·958	4·951	4·945	4·938	4·931	4·924	4·918	4·911	4·904
13	4·615	4·609	4·603	4·597	4·591	4·585	4·580	4·574	4·568	4·562	4·556	4·551	4·545	4·539	4·534
14	4·285	4·280	4·275	4·270	4·265	4·260	4·255	4·250	4·245	4·240	4·235	4·230	4·225	4·220	4·215

SECONDS

MILES PER HOUR.

Min.	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
3	18·461	18·367	18·274	18·181	18·090	18·000	17·910	17·823	17·734	17·647	17·560	17·475	17·391	17·307	17·225
4	14·117	14·063	14·006	13·953	13·900	13·846	13·793	13·740	13·688	13·636	13·584	13·533	13·483	13·432	13·380
5	11·428	11·392	11·353	11·320	11·285	11·250	11·211	11·180	11·145	11·111	11·077	11·043	11·009	10·975	10·942
6	9·600	9·576	9·549	9·523	9·490	9·473	9·448	9·424	9·399	9·375	9·350	9·326	9·302	9·288	9·254
7	8·275	8·256	8·238	8·219	8·200	8·181	8·163	8·144	8·127	8·109	8·089	8·071	8·053	8·035	8·017
8	7·272	7·258	7·243	7·229	7·214	7·200	7·185	7·171	7·157	7·142	7·128	7·114	7·100	7·086	7·072
9	6·486	6·474	6·463	6·451	6·440	6·428	6·417	6·405	6·393	6·381	6·371	6·360	6·349	6·338	6·327
10	5·853	5·844	5·834	5·825	5·815	5·806	5·797	5·778	5·778	5·769	5·760	5·750	5·741	5·732	5·723
11	5·333	5·325	5·317	5·309	5·301	5·294	5·286	5·278	5·270	5·263	5·255	5·247	5·240	5·232	5·224
12	4·897	4·891	4·884	4·878	4·871	4·864	4·858	4·851	4·843	4·838	4·832	4·825	4·819	4·812	4·806
13	4·528	4·522	4·516	4·511	4·505	4·500	4·494	4·488	4·483	4·477	4·472	4·466	4·460	4·455	4·449
14	4·210	4·204	4·200	4·195	4·190	4·186	4·181	4·176	4·171	4·166	4·161	4·157	4·152	4·147	4·142

TABLE No. XIV.—continued.

MILES PER HOUR

Min.	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
3	17·147	17·061	17·000	16·930	16·822	16·744	16·666	16·590	16·514	16·443	16·353	16·289	16·216	16·143	16·071
4	13·333	13·284	13·235	13·186	13·138	13·093	13·043	12·996	12·950	12·903	12·857	12·811	12·766	12·685	12·640
5	10·909	10·876	10·843	10·810	10·778	10·746	10·714	10·682	10·663	10·619	10·588	10·557	10·526	10·495	10·465
6	9·230	9·207	9·183	9·160	9·137	9·113	9·090	9·068	2·045	9·022	9·000	8·977	8·955	8·933	8·900
7	8·000	7·980	7·964	7·925	7·927	7·914	7·892	7·877	7·860	7·843	7·826	7·809	7·790	7·775	7·758
8	7·059	7·045	7·031	7·017	7·005	6·990	6·974	6·963	6·953	6·934	6·923	6·909	6·896	6·885	6·870
9	6·315	6·304	6·293	6·282	6·271	6·260	6·250	6·239	6·228	6·217	6·216	6·195	6·185	6·174	6·164
10	5·714	5·705	5·696	5·687	5·678	5·669	5·660	5·651	5·642	5·633	5·625	5·616	5·606	5·598	5·590
11	5·217	5·208	5·202	5·194	5·187	5·179	5·172	5·161	5·157	5·150	5·142	5·135	5·128	5·120	5·110
12	4·800	4·793	4·787	4·780	4·774	4·768	4·761	4·755	4·749	4·743	4·738	4·730	4·724	4·718	4·712
13	4·444	4·438	4·433	4·428	4·422	4·418	4·411	4·406	4·400	4·395	4·390	4·384	4·379	4·374	4·368
14	4·137	4·133	4·128	4·123	4·118	4·114	4·110	4·104	4·100	4·095	4·090	4·086	4·081	4·077	4·072

SECONDS

MILES PER HOUR

Min.	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
3	16·000	15·902	15·859	15·789	15·764	15·652	15·584	15·517	15·450	15·384	15·319	15·254	15·190	15·112	15·062
4	12·631	12·587	12·543	12·500	12·456	12·413	12·371	12·328	12·283	12·244	12·203	12·162	12·121	12·080	12·040
5	10·434	10·404	10·377	10·344	10·315	10·286	10·256	10·227	10·198	10·169	10·140	10·112	10·084	10·055	10·027
6	8·888	8·867	8·845	8·823	8·801	8·780	8·759	8·737	8·716	8·695	8·677	8·651	8·633	8·612	8·591
7	7·741	7·723	7·708	7·692	7·675	7·659	7·642	7·627	7·619	7·595	7·578	7·563	7·547	7·531	7·515
8	6·857	6·844	6·831	6·816	6·805	6·792	6·779	6·766	6·752	6·741	6·729	6·716	6·704	6·691	6·679
9	6·153	6·143	6·132	6·122	6·112	6·101	6·091	6·080	6·070	6·060	6·050	6·040	6·030	6·020	6·010
10	5·581	5·572	5·564	5·555	5·547	5·538	5·530	5·521	5·513	5·504	5·496	5·487	5·479	5·471	5·461
11	5·106	5·099	5·091	5·084	5·077	5·070	5·062	5·056	5·049	5·042	5·035	5·028	5·020	5·013	5·006
12	4·705	4·698	4·693	4·687	4·681	4·675	4·669	4·663	4·657	4·651	4·645	4·639	4·633	4·627	4·621
13	4·363	4·358	4·353	4·347	4·342	4·337	4·332	4·326	4·321	4·316	4·311	4·306	4·301	4·295	4·290
14	4·067	4·063	4·058	4·054	4·049	4·044	4·040	4·035	4·031	4·026	4·022	4·017	4·013	4·008	4·004

TO THE DIRECTORS OF THE GRAND CANAL COMPANY, ON SCREW STEAM BOATS.

GENTLEMEN, I regret exceedingly that from various causes, over which I had no control, I have been prevented until now from reporting on the two steam boats in use on your canal, although the experiments made with them have been completed some time; but I hope my preliminary examination and report on these two boats has prevented the inconvenience that would otherwise have arisen from this delay, as it has enabled you to order a boat which, I have no doubt, will be found more suited to the traffic on your canal than either of those now employed upon it. I do not, however, claim any merit for the plans or arrangement of the machinery intended for this boat, all of which were prepared by your own officers, and whatever merit it may have is entirely due to them; all that I could do was to satisfy myself from the experiments and examination of the two boats, which was the best constructed, and, under similar circumstances, produced the best effects, and to recommend to you that form of construction for the boat you were about to build, which from these experiments I was enabled to do with perfect confidence; at the same time I do not by any means pretend to say that a better form of boat, and more efficient machinery, may not be hereafter constructed, when more experience and practical knowledge shall be obtained by the working of these boats; for, when locomotive engines were first introduced upon railways, they were very much inferior to those now used. Almost every one which has been since made up to the present time has been an improvement on those previously constructed, either in strength, efficiency, or economy of working; and I have no doubt but similar, or at all events very great and important improvements will be made in steam boats for canal purposes, when they become to be more generally used and more attention shall be paid to them by practital men.

In ordeer, howevr, to enable me to report on the queries put to me by your Secretary, I thought it necessary to make a careful examination of the two boats at present at work on your canal, and also to ascertain by experiment the power and capabilities of each of these boats under different circumstances, as well in reference to the load they could carry as to the load they could haul with different velocities. In making this examination and experiment I was assisted by your excellent Secretary and intelligent Sui erintendent of Works, Mr. Talbot, who gave me every information, and aided me in every way in their power.

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The first of these boats which I examined, called No. 2 Boat, was con-
structed by Messrs. Robinsons and Russell, of London. It is built of iron,
without ribs, is 60 feet long, and 12 feet beam, and is propelled by one screw,
driven by an engine of the following dimensions:—boiler 2 feet 6 inches
diameter, containing 74 tubes of 1¾ inches diameter each; the length of the
tubes is 4 feet 6 inches, with 2 oscillating cylinders of 5¼ inches diameter,
and 15⅝ inches length of stroke. Pressure 50 ℔s, and calculated to make 120
strokes per minute; the thickness of boiler ⅜, with 5 stays of round ⅞-inch
iron to strengthen the steam chambers.

The diameter of the screw is 4 feet, width of blade 1-11¼; pitch of screw
6 feet, stern post 5¾ inches below keel level.

No 1 Boat was built at the Ringsend Works, and the engines and ma-
chinery were made and·put into her by Mr. Inshaw, of Birmingham, who
has constructed several steam boats used on English Canals. The length of
this boat is 60 feet, and its width 12 feet. The boiler is 4 feet 6 inches in
diameter, containing 48 tubes of 2½ inches diameter, and 6 feet long; the
cylinders are 7 inches in diameter; length of stroke 18 inches, and calculated
to make 120 strokes per minute, the pressure being 50 ℔s. The boat is
propelled by two screws, 4 feet pitch, 3 feet in diameter, and 2 feet long,
placed at each side of the stern post, worked with bevelled gear and two-fold
multiplying power.* This principle of construction appears to answer very
much better than that of No. 2 Boat, with one screw, for it is capable of
being stopped and the motion reversed with much greater ease than the
other, and it steers stern foremost almost as well as when running forward
which is a most important and essential requisite in any steam boat employed
in Canal traffic, where obstacles and interruptions are so frequent, and which
might be attended with danger, if the power of reversing was not easy and
effective : in this respect it is very superior to the boat with one screw, which
does not steer at all when the motion is reversed, but runs direct across the
Canal to one side or other, according to the position of the boat at the
moment of reversing. This boat (No. 2) was engaged by the builders t

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* These screws are what is usually termed *right* and *left handed* : the
consequently work in opposite directions. This is an improvement fir
adopted by Mr. Inshaw, and is found to be most important as to the workin
effect. Any person who has attentively watched the effect of a single screw
will have observed that the current of water thrown back from it does no
take a direction in a right line with the boat, but in one at a diagonal with
that line. By Mr. Inshaw's arrangement of the two screws, the two diagon
lines being in the direction of the streams from the two screws, are throw
inwards, meeting immediately behind the rudder. The *resultant* is nece
sarily a straight line of current in the centre of the canal, manifestly advan
tageous as regards the action of the screws, and strikingly so as regards th
facility with which the boat is steered, and the power of the rudder.

carry 40 tons gross, to be furnished with engines of 12-horse power, (nominal,) consisting of two oscillating cylinders, and a tubular boiler, with feed pipes and reversing gear, and capable of going with that load at about 5 to 6 miles per hour, and of propelling itself and another boat at the rate of about 3 Irish miles, or 3¾ English miles, per hour. This agreement does not however s'ate what load the boat to be propelled or towed was to carry, but it would appear to be the same as in the steam boat, that is 40 tons gross. By the experiments made with this boat, it is evident that she falls very much short of this performance, for, with 41 tons, she went only at the rate of 3½ miles per hour, instead of 5 to 6 miles; and when towing a boat loaded with 52 tons, she went at a rate of only 2¼ miles per hour, instead of 3¾. In fact, when loaded with 20 tons only, she went at the rate of 4 miles only per hour; this discrepancy would appear to arise from want of power in the engines, for it does not appear that they are more than 8-horse power, instead of 12; it may, however, be possible, that other circumstances connected with the form or arrangement of the screw may be the cause of the want of speed, but want of power in the engine is the most apparent defect; before, how-ever, drawing any conclusion from the experiments referred to, it will be proper to describe them. The first set of the experiments was made on the 24th of April; the weather was cold, but there was little or no wind to affect the free movement of the boats.

First Experiment, 24th April, 1851, was made with Steam Boat No. 2, loaded with 41 tons. The distance of half-a-mile (measured) was run in 8′ 25″, being at the rate of 3·56 miles per hour. During this experiment the pressure on the boiler was 50lbs. and the average number of strokes was 102.

Second Experiment.—In this experiment the boat was loaded with 41 tons as before, and a barge was attached to it by a tow-rope. This barge was loaded with 52 tons: the pressure was 42lbs., and the average number of strokes per minute was 87. The same distance as before was run in 13′ 6″, or at the rate of 2·29 miles per hour.

Third Experiment.—In this experiment two barges were attached to the steam boat; one was loaded with 53 tons, the other with 30 tons, besides the 41 tons in the steam boat, in all 124¼ tons. The pressure on the boiler was 50lbs. as in the first experiment, and the average number of strokes of the piston was 98, whilst the time occupied in passing over the same space was 14″ 40′, or at the rate of 2·05 miles per hour.

On the 26th April the following experiments were made with the same boat.

' *First Experiment.*—The boat was loaded with 20 tons, the pressure was 50 lbs. on the safety valve, the average number of strokes was 100 per minute, and the same distance of half-a-mile was run in 7′ 30″, or at the rate of 4·0 miles per hour.

Second Experiment.—In this experiment one barge, loaded with 50 tons, was attached to the steam boat loaded with 20 tons; the pressure as before was 50 lbs., and the average number of strokes per minute was 90¼, whilst the same space ran over required 12′ 20″, or at the rate of 2·43 miles per hour.

Third Experiment.—In this experiment two boats loaded with 50 tons each were attached to the steam boat loaded with 20 tons, in all 120 tons of goods; the pressure was 50 lbs., the average number of strokes was 94, and the space was passed over in 12′ 55″, which was at the rate of 2·31 miles per hour.

On the 5th of May the following experiments were made with No. 1 steam boat, having two screw propellers.

First Experiment.—The boat was loaded with 20 tons of goods; the same half-mile distance was run over as in the former experiments with No. 2 boat; the pressure was 45 lbs., the number of strokes averaged 110 per minute; the distance was run in 6′ 41″, which was at the rate of 4·49 miles per hour.

Second Experiment.—In this experiment a barge carrying 50 tons was attached to the steam boat, which was loaded with 20 tons; the pressure was 49 lbs. as before; the average number of strokes per minute was 101, and the time was 9′ 12″, which was at the rate of 3·26 miles per hour.

Third Experiment.—In this experiment three boats were attached to the steam boat—one was loaded with 50, the second with 27 tons, and the third with 34 tons, in all 131 tons, including the 20 tons in the steam boat; the pressure was 49 lbs., the average number of strokes per minute was 96, and the time occupied was 10′ 58″, which was at the rate of 2·73 miles per hour.

One fact, but certainly a most important one, has been established by these experiments, and that is, that a very much greater and useful effect is produced by *hauling* than by *carrying.* This fact was exemplified in every xperiment that was made, though it was more apparent in one of the boats han the other, as will be seen by reference to the experiments; it also appears that one form of boat and machinery is less affected in speed than the other by a proportional increase of weight hauled than carried; from this, it is evident that the form of boat and machinery most suitable for carrying

goods will differ from the form of boat and machinery suitable for haulage. The barges and boats on your Canal are much too large, heavy and unwieldly ; they are a heavy load in themselves, and require considerable power to move them, even at a slow rate, when empty ; they are also formed as if they were to be employed as sailing barges, similar to those on the Thames and other rivers : this is a very great mistake and quite unsuited to Canal navigation. If the boats were built 60 feet long, 6 feet 6 inches wide, with upright sides, and upright cornered bows, which would admit two of them to enter a lock at the same time, a great amount of saving would be effected on your Canal in the power required to haul such boats, as compared with those now in use, for I have no doubt that six of those boats carrying 35 tons each, would be as easily hauled as two of the present boats 50 tons each—or in the ratio of 210 to 100—and that such a steam boat as No. 1, at present in use, would be enabled to haul these six boats carrying 210 tons of goods at the rate of three miles an hour, and carrying at the same time 20 tons of goods, besides the 210 tons hauled. I would, therefore, strongly recommend you to have two such boats built, and if you found that the saving in power required for hauling was what I have stated, it would be judicious to have all new boats built on the same plan. I am well aware that it is very difficult to get parties long accustomed to a particular form of boat or carriage to adopt a different one ; but I am convinced the advantages of the light and narrow boat would be so apparent that it would in a short time be universally used in Canals in this country, as such boats are at present used in most of the Canals in England and Scotland ; and in any future engines that may be ordered for your Canal, I would recommend that the fire-box should be made as large as the construction of the boat will admit of, and that the draught up the flue be as moderate as possible, as more suitable to a turf fire than one of coke, for there cannot be a doubt, but turf or peat fuel will answer every purpose of working steam boats on the Canal, and will be very much cheaper than either coal or coke. My replies to the queries put to me will form the subject of a further report, which shall be submitted with as little delay as in my power.

<div style="text-align: right">• JOHN MACNEILL.</div>

GLOSSARY

OF

TERMS CONNECTED WITH MARINE ENGINES AND BOILERS.

(*WITH FRENCH TRANSLATIONS.*)

Air-casing, of thin sheet iron, (la chemise,) surrounds the bottom of the chimney to prevent the radiation of heat to the deck.

Air-pipe, a small copper pipe leading from the top of the hot-well through the ship's side, for the discharge of the air and uncondensed vapour pumped by the air-pump.

Air-pump, (la pompe à l'air,) is required to maintain the vacuum in the condenser by withdrawing the condensing water, air, and uncondensed vapour.

Air tubes, are small wrought-iron tubes hung in the coal-boxes from the deck and filled with water, for the purpose of ascertaining the temperature of the coals by a thermometer, as a precaution against spontaneous combustion.

Angle-iron, (cornière).

Annular-piston, is one made in the form of a ring encircling an inner cylinder which is enclosed within the external one. This arrangement is sometimes adopted to gain length of connecting-rod, by causing it to descend within the inner cylinder.

Anvil, (masse).

Ash-pits, (cendriers,) underneath the fire-bars of the furnaces, where the ashes collect.

Atmospheric or *single-acting engine*, (machine à vapeur atmospherique,) is a condensing engine in which the pressure of the steam acts during the up-stroke only, the return stroke being performed by the pressure of the atmosphere acting against a vacuum.

Auxiliary or *feeding engine*, (machine alimentaire,) fitted to supply tubular boilers with feed-water when the large engines are not working, and the ordinary feed-pumps are therefore inactive.

Axle, (tourillon).

Babbit's patent bushes, are formed of an alloy of 1 lb. copper, 50 lbs. tin, 5 lbs. regulus of antimony.

Back-balance of eccentric, is fixed to the back of the eccentric pulley for the purpose of balancing its weight on the shaft.

Back-balance of slide valves, is the weight fixed at the extremity of the valve-lever for balancing the weight of the slides.

Back-lash, is the term given to the jar which ensues when one portion of the machinery which receives motion from another (but without being always in actual contact) has its velocity so increased from some extraneous cause, that it falls back, with a sudden blow, upon the part from which it ought to derive its motion.

Back-links, the links in a parallel motion which connect the air-pump rod to the beam.

Ballast, (sable).

Banking-up the fires, raking them to the bridge of the furnace, and then smothering them with cinders and small coal, the draft being at the same time checked. By this means the fires are kept in a state of languid combustion, but are ready to burn up briskly again when steam is wanted at short notice, the red-hot mass being then broken up, raked forward, and the draft re-admitted.

Barometer or *vacuum-gauge*, (baro-mètre,) is fitted to the condenser of an engine to show the vacuum. It resembles the common weather-barometer, except that the top of the tube is in communication with the condenser.

Barrel of a pump, (corps d'une pompe).

Base-plate, see *Sole-plate*.

Beam or *side-lever engines*, (machines à balanciers,) are those in which the motion of the piston is communicated to the crank through rocking beams or levers at the sides.

Beams of a vessel, (travers).

Bearers, are the cross bars in the furnaces supporting the ends of the fire-bars.

Bear, is a small apparatus for punching holes by hand.

Bearing, neck, or *journal*, of a shaft, (coussinet d'une arbre,) is the part which revolves within the pedestal-brasses, and supports the weight or strain.

Bedding of a boiler, is the seat on which it rests.

Bilge-pumps, worked by the engine, to clear the water from the bilge of the ship.

Blowing-off, the process of ejecting the super-salted water from the boiler in order to prevent the de-position of scale or salt.

Blow-off cocks and *pipes*, are those through which the brine is eject-ed.

Blowing-through, (purger d'air,) is the process of clearing the engine of air by blowing steam through the cylinder, valves, and condenser, before starting.

Blow-through valve, (soupape à purger d'air,) is fitted between the valve-casing and the condenser for the temporary passage of the steam used in blowing through.

Boiler, low pressure, high pressure, (chaudière à basse pression, à haute pression).

Bolt, bolted, (boulon, boulonné).

Boss, (renflement,) is a centre or swelling of any kind in which a hole or eye is bored.

Box-keys, are the upright keys used for turning the nuts of large bolts, or where the common spanner cannot be applied.

Bracket pedestal or *plummer-block*, is the fixed support for the bearing of a shaft in motion, formed so that it can be fixed vertically to the frame of an engine, or the side of a beam, &c.

Brass, (bronze,) an alloy of copper, tin, and zinc, in different propor-tions. Tough brass, for engine-work, is formed of 10 lbs. copper, 1½ lb. tin, and 1½ lb. zinc. Brass, for heavy bearings, of 1 lb. copper, 2½ oz. tin, ½ oz. zinc.

Break or *brake*, (frein).

Bridge of a boiler, is the barrier of fire-bricks, or iron plates contain-ing water, thrown across the fur-nace at the extreme end of the fire-bars, to prevent the fuel being carried into the flues, and to quicken the draft by contracting the area.

Brine-pumps, (pompes de saumure,) are worked by the engines to with-draw the super-salted water from the boilers methodically, instead of by periodical blowing-off.

Bulkheads, (cloisons).

Bush, is a lining of brass, steel, or other metal, fitted in an eye or bearing, either to diminish friction or prevent rapid wear.

Callipers, are compasses with round legs, used for taking the diameter or thickness of circular or flat inside work about an engine. *Inside callipers* are used for measuring the internal diameter of a brass or hole of any kind.

Cam, for expansion, is a disc of cast iron, having the periphery cut in an irregular figure, for giving the proper motion to the expansion

valve. It is graduated in steps so as to suit the different degrees of expansion.

Carriage by sea, (transportation); *by land*, (montage).

Cast, (coulé).

Cast-iron, (fonte).

Cataract, is a contrivance introduced into marine engines for softening the fall of the expansion valves when these are made upon the Cornish principle. It consists of a little brass cylinder filled with water or oil, and fitted with a solid piston connected by a crosshead with the valve spindle. The fall of the valve is checked and regulated by the escape of the water or oil through a small hole bored for that purpose in the side of the cylinder, the piston of the cataract descending according as the liquid is forced out from before it by the pressure due to the weight of the expansion-valve.

Cement, (ciment, mastice).

Centre-boss, of the paddle-wheels, (renflement central des roues à aubes).

Chimney, (cheminée).

Chisel, (ciseau, burin).

Clack-valve, a flat valve with a hinge-joint.

Clearance of the piston, is the small space left between the piston and the top and bottom of cylinder at the end of each stroke.

Clinkers, (scories,) are the incombustible matter left on the fire-bars during the combustion of the coal.

Clinker-bar, is fixed across the top of the ash-pit to support the *slice* used for clearing the interstices of the bars.

Clothing the steam-pipes, boilers, &c., means covering them with felt and other non-conducting materials, to prevent the radiation of heat.

Coals ; coal bunkers, (les houilles, charbon de terre ; soutes à charbon).

Coal-trimmer, a man whose duty it is to work within the coal-boxes, and bring the coals to the doors at the boiler front as they continue to be consumed.

Cock, (robinet).

Cogged wheels, (roues dentées,) are those fitted with wooden teeth or *cogs*, for the purpose of lessening

friction and giving smoothness of action.

Cold-chisel, a chisel properly tempered for cutting cold iron.

Collar of a shaft, (collier,) is the projecting rim on each side of the neck or bearing, to confine it sideways during its revolution.

Common steam, (in contradistinction to *super-heated* steam,) is steam in contact with the water from which it was generated.

Condenser, (condenseur,) is the cast-iron box in which the process of condensation takes place.

Condensing engine, (machine à condensation,) is one in which the steam is condensed after leaving the cylinder, for the purpose of gaining the effect of the atmospheric pressure.

Connecting-rod, (bielle de la manivelle,) in a direct-acting engine, communicates the motion directly from the head of the piston-rod to the crank : in a side-lever engine, from the cross-tail to the crank.

Consumption of fuel, (consumation de combustible).

Counter, a little instrument employed for registering the strokes of an engine.

Coupling of a shaft, is the mode of connecting together two or more lengths of a revolving shaft, by shaping the ends into flat surfaces or bearings, which are held together by a strong iron collar or *coupling-box*.

Cover or *lap of the slide-valve on the steam side*, is the space which it advances beyond the opening of the steam-port after it has closed it, and is given for the purpose of causing the engine to work expansively, by cutting off the admission of steam before the end of the stroke.

Cover or *lap on the exhausting side* of the piston, causes the passage to the condenser to be closed before the end of the stroke, the piston being then said to be *cushioned* by the elasticity of the confined vapour, upon which it descends.

Crank ; cranked, (manivelle, coude ; coudé).

Crew of a vessel, (l'equipage d'un vaisseau).

Cross-head, (traverse, tête croissée,) in a side-lever engine, crosses the head of the piston-rod, and communicates the motion to the side-rods.

Cross-tail, in a side-lever engine, takes the motion from the side-rods and communicates it to the connecting-rod.

Cup-valve, resembles a conical valve, but has no spindle, being turned in the form of a cup or portion of a sphere.

Cushioning the piston, means that a small portion of steam is shut up between the piston and the cylinder top and bottom at the end of each stroke, which acts as a spring to soften the shock, and to give the piston a start forward after the centre is turned. This effect is produced by the lap of the side-valve on the exhausting side.

Cutter, (clavette,) is the wedge-key used, in combination with the *gib*, (contre-clavette,) for tightening the strap and brasses of a bearing, as the latter wear by friction.

Cutting off the steam for expansion, (la détente).

Cylinder-cover, (couvercle de cylindre).

Dampers, (les registres,) are iron plates, fitted by a hinge or otherwise, across the fronts of the ash-pits and the bottom of the chimney, for the purpose of regulating the draft. They are capable of being adjusted by hand to any desired area.

Dead fires, when they burn sluggishly.

Dead-plate, a flat iron plate frequently fitted before the bars of a furnace, for the purpose of coking bituminous coal upon before it is thrown back upon the fire.

Dead-water, (eau mort,) is the current following in the wake of a ship and partaking of her motion.

Deck, (pont).

Depth of a vessel, (hauteur d'un vaisseau).

Diagram of indicator, the figure traced by the pencil, from which the pressure is calculated.

Dip of the wheels, the depth of water over the top of the vertical board.

Direct-acting engines, are those in which the motion of a piston is communicated *directly* from the head of the piston-rod to the crank through the connecting-rod, without the intervention of side-levers.

Discharge, delivery, or *waste-water pipe and valve*, (tuyeau et soupape de décharge, ou de sortie,) are those through which the heated condensing water and vapour are discharged into the sea by the air-pump.

Disengaging or *disconnecting the paddles or screw* from the engines, (by suitable machinery,) permits them and their shaft to revolve freely in the brasses by the reaction of the water, by which means the speed of the ship when under canvas is not so much affected as if they were dragged through the water.

Displacement of a vessel, is the weight of water which she *displaces*, being of course equal to her own weight.

Donkey or *auxiliary engine*, (machine alimentaire) is used for feeding the boilers while the large engines are at rest.

Double-acting engine, (machine à double action,) is one in which the steam acts against a vacuum on each side of the piston alternately, as in the ordinary marine engine.

Double-acting pump is one which lifts and forces water alternately, by means of a solid piston or plunger and an entrance and exit valve communicating with each side, (as the feed and bilge pumps of a marine engine).

Double-cylinder engine, as patented by Messrs. Maudslay, has two cylinders, between which the lower end of the connecting rod descends, its motion being communicated from the piston-rod by a bent crosshead working in grooves between the cylinders.

Draught of the chimney (tirage).

Draught of water (immercion).

Drift is a round piece of steel, made slightly tapering, and used for enlarging a hole in a metal plate by being driven through it.

Drip-pipe, is a small copper pipe leading from the waste steam pipe inside, to carry off the condensed steam and other hot water which may be blown into the "trap" at the top.

Driving-wheel, (roue motrice,) in the

gearing of a screw vessel, is that which communicates motion to the small wheel or *pinion*.

Drum is a hollow cylinder fixed on a shaft for driving another shaft by a band.

Dynamometer is an instrument for indicating the thrust of the screw-propeller by means of springs and levers.

Eccentric, (l'excentrique,) is the arrangement usually adopted for giving the proper stroke to the valves. It consists of the *eccentric pulley* of cast iron, which is loose on the intermediate shaft, and the *hoop* of wrought iron lined with brass, which encircles the pulley, and gives motion to the *eccentric rod.* The eccentric *stops* or *snugs* are two little projections fixed on the intermediate shaft for the purpose of carrying round the eccentric pulley, according as it is wanted to go ahead or astern, the pulley itself being free to revolve backwards or forwards between the two stops. The weight of the pulley is balanced on the shaft by the back-balance cast on it.

Eduction or *exhaust passages* (tuyeaux de sortie, ou d'émission), through which the steam passes from the valves to the condenser.

Effective diameter of a paddle wheel is generally reckoned at one third of the breadth of the boards from each extremity of the diameter.

Effective heating surface in a boiler is that which is considered of value in evaporating the water. The bottom surface of the flues and furnaces, and one third of the whole surface of the tubes in tubular boilers, are usually rejected as *ineffective.*

Engine beams cross through the engine room at the height of the entablatures, to steady them, and receive part of the thrust of the paddle wheels.

Engine bearers or *sleepers,* (poutres de fondement,) are the longitudinal keelsons through which the foundation plate is bolted.

Engineer, engine tenter, (machiniste, mechanicien).

Entablature is the strong iron frame supporting the paddle shaft. It usually receives additional stiffness from being confined between two beams of timber, called the *entablature* or *engine beams.*

Equilibrium, Cornish, or *double-beat valves,* are frequently used in marine engines as expansion valves. Their peculiarity consists in their being pressed by the steam equally in all directions, so that they rise with a very slight force, exposing at the same time a large area of steam with a very small rise of the valve.

Escape or *priming valves,* (soupapes d'échappement,) are loaded valves fitted to the top and bottom of the cylinder, for the escape of the condensed steam, or of water carried mechanically from the boilers with the steam.

Escape-valves are also fitted to the feed pipes as a means of exit for the surplus water not used by the boilers.

Expansion gear, (l'encliquetage pour l'expansion,) is fitted to marine engines, independently of the cylinder valves, for the purpose of cutting off the steam at different portions of the stroke, according as it is wished to economize fuel more or less. It generally consists of a graduated *cam* on the paddle shaft, against which a *roller* presses and communicates the movement peculiar to the irregular surface of the cam, through a series of rods and levers to the *expansion valve,* situated between the throttle valve and the slides.

Expansion or *Fawcett joint* is a stuffing-box joint used when a straight metal pipe, (as the steam pipe,) which is exposed to considerable variations of temperature, has no *elbow* or curve in its length to enable it to expand without injury. In such a case the pipe is divided into two lengths, which are united by a steam-tight joint accurately bored and turned, so as to allow the one pipe to slip within the other, when they lengthen by expansion.

Experiment, (expérience).

Eye of a crank, &c., (encoche, œil,) is a hole bored to receive a shaft or pin.

Fawcett joint, see Expansion joint.

Feathering paddle wheels (as Morgan's patent), are those in which the requisite machinery for *feathering the boards*, or causing them to enter and leave the water in a perpendicular position. By this means, the board leaves the water without lifting it, and the effect of the wheel is somewhat increased.

Feeding apparatus, (l'appareil alimentaire,) for a marine boiler, consists of the *feed pump, feed pipe*, passing through the *refrigerator, feed cock* on the boiler, *escape valve* for the surplus water, and *water gauges* to show the level in the boiler.

Feeding engine, see *Auxiliary engine*.

Ferules (viroles) are rings of iron or brass frequently used for fastening the tubes of a tubular boiler in the tube plate.

Files, (limes).

Fire bars, (barres du foyer).

Fire grate, (grille du foyer).

Fire-hose, are made adjustible to the discharge pipes from the bilge-pumps, from the auxiliary engine where fitted, and from the hand-pump in engine room.

Fire men or stokers, (chauffeurs,) the men who work the fires.

Firing-up, urging the fires to make them form as much steam as possible.

Flange, (rebord).

Float boards or *paddle boards*, (Les aubes).

Flues, (conduits).

Foot-valve, (clapet de fond,) is situated between the bottom of the condenser and the air pump, opening towards the latter.

Forcing pumps, (pompes foulantes).

Fork, (fourche).

Fork head, the double head of a rod which divides in order to form a connection by means of a pin.

Foundation or *base plate*, (plaque du fond,) see *sole-plate*.

Fox key, is a key with a thin wedge of steel driven into the end to prevent its working back.

Frame of the engine, (châssis, cadre).

Frames of a vessel, (membrures d'un vaisseau).

Friction, (frottement).

Fuel, (combustible).

Fulcrum, (support, palier, crapaudine).

Furnace, (le foyer).

Fusible Plugs, (bondelles fusibles,) are sometimes fitted in boilers, being expected to melt by the high temperature of the confined steam, and thus allow it to escape in case of its attaining a dangerous pressure from the safety valve not acting.

Gasket, (garniture d'étoupe,) is the hemp packing, formed of soft cord plaited, which is used for making steam-tight joints.

Gauge cocks, (robinets d'épreuve,) of brass, attached to the front of the boiler for indicating the level of the water.

Gauge, steam or mercurial, (manomètre de verre mercurial,) is a syphon tube half-filled with mercury, usually employed for showing the pressure of low steam. When a marine boiler uses steam of high tension, a spiral spring is employed.

Gib (contre-clavette), is the fixed iron wedge used, in conjunction with the *cutter* or driving-wedge (clavette), for tightening the straps and brasses of the different bearings.

Gland, is the cupped collar (lined with brass,) which encircles the piston and air pump rod, &c., where it passes through the cover, being for the purpose of holding oil or tallow for lubricating, and for compressing the packing of the stuffing-box upon which it is screwed down.

Glass water gauges, attached to the fronts of the boilers for showing the level of the water.

Governor, (régulateur,) in screw engines, is an apparatus by which the steam is shut off from the cylinders (when the speed of the engine becomes too great), by the divergence of two balls from the centrifugal force, according as their velocity is increased.

Grease cock on the cylinder cover, for lubricating the piston with melted tallow, without permitting the escape of steam or the entrance of air.

Groove, (trou, entaille).

Guards for the bolts of an engine are light frames of brass or iron, into

which the nuts of the bolts fit, to prevent their working loose by un-screwing.

Gudgeon, (goujon,) is any short pin or shaft used as a bearing for a moving portion of the machinery.

Guides, (glissoirs,) are smooth surfaces between which the head of a piston rod, &c., slides to preserve its parallelism ; the sliding block attached to the cross head being called the *Guide block.*

Gun metal, an alloy of brass very generally employed in engine work. It is formed by melting together 1 lb. of tin, 1 lb. zinc, and 8 lbs. copper.

Hall's condensers, a method of surface condensation in which the steam is condensed by passing through a large number of small tubes immersed in cold water.

Hammers, (marteaux,) of three sizes, the largest being called *sledge hammer ;* the next *flogging hammer ;* and the smallest *hand hammer.*

Handle, (manette).

Hand pump, (pompe à bras,) is fitted in the engine room for filling and feeding the boilers by hand, for washing the decks, extinguishing fire, &c. It is always made capable of being attached to the engines when they are working.

Heat, heating power, (chaleur, puissance calorifique).

Helm, helmsman, (timon, timonier).

Hemp, (étoupe).

High-pressure, or more correctly *non-condensing engines,* (machines à haute pression,) are those which work simply by the excess of the pressure of the steam above that of the atmosphere. Condensing engines, although sometimes using "high-pressure" steam, are never called high-pressure engines.

High-pressure steam, (vapeur à haute pression,) is a vague expression denoting steam of a tension above 15 or 20 lbs. pressure above the atmosphere.

Holding-down bolts, are the strong screw-bolts employed to fasten the foundation plate of the engines to the ship's bottom.

Horse power, nominal, (puissance en chevaux, force de cheval,) is as-sumed equal to 33,000 lbs. raised one foot high in one minute.

Hot-well, (reservoir à eau chaude, la citerne,) is the reservoir for the water pumped out of the condenser by the air pump.

Hugging is the expression used when one vessel is running so close in the wake of another as to be influenced by the current of dead-water following her, in which case the two may continue to keep close together, although the vessel running behind may be, perhaps, a mile an hour slower than the other.

Hull or shell of a boat, (coque d'un bateau).

Incrustation or *scale,* (sédiment,) is the hard coating of salt, lime, and other mineral substances which collect on the inner surface of the plates of a boiler which is not regularly and sufficiently "blown off."

Index of a spring balance, (curseur).

Indicator, (indicateur,) is the little instrument employed for ascertaining the real power, as well as the state of efficiency of the internal parts, of a steam engine, by indicating the actual pressure in the cylinder during each stroke, and the time and manner in which the steam is admitted and shut out by the valves.

Injection, (injection,) is the process of admitting a jet of cold water from the sea into the condenser, to condense the steam as rapidly as possible.

Inside bearings of paddle shaft, (upon a bracket bolted to the ship's side,) are employed when the wheels are "overhung."

Intermediate shaft is the strong shaft crossing the centre line of the vessel and connecting the paddle shafts of the two engines.

Iron-filings, (limaille).

Joints, (charnières, articulations).

Journal, (coussinet,) is the neck or bearing part of a shaft, upon which it turns and by which it is supported.

Junk ring, is a metallic ring confining the hemp packing of the piston (when such is employed), and made

capable of being screwed down to compress it.

Keelsons, (carlingues).

Key, (clef.) a wedge piece of iron used for tightening the brasses of a bearing, &c.

Kingston's valves, are conical valves with a screwed spindle, and are very generally used for closing the orifices of the injection and blow-off pipes where they pass through the ship's side.

Knees of iron, (équerres en fer).

Luggings for the cylinder, &c., are the thin staves of wood employed in "clothing," to stop the radiation of heat and consequent condensation of steam.

Lap of the slide valve, see Cover.

Larboard engine, that on the left-hand side of the vessel when looking towards the bow.

Latent heat, (chaleur latente,) is that portion of heat which is absorbed by gases and liquids, in a latent or insensible state, during their transition from a denser to a rarer form; as when water at 212° changes into steam at 212°, and when ice at 32° changes into water at 32°.

Lead of the slide valve, (avance du tiroir,) is the small space which the valve opens to steam at the end of each stroke, upon the opposite side of the piston. It tends to check the velocity of the piston at the end of the stroke, and allows of the valve being open and ready to admit a larger supply of steam the instant the motion of the piston is reversed.

Lead of the crank, (avance de la manivelle). It is usual in direct-acting, and generally in all unbalanced engines, to give what is called lead to one of the cranks; which implies that the crank of the one engine is set a little in advance of the right angle to the other; namely, at 100° or 110° in place of 90°. This assists in rendering the motion of the piston more uniform, by moderating its velocity at the end of the stroke.

Leather, (cuir).

Length of stroke, (longueur du coup, ou de la course).

Level, (niveau).

Lever, (lévier).

Lighter or barge, (gabarre).

Links are short connecting pieces with a bearing in each end, for transmitting motion from one rod or lever to another.

Link motion, is an ingenious arrangement for working the slides, by which means the travel or stroke of the valve may be varied at pleasure, and expansion given without a separate expansion valve being required. It also affords great facilities for stopping and reversing the engines.

Log, engine-room, a tabulated summary of the performance of the engines and boilers, and of the consumption of coals, tallow, oil, and other engineers' stores.

Lubricators, (godets, ou boîtes à huile,) are the larger description of oil-cups for holding oil and distributing it to the working parts of the engines.

Main centre, (goujon central,) in side-lever engines, is the strong shaft upon which the side levers vibrate.

Manhole, (trou d'homme,) is a hole in a boiler or tank, fitted with a steam-tight cover, through which a man may enter for the purpose of cleaning and examining the interior.

Metallic packing, (for the piston,) is composed of a ring or several rings of iron or other metal, sometimes cast so as to possess elasticity in themselves, or sometimes cut into segments and pressed against the interior of the cylinder by springs so as to form a steam-tight contact

Metre, equals 39·3702 English inches

Mile, Geographical or Nautical, or knot, contains 6082·66 feet.

Mile, British Statute, contains 528 feet, 1760 yards, or 1609 mètres.

Mile-post, (borne milliaire).

Mitre-wheel, has its teeth set at a angle of 45° with the spindle, so r to transmit the motion to anoth mitre-wheel and shaft at righ angles with it.

Morgan's feathering paddle wheel, Feathering paddle wheels.

Morticed, (assemblé à mortaise).

Mud hole, (orifice de nettoiemen fitted with steam and water-

doors, through which the deposit
may be removed from the boilers.
Muntz's metal, used for bearings, &c.,
is formed of 2 parts of zinc, 3 parts
copper.

Nave of a wheel, (moyen).
Neck of a shaft, (cou sinet d'un arbre,)
is the *journal* or *bearing* on which
it turns and is supported.
Non-condensing or *high-pressure en-
gines,* (machines à haute pression,)
are those in which the principle of
condensation is not applied, the
motive power being due solely to
the excess of the pressure of the
steam above that of the atmosphere.
Notch, (encoche).
Nut, (ecrou).

Oil-cups or *lubricators,* (boîtes à huile,)
are fitted to the several bearings and
rubbing surfaces of the engine for
the purpose of lubricating them to
diminish friction.
Oscillating engines, (machines aux
cylindres oscillantes,) are those in
which the cylinders oscillate upon
hollow axes or *trunnions,* through
which the steam enters the valve
casing. By this arrangement, the
parallel motion and connecting-rod
are dispensed with, the head of the
piston-rod being attached directly
to the crank-pin.
Outside bearings to paddle shaft, when
the shaft runs through to a bearing
on the spring beams.
Overhung paddle wheels, when the
shaft does not run through to a
bearing on the spring beams, but is
supported by a bracket from the
ship's side.

Packing for the piston, slide-valves,
&c., (garniture,) is employed to
render them steam-tight, and is
formed sometimes of rings of iron
or other metal pressed outwards by
springs, (when it is called metallic
packing) ; sometimes by hemp con-
fined by a "junk ring" and com-
pressed by screws (called hemp
packing) ; and sometimes by rings
of vulcanized india rubber and
other elastic material.
Paddle wheels, paddle boxes, (roues à
aubes, tambours).
Paddle boards or *float boards,* (les

aubes) ; *paddle-arms,* (les rais des
roues).
Parallel motion, (le parallelogram,) is
the name given to the combination
of jointed rods usually employed in
side-lever engines (and others) for
preserving the parallelism of the
piston rod.
Pedestal or *plummer block* is the sup-
port for a shaft in motion, holding
the brasses on which it turns.
Pet cock or *test cock* is the name given
to a little cock sometimes fitted at
the top and bottom of the cylinder
to allow the escape of water from
above and below the piston, inde-
pendently of the escape valves fitted
for that purpose. They are kept
open until the engines are fairly
under weigh, and are then shut.
Pin, (happe, boulon).
Pitch of a screw is the distance between
the threads, or the distance which
the screw advances during each
revolution when working in a solid.
Pitch circles are the circles of contact
of two or more toothed wheels
working in combination.
Pitching of a vessel, (plongement).
Plates, (thin,) (lames, tolles).
Plug, (bouchon).
Plummer block, see *Pedestal.*
Plunger, (plongeur,) a solid piston
without valves used in the feed and
bilge pumps, &c.
Ports of the cylinder are the short
steam passages leading from the
top and bottom of the cylinder to
the slide-valve casing.
Priming or *foaming* of the boilers
implies that the water boils over
into the steam pipes which lead to
the engines, and is caused by the
water being dirty, or there being a
deficiency of steam-room in the
top of the boilers.
Priming valves, see *Escape valves.*
Radius of curvature, (rayon de courbe).
Radius rods or *bars,* (la bride du paral-
lelogram,) are the guiding rods in a
parallel motion jointed to the con-
necting links to counteract the
vibratory motion communicated by
the side levers.
Reciprocating, (alternatif).
Reefing the paddles, means disconnect-
ing the float-boards from the paddle-
arms, and bolting them again nearer
the centre of the wheel, in order to

diminish the dip when the vessel is deep. This is sometimes done by machinery in what are called *reefing paddle wheels*.

Refrigerator, is a vessel containing a number of copper tubes through which the hot brine passes after being ejected from the boiler by the brine-pump. The feed water is at the same time passed through the vessel surrounding the tubes, and has its temperature thus raised by the waste heat of the brine before entering the boiler.

Reverse or *vacuum valves*, (soupapes de sûreté intérieures,) are small loaded valves opening inwards, and fitted to the boiler to admit air when a vacuum is formed by the condensation of the steam inside, or when the pressure of the steam falls to a few pounds below the pressure of the atmosphere.

Reversing gear is the apparatus provided for reversing the motion of the engine by changing the time of action of the slide-valve. This is done by bringing the eccentric *behind* in place of *in advance of* the crank.

Rib, (tirans).

Rocking shaft, the shaft, with levers, frequently used for working the slide-valves, the notch of the eccentric rod dropping into a stud fixed in one of the levers, and the links of the slide-valve spindle being attached to the opposite lever on the same shaft.

Rubbing part, (partie frottante).

Rudder, (gouvernail).

Rust joints, made by spreading over the surfaces to be united a mixture of one ounce of sal-ammoniac to one pound of cast-iron borings.

Safety valves, (soupapes de sûreté,) are fitted to the boilers for the escape of the steam, before it attains a dangerous pressure.

Salinometer, (salinométre,) is an instrument for measuring the quantity of salt contained in solution in the water of the boiler, by indicating either the specific gravity, or the temperature at which it boils.

Scale, (sédiment,) is the hard crust of salt, lime, &c., which collects upon the interior surface of the plates of

a boiler when proper attention is not paid to "blowing off." The hammers used for loosening and removing the scale are called *scaling hammers*.

Screw, screwed, (vis, vissé).

Screw bolts, (boulons en vis, boulons taraudés).

Seat of the valve, (siége de la soupape).

Sediment collectors or *scale pans*, are shallow vessels which are sometimes fixed in boilers about the level of the water, for collecting the particles of sediment which are buoyed up to the surface by bubbles of steam, and which would otherwise settle at the bottom of the boiler.

Sensible heat, (in opposition to *latent heat*,) is free caloric, which is sensible to, or whose presence is indicated by the thermometer.

Shaft, (arbre).

Sheet iron, (tôle, fer en feuilles).

Shovel, (pelle).

Shrouds for the funnel are the supporting chains from the deck.

Side levers, in side-lever engines, (balanciers,) transmit the motion of the piston rod from the side-rods to the cross tail of the connecting rod.

Sleepers or *engine bearers*, (traverses).

Slice, (fourgon, tisonnier,) is the instrument used for clearing the air spaces between the bars of a furnace, when they become choked with *clinkers*.

Slide valves, (tiroirs, soupapes à tiroir,) are much used for the cylinder steam valves of marine engines. The two kinds most commonly found are called "long D" and "short D" valves, from the form of their cross section; the distinction being that in the first case the steam enters round the outside of the valve, and exhausts through it, while, in the second, the exhaust takes place alternately from the top and bottom of each of the two short slides, which are strongly joined together by vertical rods.

Slide-casing or *jacket* (boîte des tiroirs) is the cast-iron box within which the slide valves work.

Slip of the paddle wheel or screw is the amount which each *slips back* in its progress through the water, in co

sequence of the imperfect resistance offered by the fluid, and is therefore equal to the difference between the rate of the wheel or screw and that of the vessel.

Smith (forgeron).

Smoke box (boîte à fumée,) is the space in a tubular boiler between the ends of the tubes and the front or back of the boiler. It is fitted with doors which remove for the purpose of cleaning the tubes with *tube-brushes*, and removing ashes and soot.

Smoke-burning apparatus is sometimes fitted to boilers with the view of effecting a more perfect combustion of the inflammable gases by introducing fresh atmospheric air behind the "bridge."

Snap is a tool used by boiler-makers for giving the head of the rivet a round and symmetrical form before it cools, but after it has been *closed*.

Snifting valve, (soupape reniflante,) is the small valve fitted to the condenser, and opening outwards for the escape of the air and steam ejected during the process of "blowing through."

Socket (socle. crapandine).

Solders are alloys of a medium degree of fusibility employed for joining metals together. "Hard solder" for brass is formed of 3 parts copper, 1 part zinc: soft solder for brass, of 6 parts brass, 1 part tin, 1 part zinc. A common solder for iron, copper, or brass consists of nearly equal parts of copper and zinc.

Sole plate, base plate, or foundation plate, (plaque du fond,) is the strong plate which is bolted on the engine bearers, and forms the foundation for the engine.

Spanners are the keys used for screwing up nuts.

Spare gear, (pièces de réchange,) are carried in Government and other steamers to replace any portions of the machinery which may be broken or injured at sea.

Speed, (vitesse).

Spindle, (axe, verge).

Split pins are those which have a thin wedge of steel inserted in the end to prevent their falling out.

Springs. (reports).

Spring balance, (balance à ressort,)

is a spiral-spring weighing balance fitted with steam-tight piston, index plate, and pointer, for showing the pressure of high steam.

Spring beams are wooden beams stretched between the ends of paddle beams to support the bracket for the outside bearings of paddle-shaft.

Square, square foot, (quarré, pied carré).

Square tuck is the flat surface left at the stern of a vessel when the planks of the bottom are not worked round to the wing transom, but end in the fashion-piece.

Starboard engine is that on the right-hand side of the vessel when looking towards the bow.

Starting gear, (encliquetage régulateur,) for starting the engines, comprises a wheel for working the slide valves by hand, and at the same time bringing the eccentric into gear, so as to continue the motion of the valves; a handle to open the throttle valve, and admit the steam, one to open the blow-through valve, and another to admit condensing water through the injection cock.

Steam engine, steam boat, (machine à vapeur ; bateau à vapeur, pyroscaph).

Steam chest, (reservoir pour la vapeur,) is the reservoir for steam above the water of the boiler.

Steam room, (espace pour la vapeur,) is the capacity for steam over the surface of the water in the boiler.

Steam gauge, mercurial, (manomètre pour la vapeur,) is employed to show the pressure of steam in the boiler by marking the height to which it will raise a column of mercury in a syphon tube.

Steam-tight (etanche de vapeur).

Steam tug, (pyroscaph remorquant).

Steel, (acier).

Steersman, (timonier).

Stern, (poupe).

Still or dead water, (eau morte).

Stop valves, or communication valves, are fitted in the steam pipes where they leave the several boilers, and in the connecting pipes between the boilers, in such a manner that any boiler or boilers may be shut off from the others, and from the engines.

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Stops or **smugs of eccentric**, are the catches on the eccentric pulley and intermediate shaft, for the purpose of communicating the motion of the shaft, through the eccentric, to the slide valves, either for going ahead or astern.

Stow goods, to, (charger des marchandises).

Straight line, (ligne droite).

Strain, (effort).

Stroke of the piston (course du piston.)

Stuffing-box, (boîte à étouffe, le collet) is the mechanical arrangement by which a rod passes steam-tight through the cover of a cylinder or air-pump, &c. This is effected by the rod being surrounded at that place by a packing of hemp or gasket, which is compressed by means of the collar (with its **brass**) being screwed tight down upon it The stuffing-box is lubricated with oil or melted tallow. which is poured into the cupped collar surrounding the rod.

Sucking pump, (pompe aspirante,) is one which raises water by exhausting the air from the barrel of the pump, into which the water is forced by the external pressure of the atmosphere.

Suction pipes, (tuyaux à succion, suçoirs).

Super-heated steam, is steam whose temperature has been raised after it has left the water from which it was generated.

Supplementary engine, see **Auxiliary engine.**

Surcharged steam, is steam which has an excess of watery particles held in mechanical suspension.

Syphon oil cups, are those fitted with a wick of cotton or worsted hanging over the edge of a little tube in the middle of the cup, the oil rising in the wick by capillary attraction, and dropping down the tube on to the bearing.

Tallow, oil, (suif, huile).

Taps and **dies** are employed for forming the threads of internal and external screws. The former is a hard steel screw, grooved from end to end, so as to present a cutting section, and slightly tapered. This is turned round, by hand, inside the nut by means of the **tap wrench.** Dies are screwed nuts of hard steel, grooved in the same way, for cutting the threads of bolts.

Template, (of a base plate, for instance,) is a model or gauge of it in thin sheet iron or wood, having the bolt holes cut out, and the various centres marked, for the purpose of transferring them to the hull of the vessel.

Test cocks, see **Pet cocks.**

Thread of a screw, (filet d'une vis).

Throttle valve, (soupape regulateur,) is situated in the steam pipe, close to the slide valve casing, and is used for regulating the flow of steam, which in the marine engine is done by hand.

Ton equals 2240 lbs. ; the French **tonne** equals 1000 kilogrammes, or 2204·86 lbs. avoirdupois.

Travel of the valves, (course du tiroir,) is synonymous with their **stroke.**

Trunk-engine, is one in which the end of the connecting rod is attached to the bottom of a hollow **trunk** fitted to the upper side of the piston, and alternating with it through the interior of the steam cylinder. The trunk itself passes steam tight through the cylinder cover, by means of a stuffing box.

Trunnions of oscillating cylinders, are the hollow axes upon which they vibrate, and through which the steam passes into the belt which leads round the exterior of the cylinder to the valve casing.

Tubular boilers, are those in which the flame and hot gases, after leaving the furnaces, pass through a great number of small iron or brass tubes surrounded with water.

Tube plugs, formed of hard wood, are used for driving into the two ends of a tube that has been burst by the pressure of the steam, as a temporary remedy until a new tube can be put in.

Tug, or **towing boat,** (remorqueur).

Two-way cock, (robinet à deux eaux)

Up-take, is the name given to the flue of a boiler into which the others are gathered at the end of their course, and thus **taken up** into the foot of the chimney.

Vacuum gauge or barometer, is fitted to the condenser to show the vacuum.

Vacuum pump, is sometimes fitted to the boilers for the purpose of filling them above the level of the sea, by withdrawing the air from the inside of the boiler, when the water will of course rise by the atmospheric pressure outside.

Vacuum valves, see *Reverse valves.*

Valves, (valvules, soupapes, clapets, tiroirs).

Valve casing, (boîte du tiroir, boîte à vapeur,) is the cast-iron chest enclosing the slides.

Valve-gearing, (armature du tiroir).

Velocity, (vitesse).

Wages, (gages, salaire).

Washers, are the round pieces of thin iron or brass interposed between the nut of a bolt, and the surface upon which it is screwed down.

Waste-steam pipe leads from the *valve chest* on the top of the boilers, to carry off the steam escaping through the safety valves.

Waste-water pipe, see *Discharge pipe.*

Water gauges, namely, *glass water gauge* and the *brass gauge cocks,* are attached to the front of the boiler for showing the level of the water.

Water-tight, (etanche d'eau).

Wear, (usure).

Wedge, (coin).

Weigh-chaft, is the rocking shaft used in working the slide valves by the eccentric.

Worm wheel, is a wheel with teeth, formed to fit into the spiral spaces of a screw, so that the wheel may be turned by the screw, or *vice versâ.*