

www.e-rara.ch

Modern Marine Engineering

Burgh, Nicholas Procter

London, 1881

ETH-Bibliothek Zürich

Persistent Link: <https://doi.org/10.3931/e-rara-77350>

Chapter X.

www.e-rara.ch

Die Plattform e-rara.ch macht die in Schweizer Bibliotheken vorhandenen Drucke online verfügbar. Das Spektrum reicht von Büchern über Karten bis zu illustrierten Materialien – von den Anfängen des Buchdrucks bis ins 20. Jahrhundert.

e-rara.ch provides online access to rare books available in Swiss libraries. The holdings extend from books and maps to illustrated material – from the beginnings of printing to the 20th century.

e-rara.ch met en ligne des reproductions numériques d'imprimés conservés dans les bibliothèques de Suisse. L'éventail va des livres aux documents iconographiques en passant par les cartes – des débuts de l'imprimerie jusqu'au 20e siècle.

e-rara.ch mette a disposizione in rete le edizioni antiche conservate nelle biblioteche svizzere. La collezione comprende libri, carte geografiche e materiale illustrato che risalgono agli inizi della tipografia fino ad arrivare al XX secolo.

Nutzungsbedingungen Dieses Digitalisat kann kostenfrei heruntergeladen werden. Die Lizenzierungsart und die Nutzungsbedingungen sind individuell zu jedem Dokument in den Titelnformationen angegeben. Für weitere Informationen siehe auch [Link]

Terms of Use This digital copy can be downloaded free of charge. The type of licensing and the terms of use are indicated in the title information for each document individually. For further information please refer to the terms of use on [Link]

Conditions d'utilisation Ce document numérique peut être téléchargé gratuitement. Son statut juridique et ses conditions d'utilisation sont précisés dans sa notice détaillée. Pour de plus amples informations, voir [Link]

Condizioni di utilizzo Questo documento può essere scaricato gratuitamente. Il tipo di licenza e le condizioni di utilizzo sono indicate nella notizia bibliografica del singolo documento. Per ulteriori informazioni vedi anche [Link]

CHAPTER X.

DESCRIPTION OF PLATES.

Plates 1 and 2.—These plates are described by the firm as follows:—

The engines are of 300 horse-power, nominal power, manufactured by Messrs. Maudslay, Sons, and Field, having three horizontal cylinders, 55 inches in diameter, with a stroke of 2 feet 6 inches, giving motion to a three-threw crank shaft, with the cranks set at an angle of 120° with each other. The cylinders are entirely cased with steam, having steam jackets around their circumferences and at their ends, and are intended to work with a pressure of 25 lbs. per square-inch. The steam is cut off by the slide valve at from $\frac{1}{4}$ to $\frac{1}{8}$ of the stroke, without the use of any separate expansion valves. The slides are double ported as far as the eduction passages are concerned, but they have three steam openings in order to give the requisite area to the admission of the steam. The slides are worked by a crank shaft running across the whole length of the engines, and driven by a train of spur wheels from the main crank shaft of the engines. The two intermediate wheels of this train are mounted in a movable frame, which may be raised or lowered at pleasure, the effect of which is to vary the position of the cranks that work the slides, so as to make them cut off sooner or later, as may be required: by the same means the slide cranks are shifted into the proper position for going astern. There are two surface condensers, fitted with inclined tubes, with the steam inside the tubes, and the condensing water outside, as originally adopted by Samuel Hall. The steam passes into the condenser at the upper end of the tubes, and the condensed water is delivered at the lower end, from whence it passes to the air-pumps. Each condenser is fitted with 2,436 copper tubes, 6 feet 3 inches long, $\frac{1}{2}$ -inch diameter inside, with a thickness of No. 18 wire-gauge. The tubes are packed at each end with small screwed stuffing boxes with tape packings. The condensers, with their corresponding air-pumps, are placed opposite the two outer cylinders, the air-pumps being worked by brackets secured to the piston rods. The space between the two condensers over the cylinder

cross-heads and piston rods is occupied by the engine platform; by this arrangement all the working parts are kept well within the reach of the person in charge. Motion is imparted to the circulating pumps by rods, connected with the steam pistons; these pumps are $10\frac{1}{2}$ inches diameter, and 2 feet 6 inches stroke, and are fitted with lignum-vitæ packing to the plungers, and india-rubber foot and discharge valves. The condensed water is delivered from the air-pumps into a feed-water tank, from which it is forced into the boiler by the ordinary feed pumps. This description of engine offers the advantage of great economy of fuel, with a comparatively simple arrangement, while at the same time it gives an equable power, and the centre of gravity of the different moving parts being always the same in relation to the vessel, it does away with all the unpleasant vibration so frequently felt with quick-working engines.

The steam is generated in two boilers, of the ordinary tubular construction with return tubes over the furnaces, placed one on either side of the vessel, with the stoker's room between them. Each boiler has four furnaces, 3 feet 2 inches wide, and 6 feet 7 inches long, and is fitted with 440 brass tubes, $2\frac{1}{2}$ inches diameter outside, and 6 feet long; the chimney is 5 feet 6 inches diameter, and it is made to lower on the telescope principle.

Each of the boilers is fitted with a superheating apparatus, consisting of a series of flattened tubes, placed in rows in the up-take: the tubes are placed so as to offer as little obstruction as possible to the heated air in its passage to the chimney; each superheater has 81 tubes, 6 feet 6 inches long, and $2\frac{1}{2}$ inches diameter before they are flattened.

The screw-propeller is four-bladed, with an increasing pitch on Mr. Woodcroft's principle; it is 12 feet diameter, and has a mean pitch of 13 feet. The blades are bolted on to a spherical boss, and they are made so that the pitch can be altered and set at any pitch, from 11 feet 6 inches to 14 feet 6 inches.

The vessel is an iron-plated battery ship, with a ram

1) Diesel's Masch. besess. - König Wilhelm (1868) } von A. Tobler
 aber mit Dampfmaschinen S. 296. Fig. 151. } in Kiel 1908 besichtigt.

bow, and was built by the Thames Iron Works and Ship-building Company; it is 2,811 tons, builders' measurement, and is 220 feet long between perpendiculars, and 53 feet wide, with a draught of water of 14 feet 6 inches.

Plates 3 to 8 inclusive.—These illustrate the arrangement and details of Mr. Spencer's patent auxiliary surface condensers and engines for the iron screw steam-ship "Frankfort," of Liverpool. The type of the engine is vertical, inverted direct action. The condensers are tubular, with outside condensation; the pumps being on the combined principle, similar to those adopted by Messrs. Penn in H.M.S. "Arethusa." The motion is derived from the steam piston-rods for the pumps, and the arrangements and form of the valves can be understood from the drawings. The cylinders are fitted with the ordinary slide valves and expansion valves at the back of the same.

The following particulars will render the several portions to be understood without further notice:—

Diameter of Cylinders	20"
Length of Stroke of Piston	15"
Diameter of Combined Pumps	14"
Length of Stroke	15"
Diameter of Feed Pumps	3½"
Length of Stroke of ditto	15"
No. of Tubes in Condenser	584
Length of ditto	5' 6"
External diameter of Tubes	1¼"
Thickness of ditto, 18 wire gauge.	
Amount of Cooling Surface (sq. feet),	1,004.

Plates 9 to 14 inclusive.—A description of these engines, constructed by Messrs. Dudgeon, will be found in pages 71 to 73, inclusive. The "condensers" are described in page 259; also the "cylinders" in page 277; the "slide valve" in page 286; the "piston" in page 278, and the "link motion" in page 292; to which the following particulars, supplied by the firm, are now added:—

Nominal Horse-power Collectively	350
Actual Indicated	1540
Diameter of Cylinders Inner, 27"; Outer, 62"	
Length of Stroke	2' 0"
Width of Exhaust Steam Ports in Cylinders, 6¼" and 4"	
.. .. . Valve	3¼"
.. .. . Supply Ports in Cylinders 4" and 2"	
.. .. . Valve	3¼"
.. .. . Small Bar in Cylinders	1½"

Width of Large Bar in Cylinders	4½"
Length of Steam Ports	2' 6"
Outside Lap of Valve	1¾"
Half travel of Valve	3½"
Width of Steam Opening caused by Valve	1¼"
Diameter of Valve Rod	3¼"
Length of Link between Centres of Eccentric Rods	1' 6"
Thickness of Cylinders Inner 1½"; Outer 1¼"	
Diameter of Piston Rods Inner Cylinder	
.. .. . (1) 3¾"; Outer (2) 4½"	
Depth of Piston	8"
Diameter of Crank Shaft (bearing) 9½"	
Length of Bearings	18¼"
Diameter of Connecting Rod	9½"
Length of	4' 0"
Diameter of Air Pump	11"
.. .. . Suction Valves' Openings	4¾"
.. .. . Discharge	4¾"
Number of Suction Valves (ditto for each condenser)	18
.. .. . Discharge (ditto)	18
Diameter of Circulating Pump	11"
.. .. . Suction Valves Openings	As above.
.. .. . Discharge	Ditto.
Number of Suction	Ditto.
.. .. . Discharge	Ditto.
Thickness of Metal of Condenser	1½"
Number of Tubes in Condenser	2017
Diameter of Tubes (External)	5"
Length of Tubes	5' 10¼"
Diameter of Feed Pumps	3¼"
.. .. . Injection Pipe (Surface Condenser, with additional Jet Injection 3" diameter.)	
.. .. . Feed	3"
.. .. . Bilge Injection Cocks	3"
.. .. . Cylinder Relief Valves	4"
.. .. . Main Discharge Pipe	12"
.. .. . Exhaust Steam	13"
.. .. . Single Supply	9¼"
.. .. . Main Supply	16"
Material of Air Pump	Gun Metal.
.. .. . Feed Plunger	Ditto.
Feed Pump	Single Acting.
Distance between Centres of Cylinders	5' 6"
Diameter of Screw Propeller	10' 6"
Length on Line of Keel	3' 0"
Pitch	18' 0"
Kind of Propeller	Common.
Number of Blades	3

valves are revolving valves with four ports, and revolve at one-half the speed of the engines; the degree of expansion is regulated by spiral grooves cut in long brass sockets, as introduced and practised for some time by Maudslay, Sons, and Field. The air-pumps are horizontal, double acting pumps $26\frac{1}{2}$ inches in diameter, worked by rods direct from the pistons. The foot and discharge valves are of india-rubber with gun-metal seatings; they are placed above the level of the air-pump, the foot valves being inverted, and draining directly from the bottom of the condensers, which are placed altogether above the level of the air-pumps. The feed-pumps are worked from the cylinder crosshead, the pumps being placed under the starting platform at the end of the condenser; the valve boxes of the feed and bilge pumps are placed so as to be easily got at at all times when the engines are at work.

The screw propeller is four-bladed with moveable blades, so arranged as to allow of the pitch being readily adjusted. It is 20 feet in diameter, and the pitch can be adjusted from 20 feet to 25 feet.

The boilers are in six parts, placed forward of the engines. They have in all 30 fire-places, 7 feet 6 inches long by 3 feet wide, having an area of firegrate of 675 square feet, and are fitted with 3,600 brass tubes $2\frac{1}{2}$ inches in diameter outside and 6 feet 6 inches long; the total area of heating surface is 19,000 square feet. The two aft boilers are fitted with a superheating apparatus consisting of a number of flattened tubes placed in the boiler up-takes immediately above the level of the boiler tubes. There is one chimney 9 feet 4 inches in diameter, which is made to lower on the telescopic principle.

Plate 22.—Description of the engines and boilers of the Egyptian screw ships "Charkieh" and "Dakablieh," constructed by Messrs. J. and G. Rennie, with surface condensers and superheaters by the firm:—

These engines are on the return connecting-rod principle, with double piston-rods.

The two cylinders are on the same side of the ship and bolted together, leaving a passage between them to get at the centre bearings.

Each cylinder is $63\frac{1}{2}$ inches in diameter and 3 feet stroke.

The slides are double ported, and a separate valve (gridiron) is supplied for working expansively.

The surface condenser, on the opposite side of the ship, is fitted with vertical copper tubes $\frac{9}{16}$ inch diameter.

The steam passes through the tubes; each tube is fitted with a screw gland and stuffing-box top and bottom, and cotton packings.

Total condenser surface about 7,000 square feet.

Circulating and Air Pumps.—One of each: both are worked from the steam pistons, and are of equal diameter, and the passages are so arranged that a circulating pump can also be worked as an air-pump if the condensers are worked with injection.

The water is drawn through the condensers, and not pushed through by the circulating pump, so as to cause a more uniform flow, and dispense with shocks in the condenser. The quantity of cold water circulated is in proportion to the quantity of steam used. The air pump discharges the condensed steam into a hotwell or overboard.

Feed Pumps.—Each engine is fitted with a full-sized feed-pump in case of working by injection, drawing the water either from the hotwell or sea.

An injection valve and pipe, of full size for working with ordinary condensation, is fitted, as well as a small injection pipe for working up the quantity of water lost by evaporation.

Bilge Pump.—Each engine is fitted with one of same size as the feed-pump.

Boilers.—Four in number, having a total heating surface of about 7,500 square feet, and grate surface of 280 square feet, with Lamb's patent flues in place of tubes. Each boiler is fitted with a brine or blow-off pipe, feed regulating valve, double safety valves, stop valves, and vacuum valves.

The boilers are united into one take-up, into which is fitted a Lamb's patent Scroll Superheater, of about 800 square feet of surface, so arranged that engines may be worked with or without superheated steam.

Shafting.—The bearings in the sea are fitted with lignum-vitæ.

Screw.—Three-bladed, 15 feet 6 inches diameter, and 19 feet 6 inches pitch.

The dimensions of the vessels "Charkieh" and "Dakablieh" are as follows:—

Length between perpendiculars	260 feet
Beam	35 "
Depth amidships	26 feet 6 inches
Tonnage, O M	1557 $\frac{3}{4}$

The trial of the "Charkieh" gave the following results:—

Draft of water, forward 15 feet 6 inches
 Ditto aft 17 " 9 "
 Displacement at 16 feet 7½ inches .. 2,200 tons
 Midship section 462 square feet
 Engines.—Horizontal double piston rod. Nominal horse-power, 350.

Screw, 6-bladed, with wrought-iron blades—

Diameter 15 feet 9 inches
 Pitch 19 " 6 "

Engines with surface condensers and superheaters.

Trials outside Plymouth Breakwater:—

Revs.	Steam.	Vacuum.		Min. Sec.	Knots per Hour.
74	23	24½	First Run ..	4 52	= 12·329
74	24	24	Second do ..	4 13	= 14·229
76	23	25	Third do. ..	4 52	= 12·329
74	22	25	Fourth do. ..	4 27	= 13·483

4) 52·370

Mean of Four Runs 13·0925

Ditto, by Government Rule 13·185

	Days.	Hrs.	Miles.
Plymouth to Gibraltar	3	18	1,080
Gibraltar to Malta	3	18	981
Malta to Alexandria	3	0	819
	10	12	2,880

Mean speed, Plymouth to Alexandria .. 11·4 knots.

When working *at sea*, with 18½ lbs. steam, 71 revolutions, 24 vacuum, 18½ lbs. pressure, the result was 1,475 indicated HP.

When cutting at ½-stroke, 58 revolutions, 18½ lbs. steam, 24 vacuum, indicated power at sea, 1,166.

When working on the first trial trip, with 3-bladed screw, before 6-bladed screw was put on, indicated power, 1,860 horses; pitch of screw, 18 feet 6 inches.

The trial of the "Dakahlich," the sister vessel, was made in Stokes' Bay:

The draft of water being, forward 15 feet 6 inches
 Ditto aft .. 18 "
 Displacement in Tons 2,200
 Area of Midship section 484 square feet
 Weights on Board 815 tons.

The power developed by these engines was upwards of 1,900 HP., with a three-bladed screw of 15 feet 9 inches diameter, and 19 feet 6 inches pitch, and with parallel blades—viz., of the same width at the boss as at the outer circle—gave the vessel a mean speed of 14·2 knots. This speed, is, we believe, unequalled for a screw-vessel of these proportions and dimensions, and with so large a cargo, and contrasts favourably, in point of results obtained by indicated power, with any of the vessels in the Peninsula and Oriental Company's fleet.

Plates 23 and 24.—These depict the plan and elevations of twin-screw engines, boilers, fittings, shafting, and propeller of 200 nominal horse-power collectively, constructed by Messrs. Watt, and fitted by them in the steam ships "Medusa" and "Triton." The engines are "direct acting," with the condenser between the shafts of both engines, by which location a compact arrangement results. The condenser is of the "injection" type, and internally arranged with care as to the correct disposition of the valves. The starting wheels are at the boiler side of the engines, thus enabling the engineer to proceed direct from the deck or stoking room to his post of duty without clambering over the engines or going around them. The boilers are the ordinary multitubular type, with a cylindrical superheater. The general arrangement of the piping, &c., are so evident from the drawings, that further description is scarcely requisite.

Plate 25.—This is a plan and elevation of an arrangement of a pair of "direct acting," by the above firm last alluded to, of the same collective nominal horse-power as the last example, fitted in H.M. steam ship "Research." The "condenser" is described and illustrated in page 261, the cylinders in page 276, and the expansion valve in page 301. The remainder of the arrangement and the main dimensions are obvious from the views depicted.

Plate 26.—This type of engine, by Messrs. Humphrys, is described in pages 52 to 56 inclusive; the "condenser" in page 248; the "air pump" valves in page 271; the "link motion" in page 290; and the "starting gear" in page 295.

Plate 27.—These engines are constructed by Messrs. Penn, and fitted in H.M.S. "Arethusa," being one of the trial ships, in which the makers of the engines were not bound as to terms or price as in the usual contracts. The "type" of "engine" is described in pages 42 and 43; the "cylinders" in page 274; the "slide valves" in

page 284; and the "condensers" in page 258, to which the firm has added the following:—

Nominal Horse-power	500
Indicated ditto on official trial, April 1st, 1862	2,871
Speed of Ship	12.694 knots
Diameter of Screw Propeller	18'
No. of Blades	2
Kind of Screw	Griffiths' patent
Pitch of ditto	(mean) 23'
Revolutions per minute	70
Pressure on Safety Valves, 20 lbs. per sq. inch Vacuum	27½ to 28
Diameter of Cylinder	86½"
Effective diameter of ditto	80"
Diameter of Trunk	33"
Length of Stroke	3' 6"
Diameter of Air Pumps	20"
Length of Stroke	3' 6"
Diameter of Circulating Pumps	20"
Length of Stroke	3' 6"
Diameter of Feed Pumps	5"
Length of Stroke	3' 6"
Diameter of Condenser Tubes (outside)	1"
Length of ditto	6' 9"
No. of ditto	4,832
No. of Boilers	4
Diameter of Tubes in ditto	3"
Length of ditto	7'
No.	1,216
No. of Furnaces	16
Breadth of ditto	2' 10"
Length of ditto	7'
Diameter of Chimney	6' 8"

* Plate 28.—This is the most complete illustration in the present work, being an arrangement of a pair of return-action engines, by Messrs. Napier and Sons, comprising *six* views. As the illustrations are so complete it will be sufficient to state that the condenser is described in page 262, and that the following particulars added by the firm renders conclusion evident:—

Nominal Horse-power collectively	300
Diameter of Cylinder	63"
Length of Stroke	2' 6"
Diameter of Piston-rods	5½"
Depth of Piston	8"
Diameter of Crank Shaft	12¾"
Length of each Bearing of ditto	1' 10"

Diameter of Connecting Rod (crank end)	7½"
Length of ditto	5' 6"
„ Guide Block Surface	2' 6"
Width of ditto	16"
Diameter of Air Pump	16"
„ Circulating Pump	16"
„ Injection Pipe (1)	5½"
„ Feed (1 to each engine)	3¾"
„ Snifting Valve	2½"
„ Bilge Injection Cocks (2)	2½"
„ Cylinder Relief Valves	5¾"
„ Blow-through ditto 10½ sq. ins. area to each engine.	
„ Main Discharge Pipe	16"
„ Exhaust Steam do. (each cylr.)	20"
„ Single Supply do.	15"
„ Main ditto Pipe	16"
Thickness of Cylinders	1¼"
„ Condensers	1½"
Size of Suction Valves for Air Pump, rectangular 28 in. × 13 in.	
No. of Valves (Suction) for Air Pumps, 1 to each end of Pump.	
Discharge of Valves, 1 to each end of Pump.	
No. of Suction Valves for Circulating Pump, 1 to each end of Pump.	
Discharge of Valves, 1 to each end of Pump.	
Suction and delivery valves are alike, and are the same for both air and circulating pumps. Each valve consists of two rectangular grated openings of 2 feet 3½ inches long by 5 inches wide.	
Diameter of Condensing Tubes, ¾ inch outside.	
Tubes are about 1/10th of an inch thick.	
Length between tube-plates	6' 3"
Diameter of Circulating Water-pipe	16"
„ Discharge ditto	16"
No. of Tubes, 3,923.	
Material of Air Pump Piston, brass.	
„ Feed Plunger, brass.	
Feed Pump, single acting.	
Distance between centres of Cylinders	8' 9"
Diameter of Screw Propeller	15'
Pitch (mean)	14' 6"
Kind of Propeller, Griffiths'.	
„ Expansion Valve, Gridiron.	

3 K

* Entschickt d. Masch. der dänischen Thaumachrie: "Rolf Krake" (1863).

Grade of Expansion, maximum, 2 from commencement of stroke.
 Grade of Expansion, minimum, 6 from commencement of stroke.
 Kind of Boilers, tubular.
 No. of ditto, 4.
 Length of Tubes in each, 6 feet 6 inches, and total number 272.
 Length of Fire-grate, 5 feet 6 inches, breadth 3 feet 4 inches.
 No. of Fire-Grates, 3.
 Size of Funnel, 7 feet 9 inches by 3 feet 9 inches.

Plate 29.—Steam Launch engines and boiler, by Messrs. Rennie. The engines are vertical, direct acting, single cylinders, one to each screw shaft; surface condensers are attached to the sides of the boilers, the latter being the return tubular type. The following particulars, contributed by the firm, will be all that is necessary to appreciate the design in question :—

Kind of Boiler. Multitubular with return Tubes.
 Width of Shell of Boiler 2' 5"
 Length of ditto 4' 9½"
 No. of Tubes 40
 Outer diameter of Tubes 1¾"
 Length of ditto 3' 6"
 Width of Fire-grate 2'
 Length of ditto 2' 5½"
 Diameter of Chimney 9"
 „ Steam Dome 1' 1"
 No. of Steam Cylinders 2
 Diameter of ditto 6"
 Length of Stroke 6"
 Diameter of Piston-rod 1"
 „ Crank Shaft at Bearings .. 1¾"
 Length of Bearings 2½"
 Diameter of Feed Pumps 7⁄8"
 Length of Stroke 6"
 Diameter of Donkey Pump 1½"
 Length of Stroke 3"
 No. of Tubes in Surface Condenser .. 86
 Diameter of ditto ditto 1⁄8"
 Mode of Circulating the Water, Centrifugal Pump.

Screw Propellers, whether right or left-handed Right and Left
 Diameter of Screw 2' 6"
 Pitch of ditto 3' 6"
 Length of ditto 3½"
 No. of Blades 4
 Length of Launch 42'
 Breadth of ditto 10' 11"

	Tons. cwt. qrs. lbs.
Weight of Engines, Boiler, Centrifugal Pumps, Surface Condensers, Donkey Engine, &c., as lifted out	2 6 0 0
Stern Tube, Propellers, Shafts, Stern Brackets, Propeller Shafts, Thrust Bearings, Bolts, and Holding-down Plates	8 0 0
Sea Cocks and Discharge Pipes, Roses, Bolts, and Nuts	1 3 0
Coal Boxes, Spanner Racks, and Spanners	3 0 0
Floor Plates	2 0 0
	3 0 3 0
Water in Boilers	7 1 0
„ Condensers	3 0
	3 8 3 0
Engine Bearers of wood, and Chocks, forming part of the Boat	4 2 0
	3 13 1 0

It will be seen by the above that the total weight of the launch engine, including surface condensers, centrifugal pumps and their appurtenances, together with the water in the boiler and in the surface condensers, and of the wooden chocks and bearers fixed in the boat to carry the screw tubes, thrust block, boiler, and floor plates, is considerably under 4 tons, and excluding the surface condenser and its pipes, as in the launches hitherto adopted in the English navy, the weight will be 8 cwt. less, or 3 tons 5 cwt. 1 qr. altogether. This small additional weight of 8 cwt. is the substitute in these engines for the cumbrous tanks of fresh water placed in the ordinary launch, the weight of which, with the water in them is upwards of a ton.

TRIAL of H.M. STEAM-LAUNCH No. 10, fitted with HIGH-PRESSURE ENGINES and SURFACE CONDENSERS
by Messrs J. and G. RENNIE.

	Full Power, High Pressure, without Condensers.	Full Power, Condensing, using Condensers.
When tried	8th June, 1866	
Where tried	Stokes Bay.	
Nominal Horse Power	5 Horses.	
Makers' Name	J. & G. Rennie.	
Draught of Water {	Forward	1' 11"
	Aft	3' 0½"
Load on Safety Valve	80 lbs.	
Pressure of Steam in Boilers	80·833 lbs.	73·25 lbs.
Number of Revolutions of Engines {	Maximum	330
	Mean	326·333
Mean Pressure in Cylinders	54·958 lbs.	58·344
Indicated Horse Power	30·732	32·84
Speed of Vessel	7·897 knots.	8·054 knots.
Quantity of Coal on board	5 cwt.	
Quantity of Stores	1 day.	
Propeller {	Description Common 4-bladed and variable pitch.	
	Diameter	2' 6"
	Pitch	3' 6"
	Length	3½"
Immersion of upper edge	3"	
True mean Speed of 6 runs with and against tide, in knots	7·897	
True mean Speed of 4 runs with and against tide, in knots	6·054

Plate 30.—This is an example of paddle-wheel engines by Messrs. Watt; the description of the details will be found in Chapter V., commencing in page 193.

Plate 31.—Messrs. Maudslay's example of boiler and twin screw engines for H.M. Launches is illustrated by this plate. The cylinders are secured direct to the fire-box shell, and the shafts are supported by brackets secured below the cylinders; the latter being also sustained by stays connected to the brackets. A donkey engine feed pump is connected to the smoke box, and the engine feed pumps are worked by cranks at the extremities of the shafts. The following particulars by the firm are sufficient to understand the practicability of the arrangement in question:—

Kind of Boiler—Locomotive.

Diameter of ditto	2' 1"
Length of ditto	3' 7"
No. of Tubes	31
Outer diameter of Tubes	2"
Length of ditto	3' 7"
Width of Fire-grate	2' 1"
Length of ditto	2' 3"
Diameter of Chimney	10"
„ Steam Dome	1' 3½"

No of Steam Cylinders	4
Diameter of ditto	5"
Length of Stroke	6"
Width of Supply Port	7⁄8"
„ Exhaust Port	1½"
Length of ditto	2¼"
Width of opening caused by Slide	¼"
Outside Lap	3⁄8"
Diameter of Piston Rod	1"
„ Crank Shaft at Bearings	2"
Length of Bearings	3½"
Diameter of Feed Pumps	1¾"
Length of Stroke	2½"
Diameter of Donkey Pump	1¾"
Screw Propeller, 1 right handed and 1 left.	
Diameter of Screw	2' 6"
Pitch of ditto	3'
Length of ditto	3'
No. of Blades	4
„ Revolutions	306 to 375
Speed of Launch, 7·25 knots per hour.	
Steam pressure	65 lbs.
Length of Launch	42'
Breadth of Ditto	10' 6"
Depth of Ditto	3' 9"

	Tons. cwt. qrs.
Weight of Engines and Boiler complete	1 19 2
Weight of Water in Boiler	0 7 2
Total	2 7 0

Plate 32.—These are elevations and plan of a boiler and twin-screw engines for one of H.M. Launches, by Messrs. J. Penn and Son. The boiler is the locomotive type; the engines are secured to the sides at the fire-box end, and thus frames are dispensed with. The donkey pump is attached to the smoke box; the form of the engines, pumps, and shafting is obvious from the illustrations, without further notice, excepting the following, by the firm:—

Kind of Boiler, Locomotive.	
Number of Tubes	35
Outside Diameter	2½'
Length, ditto	3' 10"
Width of Fire-grate	2' 4"
Length	2'
No. of Steam Cylinders	4
Diameter of "	5"
Length of Stroke	6"
Screw Propellers (2), Right and Left-handed.	
Diameter	2' 6"
Pitch	4'
No. of Blades in each	4
Length of Boat	42"

Ship's Launch.
Total weight of Machinery, Boiler, Water and Wood chocks, and Engine bearers, complete, 3 tons 4 cwt. 2 qrs.

Indicated Power, 36 to 40 (collectively).

Revolutions, 300.

Speed, 8 to 8½ knots.

Plate 33.—The engines for H.M.S. "Lord Clyde" are illustrated by this plate, being the contribution of Messrs. Ravenhill and Hodgson. The type of engines is "return action," the cylinders being 116 inches in diameter, and the stroke of piston 4 feet; the cylinders are jacketed, and the grade of expansion is determined by the ordinary "gridiron valve," as adopted by Messrs. Watt and Penn. The condensers are the "surface" system, the water being circulated by centrifugal pumps, driven by auxiliary engines. Steam starting gear is

introduced to raise the link; and thus also starts the engines when the "hand" power is futile.

Plate 34.—This is a pair of twin-screw engines, and locomotive boiler, for the steam Launch lately supplied by Messrs. Forrester and Co., Liverpool, for the S.S. "Great Eastern;" the following description by the firm will readily convey a correct idea of the arrangement:—

The boiler is of the locomotive type; the barrel is 2 feet 6 inches diameter, and 5 feet long, including smoke box. There are 51 tubes, of 1½ inches outside diameter, and 4 feet long, giving a heating surface of 93 square feet; the outer fire-box is 2 feet 6 inches long, by 2 feet 11½ inches wide; the area of the fire-grate is 5 square feet. The diameter of the chimney is 9 inches, and its height, from top of smoke-box, is 7 feet. The dome is 16 inches diameter, and 2 feet high, and contains a trap to prevent water from entering the steam-pipe when the boiler primes. The safety-valves are two in number, are loaded by spring-balances to 60 lbs. pressure per square inch. The steam cylinders, of which there are two to each screw shaft, are 5 inches diameter, and 6 inches stroke of piston. The slide-valves are single ported, having a lap of ⅝ inch, and open for steam ¼ inch; the ports are ⅞ inch wide, so that a free exhaust is permitted. The forked connecting rods are 15½ inches long; and the piston rods, each 1 inch in diameter, are guided by brackets below the crosshead pin. The crank shaft is supported by the capped ends of wrought-iron columns, the upper ends of which are fixed to the cylinders, and the lower ends bolted to the fire-box. The engines are fixed to wrought-iron brackets, which are planed true after being rivetted to the boiler. The feed pumps, one to each engine, are worked by eccentrics, and are 1⅜ inches diameter, and 2½ inches stroke. All eccentric rods are of gun-metal, cast in one piece with the strap; the eccentric pulleys for the valve motion are forged with the shaft, and turned out of the solid. The donkey pump is bolted to the side of the smoke-box, its steam cylinder is 3 inches diameter; the pump plunger is 1½ inch diameter, by 3 inches stroke; the donkey is also adapted for being worked by hand.

The screw-propellers are four-bladed, each being 3 feet diameter and 3½ feet pitch. The propellers, propeller shafts, and stern tubes are of gun-metal.

Gun-metal bosses are rivetted in with the plates of the boat, for supporting the inner end of the stern tubes,

the outer ends of which are fixed in wrought-iron brackets close to the propellers, so that the shafts are entirely protected outside the boat.

The launch is 50 feet long, and 10 feet beam, and built entirely of steel plates, and also steel frames.

Plate 35.—Marine boilers have not been varied so much as the engines, simply because the requirements are more easily attained in the former than the latter. The plate under notice illustrates an example by Messrs. Dudgeon, fitted by them in the steam ship "Ruahine." To enable the "staying" portions to be clearly understood, they have been represented by *blue* lines. The arrangement of the fire boxes, tubes, and uptake is the ordinary kind, and the "superheater" is fully described in pages 157 and 159. The only features in the design presenting any novelty worthy of comment are the safety valve weights *above* the casing and the mode of lifting the valves, the remainder of the arrangement being the general practice: as the drawing is freely dimensioned the proportions can be fully understood.

Plate 36.—This is the complete plan of the engines fitted by Messrs. Penn in H.M. steam ship "Achilles," 1250 nominal horse-power collectively. This arrangement is explained in detail in pages 43 and 44.

_____ *fehlt!*

SYNOPTICAL INDEX OF PLATES.

Plate 1.—Three cylinder expansive engines, 300 H.P. collectively, fitted in the Imperial Russian iron-cased Frigate "Pervenelz," by Messrs. Maudslay, Sons and Field.

Plate 2.—Three cylinder expansive engines, 300 H.P. collectively, fitted in the Imperial Russian iron-cased Frigate "Pervenelz," by Messrs. Maudslay, Sons, and Field.

Plate 3.—Supplementary inverted engine and surface condenser, by J. F. Spencer, Patentee, for I.S.S. "Frankfort."

Plate 4.—Supplementary inverted engine and surface condenser, by J. F. Spencer, Patentee, for I.S.S. "Frankfort."

Plates 5 & 6.—Details of Supplementary inverted engine and surface condenser, by J. F. Spencer, Patentee for I.S.S. "Frankfort."

Plate 7.—Combined pump for supplementary inverted engine and surface condenser, by J. F. Spencer, Patentee, for I.S.S. "Frankfort."

Plate 8.—Details of supplementary inverted engine and surface condenser, by J. F. Spencer, Patentee, for I.S.S. "Frankfort."

Plate 9.—Twin screw Engines, of 350 H.P. collectively, fitted in the M.S. "Ruahine," constructed by Messrs. J. and W. Dudgeon.

Plate 10.—End elevation of the engines fitted in the M.S. "Ruahine," constructed by Messrs. J. and W. Dudgeon.

Plate 11.—Pistons of the engines fitted in the M.S. "Ruahine," constructed by Messrs. J. and W. Dudgeon.

Plate 12.—Cylinder of the engines fitted in the M.S. "Ruahine," constructed by Messrs. J. and W. Dudgeon.

Plate 13.—Slide valve and casing of the engines fitted in the M.S. "Ruahine," constructed by Messrs. J. and W. Dudgeon.

Plate 14.—Condensers of the engines fitted in the M.S. "Ruahine," constructed by Messrs. J. and W. Dudgeon.

Plate 15.—Transverse section of H.M. armour-cased iron ship "Hector," showing engines, 800 H.P. nominal, fitted by Messrs. R. Napier and Sons, Glasgow.

Plate 16.—Air pump trunk engine, 800 H.P. collectively, fitted in H.M. armour-cased ship "Hector," constructed by Messrs. R. Napier and Sons, Glasgow.

Plate 17.—Elevation of cylinders of the engines fitted in H.M. armour-cased ship "Hector," constructed by Messrs. R. Napier and Sons, Glasgow.

Plate 18.—Elevations of condensers of the engines fitted in H.M. armour-cased ship "Hector," constructed by Messrs. R. Napier and Sons, Glasgow.

Plate 19.—Return connecting rod, double piston rod, engines, 900 H.P. collectively, fitted in the S.S. "Roma and Venetia," constructed by Messrs. Maudslay, Sons and Field.

Plate 20.—Return connecting rod, double piston rod, engines, 900 H.P. collectively, fitted in the S.S. "Roma and Venetia," by Messrs. Maudslay, Sons and Field.

Plate 21.—Return connecting rod, double piston rod, engines, 900 H.P. collectively, fitted in the S.S. "Roma and Venetia," by Messrs. Maudslay, Sons and Field.

Plate 22.—Double piston rod, engines and boilers, 350 H.P. collectively, expansive surface condensing and superheating, fitted on board the Egyptian Government steamers "Charkieh" and "Dakahieh," constructed by Messrs. J. and G. Rennie, London.

Plate 23.—Engines and boilers, 200 H.P. collectively,

fitted in the twin screw armour-plated S.S. "Medusa and Triton," by Messrs. James Watt and Co.

Plate 24.—Transverse sectional elevations of twin screw armour-plated S.S. "Medusa and Triton," constructed by Messrs. James Watt and Co.

Plate 25.—Direct acting engines, 200 H.P. collectively, fitted in H.M.S. "Research," constructed by Messrs. James Watt and Co.

Plate 26.—Direct acting engines, 400 H.P. collectively, constructed by Messrs. Humphrys and Tennant.

Plate 27.—Expansive engines, of 500 H.P., fitted in H.M.S. "Arethusa," constructed by Messrs. John Penn and Son.

Plate 28.—Expansive engines, 300 H.P., with surface condensers, constructed by Messrs. R. Napier and Sons.

Plate 29.—Twin screw engines, boiler, and surface condensers, of one of H.M.S. Launches, by Messrs. J. and G. Rennie.

Plate 30.—Boilers and oscillating paddle-wheel engines, 300 H.P. collectively, fitted in the I.S.S. "Abigail," constructed by Messrs. James Watt and Co.

Plate 31.—Twin screw engines and boiler of one of H.M.S. Launches, by Messrs. Maudslay, Sons, and Field.

Plate 32.—Twin screw engines and boiler of one of H.M.S. Launches, by Messrs. J. Penn and Son.

Plate 33.—Arrangement of engines of 1000 H.P. for H.M.S. "Lord Clyde," by Messrs. Ravenhill, Hodgson, and Co.

Plate 34.—Twin screw engines and boiler for the Steam Launch of the "Great Eastern," by Messrs. Forrester and Co.

Plate 35.—Boiler by Messrs. Dudgeon, fitted in S.S. "Ruahine."

Plate 36.—Plan of engines, by Messrs. Penn, fitted in H.M.S. "Achilles."

SYNOPTICAL INDEX OF SUBJECTS.

	PAGE
CHAP. I.—APPLICATION OF MOTIVE POWER FOR	
PADDLE AND SCREW PROPULSION	1
Prefatorial Remarks	1
Paddle Wheel Engines	3
Paddle Wheels	7
Screw Engines	8
Screw Propellers	10
Twin Screw Propulsion	14
Compound or Expansion Engines	15
Heat and Combustion	22
High and Low Boilers	29
CHAP. II.—GENERAL ARRANGEMENT OF ENGINES ..	32
Oscillating Engines	33
Screw Engines (Inverted Cylinders, Direct Acting)	37
Double Trunk Engines (Horizontal Arrangements)	41
Single Trunk Engines	44
Return-Acting Trunk Engines	46
Single Piston Rod Engines (Direct Acting) ..	49
Double Piston Rod Engines (Return Connecting-Rod)	56
Single Guide, Return Connecting-Rod Engines ..	59
Return Connecting-Rod Engine (Slipper Guide) ..	62
Twin Screw Engines	66
CHAP. III.—ARRANGEMENT OF BOILERS, PRELIMINARY CONCLUSIONS	76
Combustion	76
Effect of Combustion	83
Proportions for Combustion	87
Action of the Flame, 88, 89, 90, 93, 96, 104, 111, 121, 133, 139, 142	
Conduction of Materials	90
Heating Surfaces	91
High Boilers	94
Effect of Heat in Low Boilers	95
Return Tubular (Side Flue) Arrangement	101
Effect of the Flame	106
"Duplicate" Return Tubular Arrangement	108
Action of the Flame on the Tube Plate	113
Values of Heating Surfaces, 114, 117, 126, 136, 143, 145, 150	
Direct Return Tubular Arrangement	114
Angular Grate Arrangement	117
Proportions of Furnaces	118
Temperature of Furnaces	119
Width of Furnaces	120
Effect of Arrangement of Furnaces	123
Effect of the Flame on the Tube Plate	124, 134
Effect of Impact	125
Direct Tubular Arrangement	127
Strength of Cylindrical Boilers	128
Cylindrical, Shell, and Fire Box Arrangement ..	136
Proportion of Cubical Space occupied by Low and High Boilers	138
Angular Tube Arrangement	140
Return (Side Steam Space) Tubular Arrangement ..	141

	PAGE		PAGE
Direct Return Tube Arrangement	143	Air Pump Valves, and modes of securing them ..	269
(Semi High and Low) Return Tubular Arrange- ment	146	Injection, and Snifting Valves and Spray Pipes ..	271
(Mid-stoking) Return Tubular Arrangement	148	Steam Cylinders	272
Table of Proportions of Marine Boilers	151	Steam Pistons	277
CHAP. IV.—SUPPLEMENTARY DETAILS OF MARINE			
BOILERS 152			
Cause and Effects of Superheating	152	Stuffing boxes	279
Cylindrical Superheaters	157	Cylinder Relief Valves	280
Tubular Superheaters	160	Blow-through Valves	283
Horizontal Tubular Superheaters	162	Slide Valves	284
Vertical Tubular Superheaters	169	Slide Valve Link Motion	287
Sheet Flue Superheaters	173	Starting Gear	295
Cause and Effect of Incrustation	175	Expansion Valves and Gear	297
Effect of Surface Condensation on Marine Boilers ..	181	Steam Throttle Valve	302
Use and Effect of Salinometers	189	Piston-Rod Guide Blocks	302
CHAP. V.—DETAILS OF OSCILLATING ENGINES FOR			
PADDLE-WHEEL PROPULSION 193			
Details of (Paddle-Wheel) Oscillating Engines ..	193	Connecting Rods	304
Cylinders	193	Lubricators	305
Condensers	195	Main Frames	307
Slide Valve Link Motion and Starting Gear	205	Cranks and Counter-balances	309
Single Eccentric Motion and Starting Gear	208	Turning Gear	309
Expansion Valves and Gear	212	Water Discharge Valves	310
Air-Pump Motions and Connections	220	Feed and Bilge Pumps	311
Centrifugal Pump	226	Donkey Engine Feed Pumps	314
Steam Piston-Rod Motion and Connections	227	Kingston Valves	316
Crank Disconnection Gear	229	Thrust Blocks and Screw Alley Fittings	316
Trunnion Plummer Block	231	Screw Propellers	319
Entablature	232	CHAP. VII.—ENGINE ROOM FITTINGS 327	
Feed and Bilge Pump	234	Engine-Room, Mechanical Telegraphs, and Arrange- ment of the Gear	327
(Supplementary Valves) Injection Valve	235	Marine Engine, Speed Governors	330
Snifting Valves	236	Engine Counters	334
Cylinder Relief Valves	237	Steam Indicators	335
Paddle-wheels	238	CHAP. VIII.—DETAILS AND FITTINGS FOR MARINE	
CHAP. VI.—DETAILS OF ENGINES FOR SCREW			
PROPULSION 244			
Injection Condensers with Trunk Air-Pumps	244	BOILERS 338	
Injection Condensers for Direct-acting Engines ..	246	Up-takes	338
Injection Condenser for Return-acting Engines ..	249	Chimney Hoisting Gear	339
Surface Condensers	253	Tubes	339
Surface Condensers for Direct-acting Engines ..	258	Fittings	340
Surface Condensers for Return-acting Engines ..	262	Clothing Steam Pipes, and Lagging Cylinders and Boilers	344
Tube Packing	264	Coal Bunkers	345
Air Pumps	266	CHAP. IX.—THE PRINCIPLES OF THE MARINE	
Pump Pistons	267	ENGINE 346	
		Variation in the Speed of the Piston and Crank Pin	346
		Delineation of the Path of the Crank Pin	346
		Geometrical Demonstrations of the Slide Valve ..	349
		Width of Ports and Bars in the Slide Valve and Cylinder	353

BOILERS.	
	PAGE
FIG. 12.—Sectional Elevation of High Boiler ..	83
FIG. 13.—Front Elevation of High Boiler	93
FIG. 14.—Low Boiler—Right-angle Tubes, designed by the Author for a Despatch Vessel	96
FIG. 15.—Return Tubular (Side-flue) Arrangement Boiler, by Messrs. Maudslay, Sons, and Field, for H.M.S.S. "Vigilant," "Wanderer," and "Osprey"	103
FIG. 16.—Duplicate Return Tubular Arrangement Low Boiler, designed by the Author for a Gunboat	109
FIG. 17.—Direct Return Tubular Arrangement Low Boiler, by Messrs. Maudslay, Sons, and Field, for H.M.S.S. "Mutine" and "Camelion"	115
FIG. 18.—Angular Grate Low Boiler, by Messrs. Maudslay, Sons, and Field, for H.M.S.S. "Ajax" and "Edinburgh"	118
FIG. 19.—Cylindrical Boiler, by Messrs. Maudslay, Sons, and Field, for H.M.S. "Niger"	128
FIG. 20.—Cylindrical Return Tubular Arrange- ment Boiler, designed by the Author for a Steam Yacht	137
FIG. 21.—Angular Tube Arrangement Boiler, by Messrs. J. and G. Rennie, for H.M.S.S. "Rein- deer" and "Perseus"	140
FIG. 22.—Return Tubular Arrangement Boiler, by Messrs. J. and G. Rennie, for S.S. "General Murillos" and "General Victoria"	141
FIG. 23.—Direct Tubular Arrangement Boiler, by Messrs. James Watt and Co., for the Bombay Steam Navigation Company	144
FIG. 24.—Direct Tubular Arrangement Boiler, by Messrs. James Watt and Co., for S.S. "Tyrsaad"	146
FIG. 25.—Direct Return Tubular Arrangement, by Messrs. James Watt and Co., for H.M.S. "Hornet"	149

SUPERHEATERS.

FIG. 26.—Cylindrical Superheaters, by Messrs. James Watt and Co.	158
FIG. 27.—Cylindrical Superheaters, by William Rowan	158
FIG. 28.—Tubular Superheaters, by Mr. Field ..	161
FIG. 29.—Horizontal Tubular Superheaters, by Mr. Field	163
FIG. 30.—Details of Horizontal Tubular Super- heaters, by Mr. Field	164
FIG. 31.—Horizontal Tubular Superheater, by Messrs. Penn	164

	PAGE
FIG. 32.—Horizontal Tubular Superheater, by Messrs. Ravenhill and Hodgson	167
FIG. 33.—Horizontal Tubular Superheater, designed by the Author	168
FIG. 34.—Vertical Tubular Superheater	170
FIG. 35.—Vertical Tubular Superheater, by Mr. E. Humphrys	171
FIG. 36.—Sheet flue Tubular Superheater, by the Author	174

SALINOMETERS.

FIG. 37.—How's Patent Salinometer	190
FIG. 38.—Long's Patent Salinometer	190

DETAILS OF OSCILLATING ENGINES.

FIG. 39.—Cylinder, by Messrs. James Watt and Co.	194
FIG. 40.—Stuffing-box and Gland, by Messrs. Ravenhill and Hodgson	195
FIG. 41.—Slide Valve and Cylinder Ports, by Messrs. Ravenhill and Hodgson	195
FIG. 42.—Condenser and Air-pumps, by Messrs. Watt	196
FIG. 43.—Ordinary Condenser and Arrangements of Air-pump Fittings	197
FIG. 44.—Improved Condenser and Air-pump, by the Author	199
FIG. 46.—Link Motion and Starting Gear, by Messrs. James Watt and Co.	206
FIG. 47.—Link Motion and Starting Gear, by Messrs. Dudgeon	207
FIG. 48.—Single Eccentric Motion and Starting Gear, by Messrs. Penn.	209
FIG. 49.—Cam Expansion Gear	217
FIG. 50.—Eccentric Expansion Gear, by Messrs. Maudslay, Sons, and Field	218
FIG. 51.—Twin Connecting-rod Head, by Messrs. Watt	220
FIG. 52.—Single Connecting-rod Head	221
FIG. 53.—Twin Eccentrics and Crosshead Motion, by Messrs. Ravenhill and Hodgson	223
FIG. 56.—Centrifugal Pump	226
FIG. 57.—Piston-rod Head	227
FIG. 58.—Rod's Connection with Piston	228
FIG. 59.—Piston Ring and Studs	229
FIG. 60.—Disconnecting Ring and Disc	229
FIG. 61.—Disconnecting Crank	231

	PAGE		PAGE
FIG. 62.—Trunnion Plummer-block, by Messrs. John Penn and Son	231	FIG. 88.—Surface Condenser for Direct-acting Engines, by Messrs. James Watt and Co.	261
FIG. 63.—Entablature, by Messrs. Ravenhill and Hodgson	233	FIG. 89.—Surface Condenser for Return-acting Engines, by Messrs. Napier	262
FIG. 64.—Feed and Bilge Pump, by Messrs. Ravenhill and Hodgson	234	FIG. 90.—Surface Condenser for Return-acting Engines, by Messrs. Maudslay	263
FIG. 65.—Injection Valve	235	FIG. 91.—Surface Condenser for Return-acting Engines, by Messrs. Maudslay	263
FIG. 66.—Spring Snifting Valve	236	FIG. 92.—Surface Condenser for Return-acting Engines, by Messrs. Rennie	264
FIG. 67.—Snifting Valve	237	FIG. 111.—Spray Pipe, by Messrs. Penn	272
FIG. 68.—Spring Relief Valve	237	FIG. 112.—Spray Pipe, by Messrs. Maudslay	272
FIG. 69.—Relief Cocks	238		
PADDLE WHEELS.			
FIG. 70.—Feathering Paddle-Wheel	240	TUBE PACKING.	
FIG. 71.—Outside Eccentric	242	FIG. 93.—Gland Tube Packing, by Messrs. Humphrys and Tennant	264
FIG. 72.—Application of Outside Eccentric	242	FIG. 94.—Gland Tube Packing, by the Author	265
DETAILS OF SCREW ENGINES.			
FIG. 73.—Trunk Air Pump, Injection Condenser, by Messrs. J. and G. Rennie	245	FIG. 95.—India-rubber Plate Tube Packing	265
FIG. 74.—Trunk Air Pump, Injection Condenser, by Messrs. R. Napier	245	FIG. 96.—India-rubber Ring Packing, by J. G. Winton	265
FIG. 75.—Condenser, Trunk Engine, Injection, by Messrs. J. Penn	247	FIG. 97.—Wood Packing, by Messrs. Penn	266
FIG. 76.—Injection Condenser, Direct-acting Engine, by Messrs. Humphrys	248	AIR PUMPS AND VALVES.	
FIG. 77.—Injection Condenser, Direct-acting Engine, by Messrs. Dudgeon	248	FIG. 98.—Vertical Double-acting Air Pump, by J. F. Spencer	266
FIG. 78.—Injection Condenser, Direct-acting Engine	249	FIG. 99.—Horizontal Plunger Air Pump	267
FIG. 79.—Injection Condenser, Return-acting Engine, by Messrs. Maudslay	250	FIG. 100.—Horizontal Disc Piston Circulating Pump	267
FIG. 80.—Injection Condenser, Return-acting Engine, by Messrs. Maudslay	250	FIG. 101.—Metallic Piston	268
FIG. 81.—Injection Condenser, Return-acting Engine, by Messrs. Ravenhill	251	FIG. 102.—Wood Packing for Piston, by the Author	268
FIG. 82.—Injection Condenser, Return-acting Engine, by Messrs. Ravenhill	252	FIG. 103.—Mode of securing the Valve Seating and Guard, by Messrs. Maudslay	269
FIG. 83.—Injection Condenser, Return-acting Engine, by the Author	252	FIG. 104.—Inverted Valve, mode of securing the Valve Seating and Guard, by Messrs. Maudslay	269
FIG. 84.—Surface Condenser for Vertical Engines, by Messrs. Humphrys	254	FIG. 105.—Multivalvular Plate	270
FIG. 85.—Surface Condenser for Direct-acting Engines, by Messrs. Penn	258	FIG. 106.—General mode of securing the Valve and Guard	270
FIG. 86.—Surface Condenser for Direct-acting Engines, by Messrs. Dudgeon	260	FIG. 107.—Mode of securing the Valve Seating and Guard, by the Author	270
FIG. 87.—Surface Condenser for Direct-acting Engines, by the Author	260	FIG. 108.—Mode of securing the Valve Seating and Guard, by Messrs. Humphrys	271
		FIG. 109.—Inverted Valve, by Messrs. Humphrys	271
		FIG. 110.—Gridiron Injection Valve	271
		ENGINE CYLINDERS AND PISTONS.	
		FIG. 113.—Cylinder, and Single Trunk Piston, by Messrs. Rennie	273
		FIG. 114.—Mode of adjusting the Brasses for the Connecting-rod Pin, by Messrs. Rennie	273

	PAGE		PAGE
FIG. 115.—Cylinder, and Double Trunk Piston, by Messrs. Penn	274	FIG. 143.—Slide Valve Link Motion, by Messrs. Humphrys	290
FIG. 116.—Cylinder and Anti-friction Trunks, by the Author	274	FIG. 144.—Slide Valve Link Motion, by Messrs. Ravenhill	291
FIG. 117.—Ordinary Cylinder, and Single Rod Piston	275	FIG. 145.—Slide Valve Link Motion, by Messrs. Dudgeon	292
FIG. 118.—Cylinder, and Single-Rod Piston, by Messrs. Watt	276	FIG. 146.—Slide Valve Link Motion, by Messrs. Napier	293
FIG. 119.—Cylinder, and Double-Rod Piston, by Messrs. Maudslay	276	FIG. 147.—Mode of connecting the Link and Valve Rod, by the Author	293
FIG. 120.—Compound Cylinder, with three Piston Rods, by Messrs. Dudgeon	277	FIG. 148.—Spur Gear Motion for working Slide Valves, by Messrs. Maudslay	294
FIG. 121.—Duplicate mode of connecting Piston Ring	277	STARTING GEAR.	
FIG. 122.—Piston Packing	278	FIG. 149.—Mitre Gearing and Bracket, by Messrs. Maudslay.	295
FIG. 123.—Compound Piston, by Messrs. Dudgeon	278	FIG. 150.—Starting Gear, by Messrs. Humphrys ..	295
FIG. 124.—Pinion and Wheel Motion for Trunk Glands, by the Author	279	FIG. 151.—Steam Starting Gear, by Messrs. Maudslay	296
FIG. 125.—Worm and Pinion Motion for Piston Rod Glands, by Messrs. Maudslay	279	FIG. 152.—Steam Starting Gear, by Messrs. Ravenhill	297
CYLINDER RELIEF VALVES.			
FIG. 126.—Patent Relief Valves, by Messrs. Penn ..	280	EXPANSION VALVES AND GEAR.	
FIG. 127.—Relief Valve, by Messrs. Penn & Son ..	281	FIG. 153.—Expansion Valve and Gear, by Messrs. Penn	298
FIG. 128.—Relief Valve, by Messrs. Maudslay ..	281	FIG. 154.—Expansion Valve and Casing, by Messrs. Rennie	298
FIG. 129.—Relief Valve, by Messrs. Ravenhill ..	282	FIG. 155.—Expansion Link, by Messrs Rennie ..	299
FIG. 130.—Relief Valve, by the Author	282	FIG. 156.—Expansion Valve and Casing, by Messrs. Maudslay	299
FIG. 131.—Relief Valve, by the Author	283	FIG. 157.—Expansion Gear, by Messrs. Maudslay ..	300
FIG. 132.—Ordinary Blow-through Valve	283	FIG. 158.—Expansion Valve and Casing, by Messrs. Ravenhill	300
FIG. 133.—Blow-through Valve, by Messrs. Penn ..	283	FIG. 159.—Expansion Gear, by Messrs. Ravenhill	300
STEAM SLIDE VALVES.			
FIG. 134.—Slide Valve, by Messrs. Penn	284	FIG. 160.—Expansion Valve, by Messrs. Watt and Co.	301
FIG. 135.—Slide Valve, by Messrs. Napier	284	FIG. 161.—Expansion Link, by Mr. Winter	301
FIG. 136.—Slide Valve, by Messrs. Rennie	285	FIG. 162.—Expansion Valve, by Mr. Winter	302
FIG. 137.—Three-ported Slide Valve, by Messrs. Maudslay	285	FIG. 163.—Ordinary Steam-throttle Valve	302
FIG. 138.—Compound Slide Valve, by Messrs. Dudgeon	286	FIG. 164.—Gear Motion for Throttle Valve, by Messrs. Maudslay	302
FIG. 139.—Mode of adjusting the Packing Rings for Slide Valves, by Messrs. Penn	286	GUIDE BLOCKS, &c.	
FIG. 140.—Packing Ring for Slide Valve, by Messrs. Maudslay	287	FIG. 165.—Single Piston-rod Guide Block, by Messrs. Humphrys	302
LINK MOTION.			
FIG. 141.—Slide Valve Link Motion, by Messrs. Penn	288	FIG. 166.—Double Piston-rod Guide Block, by Messrs. Napier	303
FIG. 142.—Slide Valve Link Motion, by Messrs. Maudslay	289	FIG. 167.—Double Piston-rod Guide Block, by Messrs. Maudslay	303

DIAGRAMS OF THE PRINCIPLE.

	PAGE
FIG. 230.—Diagram of the Paths of the Piston and Crank Pin	347
FIG. 231.—Diagram of the Path of the Crank Pin in relation to the Slide Valve's action	347
FIG. 232.—Diagram of the relative effect by the positions of the Slide Valve and Connecting Rod	348
FIG. 233.—Diagram of the relative effect by the positions of the Slide Valve and Connecting Rod	349
FIG. 234.—Messrs. Watt's mode of producing the points of Cut-off by a known Lap	349
FIG. 235.—Geometrical Diagram of the Slide Valve	350
FIG. 236.—Geometrical Diagram of the Slide Valve	351
FIG. 237.—The Author's mode of determining the Lap of the Slide Valve, Points of Cut-off, and the positions of the Eccentrics	353
FIG. 238.—Diagram of the Author's mode of producing the "Versed Sine" of the Eccentric ..	353
FIG. 239.—Mode of determining form of Link ..	354
FIG. 240.—Geometrical diagram of the Link Motion	354
FIG. 241.—Position of Link and Slide Valve for "starting"	354
FIG. 242.—Position of Link and Slide Valve for "stopping"	355
FIG. 243.—Position of Link and Slide Valve for "reversing"	355
FIG. 244.—Messrs. Watt's Link Motion	355
FIG. 245.—Result of connecting the Eccentric Rods to the ends of the Link beyond the Block Pin ..	355
FIG. 254.—Diagram of the Strains of the Connecting Rod	359
FIG. 255.—Diagram of the Strains of the Connecting Rod	359
FIG. 256.—Diagram of Centrifugal Pump	366
FIG. 257.—Diagram of Centrifugal Pump	366
FIG. 258.—Delineation of the Common Screw ..	368
FIG. 259.—Delineation of "Griffiths" Screw Propeller	368

INDICATOR DIAGRAMS.

FIG. 246.—Mode of defining an Indicator Diagram	356
FIG. 247.—The Author's Mode of testing the truth of an Indicator Diagram	357
FIG. 248.—Diagrams from Return action Engines, by Messrs. Rennie	357
FIG. 249.—Indicator Diagram from Double Trunk Engines, by Messrs. Penn	357
FIG. 250.—Series of Diagrams showing the Expan-	

	PAGE
sion of Steam by the Slide Valve and Link Motion, by Messrs. R. Napier and Sons	358
FIG. 251.—Indicator Diagrams taken from Launch Engines, by Messrs. Penn	358
FIG. 252.—Indicator Diagrams taken from Launch Engines, by Messrs. Rennie	358
FIG. 253.—Pump Diagrams, by Mr. Spencer	358

INDEX OF SUBJECTS.

Arrangement of Boilers; Preliminary Conclusions ..	76
Action of the Flame, 88, 89, 90, 93, 96, 104, 111, 121, 133, 139, 142.	
Action of the Flame on the Tube Plate	113
Angular Grate Arrangement	117
Angular Tube Arrangement	140
Air Pump Motions and Connections	220
Air Pumps	266
Air Pump Valves, and mode of securing them ..	269
Application of Motive Power for Paddle and Screw Propulsion	1
Additional resistance of Slip due to short After-body	367
Boilers; Table of Proportion of Marine	151
Blow-through Valves	283
Boilers, High and Low	29
Boilers, Arrangement of	67
Boiler, High	94
Boilers, Low, Effect of heat in	95
Boilers, Cylindrical, Strength of	128
Boilers, Proportion of Cubical Space occupied by High and Low	138
Boiler, Construction and Strength of	372
Boiler, Statistics of Marine	374
Bearings, in case of Heated	375
Boilers, Priming in case of	375
Conduction of Materials	90
Compound or Expansion Engines	15
Combustion	76
Cylindrical Shell, and Fire Box Arrangement ..	136
Cylindrical Superheaters	157
Cause and Effect of Incrustation	175
Condensers	195
Centrifugal Pump	226
Crank Disconnecting Gear	229

	PAGE		PAGE
Cylinder Relief Valves	237	Effect of Impact	125
Connecting Rods	304	Effect of Surface Condensation on Marine Boilers ..	181
Cranks and Counter-balances	309	Expansion Valves and Gear	212
Cause and Effects of Superheating	152	Entablature	232
Cylindrical Boilers, Strength of	128	Expansion Valves and Gear	297
Condensers, Injection	244	Engines, Paddle-wheel	3
Condensers, Injection, for Direct-acting Engines ..	246	Engines, Screw	8
Condensers, Injection, for Return-acting Engines ..	249	Engines, Compound or Expansion	15
Condensers, Surface	253	Engines, General Arrangement of	32
Condensers, Surface, for Direct-acting Engines ..	258	Engines, Oscillating	33
Condensers, Surface, for Return-acting Engines ..	262	Engines, Screw (Inverted Cylinders, Direct-acting)	37
Cylinders, Steam	272	Engines, Double Trunk	41
Counter-balances and Cranks	309	Engines, Single Trunk	44
Chimney Hoisting Gear	339	Engines, Return acting Trunk	46
Clothing Steam Pipes, and Lagging Cylinders and		Engines, Single Piston Rod (Direct-acting)	49
Boilers	344	Engines, Double Piston Rod (Return Connecting	
Coal Bunkers	345	Rod)	56
Crank Pin, Delineation of the Path of	346	Engines, Single Guide Return Connecting Rod ..	59
Cylinder, Width of Exhaust Port in	354	Engine, Return Connecting Rod (Slipper Guide) ..	62
Cylinder, Width of Large Bar in	354	Engines, Twin Screw	66
Connecting Rod, Sectional area of	363	Engines, Details of, for Screw Propulsion	244
Connecting Pin, Sectional area of	363	Engines, Screw, Details of	281
Crosshead for Double Piston Rods, Sectional area of	363	Engine Room Fittings	327
Crank Pin, Cranks, and Shafts	364	Engine Room Mechanical Telegraphs, and Arrange-	
Condensers and Pumps	365	ment of the Gear	327
Chimney, area of	372	Engine Counters	334
		Engineers, the duties of, in charge afloat	375
Double Trunk Engines (Horizontal Arrangement) ..	41	Engineer, before, takes charge	375
Double Piston Rod Engines (Return Connecting Rod)	56	Engineer on duty	375
Duplicate Return Tubular Arrangement of Boiler ..	108		
Direct Return Tubular Arrangement of Boiler ..	114	Feed and Bilge Pumps	234, 311
Direct Tubular Arrangement of Boiler	127	Flame, Action of the, 88, 89, 90, 93, 96, 104, 111, 121,	
Direct Angular Tube Arrangement of Boiler	143	133, 139, 142.	
Details of Oscillating Engines for Paddle-wheel		Flame, Effect of the	106
Propulsion	193	Flame, Action of, on the Tube Plate	113
Details of (Paddle-wheel) Oscillating Engines ..	193	Furnaces, Proportions of	118
Donkey Engine Feed Pumps	314	Furnaces, Temperature of	119
Details of Screw Engines	281	Furnaces, width of	120
Details of Engines for Screw Propulsion	244	Furnaces, Effect of Arrangement of	123
Details and Fittings for Marine Boilers	338	Fire Box Arrangement	136
Diagrams, Indicator	356	Frames, Main	307
Description of Plates	376	Fittings	340
		Feed Pump	371
Effect of Combustion	83	Fire, before Drawing or Banking	375
Effect of the Flame	106	Feed-water, regulation of	375
Effect of Heat in Low Boilers	95		
Effect of Arrangement of Furnaces	123	General Arrangement of Engines	32
Effect of the Flame on the Tube Plate	124	Grate Arrangement, Angular	117

	PAGE		PAGE
Geometrical Demonstrations, Link Motion	354	Pump, Centrifugal	226
Guides, friction of	361	Piston Rod Motion, Steam	227
Grate-surface, area of, in feet	372	Plummer Block, Trunnion	231
Heat and Combustion	22	Pump, Feed and Bilge	234
High and Low Boilers	29	Pumps, Trunk Air	244
Heating Surfaces	91	Pumps, Air	266
High Boilers	94	Pistons, Pump	267
Horizontal Tubular Superheaters	162	Pipes, Spray	271
Heat, Effect of, in Low Boilers	95	Pistons, Steam	277
Heating Surfaces, Values of, 114, 117, 126, 136, 143, 145, 150.		Pumps, Feed and Bilge	311
Heating Surfaces, superficial area of	372	Pumps, Donkey Engine, Feed	314
Harbour, before leaving	375	Pipes, Clothing Steam	344
Injection Condensers, with Trunk Air Pumps	244	Piston Rod, Sectional area of	363
Injection Condensers, for Direct acting Engines	246	Propellers, Paddle and Screw	366
Injection Condensers for Return acting Engines	249	Propellers, thrust of	367
Injection, Snifting Valves and Spray Pipes	271	Paddle Wheel (Feathering), Geometry of	367
Impact, Effect of	125	Propeller (Common Screw), Geometrical Delineation of	368
Incrustation, Cause and Effect of	175	Propeller ("Griffiths"), Geometrical delineation of	368
Indicator Diagrams	356	Propulsion, Water	368
Indicators, Steam	335	Paddle Wheels, proportions of	369
Kingston Valves	316	Propeller (Common Screw), proportions of	369
Link Motion, Geometrical Demonstrations	354	Propeller ("Griffiths" Screw), proportions of	369
Lubricators	305	Paddle Wheel, positive Slip and Speed of	399
(Mid-stoking), Return Tubular Arrangement	148	Propeller, Screw, positive Slip and Speed of	370
Main Frames	307	Propeller, Screw, negative Slip and Speed of	370
Marine Engine, Speed Governors	330	Priming	371
Marine Engine, Principles of	346	Plates, description of	376
Materials, Strength of	362	Return acting Trunk Engines	46
Materials, Application of	362	Return Connecting Rod Engine (Slipper Guide)	62
Oscillating Engines	32	Return Angular Tube Arrangement	141
Oscillating Engines, Details of, for Paddle-wheel Propulsion	193	Screw Engines	8
Oscillating Engines (Paddle-wheel), Details of	193	Screw Propellers	10
Prefatorial Remarks	1	Screw Engines (Inverted Cylinder, Direct-acting)	37
Paddle-wheel Engines	3	Single Trunk Engines	44
Paddle Wheels	7, 238	Single Piston Rod Engines (Direct-acting)	49
Proportions of Furnaces	118	Single Guide Return Connecting Rod Engines	59
Proportion of Cubical Space occupied by Low and High Boilers	138	Strength of Cylindrical Boilers	128
Pump Pistons	267	(Semi High and Low) Return Tubular Arrangement of Boiler	146
Proportions of Combustion	87	Supplementary Details of Marine Boilers	152
Propellers, Screw	10, 319	Sheet Flue Superheaters	173
Propulsion, Twin Screw	14	Slide Valve Link Motion and Starting Gear	205
		Single Eccentric Motion and Starting Gear	208
		Steam Piston Rod Motion, and Connections	227
		(Supplementary Valves) Injection Valve	235

	PAGE		PAGE
Angular Grate Low Boiler, by Messrs. Maudslay, Sons, and Field	118	Cylinder and Double Trunk Piston, by Messrs. Penn	274
Angular Tube Arrangement of Boiler, by Messrs. J. and G. Rennie	140	Cylinder and Anti-friction Trunks, by the Author ..	274
Air Pump, Vertical Double-acting, by J. F. Spencer	266	Cylinder and Single Rod Piston, by Messrs. Watt and Co.	276
Air Pump, Horizontal Plunger	267	Cylinder and Double Rod Piston, by Messrs. Maudslay	276
Air Casings, by Messrs. Watt	338	Compound Cylinder with three Piston Rods, by Messrs. Dudgeon	277
Air Casing and Chimney, fitted in H.M.S. "Research"	340	Compound Piston, by Messrs. Dudgeon	278
Blow-through Valve, by Messrs. Penn	283	Compound Slide Valve, by Messrs. Dudgeon	286
Boiler, High, Sectional Elevation of	83	Connecting Rod Head, by Messrs. Penn	304
Boiler, High, Front Elevation of	93	Connecting Rod Head, by Messrs. Maudslay	305
Boiler, Low, Right-angled Tubes, designed by the Author	96	Crank and Counterbalance, by Messrs. Penn	309
Boiler, Return Tubular, by Messrs. Maudslay ..	103	Common Propeller	319
Boiler, Low, Duplicate Return Tubular Arrangement, by the Author	109	Connecting Rod Head, Twin, by Messrs. Maudslay	220
Boiler, Low, Direct Return Tubular Arrangement, by Messrs. Maudslay	115	Connecting Rod Head, Single, by Messrs. Penn and Son	221
Boiler, Cylindrical, by Messrs. Maudslay	128	Crank, Disconnecting and Disc	231
Boiler, Cylindrical Return Tubular Arrangement, by the Author	137	Cocks, Relief	238
Boiler, Angular Tubular Arrangement, by Messrs. Rennie	140	Central Guidance for the Crosshead of the Piston Rods, by Messrs. Napier and Sons	60
Boiler, Return Tubular Arrangement, by Messrs. Rennie	141	Cylindrical Boiler, by Messrs. Maudslay, Sons and Field	128
Boiler, Direct Tubular Arrangement, by Messrs. Watt and Co.	144	Cylindrical Return Tubular arrangement of Boiler, designed by the Author	127
Boiler, Direct Tubular Arrangement, by Messrs. Watt and Co.	146	Cylindrical Superheaters, by Messrs. Watt and Co.	158
Boiler, Direct Return Tubular Arrangement, by Messrs. Watt and Co.	149	Cylindrical Superheaters, by William Rowan	158
Bracket and Mitre Gearing, by Messrs. Maudslay ..	295	Cylinder, by Messrs. Watt and Co.	194
Bilge Pump	312	Condenser and Air Pumps, by Messrs. Watt	196
Block, ordinary Thrust	317	Condenser, ordinary, and arrangement of Air Pump Fittings	197
Block, Adjustable Thrust, by Messrs. Maudslay ..	318	Condenser, Improved, and Air Pump, by the Author	199
Block, Plummer, for Screw Shaft	319	Condensers, Surface, by Messrs. Day, Lamb and Summers	201
Boiler details	341	Condensers, Surface, by Messrs. Watt and Co. ..	224
Blades of "Griffiths" Propeller, mode of securing and adjusting them	324	Condensers, Surface, by Messrs. Watt and Co. ..	225
Banjo Frame, by Messrs. Penn	322	Condenser, Injection, by Messrs. Rennie	245
Cam Expansion Gear	217	Condenser, Injection, by Messrs. Napier	245
Centrifugal Pump	226	Condenser, Injection, by Messrs. Penn	247
Circulating Pump	267	Condenser, Injection, by Messrs. Humphrys	248
Cylinder and Single Trunk Piston, by Messrs. Rennie	273	Condenser, Injection, by Messrs. Dudgeon	248
		Condenser, Injection, by Messrs. John Penn	249
		Condenser, Injection, by Messrs. Maudslay	250
		Condenser, Injection, by Messrs. Maudslay	250
		Condenser, Injection, by Messrs. Ravenhill	251

	PAGE		PAGE
Condenser, Injection, by Messrs. Ravenhill	252	Direct Tubular arrangement of Boiler, by Messrs.	
Condenser, Injection, by the Author	252	Watt and Co.	144
Condenser, Surface, by Messrs. Humphrys	253	Direct Tubular arrangement of Boiler, by Messrs.	
Condenser, Surface, by Messrs. Penn	258	Watt and Co.	146
Condenser, Surface, by Messrs. Dudgeon	260	Direct Return Tubular arrangement, by Messrs.	
Condenser, Surface, by the Author	260	Watt and Co.	149
Condenser, Surface, by Messrs. Watt	261	Details of Horizontal Tubular Superheaters, by	
Condenser, Surface, by Messrs. Napier	262	Mr. Field	164
Condenser, Surface, by Messrs. Maudslay	263	Donkey Engine, Vertical Feed Pump	315
Condenser, Surface, by Messrs. Maudslay	263	Donkey Engine, Horizontal Pump	316
Condenser, Surface, by Messrs. Rennie	264	Direct Loaded Safety Valves	342
Condenser Tube Packing, by Messrs. Humphrys ..	264	Diagram of the paths of the Piston and Crank Pin	347
Condenser Tube Packing, by the Author	265	Diagram of the path of the Crank Pin in relation to	
Condenser India Rubber Tube Packing	265	the Slide Valve's action	347, 348
Condenser India Rubber Ring Tube Packing, by		Diagram of the relative effect by the positions of the	
J. G. Winton	265	Slide Valve and Connecting Rod	349
Condenser Wood Packing, by Messrs. Penn	266	Diagram of Messrs. Watt's mode of producing the	
Connecting Rod Pin, Mode of Adjusting the Brasses		points of Cut-off by a known Lap	349
for, by Messrs. Rennie	273	Diagram of the Slide Valve and Crank	350, 351
Cylinder, Ordinary	275	Diagrams (Author's)	353
Crossheads of Return Action Engines, Mode for		Diagrams of Link Motion	354, 355
Guiding, by Messrs. Ravenhill	304	Diagram, Indicator	356, 357
Counterbalance and Crank, by Messrs. Penn	309	Dial Plate requiring no Pointer, by Messrs. Soul ..	340
Complete arrangement of a Mechanical Telegraph,		Dial Plate, ordinary	328
as fitted in Steam Ships	331	Dial Plate of Deck Column	330
Chimney and Air Casing, fitted in H.M.S. "Re-		Diagrams from Return Action Engines, by Messrs.	
search," by Messrs. Watt	340	Rennie	357
Chimney Hoisting Gear, by Messrs. Watt	339	Diagrams, series of, showing the expansion of Steam	
Crank Pin, Diagram of the path of, in relation to		by the Slide Valve and Link Motion, by R. Napier	
the Slide Valve's action	347	and Sons	358
Centrifugal Pump, Diagrams of	366	Diagrams, Pump, by Mr. Spencer	358
Disconnecting Ring and Disc, by Messrs. Penn and Son	229	Diagram of the strains of the Connecting Rod ..	359
Disconnecting Crank and Disc	231	Diagram of the strains of the Connecting Rod ..	359
Direct Acting Engine, Injection Condenser of, by		Diagram of Centrifugal Pump	366
Messrs. Humphrys	248	Diagram of Centrifugal Pump	366
Direct Acting Engine, Injection Condenser of, by		Delineation of the Common Screw	368
Messrs. Dudgeon	248	Delineation of "Griffiths" Screw Propeller	368
Duplicate mode of connecting Piston Ring	277	Eccentric Expansion Gear, by Messrs. Maudslay,	
Double Piston Rod Guide Block, by Messrs. Napier	303	Sons and Field	218
Double Piston Rod Guide Block, by Messrs.		Entablature, by Messrs. Ravenhill and Hodgson ..	233
Maudslay	303	Expansion Valve and Gear, by Messrs. Penn	298
Direct Acting Single Piston Rod Engines, by		Expansion Valve and Casing, by Messrs. Rennie ..	298
Messrs. Humphrys	52	Expansion Link, by Messrs. Rennie	299
Duplicate Return Tubular arrangement of Low		Expansion Valve and Casing, by Messrs. Maudslay	299
Boiler, designed by the Author	109	Expansion Gear, by Messrs. Maudslay	300
Direct Return Tubular arrangement of Low Boiler,		Expansion Valve and Casing, by Messrs. Ravenhill	300
by Messrs. Maudslay	115	Expansion Gear, by Messrs. Ravenhill and Hodgson	300

	PAGE		PAGE
Expansion Valve, by Messrs. James Watt and Co. ..	301	Feed Pump, Horizontal Donkey Engine, by Messrs.	
Expansion Link, by Mr. Winter	301	Dudgeon	316
Expansion Valve, by Mr. Winter	302	Fittings, Screw Alley	319
Engines, Oscillating	33	Fixing Stay for Banjo Frame	323
Engines, Vertical Inverted, with Injection Con-		Frame, Lifting, for small Propeller	324
densers	38	Frame, Banjo, by Messrs. Penn	322
Engines, Double Trunk, by Messrs. Penn and Son ..	42	Fire Box and Damper Doors	340
Engines, Single Trunk, by Messrs. J. and G. Rennie	44	Feed Cock and Non-Return Valves	343
Engines, Return Acting Trunk, by Messrs. Napier	47		
Engines, Direct Acting Single Piston Rod, by		Gland Tube Packing, by Messrs. Humphrys	264
Messrs. Humphrys	52	Gland Tube Packing, by the Author	265
Engines, a pair of Double Piston Rod, Return Con-		General Mode of Securing the Valve and Guard ..	270
necting Rod, by Messrs. Ravenhill	57	General Mode of Securing the Valve Seating and	
Engines, Return Action, by Messrs. Napier	60	Guard, by the Author	270
Engines, Return Action, by Messrs. Maudslay ..	63	General Mode of Securing the Valve Seating and	
Engines, Twin Screw, Single Piston Rod, Direct		Guard, by Messrs. Humphrys	271
Acting, by Messrs. Dudgeon	72	Gridiron Injection Valve	271
Engines, Twin Screw, designed by the Author ..	74	Gear Motion for Throttle Valve, by Messrs. Maudslay	302
Engines, Oscillating and Surface Condenser, by		Grate, Angular, for Low Boiler, by Messrs. Mauds-	
Messrs. Day, Lamb and Summers	201	lay	118
Eccentric, Single Motion and Starting Gear, by		Gear Motion, Spur, for Working Slide Valves, by	
Messrs. Penn	209	Messrs. Maudslay	294
Expansion Gear, Cam	217	Gearing, Mitre, by Messrs. Maudslay	295
Expansion Gear, Eccentric, by Messrs. Maudslay,		Gear, Starting, by Messrs. Humphrys	295
Sons and Field	218	Gear, Steam Starting, by Messrs. Maudslay	296
Eccentrics, Twin and Crosshead Motion, by Messrs.		Gear, Steam Starting, by Messrs. Ravenhill	297
Ravenhill	223	Gear, Expansion, by Messrs. Penn	298
Engines, Oscillating, by Messrs. Watt and Co. ..	224	Gear, Expansion, by Messrs. Maudslay	300
Engines, Oscillating, by Messrs. Watt and Co. ..	225	Gear, Expansion, by Messrs. Ravenhill	300
Eccentric, Outside	242	Guide Block, Single Piston Rod, by Messrs. Hum-	
Eccentric, Application of Outside	242	phrys	302
Expansion Joint for Telegraph Shafting	329	Guide Block, Double Piston Rod, by Messrs. Napier	303
Engine Speed Counter by Messrs. Soul	335	Guide Block, Double Piston Rod, by Messrs. Mauds-	
Eccentric, Diagram of the Author's mode of pro-		lay	303
ducing the "versed sine" of	353	Gear, Turning	310
Eccentric Rods, result of connecting to ends of the		"Griffiths" Propeller, Messrs. Ravenhill's	321
Link beyond the Block Pin	355	"Griffiths" Propeller, Messrs. Penn's	322
		Governor, Marine, Mr. Meriton's	332
Feed and Bilge Pump, by Messrs. Ravenhill and		Governor, Marine, Messrs. Miller and Knill's	333
Hodgson	234	Governor (Ball), Mr. Silver's Marine	333
Feathering Paddle Wheel	240	Governor (Wheel Momentum), Mr. Silver's Marine	335
Feed and Bilge Pumps	312	Gauge (Water), Glass Frames, &c.	341
Feed Pump, Relief Valve and Spring, by Messrs.			
Penn	314	Horizontal Plunger Air Pump	267
Front Elevation of High Boiler	93	Horizontal Disc Piston Circulating Pump	267
Frame, Main, by Messrs. Penn	308	Hand Pump	311
Feed Pump, Vertical Donkey Engine, by Messrs.		Horizontal Donkey Engine Feed Pump, by Messrs.	
Watt and Co.	315	Dudgeon	316

	PAGE		PAGE
Horizontal Tubular Superheater, by Mr. Field ..	163	Link Motion, Geometrical Diagram of the ..	354
Horizontal Tubular Superheater, by Messrs. Penn ..	164	Link Motion, Messrs. Watt's	355
Horizontal Tubular Superheater, by Messrs. Ravenhill	167	Metallic Piston	268
Horizontal Tubular Superheater, designed by the Author	168	Mode of Securing the Valve Seating and Guard, by Messrs. Maudslay	269
How's Patent Salinometer	190	Multivalvular Plate	270
Hoisting Gear, Chimney, by Messrs. Watt	339	Mode of Adjusting the Brasses for Connecting Rod Pin, by Messrs. Rennie	273
Injection Valve	235	Mode of Adjusting the Packing Rings for Slide Valves	286
India-rubber Plate Tube Packing	265	Mode of Connecting the Link and Valve Rod, by the Author	293
India-rubber Ring Packing, by J. G. Winton	265	Mitre Gearing and Bracket, by Messrs. Maudslay ..	295
Inverted Valve	269	Mode of Guiding the Crossheads of Return Action Engines, by Messrs. Ravenhill	304
Inverted Valve, by Messrs. Humphrys	271	Main Frame, by Messrs. Penn	308
Improved Condenser and Air Pump, by the Author	199	Mode of Adjusting Steam Motion for Hand Pump, by Messrs. Penn	312
Indicator, Richards'	336	Mode of Securing and Adjusting the Blades of "Griffiths" Propeller	324
Inclined Up-take and Air Casings	338	Mechanical Telegraph	329
Indicator Diagram, mode of defining	356	Mechanical Telegraph, arrangement of	331
Indicator Diagram, the Author's mode of testing the truth of	357	Marine Governor, Mr. Meriton's	332
Indicator Diagram from Double Trunk Engines, by Messrs. Penn	357	Marine Governor, Messrs. Miller and Knill's	333
Indicator Diagram taken from Launch Engines, by Messrs. Penn	358	Marine Governor (Ball), Mr. Silver's	333
Indicator Diagram taken from Launch Engines, by Messrs. Rennie	358	Marine Governor (Momentum Wheel), Mr. Silver's	333
"Kingston" Valve	317	Mud-hole or Man-hole Door	342
Key for Motion Rods of Feed and Bilge Pumps ..	313	Oscillating Engines and Surface Condensers, by Messrs. Day, Lamb and Summers	201
Link Motion and Starting Gear, by Messrs. Watt and Co.	206	Oscillating Engines with Surface Condensers, by Messrs. Watt and Co.	224
Link Motion and Starting Gear, by Messrs. Dudgeon	207	Oscillating Engines with Surface Condensers, by Messrs. Watt and Co.	225
Long's Patent Salinometer	190	Outside Eccentric	242
Link Motion, Slide Valve, by Messrs. Penn	288	Ordinary Cylinder and Single Rod Piston	275
Link Motion, Slide Valve, by Messrs. Maudslay ..	289	Ordinary Blow-through Valve	283
Link Motion, Slide Valve, by Messrs. Humphrys ..	290	Ordinary Steam Throttle Valve	302
Link Motion, Slide Valve, by Messrs. Ravenhill ..	291	Ordinary Cylinder Tallow Lubricator	306
Link Motion, Slide Valve, by Messrs. Dudgeon ..	292	Ordinary Thrust Block	317
Link Motion, Slide Valve, by Messrs. Napier	293	Oscillating Engines	33
Link, Mode of Connecting, and Valve Rod, by the Author	293	Ordinary Condenser and Arrangement of Air Pump fittings	197
Link, Expansion, by Messrs. Rennie	299	Oil Can, Suspended, and Motion Wiper for Continuous Lubrication	306
Link, Expansion, by Mr. Winter	301	Ordinary Dial Plate	328
Lubricator (Tallow, Ordinary Cylinder)	306	Piston-rod Head	227
Lubricator, Plug Cock	306	Piston-ring and Studs	229
Lubricator, Water	307		
Lifting Frame for small Propeller	324		
Link, mode of determining form of	354		

	PAGE		PAGE
Piston-packing	278	Rod's connection with Piston	228
Pinion and Wheel Motion for Adjusting Trunk-glands, by the Author	279	Relief Cocks	238
Patent Relief-valves, by Messrs. Penn	280	Relief Valve, by Messrs. Penn and Son	281
Packing-ring for Slide-valves	287	Relief Valve, by Messrs. Maudslay	281
Plug-cock Lubricator	306	Relief Valve, by Messrs. Ravenhill	282
Plummer-block for Screw-shaft	319	Relief Valve, by the Author	282
Pump, Centrifugal	226	Relief Valve, by the Author	283
Piston, Rod's Connection with	228	Return Tubular (Side Flue) arrangement of Boiler, by Messrs. Maudslay	103
Pump, Feed and Bilge, by Messrs. Ravenhill and Hodgson	234	Return Tubular arrangement of Boiler, by Messrs. Rennie	141
Paddle-wheel, Feathering	240	Ring, Disconnecting and Disc, by Messrs. Penn and Son	229
Pump, Trunk Air	245	Return Acting Trunk Engines, by Messrs. Napier ..	47
Pump, Trunk Air, by Messrs. R. Napier	245	Return Action Engines, by Messrs. Ravenhill and Hodgson	57
Pump, Air, Vertical Double-acting, by J. F. Spencer	266	Return Action Engines, by Messrs. Napier	60
Pump, Air, Horizontal Plunger	267	Return Action Engines, by Messrs. Maudslay	63
Pump, Circulating, Horizontal Disc Piston	267	Return Action Engines, by the Author	74
Piston, Metallic	268	Richard's Indicator	336
Piston, Wood-packing, by the Author	268	Rudder Posts	327
Plate, Multivalvular	270	Single Eccentric Motion and Starting Gear, by Messrs. Penn	209
Pipe, Spray, by Messrs. Penn	272	Single Connecting Rod Head, by Messrs. John Penn and Son	221
Pipe, Spray, by Messrs. Maudslay	272	Spring Snifting Valve	236
Piston, Single-trunk, by Messrs. Rennie	273	Snifting Valve	237
Piston, Double-trunk, by Messrs. Penn	274	Spring Relief Valve	237
Piston, Single-rod	275	Surface Condenser for Vertical Engines, by Messrs. Humphrys	253
Piston, Single-rod, by Messrs. Watt and Co.	276	Surface Condenser for Direct Acting Engines, by Messrs. Penn	258
Piston, Double-rod, by Messrs. Maudslay	276	Surface Condenser for Direct Acting Engines, by Messrs. Dudgeon	260
Piston-ring, Duplicate Mode of Connecting	277	Surface Condenser for Direct Acting Engines, by the Author	260
Piston, Compound, by Messrs. Dudgeon	278	Surface Condenser for Direct Acting Engines, by Messrs. Watt and Co.	261
Piston-rod Glands, Worm and Pinion Motion for Adjusting	279	Surface Condenser for Return Acting Engines, by Messrs. Napier	262
Packing-rings for Slide-valves, Mode of Adjusting ..	286	Surface Condenser for Return Acting Engines, by Messrs. Maudslay	263
Pump, Hand	311	Surface Condenser for Return Acting Engines, by Messrs. Maudslay	263
Pump, Hand, Mode of Adjusting Steam Motion for	312	Surface Condenser for Return Acting Engines, by Messrs. Rennie	264
Pumps, Feed and Bilge	312	Spray Pipe, by Messrs. Penn	272
Pump, Feed, Arrangement of Valves for	313		
Propeller, Common	319		
Propeller, Messrs. Ravenhill's "Griffiths"	321		
Propeller, Messrs. Penn's "Griffiths"	322		
Propeller (screw), Messrs. Ravenhill's "Mangin" ..	325		
Propeller, Turbine, fitted in H.M.S. "Waterwitch"	326		
Piston and Crank Pin, Diagram of the Paths of the	347		
Points of Cut-off, Messrs. Watt's mode of producing by a known Lap	349		
Pump Diagrams, by Mr. Spencer	358		
Pump (Centrifugal), Diagram of	366		
Pump (Centrifugal), Diagram of	366		
Propeller ("Griffiths" Screw), delineation of ..	368		

	PAGE		PAGE
Spray Pipe, by Messrs. Maudslay	272	Slide Valve, mode of adjusting the Packing Ring of	286
Slide Valve, by Messrs. Penn	284	Starting Gear, Steam, by Messrs. Maudslay	296
Slide Valve, by Messrs. Napier	284	Starting Gear, Steam, by Messrs. Ravenhill	297
Slide Valve, by Messrs. Dudgeon	286	Screw, Set, for Motion Rods of Feed and Bilge	
Slide Valve, by Messrs. Rennie	285	Pumps	313
Slide Valve, by Messrs. Maudslay	285	Screw Shaft, Plummer Block for	319
Slide Valve Link Motion, by Messrs. Penn	288	Spring, by Messrs. Penn	314
Slide Valve Link Motion, by Messrs. Maudslay ..	289	Stern and Rudder Posts	321
Slide Valve Link Motion, by Messrs. Humphrys ..	290	Screw Propeller, Messrs. Ravenhill's "Mangin" ..	325
Slide Valve Link Motion, by Messrs. Ravenhill ..	291	Systems of securing Tubes	340
Slide Valve Link Motion, by Messrs. Dudgeon ..	292	Steam Pipe Branch Piece	343
Slide Valve Link Motion, by Messrs. Napier	293	Steam Stop Valve	344
Spur Gear Motion for Working Slide Valves, by		Steam Whistle	344
Messrs. Maudslay	294	Safety Valve Lift Handle	341
Starting Gear, by Messrs. Humphrys	295	Safety Valve, Direct Loaded	342
Steam Starting Gear, by Messrs. Maudslay	296	Slide Valve and Connecting Rod, Diagram of the	
Steam Starting Gear, by Messrs. Ravenhill	297	relative effect by the positions of	348
Single Piston Rod Guide Block, by Messrs.		Slide Valve and Connecting Rod, Diagram of the	
Humphrys	302	relative effect by the positions of	349
Suspended Oil Can and Motion Wiper for continuous		Slide Valve, Geometrical Diagram of	350
lubrication	306	Slide Valve, Geometrical Diagram of	351
Set Screw and Key for Motion Rods of Feed and		Slide Valve, the Author's mode of determining the	
Bilge Pumps	313	Lap of, Points of Cut-off, and positions of Eccen-	
Screw Alley Fittings	319	trics	353
Single Trunk Engines, by Messrs. J. and G. Rennie	44	Slide Valve and Link, position of, for starting ..	354
Separate Condensers and Air Pumps with Double		Slide Valve and Link, position of, for stopping ..	355
Cylinder Types and Return Action, by Messrs.		Slide Valve and Link, position of, for reversing ..	355
Maudslay, Sons and Field	63	Screw (Common), delineation of	368
Sectional Elevation of High Boiler	83		
Sheet Flue Tubular Superheater, by the Author ..	174	Twin Connecting Rod Head, by Messrs. Watt	220
Stuffing Box and Gland, by Messrs. Ravenhill and		Twin Eccentrics and Crosshead Motion, by Messrs.	
Hodgson	195	Ravenhill and Hodgson	223
Superheaters, Cylindrical, by Messrs. Watt and Co.	168	Trunnion Plummer Block, by Messrs. John Penn	
Superheaters, Cylindrical, by Mr. Rowan	158	and Son	231
Superheaters, Tubular, by Mr. Field	161	Trunk Air Pump, Injection Condenser, by Messrs.	
Superheaters, Horizontal Tubular, by Mr. Field ..	163	J. and G. Rennie	245
Superheaters, details of Horizontal Tubular, by		Trunk Air Pump, Injection Condenser, by Messrs.	
Mr. Field	164	Napier	245
Superheater, Horizontal Tubular, by Messrs. Penn	164	Three-ported Slide Valve, by Messrs. Maudslay ..	285
Superheater, Horizontal Tubular, by Messrs. Raven-		Turning Gear	310
hill	167	Twin-screw Engines, designed by the Author	74
Superheater, Horizontal Tubular, by the Author ..	168	Tubular Superheaters, by Mr. Field	161
Superheater, Vertical Tubular	170	Trunks, Anti-friction, by the Author	274
Superheater, Vertical Tubular, by Messrs. Humphrys	171	Trunk Glands, Pinion and Wheel Motion for adjust-	
Superheater, Sheet Flue Tubular, by the Author ..	174	ing	279
Salinometer, How's Patent	190	Throttle Valve, ordinary Steam	302
Salinometer, Long's Patent	190	Throttle Valve, Gear Motion for, by Messrs.	
Slide Valve Packing Ring	287	Maudslay	302

	PAGE		PAGE
Thrust Block, ordinary	317	Valve, Slide, mode of adjusting the	Packing
Thrust Block, adjustable, by Messrs. Maudslay ..	318	Ring of	286
Twin-screw Engines, by Messrs. Dudgeon	72	Valve, Packing Ring for Slide	287
Turbine Propeller, fitted in H.M.S. "Waterwitch"	326	Valve, Link Motion, by Messrs. Penn	288
Telegraph, How-Gathercole	327	Valve, Link Motion, by Messrs. Maudslay	289
Telegraph, Mr. Soul's Mechanical	329	Valve, Link Motion, by Messrs. Humphrys	290
Telegraph, arrangement of a Mechanical	313	Valve, Link Motion, by Messrs. Ravenhill	291
Telegraph, Deck Column	330	Valve, Link Motion, by Messrs. Dudgeon	292
Up-take, fitted in H.M.S. "Research," by Messrs.		Valve, Link Motion, by Messrs. Napier	293
Watt	338	Valve Rod, and mode of connecting, and Link, by	
Up-take, Inclined, by Messrs. Watt	338	the Author	293
Vertical double-acting Air Pump, by J. F. Spencer	266	Valve (Slide), Spur Gear Motion for working, by	
Vertical Donkey Engine, Feed Pump, by Messrs.		Messrs. Maudslay	294
Watt	315	Valve, Expansion Gear, by Messrs. Penn	298
Vertical Tubular Superheater	170	Valve, Expansion and Casing, by Messrs. Rennie ..	298
Vertical Tubular Superheater, by E. Humphrys ..	171	Valve, Expansion and Casing, by Messrs. Maudslay	299
Valve and Cylinder Ports, by Messrs. Ravenhill ..	195	Valve, Expansion and Casing, by Messrs. Raven-	
Valve, Injection	235	hill	300
Valve, Spring Snifting	236	Valve, Expansion, by Messrs. Watt and Co.	301
Valve, Snifting	237	Valve, Expansion, by Mr. Winter	302
Valve, Spring Relief	237	Valve, ordinary Steam Throttle	302
Valve Seating and Guard, mode of securing	269	Valve, Gear Motion for Throttle, by Messrs.	
Valve, Inverted	269	Maudslay	302
Valve and Guard, general mode of securing	270	Valve, Water Discharge	310
Valve Seating and Guard, general mode of securing,		Valve, or Feed Pump, arrangement of	313
by the Author	270	Valves, Wood-packed Metal, for Feed and Bilge	
Valve Seating and Guard, general mode of securing,		Pumps	313
by Messrs. Humphrys	271	Valve, Relief, by Messrs. Penn and Son	314
Valve, Inverted, by Messrs. Humphrys	271	Valve, "Kingston"	317
Valve, Gridiron Injection	271	Valves, Direct Loaded Safety	342
Valve, Patent Relief, by Messrs. Penn	280	Valves, Non-return	343
Valve, Relief, by Messrs. Penn and Son	281	Valve, Steam Stop	344
Valve, Relief, by Messrs. Maudslay	281	Valve, Slide, Geometrical Diagram of	350
Valve, Relief, by Messrs. Ravenhill	282	Valve, Slide, Geometrical Diagram of	351
Valve, Relief, by the Author	282	Wood Packing, by Messrs. Penn	266
Valve, Relief, by the Author	283	Wood Packing for Piston, by the Author	268
Valve, Ordinary Blow Through	283	Worm and Pinion Motion for adjusting Piston Rod	
Valve, Blow Through, by Messrs. Penn	284	Glands, by Messrs. Maudslay	279
Valve, Slide, by Messrs. Penn	284	Water Lubricators	307
Valve, Slide, by Messrs. Napier	284	Water Discharge Valve	310
Valve, Slide, by Messrs. Rennie	285	Wood-packed Metal Valves for Feed and Bilge	
Valve, Three-ported Slide, by Messrs. Maudslay ..	286	Pumps	313
Valve, Compound Slide, by Messrs. Dudgeon	286	Water Gauge, &c.	341
		Whistle, Steam	344

