... of Education.

CATALOGUE

OF THE

NAVAL AND MARINE ENGINEERING COLLECTION

IN

THE SCIENCE MUSEUM, SOUTH KENSINGTON.

WITH DESCRIPTIVE AND HISTORICAL NOTES.

WAR AND MERCANTILE VESSELS;
YACHTS, BOATS, TUGS, BARGES, ETC.;
SHIP DESIGN AND CONSTRUCTION;
LIFE-SAVING APPLIANCES.

MARINE ENGINES AND BOILERS;
PADDLE-WHEELS AND SCREW PROPELLERS;
STEERING APPLIANCES;
AUXILIARY MACHINERY.

AERIAL NAVIGATION.

Second Edition, with a Supplement containing illustrations.

LONDON:
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PRINTERS TO THE KING'S MOST EXCELLENT MAJESTY.
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PREFACE.

THE collection of Models of Ships and Marine Machinery was first formed in 1864, when the Royal School of Naval Architecture and Marine Engineering was established at South Kensington by the Lords of the Committee of Council on Education, at the request of the Lords Commissioners of the Admiralty.

It consisted at first principally of models lent by the Admiralty, which were transferred to Greenwich in 1873, when the Royal School of Naval Architecture was removed thither. In the meanwhile, however, the collection had been very largely supplemented by models obtained, principally on loan, from other sources; and the owners not wishing that they should be removed from South Kensington, all but the Admiralty models were retained there as a division of the Science Branch of the South Kensington Museum.

The President and Council of the Institution of Naval Architects waited on the Lord President of the Council on the 30th June, 1887, and laid before him a memorandum relating to the collection. In this memorandum, after recapitulating the history of the collection and the various proposals that had been made with reference to it, they go on to say:

"The Council of the Institution wish to bring under the notice of the Lord President the fact that Shipbuilding and Marine Engineering is, after agriculture, the largest industry in the United Kingdom. * * * * * The importance of good museums in furthering the work of technical education cannot be overestimated; the Council of the Institution therefore specially recommend that the suggestions contained in the report of the majority of the Inter-Departmental Committee (Sir F. Bramwell's) be carried into effect, so far as regards the collection of Naval Models and Marine engines, by retaining the collection at South Kensington Museum, and by providing the requisite space for its present and future development. The Council of the Institution consider that South Kensington is the best site for the Museum, because of its central position, which is readily accessible both to professional men and to students, and also because of its proximity to the Normal School of Science (now the Imperial College of Science and Technology)."
* * * *

The collection has been increased year by year, partly by purchases and by models made to order (in some cases in the

Royal Dockyards), but principally by donations and loans from Engineering, Shipbuilding, and Shipowning firms, and from Lloyd's Committee.

The Board of Education trust that they may continue to receive liberal assistance in their endeavours to maintain a collection which may illustrate the history and development of Shipbuilding and Marine Engineering as well as the present condition of those arts.

⁂ *Many of the engine models are shown in motion daily from 11 a.m. till closing time, the motive power being supplied by a compressed air service.*

The more important objects in the Naval and Marine Engineering Collections have been photographed, and particulars of prints and lantern slides that are available may be obtained on application.

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CONTENTS.

(The objects in the various sections are arranged chronologically.)

	Page
Warships	5
Sailing	7
Steam	24
Mercantile Vessels	52
Sailing	54
Steam	60
Yachts	104
Racing	106
Cruising	117
Motor boats	122
Boats, Barges, Launches, Tugs, etc.	123
Open boats	125
Decked craft	136
Life-boats	144
Steam tug boats	149
Boats' fittings	150
Ships and Boats, chiefly of Oriental Design	152
Masts, Yards, Rigging, and Sails	168
Ship Design	172
Ship Construction	182
Wooden	186
Composite	192
Iron and steel	196
Ships' fittings, etc.	213
Slipways, Docks, etc.	220
Lighthouses, etc.	229
Life-Saving Appliances	237
Marine Engines	241
Paddle	244
Screw	261
Details	285
Marine Boilers	292
Boiler fittings	306
Propellers	315
Paddle-wheels	315
Screws	323
Other forms	341
Steering Arrangements	343
Capstans, Winches, etc.	355
Anchors, Cables, etc.	359
Logs and Clinometers	369
Dredging Appliances	374
Aërial Navigation	381
Appendix	389
List of Donors and Contributors	392
Index	396

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When a reference is made in the text it is usually to the serial numbers at the beginnings of the entries. When an object is illustrated the reference is given immediately after the entry. The numbers in the right-hand lower corners of the headings are those under which the objects are registered in the Museum.

SHIPS OF WAR.

The earliest vessels, used indifferently for all purposes, were "dug-out," *i.e.*, hollowed out of a log, as still practised by certain tribes, or else were formed of mat or wicker work. Examples of such constructions are shown in some of the Oriental boats. Such vessels were necessarily very small, the larger ones only becoming possible after some system of shipbuilding had been evolved.

Accounts of early shipbuilding are given in the records of the ancient Egyptians, and on the Mediterranean coasts great advances were made by the Phœnicians, who about B.C. 800 constructed warships having two banks of oars. About this time also the Greeks built their first warships, while in B.C. 350 they possessed a navy and a complete dockyard equipment. Their warships were provided with several banks of oars, to allow of quick evolutions in all weathers and to facilitate the use of the beak or ram with which each was provided. They were, however, small vessels, making short voyages only; the hull length was 7·5 times the beam. The Roman warships were about 5 times the beam in length, but were known as "long" ships, to distinguish them from their merchant vessels, which were only 4 beams in length; the merchantmen carried few oars, relying rather on sails, as they undertook oversea voyages; their carrying capacity was about 250 tons. The narrow or galley type of armed ship, with convicts or prisoners as rowers, remained as a naval factor in the Mediterranean until steamships became general.

Before the invention of gunpowder, fighting was of the hand-to-hand order, or at ranges at which arrows could be used; from the 12th to the 15th centuries lofty structures at the bow and stern were usually provided for the accommodation of the archers and combatants. The introduction of cannon into land warfare, about 1350, was followed by their use at sea. The early guns were placed broadside, over the gunwales, but the use of ports soon followed, and then the arrangement of the guns in tiers. These changes very gradually led to the suppression of the fighting towers, although the name survives in our word "forecastle."

Henry VIII. established the first Royal Dockyards at Deptford and Woolwich, about 1510, thus laying the foundation of our present naval system. The Cinque Ports were previously bound to supply a certain number of fighting ships in lieu of taxes, from which they were exempted, while as late as the time of the Armada the Navy was chiefly composed of vessels impressed or hired from private owners. At this period all merchant ships were prepared and equipped for fighting, with the result that many of their engagements would now be considered as of the buccaneering order.

In the 17th century the warships of all European nations embodied the following features that have since disappeared:—High stern, decorated sides, square bulkhead across the bows, spritmast and sails below the bowsprit, and a lateen sail on the mizen mast; the armament at this period was increased by the use of larger guns, rather than by adding to the numbers. With slight changes in rig and an increased weight of broadside, this type of warship survived till the beginning of the 19th century, largely owing to the action of the Navy Board in 1719, which laid down a scale of dimensions and tonnage for the construction of vessels of each rate.

In 1832 commenced the great change in the Navy due to the introduction of steam power; in that year the paddle steamer H.M.S. "Salamander" appeared, and subsequently numerous paddle-driven war vessels were constructed. In 1843 H.M.S. "Rattler" was built and fitted as a screw-propelled fighting ship. Her complete success, combined with the obvious advantages of machinery below the water-line, at once rendered the ultimate adoption of steam propulsion inevitable. These early steamships were only despatch boats or brigs, and it was not till 1848 that the screw was applied to line-of-battle ships, and then only as an auxiliary power to fully-rigged sailing vessels.

Although the use of iron for shipbuilding was a practical success by 1832, its adoption in warships was much later, for it was only in 1850 that iron beams were substituted for wooden ones, while not till 1856 were the first iron-built war vessels constructed. These were the floating batteries "Erebus," "Terror," and "Thunderbolt," designed for use in the Russian war, where the destructive effect of shell-fire upon wooden ships was very severely experienced.

In consequence of the building in France of "La Gloire," an armoured wooden ship, an immense change was inaugurated in this country by the construction in 1861 of the first iron-built armoured vessel, H.M.S. "Warrior." Since then, the arrangements of a warship have continued to diverge from those of a merchant vessel, so that now, the latter is never improvised for line of battle, but is sometimes used for subsidiary war purposes.

The early armour was of wrought iron, which well resisted the chilled cast-iron projectiles so long used, but with the introduction of steel shot a harder armour was rendered necessary. (*See "Armour,"* p. 185.)

From about 1870 till 1887 the primary guns of battleships were generally arranged in armoured revolving turrets, but since then the barbette mounting has been almost exclusively adopted, the guns being carried on a revolving platform, the base of which is protected by a stationary ring of heavy armour. In 1906, the growing importance of rapid and concentrated gun-fire at long ranges resulted in the British "Dreadnought" design, in which the universal practice of a mixed armament, of light and heavy guns, was abandoned and an augmented number of the most powerful guns were carried in a vessel of greatly increased dimensions and speed. Although this simplification of armaments had advantages as regards general fighting efficiency at extreme ranges, yet the continued improvements in torpedo-attack, at medium ranges, have shown the advisability of still carrying a number of quick-firing guns of smaller calibre.

SAILING SHIPS OF WAR.

1. Rigged model of King's Ship (11th to 13th cent.). (Scale 1 : 24.) Presented by James Dixon, Esq., 1908. Plate I., No. 1. N. 2489.

The term "King's Ship" appears to have been applied originally to the long-ships or war galleys of about 60 oars built by Alfred the Great in 875.

This model, made by Mr. F. H. Mason, R.B.A., represents an English man-of-war of the Norman and early Plantagenet periods, such as may be seen on the 13th century seals of some of the Cinque Ports. It has greater proportional beam and fuller lines than the contemporary warships of the oar-propelled galley type.

Oak was generally used in construction; the planking was worked flush and then caulked with moss, hair, and pitch; the sides were further strengthened and protected by external timbers and rubbing-pieces. Temporary structures or "castles" at the bow and stern, and smaller "top-castles" at the mast-head, were erected for the use of the fighting men. Decks and platforms were also of a portable character. Wooden shields were hung around the bulwarks for the better protection of the crew; the shields and banners of the knights were hung upon the castles. A single pole mast was used, spreading a large decorated square-sail; sail was taken in when necessary by detaching the "bonnet" or lower portion. Steering was effected by a large oar on the right-hand side. These vessels were decorated with heraldic carvings and painted in bright colours, red being a favourite colour. Their burden varied probably from 40 to 160 tons.

2. Rigged model of carrack (15th cent.). (Scale 1 : 48.) Presented by James Dixon, Esq., 1908. Plate I., No. 2. N. 2488.

This model, by Mr. F. H. Mason, R.B.A., represents a type of ship developed, largely by the Genoese, Portuguese, and Spaniards, during the 14th and 15th centuries for the purposes of the sea-borne commerce of the period. Oversea expeditions, such as those of Columbus and Vasco da Gama, were also made in vessels of similar type.

The most striking features of these vessels were:—A low freeboard amidships, a high overhanging forecastle, and a heavy superstructure at the stern. These erections, developed from the temporary fighting "castles" of earlier date, were now incorporated with the ship structure; they provided accommodation for the crew and afforded means of defence, although they increased the tendency to heavy rolling and pitching. In war vessels of the 16th century these superstructures reached extreme proportions "for majesty and terror of the enemy."

The carrack usually carried from three to four pole masts; lateen sails were always used, but upper and lower square-sails were fitted to the fore and main masts in the later and larger examples. A rudder, hung at the centre line of the stern, had, at this date, superseded the steering oar. The ship's boats were carried in the waist, when they could not be towed.

The model represents a vessel of about 150 tons burden, but during the 16th century Genoese carracks of 1,600 tons burden are recorded as having been built.

3. Engraving of "Henri Grâce à Dieu" or "Great Harry" (1514). Received 1905. N. 2393.

This engraving, from a contemporary painting ascribed to Hans Holbein, is believed to represent one of the first vessels of considerable size belonging to the Royal Navy of England.

Owing to the practice of giving the same name to successive ships of somewhat similar characteristics, it has been difficult to distinguish clearly between the "Great Harry" reputed to have been built by Henry VII. about 1488–1503 and the "Great Harry" or "Henri Grâce à Dieu" of the following reign. Authentic records, however, exist as to the building of this latter ship at Woolwich, in 1512–15, of her engagement with a French fleet off the Isle of Wight in 1545, and of her accidental destruction by fire at Woolwich in 1553. She carried four masts, each made in a single length without a separate top-mast and all square-rigged, and a long bowsprit; she was of about 1,000 tons burden, and had a crew of 700 men and an armament of 20 to 30 cannon with a large number of smaller guns.

Various drawings of this vessel are in existence. The adjacent prints of "Henri Grâce à Dieu" (No. 5), from a drawing in the Pepysian Library, Cambridge, and "The Embarkation of Henry VIII." (No. 4), show structures having abnormal proportion of height to length and breadth, which probably more nearly represent the actual type of ship in use at the beginning of the 16th century than does this engraving, which in some characteristics shows an advance towards vessels of the Elizabethan period.

4. Engraving of the Embarkation of Henry VIII. (1520). Received 1905. N. 2394.

This engraving is taken from the large painting now in Hampton Court Palace ascribed to Vincent Volpe, a contemporary Court painter; it represents Henry VIII. of England, with his fleet, leaving Dover Harbour for Calais, preparatory to his historical interview with Francis I. of France, on the Field of the Cloth of Gold.

In the foreground are views of the two forts commanding the western side of the harbour entrance, while in the background appears Dover Castle. Among the leading vessels, to the right of the picture, is shown the celebrated "Henri Grâce à Dieu" or "Great Harry," with the King standing upon the upper deck. Interesting details are given of the masting, rigging, and external design and ornamentation of ships-of-war during the early part of the 16th century; these features are in general accord with the drawing of the "Henri Grâce à Dieu" in the Pepysian Library, Cambridge, a partial reproduction of which appears in the upper part of an adjacent frame (No. 5).

5. Prints of early shipping. Presented by T. Dyer Edwardes, Esq., 1868. N. 1209.

These are a collection of woodcuts or engravings representing chiefly mediæval vessels. They include a British coracle of 50 B.C.; Mediterranean war galleys; a fireship and seven other vessels of 14th to 15th centuries; the "Great Harry" of 1503; the "Henri Grâce à Dieu" of 1514; the "Royal James" of 1675; and the ill-fated "Royal George" of 1756.

6. Rigged model of English man-of-war (1580–1600). (Scale 1 : 72). Lent by R. Morton Nance, Esq., 1908. Plate I., No. 3. N. 2456.

This model of an Elizabethan warship was made by Mr. Nance from information obtained from contemporary prints, paintings and detailed descriptions.

The hull shows features of both the round-ship or mediæval merchant vessel, and the long-ship or war galley—a combination which gave a vessel capable of carrying a considerable spread of sail and ample armament while possessing the speed and handiness associated with lightness in construction. The narrowing or housing-in of the topsides, which rendered the vessel more seaworthy and strengthened the decks as gun platforms, as well as the beakhead and the open stern galley were new features of this period, while gratings and nettings in the waist as a defence against boarders were adapted from an earlier arrangement.

Four masts are shown; the foremast is placed before the bulkhead of the forecastle and the bowsprit is stepped beside it; the two mizen masts are fitted with lateen sails only, an outrigger from the stern being used to extend the sheet of the smaller or bonaventure mizen-sail. On the ends of the bowsprit and yard-arms are sheer-hooks intended for catching in an enemy's rigging. No stay-sails were carried but the stays themselves were used for securing the standing parts of braces, bowlines, &c., the crow-foot being a favourite method of attachment. Marnetts or martinets, similar to leech lines, are shown upon the fore and main-sails, while the methods of furling adopted at this period are illustrated by the main-sail, fore top-sail and sprit-sail. The model is shown close-hauled with the fore-sail so canted as to resemble a lug-sail and having its tack hauled down to a comb-cleat under the head knee. The detachable bonnet, an equivalent of reefing, shown laced to the fore-sail, and the striking of topmasts were innovations of this period.

There is an armament of 30 large guns, besides which a number of small swivel-guns would have been carried.

The principal dimensions of the vessel are:—Length, on gun deck, 80 ft.; breadth, 26 ft.; depth of hold, 13 ft.; displacement, about 450 tons.

7. Built and rigged model of a Maltese galley. (Scale 1 : 24.) Bequeathed by Miss M. A. Peek, 1906. Plate I., No. 4. N. 1029.

This ancient model is believed to have belonged to the Knights of Malta. It is planked on the starboard side, but shows the timbers on the port.

Such armed vessels were usually rigged with three masts carrying large lateen sails; in calms they were propelled by sweeps, manned by slaves or convicts.

The dimensions would be approximately:—Length, 165 ft.; breadth, 22 ft.; breadth from gunwale to gunwale, 31 ft.; depth, 9·9 ft.; number of sweeps, 44.

8. Drawings and engraving of H.M.S. "Sovereign of the Seas," 1637. (Scale 1 : 48.) Received 1893 and 1905. N. 2044 and 2395.

The pencil sketch and the engraving give general views, and the design shows the sheer, half-breadth, body plan and stern elevation of the "Sovereign of the Seas," laid down at Woolwich in 1636 by Mr. Peter Pett, and launched in 1637; she appears to have been the first three-decked ship built in England.

In 1637 Thomas Heywood wrote: *She* hath three flush Deckes, and a "Fore-Castle, an halfe Decke, a quarter Decke, and a round house. *Her* "lower *Tyre* hath thirty ports, which are to be furnished with Demy-"Cannon and whole Cannon throughout. . . . Her middle Tyre hath "also thirty ports for Demi-Culverin, and whole Culverin: Her third *Tyre* "hath Twentie sixe Ports for other Ordnance, her fore-Castle hath twelve "ports, and her halfe Decke hath fourteene ports; *She* hath thirteene or "fourteene ports more within Board for murdering peeces, besides a great "many Loope-holes out of the Cabins for Musket-shot. She carrieth "moreover ten peeces of chase Ordnance in her, right forward; and ten "right off. . . . She carrieth eleaven anchors, one of them weighing "foure thousand foure hundred, etc," (*i.e.*, lb.). Fincham considered that "she was so gorgeously ornamented with carving and gilding that she "seemed to have been designed rather for a vain display of magnificence "than for the service of the State."

In Blake's time she was cut down a deck, and then was considered one of the finest ships in the world; she was constantly employed in the naval wars of Cromwell and Charles II., but in 1696 was accidentally burnt at Chatham, where she had gone to be rebuilt.

Burden, 1,867 tons; length of gun deck, 173 ft.; length of keel, 139 ft.; breadth, extreme, 50 ft.; depth of hold, 20 ft.; height from keel to lanthorn top, 76 ft. Armament, 102 guns.

9. Rigged model of Dutch war vessel (1650–75). (Scale 1 : 72.) Lent by R. Morton Nance, Esq., 1903. Plate I., No. 5. N. 2338.

This represents a man-of-war of the largest type in the Dutch Navy towards the end of the seventeenth century; the model was made by Mr. Nance from data obtained from contemporary drawings and some original models deposited in Continental churches. At this period the naval power of Holland equalled that of any country, but the shallow waters of her coast and harbours so limited the draught of her ships that they were generally of less tonnage than those of other powers.

The model shows the "square tuck" or "transom stern," common to the Dutch, Spanish and French men-of-war of the time, therein differing from the English rounded stern in which the outer planking was worked in continuous lines to the stern post. The channels for securing the lower rigging of the fore and main mast are fitted above the upper deck gun-ports, an improvement which was not generally adopted in the English Navy till a century later. The shape of the mast-caps, the circular tops, the use of a sprit-top mast, and of a lateen yard are also features of the period to which the model belongs.

The leading dimensions of the vessel would be approximately:—Displacement, 1,000 tons; length, 120 ft.; breadth, 42 ft.; armament, 65 guns.

10. Rigged model of an English battleship of the 17th century. (Scale 1 : 48.) Received 1895. Plate I., No. 6. N. 2072.

This shows a line-of-battle ship of the first rate, and is believed to represent H.M.S. "Royal Charles," a 100-gun ship built at Portsmouth in 1672, to the designs of Sir Anthony Deane.

The model was rigged in the Museum in 1898 from information collected from several drawings and models of the period. Although shown without top-gallant yards, it is not to be inferred that such spars were not then in use; in fair weather they were commonly fitted, but during the winter season the usual rig was as here represented.

The chief difference between this rig and that of vessels of the 19th century is in its having a sprit top-mast and jack staff on the bowsprit, and in the use of a large lateen yard and sail on the mizen mast in place of a spanker spread by a gaff and boom. The "tops" throughout are circular in plan and have a raised ledge.

The armament of the "Royal Charles" was:—Lower deck, 28 42-prs.; main deck, 26 40-prs.; upper deck, 28 18-prs. and four 16-prs.; quarter deck and forecastle, 14 6-prs. Her complement was 780 men.

The leading dimensions were:—Tonnage, 1,531 tons; length, 136 ft.; breadth, 44·6 ft.; depth of hold, 18·25 ft.; draught, 20·5 ft.

11. Engraving of an English man-of-war of the 17th century. (Scale 1 : 60.) Received 1894. N. 2055.

This represents a battleship of the first rate, mounting 100 guns, and having a complement of 710 men. It probably belongs to the period 1660–80. Details of the lower transverse framing are shown, and the names of the various parts are given in English, Dutch, French, and Italian. The usual elaborate ornamentation of the upper portions of the hull is carefully represented.

Her armament was:—Lower deck, 28 42-prs.; middle deck, 28 40-prs.; main deck, 28 18-prs.; upper deck, 12 16-prs.; poop deck, four 6-prs.

Tonnage, 1,672 tons; length, 136 ft.; breadth, 44·5 ft.; draught, 20·5 ft.

12. Engravings of 17th century war ships of the second rate. Presented by T. Dyer Edwardes, Esq., 1868. N. 1209.

These four prints from drawings by Vandevelde, illustrate the difference in the build of English and foreign warships about the year 1670.

The English ship shows a clean run, her outside planking being worked continuously to the sternpost below the gun deck, while the planking of the foreign vessels terminates in flat transom sterns; the English and Spanish chain plates are on the main deck, whilst those of the French and Dutch are on the upper.

13. Built model of H.M.S. "Chester." (Scale 1 : 48.) Lent by J. J. Dafforne, Esq., 1869. N. 1313.

This model, which has its lower masts and bowsprit stepped and tops over, is said to represent H.M.S. "Chester," a fourth-rate man-of-war, built at Woolwich in 1691, by Mr. Laurance. The intricate wood-carving in the decorations of the vessels have been carefully reproduced. She carried 48 to 54 guns, and her complement was about 230 men.

Her dimensions, taken from the model, were:—Tonnage, 618; length of keel, 128 ft.; breadth, 36 ft.; depth of hold, 14 ft.

14. Rigged model of English battleship. (Scale 1 : 64.) Lent by Mrs. Humphry, 1905. N. 2386.

This represents an English line-of-battle ship of the third rate, built on the "establishment for building ships framed in 1719," and carrying 80 guns on three decks. The class was described as inefficient; they were bad sea boats, being three-deckers on the dimensions of two-deckers; consequently none were built after 1757.

The model itself is well and accurately rigged, showing snaked fore and main stays, the method of swiftering in the lower rigging, spritsail yard, sprit topmast and yard, the introduction of the jib-boom, and top cloths used for ornamental purposes.

The armament was:—Lower deck, 28 24-prs.; middle deck, 26 12-prs.; upper deck, 26 9-prs. Complement, 650 men.

The dimensions of third-rates on the 1719 establishment were:—Burden, 1,350 tons; length on gun deck, 158 ft.; length of keel for tonnage, 128 ft.; breadth, 44·5 ft.; depth, 18 ft.

15. Oil paintings of H.M.S. "Victory." Presented by H.M. Queen Victoria, 1864. N. 1018.

This was a first-rate battleship of 100 guns built at Portsmouth in 1737. She was lost in the English Channel October 5th, 1744, when Admiral Balchen and her crew of 1,100 men perished.

Armament:—Lower deck, 28 42-prs.; middle deck, 28 24-prs.; main deck, 28 12-prs.; quarter deck, 12 12-prs.; forecastle, four 12-prs. Her complement was 1,100 men.

Tonnage, 1,921 tons; length, 174·75 ft.; breadth, 50·5 ft.; depth of hold, 20·5 ft.

16. Rigged model of English man-of-war, fourth rate (1740–5). (Scale 1 : 48.) Received 1909. N. 2525.

This represents an English warship, built in accordance with the 1733 Establishment for 50-gun ships; eight of these vessels were constructed between 1740 and 1745 under Sir J. Acworth, Surveyor of the Navy.

During the first half of the 18th century fourth-rates were counted as ships-of-the-line, capable of taking part in general engagements; at a somewhat later date, however, they were more commonly used for convoy duty, and third-rates or 64-gun ships (*see* Nos. 26 and 44) were the smallest officially recognised for line-of-battle.

The following contemporary features are illustrated by the model:—(*a*) A jib-boom, for use with a fore-and-aft head sail, now first substituted for the sprit topmast, yard and square sail; (*b*) the swiftering, or cross connection, of each pair of shrouds on the fore and main masts; (*c*) the fitting of crows-foot rigging, from the fore edges of the tops to the lower stays; (*d*) lateen yard, with fittings, on the mizen mast; (*e*) spare spars, stowed in the waist; (*f*) portable fish davit for lifting anchors; (*g*) ornamentation of stern and topsides.

The ordinary complement for these ships was 300 men, and the armament was usually distributed as follows:—Lower deck, 22 18-prs. or 24-prs. 9·5 ft. long; upper deck, 22 9-prs or 12-prs. 8·5 ft. long; quarter deck, four 6-prs. 7 ft. long; forecastle, two 6-prs. 8 ft. long. Provision was often made for carrying several guns in excess of this number.

The average dimensions of this class were:—Tonnage (b.o.m.), 860 tons; length on gun deck, 134 ft.; breadth, 38·7 ft.; depth of hold, 15·75 ft.

17. Whole model of an 18th century line-of-battle ship on launching ways. (Scale 1 : 60.) Received 1890. N. 1850.

This is an English warship of the fourth rate, mounting 64 guns; H.M.S. "Yarmouth," built at Deptford by Mr. J. Allen in 1745, was a similar vessel, and her dimensions were:—Tonnage, 1,359 tons; length, 160 ft.; breadth, 44·25 ft.; depth of hold, 19 ft.

The model shows the method of launching used in the 18th century. The flags displayed are: the royal standard of the House of Hanover 1714–1801; the Union Jack prior to the abolition of the Irish Parliament in 1801; the foul anchor of the Lords Commissioners of the Admiralty.

18. Built and rigged model of an English frigate of the 18th century. (Scale 1 : 48.) Bequeathed by T. S. Robins, Esq., 1881. Plate II., No. 1. N. 1545.

This 24-gun frigate was built about 1750. Amongst the interesting details visible are the upper and lower lateen yards on the mizen mast, the method of stowing bower and sheet anchors, the timbers and upper deck beams, and the poop and forecastle.

The guns were 9-prs., and the ship's complement 160 men.

The approximate dimensions would be:—Tonnage, 511 tons; length on gun-deck, 113 ft.; length of keel, 93 ft.; breadth, 32 ft.; depth of hold, 11 ft.

19. Engravings of English men-of-war of the 18th century. Received 1892. N. 2010.

These show details of line-of-battle ships of about the period 1750–90. The upper view represents a full-rigged 64-gun ship at anchor, and is provided with a marginal key that gives the names of the various ropes, spars, &c. The lower view is a longitudinal section of the hull of a 90-gun ship, showing the internal construction and fittings; this also is provided with a similar key.

20. Oil paintings of armed cutter "Alert." Presented by Mrs. Gibbs, 1904. N. 2356.

These two paintings, dated 1755, represent an armed cutter or sloop-of-war, similar to a class of 8-gun vessels built in 1753–4 from the designs of Sir J. Acworth.

Many such vessels were built or purchased for the Navy during the latter half of the 18th century; they varied in size from 50 to 200 tons and were chiefly employed for the suppression of smuggling, which was at its height at that period.

The vessel shown would have a complement of about 60 men. Tonnage (b.o.m.), 145 tons; length, on gun deck, 75·5 ft.; length on keel, 62 ft.; breadth, extreme, 21 ft.; depth of hold, 9·5 ft.

21. Oil painting, "Launch at Deptford Dockyard" (about 1750). Painted by J. Clevely. Received 1867. N. 1096.

This yard, established early in the reign of Henry VIII., was closed for shipbuilding in April, 1869, and is now used as one of the principal victualling establishments for the Navy. The picture shows very accurately the rig of the different ships at anchor, also the uniforms of the period.

22. Oil paintings of H.M.S. "Royal George." Presented by H.M. Queen Victoria, 1864. N. 1017.

These show bow and stern views of H.M.S. "Royal George," a first-rate battleship of 100 guns. She was laid down at Woolwich in 1746, launched in 1756, and foundered at Spithead August 29th, 1782, in consequence of her "being heeled to come at the pipe that leads to the well." She remained in the spot where she had sunk until 1839, when by means of the diving bell many of her guns and stores were recovered, her hull being then blown up.

Her armament was:—Lower deck, 28 42-prs.; middle deck, 28 24-prs.; main deck, 28 12-prs.; quarter deck, twelve 12-prs.; forecastle, four 12-prs. Her complement was 800 men.

Tonnage, 2,041 tons; length, 178 ft.; breadth, 51·75 ft.; depth of hold, 21·5 ft.

23. Rigged model of H.M.S. "Juno." (Scale 1 : 24.) Lent by S. T. G. Evans, Esq., 1898. Plate II., No. 2. N. 2167.

This vessel was built on the Thames in 1757 by Mr. Alexander, to the designs of Sir T. Slade, who then held the post of Constructor to the Navy.

She was one of the first typical frigates, carrying her armament on one deck and being built for service as a swift independent cruiser. Her armament was 32 9-prs., and her complement 220 men.

Tonnage, 667 tons; length, 127·83 ft.; breadth, 34·25 ft.; depth of hold, 11·83 ft.

24. Built half-model of 50-gun frigate (1743–63). (Scale 1 : 48). Received 1899. N. 2186.

This shows the above-water form of an English fourth-rate man-of-war built during the middle of the 18th century.

H.M.S. "Romney" laid down at Woolwich in 1759 and launched in 1762, was typical of the class and had the following principal dimensions:—Length on gun-deck, 146 ft.; length on keel, 120·7 ft.; breadth, extreme, 40·37 ft.; tonnage (b.o.m.), 1,046 tons.

Although nominally rated as 50-gun frigates these vessels carried 54 and occasionally 58 guns. The bulwarks and gun ports to the poop-deck were probably additions, made during reconstruction at a later date.

25. Built model of H.M.S. "Triumph." (Scale 1 : 48.) Received 1892. Plate I., No. 7. N. 2009.

This two-decked 74-gun line-of-battle ship was launched at Woolwich Dockyard in 1764. She was designed by Sir Thomas Slade on the lines of the "Invincible" captured from the French by Lord Anson and Sir Peter Warren on the 3rd of May, 1747.

Her armament was:—Lower deck, 28 32-prs.; main deck, 30 18-prs.; quarter deck, twelve 9-prs.; forecastle, four 9-prs. Her complement was 650 officers and men.

Tonnage, 1,825 tons; length, 171·25 ft.; breadth, 49·75 ft.; depth of hold, 21·25 ft.

26. Rigged model of 64-gun ship. (Scale 1 : 48.) Received 1899. Plate II., No. 3. N. 2202.

From 1719 till about 1745 the British ships-of-war were constructed upon a fixed scale of dimensions, with the result that, through the absence of development, our ships of each class became inferior in both size and sailing qualities to those of other powers; several engagements having demonstrated this result, the regulations were abandoned and new designs prepared giving larger dimensions and finer lines which were partly obtained from those of captured vessels.

The model built by Messrs. Perry & Co., and rigged in the Museum in 1901, represents a man-of-war of the third rate built on the new system in 1764 by John Perry at Blackwall from designs by Sir T. Slade of the Admiralty. It shows in detail the fittings of the improved vessels, including the cabin, belfry, riding bitts, galley, capstans, and the glazing of the stern and quarter galleries, with other details of the period.

The armament would be:—Lower deck, 26 18 or 24-prs.; main deck, 26 9-prs.; quarter deck, ten 9-prs.; forecastle, two 9-prs. Ship's complement, 500 men.

The name of the vessel represented is uncertain, but her leading dimensions were probably:—Tonnage, 1,380 tons; length on gun deck, 159·3 ft.; length on keel, 130·75 ft.; breadth, 44·5 ft.; depth, 18·75 ft.

27. Rigged model of H.M.S. "Duke." (Scale 1 : 48.) Lent by S. T. G. Evans, Esq., 1898. N. 2166.

This second-rate line-of-battle ship of 98 guns is of uncertain origin, but she is known to have been rebuilt at Plymouth in 1776 by J. Pownall. She took part in the battle of Belleisle in 1759, and in Rodney's victory of April 9th, 1762, in the West Indies.

Her armament was:—Lower deck, 28 32-prs.; middle deck, 28 18-prs.; main deck, 32 12-prs.; quarter deck, four 12-prs.; poop deck, four 6-prs.; forecastle, two 12-prs. Her complement was 750 men.

Tonnage, 1,931 tons; length, 177·5 ft.; breadth, 50 ft.; depth of hold, 21·16 ft.

28. Oil paintings of H.M.S. "Barfleur." Presented by H.M. Queen Victoria, 1864. N. 1019.

This was a second-rate battleship of 90 guns, laid down at Chatham in 1762, launched 1768, and broken up in 1819.

Armament:—Lower deck, 28 32-prs.; main deck, 32 18-prs.; upper deck, 30 9-prs. Her complement was 750 men.

Tonnage, 1,750 tons; length, 177·6 ft.; breadth, 50·4 ft.; depth of hold, 21 ft.

29. Oil paintings of H.M.S. "Royal Oak." Presented by H.M. Queen Victoria, 1864. N. 1020.

This was a third-rate battleship of 74 guns, laid down at Devonport in 1766, launched 1769, and broken up in 1815.

Armament:—Lower deck, 28 32-prs.; main deck, 28 18-prs.; quarter deck, 14 9-prs.; forecastle, four 9-prs. Her complement was 650 men.

Tonnage, 1,606 tons; length, 168·5 ft.; breadth, 46·75 ft.; depth of hold, 20 ft.

30. Oil paintings of H.M.S. "Intrepid." Presented by H.M. Queen Victoria, 1864. N. 1021.

This was a third-rate battleship of 64 guns, laid down at Woolwich in 1767, launched 1770, and sold out of the Service in 1828.

Armament:—Lower deck, 26 24-prs.; main deck, 26 18-prs.; quarter deck, ten 9-prs.; forecastle, two 9-prs. Her complement was 500 men.

Tonnage, 1,374 tons; length, 159·5 ft.; breadth, 44·4 ft.; depth of hold, 19 ft.

31. Oil paintings of H.M.S. "Kingfisher." Presented by H.M. Queen Victoria, 1864. N. 1027.

This was a 14-gun sloop-of-war laid down at Chatham in 1769, launched 1770, and burnt at Rhode Island in 1778.

The armament was 14 6-pr. guns, and the complement 125 men.

Tonnage, 302 tons; length, 98·75 ft.; breadth, 26·83 ft.; depth of hold, 12 ft.

32. Oil paintings of H.M.S. "Portland." Presented by H.M. Queen Victoria, 1864. N. 1022.

This was a fourth-rate battleship of 50 guns, laid down at Sheerness in 1767, launched 1770, and sold out of the Service in 1807.

Armament:—Lower deck, 22 24-prs.; main deck, 24 18-prs.; quarter deck, four 9-prs. Her complement was 350 men.

Tonnage, 1,044 tons; length, 146 ft.; breadth, 40·5 ft.; depth of hold, 17·5 ft.

33. Oil paintings of H.M.S. "Ambuscade." Presented by H.M. Queen Victoria, 1864. N. 1024.

This was a fifth-rate battleship of 32 guns, laid down at Messrs. Adams & Co.'s yard on the Thames in 1771, and launched in 1773. She was taken by the "Bayonnaise" in December 1798, and afterwards retaken and broken up in 1813.

Armament:—Main deck, 26 12-prs.; quarter deck, four 6-prs.; forecastle, two 6-prs. Her complement was 215 men.

Tonnage, 684 tons; length, 126·25 ft,; breadth, 35·16 ft.; depth of hold, 12·16 ft.

34. Oil paintings of H.M.S. "Enterprize." Presented by H.M. Queen Victoria, 1864. N. 1025.

This was a sixth-rate battleship of 28 guns, laid down at Deptford in 1771, launched in 1774, and broken up in 1807.

Armament:—Main deck, 24 12-prs.; quarter deck, four 6-prs. Her complement was 200 men.

Tonnage, 594 tons; length, 120·5 ft.; breadth, 33·5 ft.; depth of hold, 11 ft.

35. Oil paintings of H.M.S. "Experiment." Presented by H.M. Queen Victoria, 1864. N. 1023.

This was a fourth-rate battleship of 50 guns, laid down at Messrs. Adams & Co.'s yard on the Thames in 1772, and launched in 1774.

She was dismasted in a gale and taken by the French fleet in 1779 on her passage from New York to Savannah.

Armament:—Lower deck, 20 24-prs.; main deck, 22 18-prs.; quarter deck, six 9-prs.; forecastle, two 9-prs. Her complement was 300 men.

Tonnage, 923 tons; length, 140·75 ft.; breadth, 38·75 ft.; depth of hold, 16·58 ft.

36. Oil paintings of H.M.S. "Sphinx." Presented by H.M. Queen Victoria, 1864. N. 1026.

This was a sixth-rate battleship of 20 guns, laid down at Portsmouth in 1773, and launched in 1775. She was taken by the French in 1779, retaken the same year by H.M.S. "Proserpine," and broken up at Portsmouth in 1811.

Her armament was 20 6-prs., and complement 160 men.

Tonnage, 429 tons; length, 108 ft.; breadth, 30 ft.; depth of hold, 9·6 ft.

37. Rigged model of "Fair American." (Scale 1 : 32.) Lent by Sir Frank Short, 1900. N. 2215.

This was a 14-gun brig which under the command of Stephen Decatur, senr., became famous as an American privateer during the War of Independence, 1775–81. She was ultimately captured, and then sailed as a British privateer.

Her dimensions, as taken from the model, appear to have been:—Tonnage, b.o.m., 160 tons; length of gun deck, 69 ft.; breadth, 23 ft.; depth of hold, 11 ft.

38. Whole model of English man-of-war. (Scale 1 : 48.) Received 1894. N. 2043.

This represents a third-rate 70-gun ship, similar to H.M.S. "Boyne" built at Plymouth in 1776.

Her armament was:—Lower deck, 26 32-prs; main deck, 26 18-prs.; upper deck, 12 9-prs.; poop, six 6-prs. Her complement was 520 men.

Tonnage, 1,426 tons; length, 162 ft.; breadth, 44·66 ft.; depth of hold, 19·33 ft.

39. Rigged model of "Le Sceptre." (Scale 1 : 96.) Received 1871. N. 1330.

This represents a French line-of-battle ship of 74 guns, which took part in some of the most important actions during the war 1778–82.

Her armament was:—Lower deck, 28 36-prs.; main deck, 30 18-prs.; quarter-deck and forecastle, 16 8-prs. Her complement was 690 men.

Tonnage, 1,832 tons; length, 173·6 ft.; breadth, 49·6 ft.; depth of hold, 21·6 ft.

40. Built model of H.M.S. "Cleopatra." (1779.) (Scale 1 : 48.) Received 1907. N. 2441.

This 32-gun frigate was built at Bristol in 1779 from the designs of Sir J. Williams, Surveyor of the Navy. She was captured near the West Indies on 17th February, 1805, by the French 40-gun frigate "Ville de Milan," but was retaken, with her captor, by the British 50-gun frigate "Leander" six days afterwards.

The model shows all the important structural details and fittings of lower, main, quarter, and forecastle decks and also the general system of colouring and decoration adopted at this period.

The ship's complement was 222 men and, at the date of this action, her armament probably consisted of 26 long 18-prs. on the main deck, two long 9-prs. together with ten 24-prs. (carronades) on the quarter and forecastle decks.

Tonnage (b.o.m.), 689 tons; length, on gun-deck, 126·4 ft.; length of keel, 104·5 ft.; breadth, 35·2 ft.; depth, 12·1 ft.

The vessel is represented on a building slip ready for launching. The launching arrangements consist of (*a*) A fixed wooden structure or "ground ways" built up from the floor of the slip-way and forming an inclined plane, usually with a fall of ·625 in. to 1 ft. (*i.e.*, 1 in 19); (*b*) Two movable structures forming a "cradle," extending over three-fourths of the vessel's length, by which the whole weight of the hull is carried. Premature sliding of the cradle down the ways is prevented by short diagonal props or "dog-shores," shown on each side of the ship at the upper end of the ways; the dog shores are knocked away simultaneously when the launching operations begin. To prevent lateral movement of the cradle during its downward course, stout battens or "ribbons" are fitted to the upper edge of the ground-ways and held in position by the series of transverse props or shores shown on each side of the slipway.

41. Rigged model of English sloop-of-war, 18th cent. (Scale 1 : 48.) Received 1881. Plate II., No. 4. N. 1564.

This represents a ship-rigged sloop of about 1780, which carried 18 6-pr. guns and 125 men.

The masting and rigging of the model were added in the Museum in 1904–5.

Approximate dimensions:—Tonnage (b.o.m.), 300 tons; length of gun deck, 100 ft.; length of keel, 82 ft.; breadth, 26·3 ft.; depth of hold, 12 ft.

42. Rigged model of English sloop-of-war. (Scale 1 : 48.) Received 1881. N. 1565.

This represents a schooner-rigged sloop-of-war built about 1780. The term sloop-of-war was applied to a class of vessel carrying from 4 to 18 guns, and rigged as schooner, brig, or ship; they were used to cruise against privateers or in the prevention of contraband trade. The model was rigged in the Museum in 1902.

The armament would be about 12 6-prs., and the complement 30 to 50 men.

The approximate dimensions of the schooner represented were:—Length of keel, 56 ft.; breadth, 20·5 ft.; depth of hold, 8 ft.; tonnage (b.o.m.), 120 tons.

N.B.—In the Merchant Service the term sloop was confined to a type of single-masted vessel resembling a cutter, but having also a square sail.

43. Rigged model of 32-gun frigate. (Scale 1 : 48.) Received 1877. N. 1481.

The frigate, a fast vessel of medium size carrying her main armament on one deck, appears to have been generally introduced into the Royal Navy about 1756. The original vessels, of 28 to 32 guns and 600 to 700 tons burden, having proved highly successful for scouting and independent cruising purposes, the type gradually increased in numbers and dimensions; early in the 19th century vessels of 50 to 60 guns and 1,500 tons burden were built and when steam propulsion was introduced in 1850, the last of the sailing frigates had reached 2,100 tons burden.

This model was rigged in the Museum in 1907; it agrees in general dimensions with a class of 32-gun frigates built in 1783–6 from the designs of Sir J. Williams. These were classed as fifth-rate vessels and the "Meleager," a typical ship, built in 1785, had the following principal particulars:—Ship's complement, 220 men; armament, 26 12- or 18-prs. on main deck; four 6-prs. on quarter-deck; two 6-prs. on forecastle deck. Dimensions:—Tonnage (b.o.m.), 678 tons; length on gun deck, 126 ft.; breadth, 35 ft.; depth, 12·15 ft.

44. Rigged model of English 64-gun ship. Period 1780–90. (Scale 1 : 48.) Received 1881. Plate II., No. 5.

N. 1562.

The vessel represented is a man-of-war of the third rate at the close of the 18th century. The model was rigged in the Museum in 1902; it differs chiefly from the similar ship of about 1760 (No. 26) in having a gaff instead of a mizen or lateen yard.

The lateen yard, inclined at about 45 deg. and used for spreading a triangular sail, had been employed for centuries for carrying the fore-and-aft sail on the mizen mast of war ships, but in the 18th century the present gaff or half-yard began to be adopted. At first the gaff was confined to ships carrying less than 50 guns, but by the end of the 18th century it had completely supplanted the lateen yard, probably through the inconvenience of the latter, and the difficulty in working it.

The vessel is shown carrying three poop lanterns and a lantern in the maintop, these giving by night the distinguishing mark of a flag officer's ship. Across the forecastle is a "fish-davit"—a spar used in the 18th century for fishing the anchors; in the *Naval Expositor* (1752) it is thus described:—
"A piece of timber in a ship, having a notch at one end, in which by a strap
" hangs a block called the fish-pendant block, the use of which is to haul up
" the flook of the anchor, in order to fasten it to the ship's bow; this davit
" is shiftable from one side to the other as occasion requires."

Armament:—Lower deck, 26 32-prs.; main deck, 26 24-prs.; upper deck, 12 12-prs. Her complement was 500 men.

Tonnage, 1,374 tons; length on gun-deck, 159·5 ft.; length of keel, 131 ft.; breadth, 44·5 ft.; depth, 19 ft.

45. Built model of H.M.S. "Queen Charlotte." (Scale 1 : 48.) Lent by Hyde Clarke, Esq., D.C.L., 1881. N. 1561.

This 100-gun three-decked line-of-battle ship was designed by Mr. Edward Hunt, as a sister ship to the "Royal George," and launched at Chatham in 1790. She was Lord Howe's flagship in the action off Brest, 1st June, 1794, and was accidentally burnt off Leghorn in 1800.

The armament was:—Lower deck, 30 32-prs.; middle deck, 28 24-prs.; main deck, 30 18-prs.; quarter-deck, ten 12-prs.; forecastle, two 12-prs.

Tonnage, 2,286 tons; length, 190 ft.; breadth, 52·5 ft.; depth of hold, 22·3 ft.

46. Oil paintings of an English warship. Presented by F. A. B. Bonney, Esq., 1865. N. 1046.

This represents a third-rate battleship mounting 64 guns. The paintings, which are on copper, were used in the royal nursery for the instruction of Prince William Henry, afterwards William IV.

Armament:—Lower deck, 26 24-prs.; main deck, 26 18-prs.; quarter-deck, ten 9-prs.; forecastle, two 9-prs. Her complement was 500 men.

The leading dimensions of such a ship would be about:—Tonnage, 1,374 tons; length, 159·5 ft.; breadth, 44·5 ft.; depth of hold, 19 ft.

47. Sepia drawing of a felucca and H.M.S. "Sanspareil" (1794). Received 1890. N. 1841.

This drawing, by J. T. Serres (b. 1759, d. 1825), represents a longitudinal section of a felucca, a small decked vessel in general use in the Mediterranean. Such craft have usually two masts carrying lateen sails, and there is frequently a rudder at each end.

The "Sanspareil" was an 80-gun ship, captured from the French on June 1st, 1794, and broken up at Devonport in 1842. As the sketch was made on June 24th, 1794, it probably represents the dismasted ship as she appeared on June 13th, when being towed into Portsmouth Harbour with the six other prizes.

48. Rigged model of "Le Vengeur." (Scale 1 : 64.) Received 1881. N. 1566.

This represents a French 74-gun line-of-battle ship sunk off Brest in Lord Howe's action, 1st June, 1794. The model was made of bone by prisoners of war confined in Porchester Castle in 1798.

The armament was:—Lower deck, 28 36-pr. guns; main deck, 30 18-pr. guns; quarter-deck and forecastle, 16 8-pr. guns. Her complement was 690 men.

Tonnage, 1,750 tons; length, 170 ft.; breadth, 44·5 ft.; depth of hold, 22 ft.; draught, 21·5 ft.

Weight of hull and masts, 1,437 tons; total weight of ship and stores for a six months' cruise, 3,548 tons.

49. Whole model of French three-decker. (Scale about 1 : 144.) Lent by Vaughan Pendred, Esq., 1876. N. 1419.

This model in bone was made by French prisoners during the Peninsular War of 1807–14. It represents one of the largest first-rate ships of that period, probably a similar vessel to the "Commerce de Marseilles," a 120-gun line-of-battle ship captured at Toulon in 1793, which had the following dimensions:—Tonnage, 2,747 tons; length, 208·33 ft.; breadth, 54·83 ft.; depth of hold, 25 ft. Armament:—Lower deck, 34 32-prs.; middle deck, 34 24-prs.; main deck, 34 12-prs.; quarter-deck, 14 12-prs.; forecastle, four 12-prs. Her complement was 1,100 men.

50. Rigged model of H.M.S. "Ajax." (Scale 1 : 24.) Presented by Admiral the Earl of Hardwicke, R.N., F.R.S., 1865. Plate II., No. 6. N. 1044.

This represents a 74-gun line-of-battle ship laid down at Messrs. Randall's yard, Rotherhithe, in 1795, and launched in 1798. She took part in the battle of Trafalgar, 1805, and was accidentally burnt near the Dardanelles two years later, when forming one of Sir J. Duckworth's squadron for forcing that channel. The model was constructed by Sir Joseph Sydney Yorke, Bart., between the years 1797–1808.

Her armament was:—Lower deck, 28 32-prs.; main deck, 30 24-prs.; quarter-deck, 14 9-prs.; forecastle, two 9-prs. Her complement was 540 men.

Tonnage, 1,953 tons; length, 182·25 ft.; breadth, 49·25 ft.; depth of hold, 21·25 ft.

51. Rigged model of French warship "Héros." (Scale 1 : 96.) Lent by Mrs. Scott, 1904. N. 2350.

This represents a 74-gun line-of-battle ship which was present at the battle of Trafalgar and afterwards escaped to Cadiz, where she remained several years; the model, which is made of bone, possesses considerable detail and is believed to have been the work of some of the crew. It shows the two long boats carried in a well in the waist, from which they were hoisted out by the yard tackles, a method of working which remained in general use till the adoption of derricks or davits; for many years, however, it had been usual to carry a boat in davits at the stern, as represented.

The armament was:—Lower deck, 28 36-prs,; main deck, 30 18-prs.; quarter-deck and forecastle, 16 8-prs. and on the poop six carronades, which, however, were not counted in the classification. The ship's complement was 690 men.

Tonnage, 1,680 tons; length of keel, 145 ft.; breadth, extreme, 46 ft.; depth of hold, 22 ft.

52. Built model of armed cutter. (Scale 1 : 16.) Lent by Messrs. Linton Hope & Co., 1903. N. 2339.

This is a shipbuilder's model representing the lines and details of the planking of a small armed cutter of the period 1775–1825. The vessel had a full body forward, with a sharp clean run aft, leaving practically no parallel length amidships, and was an extreme example of a general form which was popular with builders of fast sailing craft before 1845; the lines of the model also bear a close resemblance to those of the Southampton fishing "hoys" famous about 1820 for excellent sailing and sea-going qualities.

Her armament probably consisted of from 6 to 10 light guns or swivels and her principal dimensions would be:—Tonnage, b.o.m., 45 tons; length, on deck, 41 ft.; breadth, extreme, 17·5 ft.; draught, mean, 9 ft.

53. Sheer draught of H.M.S. "Endymion." (Scale 1:48.) Presented by H. Y. Powell, Esq., 1886. N. 1702.

This shows the complete lines of this frigate, built in 1797 from the lines of the French frigate "Pomone." The "Endymion" was considered to be one of the fastest vessels in the navy during the reign of George III., and was broken up in 1860.

Armament:—Although rated as a 40-gun ship, she frequently carried 46, arranged as follows: Main deck, 26 24-prs.; quarter-deck, 18 32-pr. carronades; forecastle, two 9-prs. Her complement was 320 to 350 men.

Displacement, for foreign service, 1,695 tons; displacement, for home service, 1,594 tons; length on lower deck, 159·25 ft.; length of keel, 132·3 ft.; breadth, extreme, 42 ft.; breadth, moulded, 41·3 ft.; depth of hold, 12·3 ft.; area of midship section, 510 sq. ft.

54. Rigged model of H.M.S. "Caledonia." (Scale 1 : 60.) Lent by R. F. Harvey, Esq., 1888. N. 1806.

This 120-gun three-decked line-of-battle ship, designed by Sir W. Rule, was launched at Devonport in 1808. In 1856 she became the hospital ship at Greenwich, and was renamed the "Dreadnought." When launched this vessel had a square stern, which was afterwards rounded. In her time people considered her to be the finest vessel of her class, and she was the favourite ship of Admiral Lord Exmouth.

The model shows fidded royal masts, main and forestays snaked, the lead of the mizen top-gallant and royal braces to the spanker gaff, fore and main belly stays, double martingale, three spritsail yards, the boat stowed in the waist, &c. The eight davits in the waist and on the quarters are probably modern additions to the model.

Her armament was:—Lower deck, 32 32-prs.; middle deck, 34 24-prs.; main deck, 34 18-prs.; quarter-deck, 16 12-prs.; forecastle, four 12-prs. Her complement was 875 officers and men.

Tonnage, 2,616 tons; length, 205 ft.; breadth, 54·5 ft.; depth of hold, 23·1 ft.

55. Rigged model of an English warship. (Scale 1 : 720.) Lent by Harold Burke, Esq., 1894. N. 2025.

This represents an 80-gun line-of-battle ship of the period 1795–1813. Although this model is so small, the rigging is remarkably accurate and complete, even the "snaking" of the fore and main stays being represented.

The armament was:—Lower deck, 30 32-prs.; main deck, 32 24-prs.; quarter-deck, 14 12-prs.; forecastle, four 12-prs.

The approximate dimensions of the ship were:—Burden, 2,000 tons; length, 184 ft.; breadth, 50 ft.; depth of hold, 22 ft.

56. Whole model of English frigate. (Scale 1 : 48.) Received 1885. N. 1563.

This represents a 50-gun vessel specially designed in 1813 to cope with the more powerful frigates then being introduced abroad.

Her armament was:—Main deck, 30 24-prs.; quarter deck, 16 42-pr. carronades; forecastle, two 42-pr. carronades and two 24-prs. Her complement was 480 men.

Her dimensions were approximately:—Tonnage, 1,458 tons; length, 172 ft.; breadth, 44 ft.; depth of hold, 14 ft.

57. Whole model (Scale 1 : 288) and drawing (Scale 1 : 48) of the "Duke of Kent." Presented by John Scott Tucker, Esq., 1865. N. 1052–4.

This proposed four-decked line-of-battle ship to mount 170 guns was designed by the late Mr. Joseph Tucker, Surveyor of the Navy, 1813–31. The design, prepared in 1809, contained the following improvements, many of which were afterwards adopted by Sir W. Symonds, viz.: A round bow, an oval or elliptical stern; hawseholes in the middle deck; quarter ports for guns on each deck; vertical stern post; round rudder head; reduced rake of stern; a greater proportional breadth of beam; greater rise in floor timbers; greater elevation of ports from water line; greater height between decks; greater weight of armament.

Proposed armament:—Lower deck, 36 32-prs.; lower middle deck, 36 32-prs.; middle deck, 36 24-prs.; upper deck, 38 18-prs.; quarter-deck, ten 12-prs. and six 32-pr. carronades; forecastle, four 12-prs. and four 32-pr. carronades.

The model of this proposed vessel has its lower masts and bowsprit stepped and a midship transverse frame (scale 1 : 24) is also shown.

The leading dimensions of the proposed ship were:—Burden, 3,700 tons; length of gun-deck, 221·5 ft.; length of keel for tonnage, 178·7 ft.; breadth, extreme, 62·4 ft.; breadth, moulded, 61·6 ft.; depth of hold, 26 ft.

58. Built and rigged model of H.M.S. "Ariadne." (Scale 1 : 24.) Presented by Sir D. H. Macfarlane, 1883. N. 1594.

This sailing frigate was built at Portsmouth in 1816, and sold out of the service in 1841. The model is believed to have been constructed and rigged under the supervision of Captain Marryat (the novelist), who commanded the vessel in 1828–30. It shows the main deck with its complete battery, the flush upper deck with its hammock nettings, and 20 carronades; these small guns were not, however, counted in a ship's armament until 1817.

Armament:—Main deck, 20 32-prs., six 18-prs., and two 9-prs.; upper deck, 20 32-pr. carronades. Complement, about 180 men.

Tonnage, 511 tons; length, 121·6 ft.; breadth, 31·3 ft.; depth of hold, 12 ft.

59. Rigged model of 120-gun ship. (Scale 1 : 120.) Lent by H. Edenborough, Esq., 1901. N. 2265.

This represents a line-of-battle ship of the first rate at the commencement of the 19th century, a class of which only four were constructed in England between 1808 and 1827. The model probably represents the "Prince Regent," launched at Chatham in 1823; another of the four was the "Caledonia" (*see* No. 54).

The rigging of the model is very complete and shows fidded royal masts, snaked fore and main stays, and sprit and sprit topsail yards in position; also the arrangements for working the boats. The whole of the hull of the model is built, and the bottom is coppered; the bow has the square forecastle, which prevailed for many years and was only abandoned when it was discovered that the flat surfaces were penetrated by grape shot more readily than the rounded bow.

The armament was:—Lower deck, 32 32-prs.; middle deck, 34 24-prs.; main deck, 34 18-prs.; quarter-deck, 16 12-prs.; forecastle, four 12-prs. Complement, 875 men.

Tonnage, 2,602 tons; length on gun deck, 205 ft.; length on keel, 170·9 ft.; breadth, extreme, 58 ft.; depth of hold, 23·16 ft.

60. Built and rigged model of a Revenue cutter. (Scale 1 : 32.) Received 1877. N. 1482.

This belongs to the period 1810–30, but the anchor, compass, davits, boats, and after skylight are later additions. She carries 14 guns and 4 swivels.

Tonnage, 130 tons; length, 85 ft.; breadth, 24 ft.; depth, 13·3 ft.; draught, 11 ft.

61. Rigged model of Service yacht. (Scale 1 : 48.) Presented by J. J. Miller, Esq., 1894. N. 2030.

This represents a class of cutter used by the Admiralty about 1830 for harbour service, as tenders to the flag ships; similar vessels were also used in the Customs service. They usually carried a mainsail, foresail, jib, and gaff topsail; also a yard for spreading a square sail when running before the wind. The model was rigged in the Museum in 1902.

The approximate dimensions were:—Tonnage (b.o.m.), 135 tons; length of keel, 68 ft.; breadth, 20 ft.; depth of hold, 8 ft.

62. Rigged model of H.M.S. "Vanguard." (Scale 1 : 48.) Received 1889. Plate II., No. 7. N. 1822.

This 80-gun, two-decked vessel, built at Pembroke in 1835, was the first line-of-battle ship constructed from the designs of Sir W. Symonds.

Owing to the removal of some of the limitations that had been placed upon the dimensions of vessels of the various rates, the "Vanguard" was made broader in proportion to her length than any of her predecessors, and was also given finer lines and more angular sections below the water-line. These special features are, however, more clearly illustrated by the adjacent models of the "Albion" and the "Fantôme," by the same designer. She took part in the experimental trips of H.M. ships in 1836–46, and showed comparatively good speed and handiness under sail, but had a tendency to pitch in a head sea and to roll deeply when before the wind.

The model is built throughout and copper fastened; it was rigged in the Museum in 1903 in accordance with the table of standard dimensions for masts and yards prepared by Sir W. Symonds. Adjacent to it is represented the temporary cradle and ground-ways used in launching such a vessel.

The "Vanguard" carried 650 men, and her armament consisted of:—Lower deck, 20 32-prs. and eight 8-in. guns; main deck, 24 32-prs. and four 8-in. guns; quarter deck and forecastle, 24 32-prs.

Tonnage (b.o.m.), 2,609 tons; length on lower deck, 190 ft.; breadth, extreme, 57 ft.

63. Rigged model of H.M.S. "Fantôme." (Scale 1 : 39.) Received 1888. Plate II., No. 8. N. 1809.

This brig-rigged sloop-of-war was launched at Chatham in 1839, and sold out of the Navy in 1865. She was designed by Sir William Symonds.

who gave her the finer lines and steeper floors which he introduced into the underwater form of British war vessels. At about the same time 13 similar war brigs were also constructed.

This model was masted and rigged in the Museum in 1902–3, the masts, yards, &c., being made in accordance with the dimensions established by Sir W. Symonds in 1836.

The armament of the "Fantôme" consisted of four 32-prs. and twelve 32-pr. carronades, and her complement was 130 men.

Tonnage (b.o.m.). 485 tons; length, on deck, 105 ft.; breadth, extreme 33·5 ft.; depth, 14·8 ft.

64. Whole model of H.M.S. "Albion." (Scale 1 : 48.) Received 1894. N. 2042.

This was a 90-gun sailing line-of-battle ship, designed by Sir W. Symonds, and launched at Devonport in 1842. She took part in the bombardment of Sebastopol in 1854, where she suffered most severely. In 1861 she was converted into a screw ship.

Her armament was:—Lower deck, 28 32-pr. 56 cwt. guns and four 68-pr. 112 cwt. guns; main deck, 26 32-pr. 56 cwt. guns and six 8-in. 65 cwt. guns; quarter-deck, 16 32-pr. 42 cwt. guns and two 8-in. 52 cwt. guns; forecastle, eight 32-pr. 42 cwt. guns. Her complement was 820 men.

Tonnage, 3,111 tons; length, 204 ft.; breadth, 60 ft.; draught, 18·75 ft.

65. Whole models of sailing corvettes. (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1276–7.

These vessels are designed on Mr. Scott Russell's "wave principle," but have the following features advocated by Admiral E. G. Fishbourne in 1845 as desirable in a sailing ship-of-war:—The buttock lines are continuous curves, to minimise pitching; with the same object, a fine bow and a full after-body are provided. To promote steady steering there is a long run of perpendicular side, a long keel, a lean fore-foot, and a fine heel, while to insure powerful action of the rudder the draught of water is greatest aft; the floor rises aft from the midship section.

Length on load water-line, 124 or 130 ft.; breadth, extreme, 31 ft.; depth at side, 16 ft.

66. Half block model of H.M.S. "Recruit." (Scale 1 : 48.) Received 1899. N. 2185.

This 12-gun brig was built of iron in 1846 at Blackwall by Messrs. Ditchburn & Mare, and is interesting as being the first iron-built fighting ship constructed for the British Navy.

She was designed to compete with a number of wooden brigs of the same rating then under construction, but so strong was the prejudice against the use of iron for war-vessels that the intended trials were never made, and the "Recruit" was eventually sold out of the Service.

Although the new material was meanwhile adopted in troopships, floating batteries, &c., it was not till 15 years later that iron construction became general for battleships.

The principal dimensions were:—Length on keel, 114·4 ft.; breadth, 30·6 ft.; draught, 12·5 ft.; tonnage (b.o.m.), 462 tons.

67. Water-colour drawing of a frigate and a Revenue cutter. Painted and presented by W. F. Settle, Esq., 1890. N. 1674.

The frigate is a 50-gun wooden vessel of the type constructed about 1850. It is represented under double-reefed topsails, foresail, jib, and spanker, with the wind on her beam in a heavy sea. The cutter is running before the wind with her jib and a square sail set.

68. Whole model of an armed schooner. (Scale 1 : 48.) Received 1907. N. 2443.

This represents a small fast schooner, dated about 1850, fitted to carry an armament of 18 light guns.

Her approximate dimensions were:—Tonnage (b.o.m.), 100 tons; length of keel, 68 ft.; breadth, extreme, 19 ft.; draught, mean, 8 ft.

69. Lithograph of H.M.S. "St. George." Received 1910. N. 2538.

This lithograph by T. G. Dutton from a painting by W. H. Harvey, R.N., represents the sailing three-decker "St. George" of 120 guns, as commissioned for service with the Baltic Fleet in the operations against Russia in 1854.

The vessel was built of wood at Devonport about 1840 from the designs of Sir W. Rule and had the following dimensions:—Burden, 2,710 tons; length, gun deck, 206 ft.; breadth, 54·6 ft.; depth, 23 ft.

In 1859 she was converted to a screw-propelled two-decker carrying, at first, 91 guns and afterwards 72 guns. She was removed from active service in 1869.

70. Lithograph of mortar boats in action. Received 1905. N. 2397.

This shows the early mortar boats "Firm," "Flamer," and "Hardy" engaging the Quarantine Battery, Sebastopol, on August 15th, 1855.

At the outbreak of the Russian War, in 1854, a number of these small shallow-draught vessels were rapidly built by various shipbuilders in the United Kingdom, to the order of the British Admiralty, for operations against land batteries in the Baltic and Black Seas. They each carried amidships a single 13-in. mortar, weighing about 5 tons and throwing a 200 lb. shell; they were usually towed into action by steamers, but were cutter or yawl rigged for independent manœuvring if necessary.

Their approximate dimensions were:—Tonnage (b.o.m.), 100 tons; length, 60 ft.; breadth, 20 ft.; depth, 6·5 ft.; draught, 3 ft.

STEAM-PROPELLED SHIPS-OF-WAR.

71. Aquatint of H.M.S. "Terrible." Woodcroft Bequest, 1903. N. 2313.

This paddle-wheel frigate, built of wood at Deptford in 1845, from the designs of Mr. Oliver Lang, was, when first commissioned, one of the most powerful steam war-vessels in the world. During the Crimean War she took part in the operations around Sebastopol, and by her excellent steaming qualities was enabled to weather the disastrous gale in the Black Sea in 1854. In 1869 she assisted in towing the first Bermuda floating dock (*see* No. 734) across the Atlantic.

The hull of the "Terrible" was specially constructed to resist the stresses of her heavy armament and machinery, the timbers of the ship's sides being so closely fitted and combined as to form a complete watertight body before the external planking was added.

She was propelled by a set of direct acting engines of the twin cylinder type, similar to those of the "Devastation" (*see* No. 808), made by Messrs. Maudslay, Sons and Field; there were altogether four cylinders 72 in. diam. by 96 in. stroke, and the paddle-wheels were 34 ft. diam. with floats 13 ft. wide by 2·6 ft. deep. Steam at 15 lb. pressure was supplied by four double-ended tubular boilers of box form, each with 6 furnaces. The engines made 16 revs. per min., indicated about 2,000 h.p., and gave the vessel a speed of 10·9 knots.

The original armament of 20 guns consisted of four 56-prs. (Monk's) and four 68-prs. on each deck, together with three 12-prs. and a field piece.

Length (b.p.), 226 ft.; breadth inside paddles, 42·5 ft.; depth in hold, 27 ft.; burden (o.m.), 1,847 tons; displacement, 3,189 tons.

72. Rigged model of a paddle frigate. (Scale 1 : 48.) Made and bequeathed by Elisha Davis, Esq., 1910. N. 2544.

This represents a steam frigate typical of the larger war-steamers built about 1840 for British and foreign navies before the adoption of screw-propulsion.

Her armament of 32 guns, probably 68-prs., is carried on two decks, and includes two more powerful guns, on slides and traversing carriages, one at each end of the vessel on the upper deck. She shows a single telescopic funnel, and carries two special flat-bottomed boats as covers to her paddle-boxes. She is fully rigged, for cruising under sail alone.

Approximate dimensions:—Burden, 1,400 tons; length, 210 ft.; breadth, between paddles, 40 ft.

This class of vessel was generally constructed of oak frames and teak planking. Side-lever engines with flue boilers were largely fitted to the earlier examples, while direct-acting engines and tubular boilers became more common in later ships. Steam pressures were from 6 lb. to 15 lb., and the speeds varied from 7 to 12 knots with 500 to 1,000 indicated h.p.

73. Rigged model of H.M.S. "Highflyer." (Scale 1 : 48.) Received 1902. Plate III., No. 1. N. 2291.

This ship-rigged wooden corvette was built by Messrs. Mare & Co. at Blackwall in 1850–1 from the designs of the Admiralty. She had two complete decks and a short forecastle, and her lines were full at bow and stern with but little rise of floor amidships. The guns were carried on the upper deck, while the spaces between the decks were well ventilated through a number of rectangular openings in the ship's side.

The "Highflyer" was one of the first warships fitted with a lifting screw, and the model shows how this was carried out and the method in which the wooden stern and rudder post were strengthened, by the addition of metal strips and knees, against the stresses resulting from the working of the screw propeller. The engines were of horizontal type, made by Messrs. Maudslay, Sons and Field, and, during the trials on the Thames in 1852, indicated 770 h.p. with a boiler pressure of 14 lb. and gave a speed of 9·4 knots.

The original armament consisted of a 10-in. pivot gun forward, and 20 8-in. guns on the broadside; the complement was 220 men.

Displacement, 1,775 tons; tonnage (b.o.m.), 1,153 tons; length, 192 ft.; breadth, 36·4 ft.; depth, 22·7 ft.; mean draught, 16·5 ft.

74. Whole model and drawing of gun-boats "Nix" and "Salamander." (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1230–1.

These two paddle-wheel gun-boats were built and engined in 1851, by Messrs. Robinson and Russell, for the Prussian Government. During the Crimean War they were obtained by the English Government, in exchange for the 36-gun frigate "Thetis," and under the names "Recruit" and "Weser" were actively engaged.

They were double-ended and could go either end foremost, while their load draught with coals for 2,000 miles was only 7 ft.

The engines were of the oscillating condensing type, with two cylinders 48 in. diam. by 54 in. stroke, and at 33 revs. per min. indicated 754 h.p.

Steam at 15 lb. pressure was supplied by four tubular boilers, 14 ft. long, 8 ft. wide, and 6·5 ft. high, with a total grate area of 126 sq. ft. The weight of the engines, boilers and water was 124 tons, and the coal bunker capacity was 160 tons.

The paddle-wheels were 17 ft. diam. and had fixed floats 7 ft. by 2 ft. There were two masts and a sail area of 415 sq. yds. The speed was 11·6 knots.

Load displacement, 468 tons; tonnage (b.m.), 540 tons; gross register, 334 tons; length on load water line, 178 ft.; breadth, extreme, 26 ft.; depth at side, 10·6 ft.; draught, loaded, 7 ft.; immersed midship section, 175 sq. ft.

75. Whole model and drawings of paddle frigate "Dantzig." (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1227–9.

This wooden vessel was built and engined by Messrs. Robinson and Russell, at Millwall, about 1851, for the Prussian Navy.

Her principal feature was the arrangement, patented by Mr. Russell in 1850, by which a paddle steamer was enabled to carry a larger armament than usual, guns being placed on the sponsons in positions usually occupied by deck houses. The bulwarks spread out at the sponsons, thereby increasing the deck space, on which the guns could be readily moved; at each sponson was a gun, two firing forward and two aft.

Tonnage (b.m.), 1,280 tons; length on deck, 230 ft.; breadth, extreme, 34·33 ft.; depth in engine-room, 20·25 ft.; mean draught, 15 ft.; diameter of paddle-wheels, 24·33 ft.

76. Lithograph of H.M.S. "Agamemnon." Received 1905. N. 2396.

This second-rate line-of-battle ship was built of wood at Woolwich, from the designs of Mr. J. Edye, Acting Surveyor of the Navy, and was launched in 1852. She was the first screw line-of-battle ship designed for the British Navy, and as the flagship of Rear-Admiral Sir E. Lyons, G.C.B., took part in the combined land and sea attack on Sebastopol. In 1857–8 she was employed in conjunction with the U.S. frigate "Niagara" in laying the first Atlantic telegraph cable.

She had horizontal trunk engines, made by Messrs. John Penn and Son, with two cylinders 70 and 75 in. diam., by 42-in. stroke, indicating 1,839 h.p., and driving a propeller 18 ft. diam., 3·3 ft. long, and 20·5 ft. pitch, which, at 60 revs. per min., gave a speed of 11 knots.

Armament:—Lower deck, 36 8-in. guns, 65 cwt.; main deck, 34 32-prs., 56 cwt.; upper deck, three 8-in., 95 cwt.; upper deck, ten 18-in., 85 cwt.

The complement was 820 men.

Displacement, 3,750 tons; burden, 3,102 tons; length, 230 ft.; breadth, 55·5 ft.; depth, 24·5 ft.; draught of water aft, 20·3 ft., forward, 17·6 ft.

77. Rigged model of H.M.S. "Himalaya." (Scale 1 : 48.) Lent by J. Hughes, Esq., 1888. N. 1807.

This was a ship-rigged passenger and cargo steamer, built of iron at Blackwall in 1853, for the Peninsular and Oriental Co. In 1854 she was purchased by the Government, fitted as a troopship, and employed in that capacity during the Crimean War and subsequently, but is now used as a coal hulk at Devonport.

She had six watertight bulkheads, and stowed 1,200 tons of coal. Her complement was 213 men.

The engines, by Messrs. John Penn and Son, were on the trunk system, with two cylinders, 84 in. diam. by 42-in. stroke, indicating 2,500 h.p. at 55 revs. per min. These drove a single propeller 18 ft. diam. by 28 ft. pitch, weighing 7 tons.

In 1854 she made a record passage from Gibraltar to Malta in 74·5 hours, at a mean speed of 13·5 knots.

Displacement, 4,690 tons; length, 340 ft.; breadth, 46·2 ft.; depth, 34·3 ft.; draught, 21·4 ft.

78. Lithograph of launch of H.M.S. "Royal Albert." Received 1908. N. 2506.

This lithograph, by T. G. Dutton and W. Simpson, represents the launching of H.M.S. "Royal Albert" at Woolwich Dockyard in 1854. A number of contemporary paddle steamers, sailing vessels and river craft are included in the picture.

The "Royal Albert" was designed by Mr. Oliver Lang and was laid down in 1842 as a wooden built sailing line-of-battle ship; before launching, however, she was converted into a screw steamship. Her engines were of the horizontal trunk type, made by Messrs. John Penn and Son (*see* No. 845) with cylinders equivalent in diameter to 64·25 in. by 40-in. stroke; on trial in November, 1854, with a steam pressure of 20 lb. per sq. in. and at 69 revs. per min., the engines indicated 1,800 h.p., giving the vessel a speed of 13 knots. She was fitted with a propeller 17 ft. diam. and 19 ft. pitch.

Her large armament of 131 guns was thus distributed:—Lower deck, ten 8-in. shell guns and 26 long 32-prs.; middle deck, six 8-in. guns and 30 32-prs.; main deck, 38 32-prs.; upper deck, 20 32-prs.; forecastle deck, one 68-pr.

The principal dimensions of the vessel as completed were:—Length (b.p.), 232·75 ft.; breadth, extreme, 61·5 ft.; depth, extreme, 66 ft.; depth of hold, 24·2 ft.; burden (b.o.m.), 3,726 tons; displacement, 5,571 tons.

79. Lithograph of "The Fleets Becalmed." Received 1910. N. 2535.

This lithograph, by R. Carrick and T. G. Dutton, from an original by O. W. Brierly, represents the allied British and French Fleets in the Baltic in 1854. In the foreground, getting up steam, are the following early types of British warships:—

"Blenheim," screw two-decker, of 56 guns, built at Deptford in 1813 as a 74-gun ship and converted about 1846. She was of 1,747 tons burden and had horizontal direct-acting engines, by Messrs. Seaward and Capel, giving a speed of 6·5 knots. "Majestic," screw two-decker of 80 guns, built at Pembroke in 1843–9 and converted to screw 1853. Burden, 2,590 tons; length, 190 ft.; breadth, 57 ft. "Princess Royal," screw two-decker of 91 guns, built at Portsmouth in 1841–54. She had horizontal engines, by Maudslay, Sons and Field, of 1,491 indicated h.p., giving a speed of 11 knots. Burden, 3,130 tons; length, 217 ft.; breadth, 58 ft. "Royal George," screw three-decker of 120 guns, built at Chatham in 1827–53. She had horizontal trunk engines, by John Penn and Son, giving a speed of 9·3 knots. Burden, 2,616 tons; length, 205 ft.; breadth, 54·5 ft. "Lightning," paddle despatch vessel of 3 guns. Burden, 296 tons.

80. Lithograph of "The Fleet at Anchor." Received 1910. N. 2534.

This lithograph, by T. G. Dutton, from an original by O. W. Brierly, shows a number of typical British men-of-war which took part in the operations of 1854 against Russia in the Baltic and Black Seas. The vessels are moored with their principal sails loosened for drying and their crews in the rigging preparing to furl sails; some ships' boats, employed on various duties, appear in the foreground. All the vessels shown were of wood construction; available particulars of each are given in the accompanying table:—

Name.	Type.	Guns.	Built.	Length.	Breadth.	Burden.
				Feet.	Feet.	Tons.
Duke of Wellington	Screw three-decker	131	1849–52	240·5	60·1	3,771
Queen	Sailing three-decker	116	1833–40	204·2	60	3,104
St. Jean d'Acre	Screw two-decker	101	1851–3	238	55·3	3,199
Agamemnon	Screw two-decker	91	1849–53	230	55·5	3,102
Prince Regent	Screw two-decker	90	1823	—	—	—
Ajax	Screw two-decker	58	1848	176	48·5	1,760
London	Sailing two-decker	92	1840	205·5	54·4	2,626
Imperieuse	Screw frigate	60	1850–3	212	50	2,355
Amphion	Screw frigate	36	1845	177	43·5	1,290
Encounter	Screw corvette	14	1845	190	33·1	953
Sidon	Paddle frigate	22	1845–6	208	37	1,330
Leopard	Paddle frigate	12	—	—	—	1,412
Black Eagle	Paddle auxiliary	1	1831	168	26·4	540

81. Lithographs of war-vessels (1765–1878). Received 1907.
N. 2433.

The vessels represented are :—

Name.	Type.	Launched.	Length.	Breadth.	Displacement.
			Feet.	Feet.	Tons.
Trafalgar - -	Sailing two-decker, wood	1841	206	54·6	3,850
Victoria & Albert	Wood - - -	1855	300	40	2,470
Victory - -	Sailing three-decker, wood	1765	186	52	3,800
{ Shah - -	Screw frigate, iron	1873	334·7	52	5,700
{ Huascar -	Turret-ship, iron -	1866	200	35	1,100
Duke of Wellington	Screw three-decker, wood	1852	240·5	60	6,071
Royal Alfred -	Screw frigate, wood	1864	273	59	6,000
Volage - -	Screw corvette, iron	1874	270	42	3,080
Warrior - -	Screw frigate, iron	1860	380	58	9,000
Serapis - -	Screw troopship, iron	1866	370	49	6,211
Narcissus - -	Screw frigate, wood	1859	228	51·2	3,548
Bellerophon -	Central battery, iron	1866	300	56	7,550
Iron Duke -	Central battery, iron	1871	280	54	6,010
Minotaur - -	Screw frigate, iron	1867	400	59·4	10,700
Agincourt - -	Screw frigate, iron	1868	400	59·4	10,600
Hercules - -	Central battery, iron	1868	325	59	8,500
Captain - -	Turret-ship, iron -	1869	320	53	6,950
Neptune - -	Turret-ship, iron -	1878	300	63	9,310
{ Excellent -	Sailing three-decker, wood	1810	190	52·3	3,994
{ Calcutta -	Sailing two-decker, wood	1831	196·5	51·5	2,590
{ Vernon - -	Sailing frigate, wood	1832	176	52·7	2,388
Glatton - -	Turret-ship, iron -	1872	245	54	4,910
Inconstant -	Screw frigate, iron	1868	337·3	50·25	5,780

82. Drawing of H.M.S. "Marlborough." (Scale 1 : 48.) Maudslay Collection, 1900. N. 2251.

The "Marlborough" was a wooden line-of-battle ship of 131 guns, designed by the Admiralty and laid down in 1850 at Portsmouth as a sailing vessel, but converted for auxiliary screw propulsion in 1852 and launched in 1855.

The engines, by Messrs. Maudslay, Sons & Field, were of the return connecting-rod type with two cylinders 82 in. diam. by 48 in. stroke (*see* No. 834). With a boiler pressure of 20 lb. they made 57·5 revs. per minute and indicated about 3,000 h.p., which gave the vessel a speed of 11·2 knots; the slip of the screw was 21·8 per cent. The screw was 19 ft. diam., 25·3 ft. pitch, and 3·5 ft. long, with two blades, and was arranged for being lifted when not in use.

Her armament was :—Lower deck, ten 8-in. guns and 26 32-prs.; middle deck, six 8-in. and 30 32-prs.; main deck, 38 32-prs.; upper deck, 20 32-prs. and one 68-pr. Her complement was 1,100 men.

Displacement, 6,050 tons; length, 245·5 ft.; breadth, 61·2 ft.; depth, 25·8 ft.; draught, mean, 26·3 ft.

83. Whole models of gun-boats "Bann" and "Brune." (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1862. N. 897.

These small paddle-wheel gun-boats were built by Messrs. Russell & Co. in 1856, as improvements on the "Nix" and "Salamander" (*see* No. 74), which were found to be too limited in accommodation. Additional room was obtained by adopting the usual form of stern while retaining the facilities for going in either direction. They were, however, of smaller size, and had a load draught of only 4 ft., with coal sufficient for 800 miles.

They were constructed on the longitudinal system and with "wave-lines." Bulkheads separated the coal bunkers on the sides from the engine and boiler rooms, and these bulkheads were united at the top by a continuous covering plate, so that each side of the ship was a complete box girder.

The engines were of the angular oscillating condensing type, with two cylinders 40 in. diam. by 42 in. stroke, working on a single crank; when making 36 revs. per min. they indicated 364 h.p.

Steam at 20 lb. pressure was supplied by two tubular boilers, 15 ft. long, 6·8 ft. wide, and 7 ft. high, having a total grate area of 72 sq. ft. and 1,616 sq. ft. of heating surface. The weight of the boilers was 10·15 tons and of the water in them 24 tons.

The paddle-wheels were 13 ft. diam., and each had 14 fixed floats 6·5 ft. by 1·5 ft. There were also three pole masts, with fore and aft sails having a total area of 240 sq. yds.

Load displacement, 193 tons; tonnage (b.m.), 267 tons; length, on load water line, 140 ft.; breadth, extreme, 20 ft.; depth at side, 8·5 ft.; draught of water, laden, 4 ft.; immersed midship section, 75·76 sq. ft.

84. Rigged model of H.M.S. "Racoon." (Scale 1 : 64.) Lent by H.R.H. the Duke of Saxe-Coburg-Gotha, K.G., 1865. N. 1064.

This ship-rigged spar-decked corvette was built of wood, and launched at Chatham in 1857, to the designs of Sir Baldwin Walker.

The engines were of 400 h.p., and drove a single screw.

The armament was:—Main deck, 20 8-in. guns, weighing 60 cwt.; upper deck, two 68-pr. guns, weighing 95 cwt.; ship's complement, 280 men.

Burden, 1,467 tons; length, 200 ft.; breadth, 40·3 ft.; depth, 22·6 ft.

85. Water-colour drawing of H.M.S. "Victoria." (1859.) Presented by C. L. Pickering, Esq., 1895. N. 2070.

This represents H.M.S. "Victoria," the last and finest line-of-battle ship constructed of wood for the British Navy. She was a 121-gun three-decker, launched at Portsmouth in 1859, commissioned in 1864, and discarded in 1867, after having served as flagship in the Mediterranean.

The picture, painted by Mr. Pickering in 1860, shows a general view of the ship, together with an enlarged detailed view of the bow. She was built for screw propulsion, and her engines, which were of the horizontal return-connecting-rod type, by Maudslay, indicated 4,400 h.p.; the boilers supplied steam at 22 lb. pressure, and the speed attained was 12 knots.

Her armament was:—Lower deck, 32 8-in. guns; middle deck, 32 32-prs.; main deck, 34 32-prs.; upper deck, 22 32-prs., one 68-pr.; and her complement was 1,130 men.

Length, over all, 300 ft.; length between perpendiculars, 260 ft.; breadth, extreme, 60·08 ft.; breadth, moulded, 58·4 ft.; depth of hold, 26·8 ft.; tonnage, 4,126 tons.

86. Whole model of a proposed warship. (Scale 1 : 96.) Contributed by Messrs. Westwood and Baillie, 1865. N. 1076.

This design was submitted to the Admiralty in 1862 by Messrs. Westwood and Baillie. It shows a broadside battery, supplemented by a number of fixed semi-circular towers, each provided with three ports which permit a single gun, pivoted within, being trained through a considerable angle. Direct fore-and-aft fire is obtained through ports in the bow and stern.

Length (b.p.), 365 ft.; breadth, 60 ft.; draught, 22·5 ft.; displacement, 8,000 tons; armament, 22 guns.

87. Half block model of a corvette of the "Alabama" class. (Scale 1 : 64.) Designed and lent by Geo. Turner, Esq., 1864. N. 1035.

The "Alabama" was built at Messrs. Laird's yard, Birkenhead, and launched on the 15th May, 1862. She left Liverpool on the 29th May, proceeding to the Azores, and remained at Terceira until the arrival of a vessel from London, having on board six guns, ammunition, coals, &c. for her. Two days after, the screw steamer "Bahama" arrived, having on board Capt. Raphael Semmes, of the Confederate Navy, and other officers, besides two more guns. The transfer of the guns and stores having been completed, the "Alabama" (now first known by that name) sailed from Terceira on August 24th, 1862, with 26 officers and 85 men. Her escape cost the British nation 3,000,000*l.* in 1873.

She was a wooden-built, three-masted, barque-rigged screw steamer. Her engines were horizontal, of 300 nominal h.p., and she stowed 350 tons of coal. Her speed under steam was 12 to 13 knots, and under steam and sail 15 knots. The armament was six 32-prs. on the broadside, and two pivot guns amidships, one of them being a 100-pr. Blakeley.

Register, 1,040 tons; length, 220 ft.; breadth, 32 ft.; depth, 17 feet.

She was sunk in action off Cherbourg on June 19th, 1864, by the U.S.S. "Kearsarge."

88. Whole model of the cruiser "Shenandoah." (Scale 1 : 48.) Lent by John Jones, Esq., 1896. N. 2091.

This represents the composite-built, full-rigged clipper ship "Sea King," built at Glasgow in 1863 for the China trade. She had an auxiliary screw, which could be lifted when the wind was favourable, and made the passage home from Shanghai in 79 days, including five days employed in coaling.

The vessel was afterwards purchased by agents of the Confederate States of America, who sent her to sea armed as a privateer, when she soon became notorious as the cruiser "Shenandoah." During the American war (1860–64) she destroyed 37 ships of the Northern States, chiefly whalers, causing the price of sperm oil to rise from 70*l.* to 120*l.* per ton; in November, 1865, she proceeded to Liverpool to surrender, and was handed over to the United States. She carried a crew of 133 men.

Her engines were of 200 nominal h.p.; register tonnage, 1,018 tons; length, 220 ft.; breadth, 32·5 ft.; depth, 20·5 ft.

89. Lithograph of U.S. ironclad "Dictator." Presented by J. Ericsson, Esq., 1865. N. 705.

This early ironclad ram of the "Monitor" type was built in 1863, during the American Civil War, at the Delamater Iron Works, U.S.A., from the design of Mr. Ericsson. Her frames were of iron, and the wooden skin was 3·5 ft. thick. Her sides were protected by 11 in. of iron, 5 in. of which were solid bars 5 in. by 3 in., and the rest in single 1-in. plates; the deck was plated with 1·5 in. of iron. A solid ram, built up of oak and iron, projected 22 ft. beyond the bow, and there was a single turret 24 ft. inside diam., protected by 15 in. of iron in plates 1 in. thick, the whole weighing 500 tons.

She was propelled by an Ericsson vibrating lever-engine, with two cylinders 100 in. diam., by 48-in. stroke, indicating 5,000 h.p. The screw was 21·5 ft. diam., by 34 ft. pitch, and was in a single casting weighing 17·4 tons.

Steam was supplied by six boilers, with 56 furnaces, a grate area of 1,120 sq. ft., and a heating surface of 34,000 sq. ft. The speed attained was 8·3 knots, while the coal consumption at full speed was 7·3 tons per hour.

The armament consisted of two smooth-bore 15-in. Ericsson guns, throwing a spherical shot weighing 460 lb., propelled by a charge of 80 lb. of powder.

Tonnage, 3,033 tons; length, 320 ft.; breadth, 50 ft.; depth of hold, 22 ft.; draught of water, 20 ft.

90. Whole model of H.M.S. "Helicon." (Scale 1 : 48.) Received 1901. N. 2273.

This paddle steamer was built of wood at Portsmouth, in 1861-65, as a despatch vessel, but after serving in this capacity for some years she was, in 1885, converted into an Admiralty yacht and renamed "Enchantress."

For many years prior to the building of the "Helicon" it had been contended that a projecting cutwater, or "plough bow," was conducive to speed, and it was with the object of settling this question that Sir E. J. Reed decided to experiment upon the two identical vessels, "Helicon" and "Salamis," then under construction. He accordingly had the forebody of "Helicon" remodelled, by removing the overhanging head-knee and rails, giving it fuller sections forward, and extending the cutwater 5 ft. at about the water line till the lines shown in the model were arrived at. The lines of "Salamis" were not altered, and both ships were fitted with engines, made from the same patterns, by Messrs. Ravenhill, Salkeld & Co., and having a pair of oscillating cylinders, 61 in. diam. by 54-in. stroke, driving paddle-wheels 20·5 ft. diam. During 1865 a number of trials were made with the two vessels, with the result that "Helicon" proved to be from 1 to 1·5 knots faster and to pitch less than "Salamis," but her success was generally conceded to be partly due to her additional length of water line and increased buoyancy forward.

Both the British and French Admiralties adopted the "plough" bow in their early ironclads, and in later French warships a prolongation of the bow just below the water line was combined with the ram. At the time of the trials, the engines of "Helicon" indicated 1,610 h.p., and gave her a speed of 14·5 knots.

Displacement, 945 tons; length (b.p.), 220 ft.; breadth, 28·2 ft.; draught, mean, 10·1 ft.

A photograph of the vessel is also shown.

91. Water colour drawing of H.M.S. "Bellerophon," by W. Mitchell, 1873. Received 1899. N. 2197.

This iron-built armoured frigate was designed by Sir E. J. Reed in 1863 and completed for sea three years later. She was 80 ft. shorter than the "Warrior" of 1861, and 100 ft. shorter than the "Minotaur" of 1867, which was, however, an earlier design; as regards protection, cost, and handiness, she was a great advance upon both of these earlier types.

She was ship-rigged and had two telescopic funnels; the lower masts were built of iron, while most of the smaller spars were of steel. The hull was protected by a complete water-line belt of 6-in. armour, and there was a central battery, with its deck 9 ft. above the water-line, protected by similar armour and terminal bulkheads 5 in. thick; the conning tower was armoured with 8-in. plates.

This vessel was one of the first built with the projecting spur ram; she was fitted with the Stanhope balanced rudder, while her internal construction embodied several important departures from previous practice (*see* No. 659).

She was propelled by a set of horizontal direct-acting trunk engines, constructed by Messrs. J. Penn and Son at Greenwich; with a boiler pressure of 26 lb. they indicated 6,048 h.p., and with a two-bladed Griffiths screw gave a speed of 14·2 knots. During some light-draught trials with a four-bladed propeller, "negative slip" was obtained, the speed of the ship being 13 per cent. in excess of that deduced from the pitch of the screw. She carried 600 tons of coal and had a steaming radius of 2,000 nautical miles at medium speed.

Her original main armament consisted of ten 12-ton M.L.R. guns in the citadel and several 6·5-ton guns for fore-and-aft fire, but this was subsequently improved and Q.F. guns added.

Displacement, 7,550 tons; length, 300 ft.; breadth, 56 ft.; draught, 26·6 ft.

92. Lithographs of war-vessels launched at Blackwall (1860–96). Received 1907. N. 2434.

The following table gives particulars of the vessels represented:—

Name.	Type.	Navy.	Date.	Length.	Breadth.	Displacement.
				Feet.	Feet.	Tons.
Warrior - -	Screw frigate, iron	British	1860	380	58	9,000
Minotaur - -	Screw frigate, iron	British	1867	400	59·4	10,700
Victoria - -	Screw frigate, iron	Spanish	1865	318	55·9	7,250
König Wilhelm	Screw frigate, iron	German	1868	355	60	9,757
King George -	Central battery, iron	Greek	1867	200	32·9	1,774
Avni Illah -	Central battery, iron	Turkish	1869	226·3	36	2,400
Messoudiye -	Central battery, iron	Turkish	1874	331·4	59	9,120
Vasco da Gama	Central battery, iron	Portuguese	1876	200	40	2,479
Blenheim -	Cruiser, steel -	British	1890	375	65	9,000
Benbow - -	Battleship, steel -	British	1888	330	68·5	10,600
Sanspareil -	Battleship, steel -	British	1889	340	70	10,470
Grafton - -	Cruiser, steel -	British	1892	360	60	7,350
Fuji - -	Battleship, steel -	Japanese	1896	374	73	12,320

93. Rigged model of Turkish frigates "Osmanea," "Azizea," and "Orkhanea." (Scale 1 : 48.) Presented by Messrs. R. Napier and Sons, 1867. Plate III., No. 2. N. 1168.

These three armour-clad frigates were built of iron at Glasgow in 1864–66. The side armour is 5·25 in. and 4 in. thick.

The engines have two cylinders 92 in. diam., by 48-in. stroke, indicate 2,600 h.p., and give a speed of 12 knots; the propeller is 20 ft. diam., and 28·5 ft. pitch. Capacity of coal bunkers, 750 tons.

The armament originally intended was to have been 42 guns, but this was altered and the vessels were converted into barbette ships. The ship's complement was 600 men.

Displacement, 6,450 tons; length, 293 ft.; breadth, 56 ft.; depth of hold, 24·8 ft.; draught, 25·6 ft.

A photograph, N. 1311, is also exhibited.

94. Whole models of proposed warships. (Scale 1 : 48.) Lent by Geo. Turner, Esq., 1864. N. 1032–4.

These designs for three classes of warships were prepared by Mr. Turner, of Woolwich Dockyard. Each provides a central main battery, with sloping sides; while a fore-and-aft fire is given by guns at the height of the spar deck, behind a transverse semi-circular shield at each end of the broadside battery. The arrangement has to some extent been incorporated in several war-vessels of later date.

(*a*) represents a vessel of the following dimensions:—Length (b.p.), 444 ft.; breadth, 66 ft.; draught, 27 ft.; displacement, 13,000 tons; armament, 34 heavy guns.

(*b*) has a "ram" bow, and has the following dimensions:—Length (b.p.), 330 ft.; breadth, 64 ft.; draught, 27 ft.; displacement, 9,000 tons; armament, 22 heavy guns.

(*c*) has a "ram" bow; the dimensions are:—Length (b.p.), 210 ft.; breadth, 40 ft.; draught, 25 ft.; displacement, 3,000 tons; armament, eight heavy guns.

95. Whole model of Brazilian gunboats "Colombo" and "Cabral." (Scale 1 : 48.) Presented by J. K. Rennie, Esq., 1893. N. 1410.

These twin-screw armoured gunboats were built of iron at Greenwich in 1866 by Messrs. J. and G. Rennie, to the order of the Brazilian Government. They are constructed with central batteries, and can fire two guns right ahead, two right astern, or four on the broadside.

Their speed was 10 knots, and armament four 68-pr. 95-cwt. guns. When leaving England for Brazil their ends were housed over as far as the batteries to fit them for the ocean voyage.

Tonnage (b.o.m.), 858 tons; length, 160 ft.; breadth, 34 ft.; depth, 17 ft.

96. Rigged model of H.M.S. "Northumberland." (Scale 1 : 24.) Contributed by the Millwall Iron Works and Shipbuilding Co., 1865. N. 1071.

This armoured first-class cruiser was built of iron at Millwall in 1865, and completed in 1868, from designs prepared by the Admiralty. The model, which represents the ship with three masts and 58 guns, was made before the masting and the armament were settled; on launching she had five masts and 28 guns. She was re-boilered and her armament increased in 1895, but is now a depôt hulk.

The engines are represented by a separate model (*see* No. 845.).

Her armour is 5·5 in. thick, with 9-in. teak backing. The armament on launching was:—On the main deck, four 12-ton 9-in. M.L.R. guns and 22 9-ton 8-in. M.L.R. guns; on the upper deck, two 6·5-ton 7-in. B.L.R. guns. Ship's complement, 701 men.

The "Northumberland" was the first vessel in the Navy fitted with Mr. Macfarlane Gray's steam steering gear, which was originally invented for the "Great Eastern." She has two sisters, the "Agincourt" and "Minotaur" (*see* prints, No. 81).

Displacement, 10,780 tons; length, 400·25 ft.; breadth, 59·3 ft.; depth of hold, 21·08 ft.; draught, 27·25 ft.

97. Photograph of H.M.S. "Malabar." Presented by Messrs. R. Napier and Sons, 1869. N. 1311.

This barque-rigged screw-propelled troopship was built of iron at Glasgow in 1867 by Messrs. R. Napier and Sons, from designs prepared by the Admiralty. She was one of the five troopers built expressly for the conveyance of soldiers between England and India. On the discontinuance of this service she was sent to Bermuda as a receiving ship.

The engines were simple, with two cylinders 94 in. diameter by 48 in. stroke, which indicated 4,890 h.p., and gave a speed of 13 knots. The coal bunker capacity was 1,254 tons. The ordinary trooping capacity was 1,200 men.

Displacement, 6,211 tons; length, 360 ft.; breadth, 49 ft.; depth of hold, 22·3 ft.; draught of water, 20 ft.

98. Rigged model of Halsted's first-rate warship. (Scale 1 : 48.) Presented by Messrs. R. Napier and Sons, 1867.
N. 1170.

This is one of a series of models prepared for illustrating the system of warships proposed in 1866 by the late Vice-Admiral E. P. Halsted. The ships were designed by Mr. C. F. Henwood; the turrets and the tripod system of masting were arranged by Capt. Cowper Coles, R.N., while the guns were to be on Sir Joseph Whitworth's hexagonal system, mounted on muzzle pivoting carriages designed by Capt. Heathorn, R.A., and worked by the gear of Capts. Scott and Cunningham.

Admiral Halsted and his colleagues proposed the construction of a limited number of types of warship, from which any special requirements of a navy could be met, and this complete collection of models was prepared to show the type and size of the vessels which were to be their standards. It was considered that by the uniformity of arrangement and the repetition of parts thus obtainable, the cost of naval armaments would be very greatly reduced.

The leading feature of these vessels is the combination of the turret and broadside systems of gun mounting; there are, however, many other peculiarities in the scheme, the details of which have been carefully worked out, so that the designs and models give much information on the methods of construction in favour at the period.

This model of the proposed "Dreadnought" represents the highest class of battleship provided for. She was to be constructed with longitudinal and transverse frames, similar to those of H.M.S. "Achilles," "Agincourt," &c., with inner and outer skins. The space between the two skins and at the ends was to be divided into watertight cells, while armour and composite backing were to extend the whole length of the ship, reduced, however, in thickness at the ends. There were to be seven turrets, with 8 in. of iron and a heavy composite backing, while the side armour of the hull was to be of 6-in. plates similarly backed. The model shows a flying deck constructed as a girder, from which the yards were to be worked, boats stowed, &c.; the ship's rails are made to fall outwards when cleared for action. The vessel is ship-rigged, with iron tripod masts, topmasts and topgallant masts fidded abaft the lower masts, and double topsail yards. Horizontal screw engines were to be employed, and these are arranged amidships with boiler rooms before and abaft, which explains the great distance between the funnels. A single screw is provided which can be lifted when not in use.

The turrets carry 14 Whitworth 9-in. guns, and on the main deck is a battery of four 7-in. guns, and ten 4-in guns.

Tonnage (b.o.m.), 10,764 tons; length, 455 ft.; breadth, 70 ft.; depth, 28 ft.; draught, 26·5 ft.

99. Half block model of Halsted's second-rate warship. (Scale 1 : 48.) Presented by Messrs. R. Napier and Sons, 1867.
N. 1173.

This proposed "Powerful" represents a design on Vice-Admiral Halsted's system; there are six turrets with two guns in each. The ship is represented as being in a dry dock and resting on the blocks; the starboard side is complete, but the port side shows a longitudinal section of the vessel.

Displacement, 13,602 tons; tonnage (b.o.m.), 9,652 tons; length, 438·75 ft.; breadth, 67·5 ft.; depth, 28 ft.; draught, 26·6 ft.

100. Half block model of Halsted's third-rate warship. (Scale 1 : 48.) Presented by Messrs. R. Napier and Sons, 1867.
N. 1174.

This "Dauntless" resembles the proposed "Powerful" (*see* No. 99), but is smaller and has only five turrets.

Displacement, 12,100 tons; tonnage (b.o.m.), 8,618 tons; length, 422·5 ft.; breadth, 65 ft.; depth, 28 ft.; draught, 26·5 ft.

101. Half block model of Halsted's fourth-rate warship. (Scale 1 : 48). Presented by Messrs. R. Napier and Sons, 1867.
N. 1175.

This "Formidable" is a smaller modification of the proposed "Powerful" (*see* No. 99), and has only four turrets.

Displacement, 10,000 tons; tonnage (b.o.m.), 6,778 tons; length, 390 ft.; breadth, 60 ft.; depth, 26·5 ft.; draught, 25·5 ft.

102. Half block model of Halsted's fifth-rate warship. (Scale 1 : 48.) Presented by Messrs. R. Napier and Sons, 1867.
N. 1176.

"This "Defence" is a still smaller modification of the proposed "Powerful" (*see* No. 99), and has only three turrets.

Displacement, 9,100 tons; tonnage (b.o.m.), 5,906 tons; length, 373·75 ft.; breadth, 57·5 ft.; depth, 26·5 ft.; draught, 25·5 ft.

103. Rigged model of Halsted's sixth-rate warship. (Scale 1 : 48.) Presented by Messrs. R. Napier and Sons, 1867.
N. 1171.

This "Active" is a corvette combining the turret and broadside construction. The vessel is ship-rigged, with iron tripod lower masts, topmasts and topgallant masts fidded abaft the masts, and double topsail yards. She has a flying deck from which the yards, boats and anchors would be worked, and an upper deck with two turrets each armed with two Whitworth 9-in. guns, whilst on the main deck would be ten Whitworth 7-in. broadside guns.

Tonnage (b.o.m.), 4,926 tons; length, 367·5 ft.; breadth, 52·5 ft.; depth, 25 ft.; draught of water, 24·5 ft.

104. Half block model of Halsted's seventh-rate warship. (Scale 1 : 48.) Presented by Messrs. R. Napier and Sons, 1867.
N. 1177.

The "Vigilant" was to have two turrets with two guns in each, and a small broadside armament.

Displacement, 7,400 tons; tonnage (b.o.m.), 4,615 tons; length, 346·25 ft.; breadth, 52·5 ft.; depth, 25 ft.; draught, 24·5 ft.

105. Whole model of Halsted's eighth-rate warship. (Scale 1 : 48.) Presented by Messrs. R. Napier and Sons, 1867.
N. 1172.

This "Vedette" was to have a single turret containing two Whitworth 9-in. guns, and on her main deck ten Whitworth 5·5 in. guns; she was to be used as a despatch vessel.

Displacement, 5,700 tons; tonnage (b.o.m.), 3,648 tons; length, 332·5 ft.; breadth, 47 ft.; depth, 23 ft.; draught, 22·5 ft.

Several sections and details of the Halsted vessels are shown in the construction models (*see* Nos. 656–7 and 710–1).

106. Whole model of circular floating battery. (Scale 1 : 72.) Lent by W. Smith, Esq., 1870.
N. 1319.

This arrangement was designed and patented by Mr. John Elder in 1867. It was to have been armour-plated, divided into a great number of compartments, and armed with 26 guns in a lower battery and 10 in a central one. The sharp-edged circumference was to be used as a ram, and many other modifications were suggested, but the battery represented was to have been of the following dimensions:—Diameter, 144 ft.; freeboard, 6 ft.; draught, 9 ft.

This proposal of Mr. Elder's is probably the first design for a circular battery ship propelled by steam machinery. In 1874–6 the plan was re-invented and developed by the Russian naval architect, Admiral Popoff, in his "Popovkas" (*see* No. 112); the "Livadia" is another modification of this design (*see* No. 394).

107. Photograph of Dutch turret ram "De Buffel." Presented by Messrs. R. Napier and Sons, 1869. N. 1311.

This armour-clad twin-screw ram was built of iron at Glasgow in 1868, by Messrs. R. Napier and Sons. She is constructed with a double bottom, and is plated with iron armour 6 in. thick, backed with 10 in. of teak and an inner skin of 1-in plate; this armour belt reaches from 2 ft. above the water line to 3 ft. below. The main deck consists of 6-in. oak on a 1-in. plate, while the wall round the base of the turret is composed of 8-in. plates backed by 12-in. teak on a 1-in. inner skin. The armour and backing of the turret are similar to that of the belt.

She is propelled by two sets of simple engines each with two cylinders 56 in. diam., by 24 in. stroke. The propellers are 7 ft. diam., 8·5 pitch, and with 2,000 indicated h.p. the speed is 11·2 knots. Steam at 30 lb. pressure is supplied by four boilers, and the coal bunker capacity is 160 tons.

The armament is:—One 11-in. 28-ton B.L.R., two 3-in. B.L.R., and six machine guns.

Displacement, 2,260 tons; length, 206 ft.; breadth, 40·4 ft.; depth, 24 ft.; draught, 16·2 ft.

108. Photograph of Dutch monitor "De Tÿger." Presented by Messrs. R. Napier and Sons, 1869. N. 1311.

This armour-clad twin-screw monitor was built of iron at Glasgow in 1868, by Messrs. R. Napier and Sons. She is constructed with a double bottom, and is protected by an armoured belt 5 ft. deep; the thickness of the plates is 6·5 in. amidships, tapering to 5 in. at the bow and 4·5 in. at the stern. The turret, which is 23 ft. diam., has plating 8 in. thick and a 9·75 in. backing of teak. There are no bulwarks, but simply a falling rail, and her freeboad of 3 ft. can be reduced to 2 ft. by filling the double bottom.

She is propelled by two sets of engines, each with two cylinders 30 in. diam. by 18 in. stroke. The propellers are 7 ft. diam. by 8·5 ft. pitch; and with 680 indicated h.p. give a speed of 8·2 knots.

The armament is:—One 11-in. 28-ton B.L.R., one 3-in. B.L.R., and four machine guns.

Displacement, 1,450 tons; length, 187 ft.; breadth, 44·5 ft.; depth, 11·5 ft.; draught, 9·2 ft.

109. Rigged model of German warship, "König Wilhelm I." (Scale 1 : 96.) Lent by Sir E. J. Reed, K.C.B., 1876. N. 1408.

This iron-cased frigate, designed by Sir E. J. Reed, and built of iron at Millwall in 1869, was originally intended for the Ottoman Government, but when about half finished was purchased by the Prussian Government.

She is constructed on the longitudinal system, with a series of wrought iron girders, spaced 7 ft. apart, running along her completely from stem to stern. These are connected by wrought iron ribs spaced 4 ft. apart below the water-line, but only 2 ft. apart above it. Within both frames and ribs comes another iron skin 1 in. thick, so as literally to make a double ship, the inner one being 4·5 ft. apart from the outer.

The armour is 8 in. thick, with a 10-in. teak backing amidships, tapering towards the ends and below the water-line. Near the bow and stern are armoured bulkheads, with 6 in. of armour and 18 in. of teak continued from the lower deck up through the main deck, and to a height of 7 ft. above the spar deck. On the spar deck these shields are curved and pierced with gun ports and loopholed for musketry. Within these shields were four Krupp B.L. 300-prs., which could be fired either fore and aft or as broadside guns. Twenty-three similar guns completed the armament, which, however, has since been altered.

The engines, by Messrs. Maudslay, Sons and Field, are simple with three cylinders 95 in. diam., by 54 in. stroke. The cut-off in the cylinders can be varied from one-third to one-sixth of the stroke, and the valves are driven by Sell's gear (*see* No. 839).

Steam at 30 lb. pressure is supplied by eight boilers, arranged four on either side of the vessel, with the stokehold between them; there are five furnaces in each boiler, and a total of 890 sq. ft. of grate surface and 22,600 sq. ft. of heating surface. The coal bunker capacity is 700 tons.

The propeller is four-bladed, 23 ft. diam., and 22·5 ft. pitch, which at 64 revs., with 8,350 indicated h.p., gave a speed of 14·5 knots.

Displacement, 9,757 tons; length, 355 ft.; breadth, 60 ft.; depth, 41·75 ft.; draught, 25·42 ft.

110. Rigged model of H.M.Ss. "Arrow" and "Bonetta." (Scale 1 : 48.) Presented by Messrs. J. and G. Rennie, 1893. N. 1411.

These twin-screw gunboats, built of iron at Greenwich in 1871 by Messrs. J. and G. Rennie, were, with about 20 similar vessels, constructed for river and coast service.

The engines are of 110 h.p., giving a speed of 8·7 knots; the coal bunkers hold 25 tons.

The armament is one 10-in. 18-ton M.L.R. gun, carried right forward in the bow on a platform that can be lowered by gearing to obtain more stability when at sea. The steering wheel is placed directly in rear of the gun, as training is chiefly done by the rudder. The ship's complement is 31 officers and men.

Displacement, 254 tons; length, 85 ft.; breadth, 26·16 ft.; draught, 6·25 ft.

111. Rigged model of H.M.S. "Neptune." (Scale 1 : 48.) Contributed by Messrs. Samuda Bros., 1882. N. 1576.

This double-turret, barque-rigged armour-clad, constructed at Poplar in 1874, was designed by Sir E. J. Reed for the Brazilian Government, and named the "Independencia," but before completion she was purchased by the British Government, and re-named the "Neptune." Her bottom was sheathed with wood and coppered.

She was driven by trunk engines with two cylinders 118 in. diam., by 54 in. stroke, which, with a boiler pressure of 27 lb., indicated 8,000 h.p. at 64·2 revs. per min., and gave a speed of 14·2 knots. There were eight boilers, contained in two watertight compartments.

The propeller was 26 ft. diam. and 23 ft. pitch. The armament was four 12·5-in. 38-ton M.L.R., two 9-in. 12-ton M.L.R., six 6-pr. Q.F., eight 3-pr. Q.F., ten machine guns, and two torpedo tubes. The armour was 12·75 in. thick on the broadside, 11 in. and 13 in. on the turrets, and there was a 3-in. iron protective deck.

Displacement, 9,130 tons; length, 300 ft.; breadth, 63 ft.; depth, 25·4 ft.

112. Half model of the "Admiral Popoff." (Scale 1 : 48.) Lent by the Russian Embassy, 1876. N. 1424.

This circular, armour-plated, floating battery was built at Nicolaieff in 1875, from the design of the Russian naval architect, Admiral Popoff. She is constructed of iron, and has a double bottom, sheathed with wood and coppered; the bottom is flat, and is fitted with 12 external box girders, or keels, each about 12 in. square, fixed parallel to the intended axis of the vessel. The bottom is formed with 8 radial watertight frames, intersected by two rings of web frames, which thus divide it into 24 compartments. There is a single rudder, which is, however, of exceptional length.

The central part of the upper deck is occupied by a circular breast-work, about 7 ft. high, carrying two heavy guns, mounted *en barbette* on fixed slides, the guns being trained by turning the ship. Around this citadel are deck-houses for the accommodation of the men. The armour of the vessel and its citadel is in two layers, having a total thickness of 18 in.; the side armour extends from the upper deck, which is 1·5 ft. above load water-line, to 4·5 ft. below the water-line, and the upper deck is protected by horizontal armour 3 in. thick.

The vessel is propelled by eight two-stage expansion vertical engines; four of these each work an independent screw 10·5 ft. diam., whilst the other four, arranged and worked in pairs, drive the two remaining screws, which are three-bladed and of much larger diameter, their blades reaching below the keel level. When in shallow water these larger screws are fixed with the upper blades vertical, in which position the screws are above the bottom of the vessel.

The power exerted is 3,066 indicated h.p., and the speed attained 8 knots. The bunker capacity is 250 tons.

Armament:—Two 12-in. 40-ton guns, two Q.F. guns on each side of the superstructure, and six smaller guns.

Displacement, 3,553 tons; extreme diameter, 121 ft.; height of barbette above load water-line, 13·25 ft.; draught of water, 13 ft.

113. Rigged model of Mexican gunboats "Mexico" and "Democrata." (Scale 1 : 48.) Presented by Messrs. J. and G. Rennie, 1879. Plate III., No. 3. N. 1513.

These three-masted, schooner-rigged, sister gunboats were built of iron in 1875 by Messrs. J. and G. Rennie for the Mexican Government.

Their armament is two 6·5 in. 4-ton M.L.R., and two 20-prs.; the speed 11 knots.

Displacement, 450 tons; length, 140 ft.; breadth, 25 ft.; draught, 11 ft.

114. Rigged model of Portuguese ironclad "Vasco da Gama." (Scale 1 : 96.) Received 1907. Plate III., No. 4. N. 2431.

This twin-screw, iron-built and armoured battleship was constructed for the Portuguese Government by the Thames Iron Works and Shipbuilding Co. at Blackwall in 1875–6, from the designs of Mr. G. C. Mackrow. She was lengthened, re-armed and re-boilered by Messrs. Orlando at Leghorn in 1902–3.

The model represents an unusually small example of a sea-going armour-clad; she was designed for the defence of Lisbon and the Tagus, and still (1910) ranks as the only "battleship" in the Portuguese Navy.

Cellular construction was adopted throughout and external protection was given by a complete belt of 9–10-in. side armour, which was carried well below the water-line in the neighbourhood of the ram bow.

Her main armament consisted originally of two 10·25-in. rifled Krupp guns in an octagonal battery amidships, and one 5·9 in. gun astern. These have now been replaced by two 8-in. Q.F. guns, carried in barbettes forward, and one 6-in. Q.F. gun astern.

She was propelled by two sets of two-stage expansion engines made by Messrs. Humphrys, Tennant & Co., which developed on trial a total of 3,625 indicated h.p. and gave an average speed of 13·25 knots. By the use of Yarrow water-tube boilers and a general improvement in the vessel's form, the speed has now been increased to about 15·5 knots.

The original dimensions were:—Displacement, 2,479 tons; length (b.p.), 200 ft.; breadth, 40 ft.; draught (maximum), 19 ft. These particulars as reconstructed are:—Displacement, 2,972 tons; length, 233 ft.; breadth, 40 ft.; draught (maximum), 20 ft.

115. Whole model of H.M.Ss. "Orion" and "Belleisle." (Scale 1 : 48.) Contributed by Messrs. Samuda Bros., 1882. N. 1577.

These two central-battery, armour-clad, iron ships were built at Poplar in 1876 for the Ottoman Government, but were purchased before completion for the British Navy. The armour belt is 12 in. and 7 in. thick, and the plates 10 in. thick on the central battery, while there is a 3-in. iron protective deck.

The engines indicated 2,600 h.p., driving twin screws at a speed of 11·9 knots.

The armament is four 12-in. 25-ton M.L.R. and six 6-pr. Q.F., with machine guns and torpedo tubes. The complement of officers and men is 284.

Displacement, 4,870 tons; length, 245 ft.; breadth, 52 ft.; draught, 21 ft.

116. Whole model of first class torpedo boat "Lightning." (Scale 1 : 24.) Lent by Messrs. John I. Thornycroft & Co., Ltd., 1909. N. 2517.

One of the earliest of specially designed torpedo craft was a steel-built launch constructed by Messrs. Thornycroft & Co., in 1873, for the Norwegian Navy; similar boats for most of the other European Navies quickly followed, but this model represents the first actual torpedo boat in the British Navy. It was built at Chiswick in 1876, for independent harbour or coastal service, and was known as H.M.S. "Lightning." Twelve vessels of this class were eventually added to the British Navy.

A "plough bow" or extended cutwater (*see* No. 90) was a noticeable feature of these boats as well as of the smaller class of early British torpedo craft; but it was discarded in subsequent designs in favour of a nearly upright stem. The hull was of galvanised steel and well sub-divided by transverse watertight bulkheads; side coal bunkers gave protection to the machinery spaces. The shell plating was ·125 in. thick amidships, and slightly less at the forward and after ends. A cement covering was given to the upper deck. There was a conning tower, inside which were the engine-room telegraphs and voice tubes, and the firing gear for torpedoes; steering could also be effected from this position or from the deck. Two 14-in. Whitehead torpedoes are shown amidships upon transporting carriages and rails; they were discharged, by means of compressed air, from a pivoted tube mounted in the bows.

Locomotive boilers were used, and the propelling engines were of the two-stage expansion type fitted with surface condensers. With 350 i.h.p. a speed of 19·4 knots was made in light condition, while a speed of 18 knots was guaranteed under service conditions.

To improve the manœuvring qualities of this vessel she was, before commissioning, fitted with a new form of rudder and guide-blade propeller patented by Mr. J. I. Thornycroft in 1873 and 1879. In 1877, 1881, and 1883 a series of experiments were made on the "Lightning" with various forms of guide-blade propellers (*see* No. 998).

Displacement, 30 tons; length, 84 feet; breadth, 10·9 feet: draught (mean), 5 feet.

117. Whole model of second class torpedo boat. (Scale 1 : 24.) Lent by Messrs. John I. Thornycroft & Co., Ltd., 1909. N. 2518.

This represents an early type of torpedo boat for carrying on shipboard. It is similar in general design to No. 116, but of smaller dimensions, and was built of steel at Chiswick in 1879 by Messrs. Thornycroft, who eventually completed about 70 of these craft for Great Britain and the Colonies, as well as a large number for France and Italy.

The average weight of these boats, with equipment, was about 10·5 tons, and they were stowed on the upper decks of large warships; special davits were fitted for lifting and lowering them.

Locomotive boilers were used, and the initial steam could be raised quickly by a steam heating apparatus fed from the ship's boilers. The engines were of two-stage expansion type with surface condensers; with 170 indicated h.p. a speed of 17·75 knots was realised.

An armament of two 14-in. Whitehead torpedoes was carried amidships. The method of discharge, patented by Mr. J. I. Thornycroft in 1877, differed from that adopted on the larger boats, in that a light steel discharging frame or cradle on each side, carried a torpedo in stowing position, and by means of a rocking shaft, suspension levers, and tackles, the whole could be rapidly lowered to a firing position below the water-line. Other forms of dropping or discharging gear were also fitted on this type of vessel.

Length, 60·3 feet; breadth, 7·5 feet.

118. Photograph of Chilian cruiser "Esmeralda." Presented by Sir W. G. Armstrong, Mitchell & Co., 1884. N. 1672.

This twin-screw cruiser, built at Newcastle in 1884, was designed, constructed, armed, and equipped by Sir W. G. Armstrong, Mitchell & Co. for the Chilian Government. She was the first example of the modern protected cruiser class.

The "Esmeralda" is framed on the ordinary transverse system, and has three decks; the upper or gun deck is 11 ft. above water, the main deck about 5 ft., and the lower or arched protective deck, which is of 1-in. steel and extends from stem to stern, is at the middle 1 ft. below water level, and at the sides 5 ft. It forms a protection to the engines, boilers, magazines, and all vital parts of the ship, while the main deck is occupied by the quarters of the officers and crew. Minute sub-division of the hold space below the protective deck and of the space between it and the main deck is effected by means of transverse and longitudinal bulkheads and of horizontal flats or platforms; cork is also packed in cellular spaces, to ensure sufficient buoyancy and trim in case the water-line region should be riddled. The bow is provided with a ram.

She is propelled by two independent sets of two-stage expansion engines, with cylinders 41 in. and 82 in. diameter by 36 in. stroke, driving twin screws, which, with 120 to 130 revs. and 6,500 indicated h.p., gave a speed of 18·25 knots.

Steam, at 90 lb. pressure, is supplied by four double-ended boilers 13 ft. diam., and 18·5 ft. long, each with six furnaces supplied with forced draught. Her coal bunker capacity is 600 tons, or sufficient for 8,000 miles at a speed of 8 knots, or 6,000 miles at 10 knots. Her armament is :—Two 25-ton 10-in. B.L.R. guns, protected by steel screens, and having a training arc of 120 deg. on either side of the keel; six 4-ton 6-in. B.L.R. guns; two 6-pr. Q.F., and a number of machine guns, as well as three torpedo tubes. She is fitted with two military masts, with a Gardner gun in each.

Displacement, 3,000 tons; length, 270 ft.; breadth, 42 ft.; draught of water, 18·5 ft.

119. Masted whole model of Japanese cruisers "Naniwa" and "Takachiho." (Scale 1 : 48.) Lent by Sir W. G. Armstrong, Mitchell & Co., 1887. N. 1724.

These deck-protected cruisers, built of steel at Newcastle-on-Tyne in 1885 for the Japanese Government, played a prominent part in the war between China and Japan. The "Naniwa," before the declaration of war between the two countries, sank the "Kowshing," with 1,200 Chinese soldiers on board; both cruisers afterwards took part in the battle of Yalu and the subsequent operations. They are each fitted with two military masts, and to provide for ramming have their stems formed of solid steel forgings, strongly supported by the protective decks.

They have two sets of horizontal two-stage expansion engines driving twin screws, the engine-rooms being distinct. At the official trial of the "Naniwa" a mean speed of 18·7 knots was obtained with 7,235 indicated h.p. at 125 revs. per min.

Steam is supplied by six steel boilers 19 ft. by 11 ft., with a collective heating surface of 15,600 sq. ft. The total coal stowage is 800 tons, which is capable of driving the ship 9,000 miles, at a speed of 13 knots.

Their armament is :—At the bow and stern, two 10-in. guns, 35 calibres in length, are mounted on revolving centre-pivot carriages, giving an uninterrupted arc of fire of 240 deg. Spaced along each broadside on sponsons are six 6-in. guns, 35 calibres in length, with a horizontal range of 130 deg., mounted on Vavasseur centre-pivot automatic carriages, and covered by steel shields. Along the upper works, and in the tops, are a number of machine guns, while at the ends of the bridge are placed two 6-pr. Q.F. guns. The crew consists of 325 officers and men.

Displacement, 3,650 tons; length, 300 ft.; breadth, 46 ft.; draught, 18·5 ft.

120. Rigged model of H.M.S. "Alacrity" and "Surprise." (Scale 1 : 48.) Lent by Palmers Shipbuilding and Iron Co., 1887. N. 1726.

These three-masted, schooner-rigged, despatch vessels were built of steel in 1885 at Jarrow.

Each is propelled by two sets of horizontal two-stage expansion engines, with cylinders 26 in. and 50 in. diam., by 34 in. stroke. The engines are protected by an inclined steel deck. The indicated h.p. with forced draught was 3,180 at 135 revs. per min., giving a speed of 18 knots; while under natural draught the h.p. was 2,160, the revs. 124, and the speed 16·5 knots.

Steam at 100 lb. pressure is supplied by two boilers 10·3 ft. diam. and two 9·5 ft. diam., all 17 ft. long. The total heating surface is 7,032 sq. ft., and there are ten corrugated furnaces. The forward and after stokeholds are distinct from one another.

The twin screws are of gun-metal, and three-bladed, 11 ft. diam., 14·7 ft. pitch, and 13·5 ft. between centres.

The armaments are :—"Alacrity," ten 6-pr. Q.F., and two machine guns. "Surprise,"—four 5-in., four 6-pr. Q.F., and two machine guns.

Displacement, 1,400 tons; length, 250 ft.; breadth, 32·5 ft.; draught, 13 ft.

121. Whole model of shallow-draught war steamer. (Scale 1 : 24.) Lent by Messrs John I. Thornycroft & Co., Ltd., 1909. N. 2521.

This represents in general features the design of shallow-draught steamer used by the Gordon Relief Expedition on the River Nile. Five of these were constructed at Chiswick in 1885, and for convenience in transport each vessel was made in eight separate sections.

The hull was of light steel framing and plating, with bullet-proof nickel plates ·25 in. thick around the machinery spaces, deck houses, and conning tower. A longitudinal middle line bulkhead passed through the engine and boiler rooms, and further sub-division was obtained before, and abaft these, by transverse watertight bulkheads. There was a loopholed deck house below and a conning tower above the superstructive deck. Steam steering engines, as well as a hand tiller, were used for working the three rudders. A steam capstan in the bow provided powerful haulage in case of grounding or when navigating rapids.

There were two complete sets of propelling engines of two-stage expansion type with surface condensers. Each line of shafting is shown with two propellers, and, to increase the available depth of water, they are arranged in tunnels or recesses formed under the bottom. A system of propulsion with guide-blade screws was adopted on some of these vessels. With 400 indicated h.p. a speed of 17 knots was attained.

Displacement, 73 tons; length, 140 ft.; breadth, 21 ft.; draught (fully laden), 2 ft.

122. Whole model of guard boat for mine-fields. (Scale 1 : 24.) Lent by Messrs. John I. Thornycroft & Co., Ltd., 1909. N. 2520.

This represents a design, prepared by Messrs. Thornycroft about 1885, for a guard boat for use in the vicinity of explosive mines.

Rapid manœuvring power is provided by twin rudders of the fin-shaped balanced form, which partially enclose a single propeller. Special side and under guards are added to prevent the fouling of the propeller blades. Two machine guns, behind a loop-holed shield aft, and a 3-pr. Q.F. gun forward, specially mounted and screened, constituted the proposed armament.

The overall dimensions were to be:—Length, 52 ft.; breadth, 10 ft.

123. Whole model of torpedo gunboat. (Scale 1 : 48.) Presented by Messrs. J. and G. Rennie, 1893. N. 2018.

This represents a torpedo boat destroyer of the "Sharpshooter" class, designed in 1886.

The engines were intended to develop 4,500 indicated h.p., and, driving twin screws, to give a speed of 21 knots, but difficulties were experienced with the locomotive boilers, and it was not found possible to obtain more than 3,700 indicated h.p., and a speed of 20 knots. The coal bunker capacity was about 100 tons.

The armament shown in the model is one 4·7-in. Q.F. on the forecastle, and four 3-pr. Q.F.'s, with bow and stern torpedo tubes and two launching carriages.

Displacement, 735 tons; length, 230 ft.; breadth, 27 ft.; depth, 11 ft.; draught, 8·25 ft.

124. Rigged model of H.M.S. "Victoria." (Scale 1 : 48.) Lent by Sir W. G. Armstrong, Mitchell & Co., 1887. Plate III., No. 5. N. 1723.

This single-turret, steel-armoured, first class battleship, built at Newcastle-on-Tyne in 1887, was sunk in a collision with H.M.S. "Camperdown," June 23rd, 1893, off the coast of Syria, with the loss of 339 officers and men.

The armour was compound, and from 16 to 18 in. thick, while there was a protective deck 3 in. thick.

The engines were two three-stage expansion sets, with cylinders 43 in., 62 in. and 96 in. diam., by 51 in. stroke. Steam at 135 lb. pressure was supplied by eight steel boilers, with four furnaces in each, the whole being fired from four independent stokeholds. She stowed 1,200 tons of coal.

The collective indicated h.p. under natural draught was 8,038, which gave a speed of 16 knots, while under forced draught it was 14,244 at 100·8 revs., which gave a speed of 17·25 knots. The twin propellers were 16 ft. diam.

The armament was two 16·25 in. 111-ton B.L.R., one 29-ton B.L.R., twelve 6-in B.L.R., twelve 6-pr. Q.F., twelve 3-pr. Q.F., eight machine guns, and several torpedo tubes.

Displacement, 10,470 tons; length, 340 ft.; breadth, 70 ft.; depth, 27·25 ft.

125. Rigged model of H.M.S. "Benbow." (Scale 1 : 48.) Lent by the Thames Ironworks and Shipbuilding Co., 1898. N. 2109.

This first class battleship was built of steel at Blackwall in 1888, and is one of the "Admiral" class.

The hull is divided into 190 compartments, and the double bottom is carried beyond the citadel bulkheads in both directions; further protection against injury from below is afforded by a watertight platform over the hold throughout the entire length of the ship. Between this platform and the protective deck are the boilers, engines, and magazines; from the hold up to the main deck there are practically three skins.

Protection from shot and shell is afforded by a belt of steel-faced armour 18 in. thick and about 150 ft. in length, covering the sides amidships to a depth of 5 ft. below the load water-line, and to a height of 2·5 ft. above it. Over the part so covered is a 3-in. steel deck, built up of two thicknesses of ·5-in. plating and one 2 in. thick. Below this midship protective deck there is a splinter deck ·375 in., to further protect the machinery and forced draught arrangements. Across the ends of this citadel are bulkheads of 18-in. armour.

The sides of the auxiliary battery, above the upper deck, are of steel 1 in. thick, but its sloping ends have 6-in. armour as a protection against a raking fire. When the coal bunkers along the sides of the ship are full, they oppose a thickness of 9 ft. of coal to the passage of shot. On the lower deck is a horizontal athwart-ship chamber, into which water can be introduced to check excessive rolling (*see* No. 606).

The two barbettes each cover a space on the upper deck of about 45 ft. by 60 ft., being pear-shaped in plan, so as to leave room for the loading gear; they have steel-faced armour 12 to 14 in. thick. An ammunition trunk, plated with 12-in. armour, protects the charge while being raised from the magazines. A wire rope raises the 1,800-lb. projectiles and the 960-lb. charges, which are in two portions.

She is propelled by two sets of three-stage expansion engines, which, under forced draught, indicate 11,500 h.p., and give a speed of 16·75 knots.

Steam at 90 lb. pressure is supplied by 12 oval-shaped steel boilers, arranged athwart-ships, each boiler 12·3 ft. wide, 14·83 ft. high, and 9·92 ft. long; there are 36 furnaces, and 20,440 sq. ft. of heating surface while the forced draught is supplied by 8 fans, 5 ft. diam. The coal bunker capacity is 1,200 tons, sufficient for 7,100 miles at 10 knots. The twin screws are 16 ft. diam. and four-bladed.

The armament consists of two 16·25 in. 111-ton breech-loading guns, one in either barbette, having a muzzle velocity of 2,100 ft. per sec. and a penetration of 32·5 in. of iron at 1,000 yds. The auxiliary armament consists of ten 6-in. Q.F. with a penetration of 10·3 in., eight 6-pr. Q.F., ten 3-pr. Q.F., seven machine guns, and two boat guns. She has one fixed torpedo tube in the bow and four launching carriages for torpedoes on the broadside. The ship's complement is 430 men.

Displacement, 10,600 tons; length, 330 ft.; breadth, 68·5 ft.; depth, 37·12 ft.; draught of water, 28·3 ft.

126. Rigged model of H.M.S. "Orlando." (Scale 1 : 48.)
Lent by Palmers Shipbuilding and Iron Co., 1891.
N. 2000.

This first class, belted, deck-protected, steel-built cruiser was launched in 1888 at Jarrow-on-Tyne; she is fitted with two military masts.

She has two sets of three-stage expansion engines, with cylinders 36 in., 52 in., and 78 in. diam. by 42 in. stroke, indicating 8,500 h.p., and driving twin screws 14·5 ft. diam. and 18·75 ft. pitch.

The belt is of compound armour 10 in. thick, while there is a steel protective deck 2 in. thick, which extends from just above the water-line to 5·5 ft. below. The armament consists of two 9·25-in. 22-ton B.L.R., ten 6-in. B.L.R., sixteen 6-pr. and 3-pr. Q.F., six machine guns, and torpedo tubes. The ship's complement is 484, and she has a coal bunker capacity of 900 tons.

Displacement, 5,600 tons; length, 300 ft.; breadth, 56 ft.; draught, 22·5 ft.

127. Rigged model of H.M.S. "Magicienne." (Scale 1 : 48.) Lent by the Fairfield Shipbuilding and Engineering Co., 1901. N. 2268.

This third class cruiser was built of steel at Glasgow, in 1888, by the Fairfield Co., from the designs of Sir W. H. White, Director of Naval Construction. She is barque-rigged and is fitted with twin screws.

The hull is constructed with a cellular double bottom, for carrying water ballast, and is divided into ten watertight compartments, two of which are occupied by the engines and two more by the boilers. The ram, stern and rudder posts, together with the brackets for the screws, are bronze castings, weighing altogther about 45 tons. Being intended to keep at sea, she is sheathed with two 3-in. layers of teak and an outer sheathing of copper. The rudder is of the balanced type and can be worked by hand or steam gear from the bridge, conning tower, or from below. There is a 2-in. protective deck, springing from 5 ft. below the water-line and rising 1 ft. above it amidships.

The "Magicienne" was one of the last war-vessels fitted with horizontal engines; these are of the three-stage expansion type, and are in two sets, with cylinders 34·5 in. diam., 51 in. diam., and 76·5 in. diam. by 36 in. stroke. Steam at 155 lb. pressure is supplied by four double-ended Scotch boilers, each with six corrugated furnaces and three combustion chambers; the total grate area is 535 sq. ft., and the heating surface 13,616 sq. ft. On trial with a forced-draught pressure of 2·2 in. of water and an engine speed of 140 revs. per min., the total indicated h.p. was 9,280, and the speed attained 18 knots. The coal bunker capacity is 400 tons, which gives a radius of action, at 10 knots, of 8,000 nautical miles.

Her armament is:—Six 6-in. B.L. guns, nine 6-pr. Q.F., one 3-pr. Q.F., and six torpedo discharge tubes. Complement, 300 men.

Displacement, 2,950 tons; length, 265 ft.; breadth, 42 ft.; draught of water, 17·5 ft.

128. Drawing of H.M.S. "Blake." (Scale 1 : 48.) Maudslay Collection, 1900. N. 2253.

The "Blake," a first class twin-screw deck-protected cruiser, was designed by the Admiralty and built of steel at Chatham in 1889–91.

Her engines, which were a new departure in the Navy, consist of four distinct sets of three-stage-expansion inverted engines, coupled in pairs to the two propeller shafts; the cylinders are 36 in., 52 in., and 80 in. diam. by 48 in. stroke. The forward sets are so arranged as to be easily disconnected when only slow or moderate speeds are required. Each set has an air pump, 33 in. diam. by 2 ft. stroke, and a surface condenser with a cooling area of 2,250 sq. ft.; also an independently driven centrifugal pump 45 in. diam. for circulating, but capable of drawing from the bilge. Steam at 155 lb. is supplied by six doubled-ended Scotch boilers, with eight furnaces in each fitted for forced draught; the total fire grate area is 863 sq. ft., and the heating surface 26,936 sq. ft. The screws are 18·25 ft. diam. and 24·5 ft. mean pitch.

At her trial in 1891, with steam at 125·5 lb., air pressure ·42 in., and 88·8 revs. per min., 14,525 indicated h.p. was developed and a mean speed of 19·12 knots attained. Under forced draught it was expected that 17,000 indicated h.p. would be developed and a speed of 22 knots realised, but this was never tested.

Her armament was:—Two 9·2-in. 22-ton B.L.; ten 6-in. 5-ton B.L.; sixteen 3-pr. Q.F.; eight machine guns and four torpedo tubes; her complement was 570 men.

Displacement, 9,000 tons; length, 375 ft.; breadth, 65 ft.; draught, 25·7 ft.; coal stowage, 1,500 tons.

129. Rigged model of first class torpedo boat. (Scale 1 : 48.) Lent by Messrs. John I. Thornycroft & Co., Ltd., 1909. N. 2519.

This represents an improved type of torpedo boat built at Chiswick in 1892. The shape of stern, the flattened after-sections, and the steering arrangements were novel features, afterwards adopted in larger vessels of the "Daring" class (*see* No. 130) and similar destroyer types. Steering was effected by twin rudders of the fin-shaped, balanced form, placed outside and abreast of the propellers.

Water-tube boilers of the "Thornycroft" type were installed, with two sets of three-stage expansion engines; together these developed about 2,000 indicated h.p. and gave a service speed of 23 knots.

The armament consisted of three 3-pr. Q.F. guns and three 18-in. torpedo tubes; two of these latter were pivoted on the after deck and the other formed a fixed bow-tube, an arrangement now obsolete.

Displacement, 130 tons; length, 140 ft.; breadth, 15·5 ft.; draught, 5·3 ft.

130. Diagrams showing the development of torpedo boat destroyers. (Scale 1 : 32.) Contributed by Messrs. John I. Thornycroft & Co., 1895. N. 2059.

These were prepared to illustrate a paper by Messrs. J. I. Thornycroft and S. W. Barnaby, read before the Institution of Civil Engineers in 1895.

Fig. 1 represents the earliest type of vessel specially designed to capture or destroy torpedo boats. It was introduced in 1885, the intentions being that with high speed and some armament such craft would overtake torpedo boats and sink them by gun fire. They were 125 ft. in length, of 65 tons displacement, 19 to 21 knots speed, and they carried two 3-pr. Q.F. guns and three Nordenfeldts. Fifty-four of these vessels were constructed, but before completion they were changed into torpedo boats.

Fig. 3 represents a larger type, built in 1886, and known as the "Rattlesnake" class. The length was 200 ft.; displacement, 550 tons; speed, 18·5 knots; and armament, one 4-in. gun, six 3-prs., and four torpedo tubes. This was followed by a still larger type forming the "Sharpshooter" class of "torpedo gunboats" (*see* No. 123) in which the length is 230 ft.; displacement, 735 tons; and the speed, 19 to 20 knots (with locomotive boilers).

Fig. 4 shows the "Speedy," built in 1892. Its length is 230 ft.; displacement, 810 tons; and speed, 20·5 knots, with Thornycroft water-tube boilers (*see* No. 902). The armament is two 4·7-in. Q.F. guns, four 3-prs., and three torpedo tubes.

Fig. 5 shows a vessel of the "Dryad" class, commenced in 1893. The length is 250 ft.; displacement, 1,070 tons; speed, 19 knots. The armament is two 4·7-in. Q.F. guns, four 6-prs., and three torpedo tubes. Although these larger dimensions permitted heavier armament, with better protection and sea-going qualities, there was no corresponding increase in speed, while the speeds of torpedo boats had reached 26 to 27 knots. To meet this difficulty a smaller type of destroyer, represented by Fig. 2, and known as the "Daring" class, was introduced in the same year. The length is 185 ft.; displacement, 260 tons; armament, one 12-pr. gun and six 6-prs. These vessels, while having less draught of water than many torpedo boats, have attained a speed of over 29 knots.

Fig. 6 shows the general appearance of the "Daring" when fully equipped and under steam. A wall diagram in an adjoining section shows also the curves of weight, buoyancy, &c., for this vessel.

131. Rigged model of H.M. paddle tug "Dromedary." (Scale 1 : 48.) Lent by Messrs. Barclay, Curle & Co., 1905. Plate III., No. 6. N. 2375.

The steel, paddle-wheel tug was built in 1894 by Messrs, Barclay, Curle & Co., for the Admiralty, and is employed for towing and general harbour purposes at Portsmouth.

The engines are two-stage expansion with oscillating cylinders 31 in. and 55·37 in. diam. by 56·5 in. stroke, and indicate 1,266 h.p. at a speed of 12 knots. Two Scotch boilers supply steam at 75 lb. pressure, and the vessel carries auxiliary machinery in addition to two fire engines, and distilling apparatus. The paddle-wheels can be driven independently of each other, and each contains nine floats, 9 ft. by 3 ft. 4 in.

Displacement, 680 tons; length, 144 ft.; breadth over plating, 27·4 ft.; mean draught, 10·75 ft.

132. Whole model of Russian destroyer "Sokol." (Scale 1 : 32.) Presented by Messrs. Yarrow & Co., 1900. Plate III., No. 7. N. 2257.

This torpedo boat destroyer, built by Messrs. Yarrow & Co. in 1895, proved herself on trial to be the fastest steamer afloat and was the first vessel that attained a speed of 30 knots. The hull is constructed of nickel steel, and, to further minimise the weight, aluminium is used in many of the fittings, while aluminium and special bronzes are extensively resorted to for portions of the machinery.

The vessel is propelled by twin screws driven by three-stage expansion engines with cylinders 18 in., 26 in., and 39·5 in. diam. by 18 in. stroke, which are together capable of developing 4,400 indicated h.p. Steam at 160 lb. pressure is supplied by eight Yarrow water-tube boilers, each fitted with a transverse diaphragm separating it from the stokehold so as to protect the stokers from the steam or water that would escape should the boiler be pierced by shot. On the preliminary trial the mean speed for the measured mile was 30·28 knots, and the power exerted 4,039 indicated h.p.

On the official trial of the "Sokol," partly loaded, the mean speed of six runs was 29·77 knots with 405 revs. per min. of the engines. For the total run of three hours, the speed was 29·76 knots and the coal consumed 10·35 tons, with an air pressure in the stokehold of 1·12 in.; the steam pressure was 160 lb., and the mean indicated h.p. 3,800, giving a coal consumption of 2·03 lb. per i.h.p. per hour.

The armament consists of one 12-pr. Q.F. gun on the steering tower forward, and three 6-pr. Q.F. guns on deck, also two swivel deck torpedo tubes for discharging 16-in. torpedoes over either beam.

Displacement, 240 tons; length, 190 ft.; breadth, 18·5 ft.; draught, 7 ft.

133. Half block model of H.M.S. "Powerful." (Scale 1 : 150.) Received 1905. N. 2363.

This first class protected cruiser was built of steel at Barrow-in-Furness in 1895–7 by the Naval Construction and Armaments Co.; she was repaired and refitted in 1902, by their successors Messrs. Vickers, Sons & Maxim.

The vessel was a new departure in Admiralty practice, embodying many of the features of ocean mail steamers; she was about 100 ft. longer than any previous British warship, and was, with her sister ship the "Terrible," the first large vessel in H.M. Navy fitted with water-tube boilers.

Protection is given to the vital parts of the ship by a curved steel deck, from 3 in. to 6 in. thick, extending over the full length and associated with protecting coal spaces to the height of the main deck abreast of the engine and boiler rooms. In the more recent "armoured" cruisers, which have now practically superseded the "protected" type, such protection is supplemented by a deep belt of vertical side armour.

The "Powerful" is propelled by two sets of inverted three-stage expansion engines, each with four cylinders; a high pressure 45 in., an intermediate 70 in., and two low pressure cylinders 76 in. diam., with a common stroke of 48 in. Steam at 260 lb. is supplied by 48 Belleville boilers (*see* No. 903) arranged in eight groups in separate watertight compartments. During the official trials in unfavourable weather, a speed of 21·8 knots was realised with 29,000 indicated h.p.

The model represents the vessel after the addition of four 6-in. guns (in casemates) to the armament which now consists of:—Two 9·2-in. B.L.R.

guns, one forward and the other aft; 16 6-in. Q.F.; 14 12-prs. and eight 3-prs., with four submerged torpedo tubes. Her complement is 840 men.

Displacement, 14,200 tons; length, over all, 538 ft.; breadth, 71 ft.; draught, 22 ft.

134. Rigged model of H.M.S. "Diadem." (Scale 1 : 48.) Lent by the Fairfield Shipbuilding and Engineering Co., Ltd., 1907. N. 2448.

This first class protected cruiser, which was built and engined at Glasgow in 1896–8, by the Fairfield Co., is representative of a class of eight vessels, similar in design to their immediate predecessors the "Powerful" and "Terrible" (*see* No. 133), but having smaller dimensions; they have also less speed but retain the important features of a high gun platform and large coal supply while a reduction in draught of water enables them to pass through the Suez Canal.

The hull of the "Diadem" is of Siemens steel and the cellular system of construction is adopted amidships, with a close watertight sub-division of all spaces at the extremities. To permit of long periods at sea without dry docking, the underwater portion is sheathed with wood and copper, galvanic action being minimized by the use of phosphor bronze castings for the stem and stern posts, rudder-frame, and propeller brackets. Excessive rolling of the ship is prevented by two bilge keels 3 ft. in depth and about 210 ft. long.

There is no side armour, but a thick arched deck, protecting the most vital portions, extends from end to end in the region of the water-line; this deck has a total thickness of 4 in. amidships tapering to 2·5 in. at the extremities. Coal stowage above and below the water-line gives additional protection to the machinery spaces. Communication pipes and wires, ammunition hoists, &c., are specially protected by armour tubes and towers.

The main armament consists of 16 6-in. Q.F. guns, twelve of which are enclosed in broadside casemates of 4·5 in. armour, while the remainder are carried in pairs behind armour shields, on the poop and forecastle. Two submerged torpedo tubes are fitted forward and one above-water tube at the stern.

The external details of the anchor and cable arrangements, both forward and aft, are well illustrated. The capstans, riding-bitts, and other deck fittings are shown, the capstan engines being, as usual in H.M. ships, below the protective deck. The main cables are 2·375 in. diam. and the bower anchors, of improved Martin type, weigh 5·5 tons each; a simple method of carrying these latter, in a vertical position, is here shown.

The vessel is propelled by two sets of three-stage expansion engines each having four cylinders with diameters 34 in., 55 in., and 64 in. (two) by 48 in. stroke. Steam is supplied by 30 water-tube boilers of the Belleville type (*see* No. 903) at a pressure of 300 lb. per sq. in. which is reduced to 250 lb. at the engines. It is interesting to note that these were the first Belleville boilers in H.M. Navy to be permanently fitted with the "economiser," an improvement in the form of a smaller boiler or feed-water heater constructed of 2·75-in. tubes which is placed, with an intervening combustion chamber, over the main boiler of 4·5-in. tubes. This arrangement results in more perfect combustion, lower temperature of the funnel gases, and considerable economy in fuel; it has been generally adopted in all subsequent vessels fitted with this type of steam generator.

During full-power steam trials in 1898 the "Diadem," on a draught of 25·3 ft., realised a speed of 20·6 knots with 17,188 indicated h.p.

Her normal coal supply is 1,000 tons, but provision can be made for carrying about 2,000 tons if necessary.

Displacement, 11,000 tons; length (b.p.) 435 ft.; breadth, 69 ft.; draught, 26 ft.

135. Rigged model of H.M.S. "Good Hope." (Scale 1 : 48.) Lent by the Fairfield Shipbuilding and Engineering Co., Ltd., 1908. N. 2492.

This first class armoured cruiser was built and engined at Glasgow in 1900–2 by the Fairfield Co., and is representative of a class of four vessels of about the same dimensions as H.M.S. "Powerful," but superior in offensive and defensive qualities and in speed. The chief improvement consists in the addition of a broadside belt of armour 396 ft. long terminating at the after end in a 5-in. bulkhead. The after portion outside the armoured belt has a protective deck 2·5 in. thick, while within the belt there are two protective decks of 1·5 in. and 1 in. respectively.

Several structural alterations have been made from the design adopted in the "Powerful" which have diminished the displacement of the vessel. There is no poop, and the boat deck has been omitted. Wood and copper sheathing has been dispensed with and there are no military tops to the masts. Although cowls are fitted on the model, these have been replaced on the vessel by wind sails for giving air to the fans in the shafts communicating with the machinery spaces. The three after funnels are oval in plan as a larger number of boilers exhaust into each of them than into the forward one.

The main armament consists of two 9·2-in. B.L. guns within barbettes of 6-in. armour, and sixteen 6-in. Q.F. guns mounted within two-storey casemates of 5-in. armour. Two submerged torpedo tubes are fitted forward, one on each side of the vessel; their positions are indicated on the hull of the model. An important addition in the gun fittings is a sighting hood fitted upon all the upper casemates, which enables the gunner to see all round without exposing himself.

The external fittings are fully shown. The anchors are stowed horizontally and made snug to the ship's side; this is a noticeable departure from previous ships (*see* No. 134). Electricity is in extended use for working the ventilating fans, gun-hoists, &c.; hydraulic power is used for the boat-hoisting gear.

The vessel is propelled by two sets of inverted three-stage expansion engines, each having four cylinders with diameters of 43·5 in., 71 in. and (two) 81·5 in. respectively, by 48 in. stroke. Separate condensers, each with its own air pump, are provided for the low pressure cylinders. Great rigidity of the framing is obtained by supporting each cylinder by two cast standards at the rear, with the usual steel columns in front, four points of support instead of three being thus obtained. Steam is supplied by 43 Belleville boilers of the economiser type, containing 382 elements in all, giving a total heating surface of 71,964 sq. ft., and a grate area of 2,314 sq. ft.

The steering gear is of the right- and left-handed screw type. This arrangement occupies comparatively little space athwartship and so is specially suitable for a fine-ended cruiser.

During her trials in 1902, the "Good Hope" on a draught of 26·1 ft. realised a speed of 23·05 knots, with 31,071 indicated h.p. and a steam pressure of 278 lb. per sq. in. at the boilers.

Displacement, 14,100 tons; length (b.p.), 500 ft.; breadth, 71 ft.; depth, 40 ft.; draught, 26 ft.

136. Drawing of torpedo boat destroyer, "Nembo" class. (Scale 1 : 32.) Received 1908. N. 2495.

The "Nembo" class of ten twin-screw torpedo boat destroyers was built in Italy in 1901–6, for the Italian Navy, from the designs of Messrs. J. I. Thornycroft & Co.; six of them were constructed at Naples by Messrs. C. & T. T. Pattison, and the remainder at Genoa by Messrs. Ansaldo, Armstrong & Co. In general characteristics these vessels resemble the "Coquette," "Cygnet," "Cynthia," "Mallard," and "Stag," built by Messrs. Thornycroft in 1896–1901 for the British Navy. Four vessels of this type were also built at Chiswick in 1901 for the Japanese Navy, and these took part in the Russo-Japanese War in 1905. A similar vessel was built for the German Navy in 1898, and one of larger dimensions for the Swedish Navy in 1905.

The drawing shows (i) a complete sectional longitudinal elevation, (ii) an above-deck half-plan and a sectional under-deck half-plan. From these the main framing, watertight sub-divisions and principal structural features of the hull can be seen, together with the general arrangement of armament, main and auxiliary machinery, boilers, coal-bunkers, magazines, store-rooms, cable-lockers, anchor and capstan gear, and the men's quarters.

There are two sets of three-stage expansion, four-cylinder engines, each having a high, intermediate, and two low pressure cylinders 22 in., 29 in., and 30 in. diam. respectively, by 18 in. stroke. The axes of the cylinders are inclined alternately to the right and to the left of the vertical, so as to save longitudinal space. Steam is supplied at 220 lb. per sq. in. by three Thornycroft water-tube boilers each in a separate compartment, protected at the sides and forward ends by coal-bunkers, which have a total capacity of 80 tons; with about 6,000 indicated h.p. a speed of 30 knots was attained on trial by these boats. Engines of this type are further illustrated in the Marine Engineering Gallery by wall diagrams of H.M.S. "Daring" (*see* No. 861), and the boilers by a sectional model (*see* No. 908).

The armament of the "Nembo" class consists of two 18-in. torpedo tubes carried aft, five 6-pr. Q.F. guns, and one 12-pr. Q.F. gun, the latter mounted upon the conning tower forward. There is a complement of 53 men.

Length, 210 ft.; breadth, 19·5 ft.; draught (maximum), 7·75 ft.; displacement, 330 to 350 tons.

137. Diagrams of typical modern warships. (Scale 1 : 60.) Lent by the Right Hon. Earl Brassey, K.C.B., 1905.
N. 2365.

The six diagrams shown above represent types of modern war-vessels selected from the British, French, German and Italian Navies. They were prepared to illustrate a paper read by Lord Brassey in March, 1905, before the Institution of Civil Engineers in which he suggested the construction of a number of powerful vessels, of relatively small displacement and draught, for service in shallow waters. The "Vittorio Emanuele" was taken as an existing vessel embodying some of the features of the type proposed.

The following are the principal particulars of the vessels shown:—

Name.	Displacement (Tons).	Length (Feet).	Breadth (Feet).	Draught (Feet).	Armour (Inches).	Armament.	Speed (Knots)
"Vittorio Emanuele" (Italy).	12,425	435·5	73·5	27·25	10 to 4	2 12-in. 12 8-in.	22
"Braunschweig" (Germany) 1904.	12,997	398·5	73·5	24·5	10 to 4	4 11-in. 14 6·7-in.	18
"République" (France).	14,635	439	79·5	27·5	11 to 6	4 12-in. 18 6·4-in.	18
"King Edward VII." (Great Britain) 1905.	16,350	425	78	26·75	12 to 6	4 12-in. 4 9·2-in. 10 6-in.	19
"Lord Nelson" (Great Britain).	16,500	410	79·5	27	12 to 8	4 12-in. 10 9·2-in.	18
"Duke of Edinburgh" (Great Britain).	13,550	480	73·5	27	6 to 3	6 9·2-in. 10 6-in.	22·3

138. Rigged model of H.M.S. "Lord Nelson." (Scale 1 : 48.)
Lent by Palmers Shipbuilding and Iron Co., Ltd., 1910.
Plate III., No. 8. N. 2559.

This twin-screw first class battleship was built and engined by the Palmer Co. at Jarrow-on-Tyne in 1904–8 from the designs of Sir P. Watts.

In dimensions and general structural arrangements this vessel differs but slightly from typical warships of the previous ten years; in armour and armament, however, a notable advance is made.

A main battery of four 12-in. guns in barbettes is retained, but in place of a secondary battery consisting chiefly of 6-in. guns, there is a battery of ten 9·2-in. guns enclosed in a central citadel. This powerful concentration of gun power is peculiar to the "Lord Nelson" and the "Agamemnon" in the British Navy and immediately preceded the general adoption of the "Dreadnought" design with a single battery of ten 12-in. guns. For repelling torpedo craft a number of light guns, chiefly 12-pr. and 3-pr., are mounted upon a central superstructure which is likewise used for a navigating and searchlight platform and a boat deck. Five submerged tubes for the discharge of 18-in. torpedoes are fitted; four of these are on the broadside and one at the stern.

The heavy guns are protected at their bases by a lower tier of 12 to 14-in. Krupp armour and an upper tier of 8 in. extending from the main to the upper deck; beyond the citadel the side armour tapers to 6 in. at the bow and to 4 in. at the stern. Special protection against explosive mines or torpedoes is provided by a thick fore-and-aft bulkhead of nickel steel extending along each side of the machinery spaces and between the inner bottom plating and the protective deck. A complete set of torpedo defence nets are also fitted to the actual vessel.

The propelling machinery consists of two complete sets of three-stage expansion engines; these are in separate compartments having no communicating doorways. In each set there are four steam-jacketed cylinders, a high pressure of 32·75 in., an intermediate pressure of 52·75 in. and two low pressure of 60 in. diam., with a common stroke of 48 in.; double ported valves with relief frames are fitted to the low-pressure cylinders and piston valves to the others. Forced lubrication is used throughout. The propellers are of manganese bronze of 15 ft. diam., and 19 ft. pitch. Steam at 275 lb. maximum pressure, is generated in 15 water-tube boilers of the Babcock & Wilcox type; they have a total grate area of 848 sq. ft. and a heating surface of 50,265 sq. ft. During full-power trials in 1908 a speed of 18·9 knots was realised with 17,445 i.h.p. There is bunker capacity for 900 to 2,200 tons of coal and 400 tons of oil fuel. Rapid manœuvring is a special feature of this design.

Hinged davits are shown attached to the superstructure and also derricks to each of the two masts; these are used for lifting the boats and other heavy loads. The larger derrick to the tripod main mast is worked by hydraulic power. The observation and gun fire control positions are shown upon the masts as well as the light spars and rigging used in connection with wireless telegraphy.

Displacement, 16,500 tons; length (water-line), 435 ft.; breadth, 79·5 ft.; draught, mean, 27 ft.; complement, 747 men.

On adjacent wall diagrams (*see* No. 137) the "Lord Nelson" is compared with previous or contemporary warship types in British and foreign navies.

139. Rigged model of H.M. destroyer "Viking." (Scale 1 : 48.)
Lent by Palmers Shipbuilding and Iron Co., Ltd., 1910.
N. 2560.

This represents one of the larger examples of the "Tribal" class of ocean-going torpedo boat destroyers; she was built and engined by the Palmer Co. at Jarrow-on-Tyne in 1908–10. A special steel of high tensile strength is used in the construction of the hull.

For propulsion a three-shaft arrangement of Parsons steam turbine is installed and is estimated at 15,500 shaft h.p. Steam is supplied by six modified Yarrow water-tube boilers burning oil fuel, and a separate funnel is fitted to each boiler. On trials, in April 1910, a speed of 33·7 knots was attained. There is bunker capacity for about 100 tons of fuel and a steaming radius of 1,500 miles is possible at low speeds.

The armament consists of two 18-in. deck torpedo tubes and two 4-in. (25 lb.) B.L. guns; one of these latter is carried aft, and the other forward upon a raised platform in front of the navigating and searchlight positions.

There are two lightly rigged masts fitted for the reception of wireless telegraphic apparatus.

Displacement, 1,050 tons; length between perpendiculars, 280 ft.; breadth, 27·3 ft.; draught, mean, 9 ft.; complement, 71 men.

Similar in general design and armament but differing slightly in dimensions, equipment, and speed are the following :—"Crusader," "Maori," "Nubian," and "Zulu."

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140. Drawings and photographs of Garrett's submarine boat "Resurgam." Contributed by Messrs. Cochran and Co., 1882. N. 1586.

In 1878, Mr. G. W. Garrett experimented in the Liverpool Docks with a small boat of this type, which was driven by manual power. From the experience thus obtained the vessel represented was constructed in 1879 by Messrs. Cochran and Co., but it was lost at sea soon afterwards, before it had been fully tried.

Its extreme length was 40 ft., and the maximum diameter 9 ft., but this included a wooden sheathing jacket 2 ft. thick round the middle length. The boat was built of steel, and could be completely closed. It had a single propeller, and a pair of horizontal rudders amidships, as well as an ordinary rudder aft, and was controlled by three men.

The engine was of the return connecting-rod, surface condensing type, and received steam from an internally fired cylindrical boiler, loaded to 150 lb. pressure. When moving submerged the furnace, &c. were closed, the heat in the boiler water supplying the steam required; in this way a submerged steaming radius of 12 miles was believed to be obtainable. An air purifying device was fitted for the support of the crew while thus confined.

141. Whole model of submarine torpedo boat. (Scale 1 : 16.) Lent by Messrs. Vickers, Sons and Maxim, 1903. N. 2336.

This represents, generally, the first submarine war-vessel introduced into H.M. Navy and built by Messrs. Vickers, Sons and Maxim in 1901. It is of the type invented by Mr. J. P. Holland, of the United States, who constructed his first experimental boat in 1877, and finally patented the essential details of the design in 1895. Compared with other submarines its most distinctive feature is its method of submergence as, instead of sinking horizontally with a level keel, it dives at a small angle like a porpoise until the required depth is reached, when it is again caused to take a horizontal position and course.

The plating and framing of the boat are of steel, and of sufficient strength to withstand the water pressure at a depth of 100 ft.; watertight decks and bulkheads stiffen the structure as a whole, and reduce the danger from a collision, while the external portions of the hull are so formed as to minimise the risk of ropes or nets becoming entangled. A superstructure deck or platform is provided for use when the boat is running on the surface, and there is an armoured conning tower amidships, 32 in. diam. and 4 in. thick, for the use and protection of the navigator. Water ballast tanks throughout the length provide means for altering the draught, also for preserving longitudinal trim, and keeping the displacement constant in different waters; they are also utilised in the automatic arrangements for compensating for the discharged weights, including fuel and torpedoes.

Two vertical and two horizontal rudders control the steering and diving respectively, and these may be operated by hand or engine power. Compressed air is used for mechanical purposes, and for ventilating the interior when entirely submerged, while reducing and safety valves limit the pressure to about one atmosphere.

From the outer deck rises a periscope, consisting of a tube, about 10 ft. high, fitted at its ends with an arrangement of lenses and reflectors, which enables a view of surrounding objects to be obtained by the navigator when the boat is submerged; the tube also assists the ventilation under certain conditions of submergence. The interior of the vessel is lighted by glazed openings in the hull, and by portable incandescent electric lamps.

The boat is propelled by a single screw, which, when running at the surface, is driven by a gasolene engine of 160 h.p. and gives a speed of 9 knots, while the fuel supply permits of a total run of 400 nautical miles. When submerged, an electric motor is substituted which gives a speed of 7 knots, while the storage battery supplying it has sufficient capacity to a run of four hours; the main engine may, however, be utilised for re-charging the accumulators.

At the forward end of the boat is a torpedo expulsion tube, and there is storage capacity for five torpedoes each 11·6 ft. long. An adjacent diagram shows the general arrangement of the framing, machinery, and torpedo stowage.

Displacement, submerged, 120 tons; length, over all, 63·3 ft.; breadth, extreme, 11·75 ft. Later submarines built for H.M. Navy are 135 ft. long, and have a surface speed of 14 knots.

MERCANTILE VESSELS.

The early merchant ships of the present era down to about the 16th century, did not differ materially from the warships, although at the earlier periods when Greece and Rome were most prosperous, the fighting and the commercial fleets were, as at present, quite distinct.

Shipbuilding was for ages entirely empirical, and till the middle of the 19th century advanced but very slowly in both design and construction, excepting, however, during a portion of the 17th century. The material used for all parts was wood; knees, breast-hooks, and pillars, of iron were not introduced till about 1810, tree-nails being used for the planking, and copper fastenings for special parts.

The use of iron for the skin of a vessel was tried by John Wilkinson, the ironmaster, as early as 1787, but the P.S. "Aaron Manby," built at the Horseley Ironworks, Tipton, in 1821, was the first steamer built entirely of iron. The practical introduction of iron shipbuilding dates, however, from 1829, when John Laird of Birkenhead commenced its construction; in 1832, iron vessels were built on the Thames, Clyde, and Tyne. A steamer "Sirius" of 1837 and of 180 tons was the first iron vessel classed by Lloyd's, but the innovation was generally opposed by shipowners, builders, and naval authorities, and it was not till the building in this material of the S.S. "Great Britain" (1843) by the younger Brunel, and subsequently her survival of nearly a year's exposure while stranded in Dundrum Bay in 1846, that iron came into general favour. The substitution of iron for wood caused a saving in weight of about 35 per cent., while since about 1870 the introduction of mild steel has reduced the metal scantlings 15 per cent., so leaving a steel hull only about one-half the weight of a wooden one.

Owing to the fouling of iron vessels on long voyages and the consequent reduction of speed, many attempts were made at directly sheathing an iron ship with copper, &c., but through the resulting galvanic action these were abandoned, and a "composite" system of construction with wood planking on iron frames was adopted: the "Tubal Cain" of 787 tons, built in 1851, is the first ship of this class in Lloyd's Register, but the famous China tea clippers were the most celebrated examples of this system of building. The method, however, proved to be expensive, and is now only used for special purposes.

An account of the development of marine steam propulsion is given on pages 241–4. The growth of the transatlantic service forms a general record of the continuous development of the mercantile steam marine and it is very clearly indicated in a scale diagram of the ships of one of the largest companies (*see* No. 305). The pioneer Atlantic liner was the P.S. "Great Western" (1837) of 1,320 tons, which took about 14·5 days in her runs between Bristol and New York (*see* No. 182). In 1909 the S.S. "Mauretania" of 31,940 tons (*see* No. 607) steamed from Queenstown to New York in 4·45 days.

The advantage of large capacity for long voyages has resulted in the building of steel sailing vessels of upwards of 4,000 tons register, the requisite sail area being obtained by the use of four to seven masts. Some modern sailers have been fitted with small auxiliary steam power, by which they can be economically driven through a district of calm at a speed of about six knots.

The classification and registration of vessels dates back to the time of the Phœnicians, the earliest merchants; the present insurance register has, however, developed from the "ships lists" prepared by the proprietor of Lloyd's Coffee House, about the year 1700. In 1834 a great expansion was effected, and Lloyd's Register of British and Foreign Shipping was established in its present form, and on an international basis. The classification, necessary for a register suited for insurance purposes, has resulted in careful surveys and investigations that have greatly advanced the whole science of naval construction as well as the shipping industry.

SAILING MERCHANT VESSELS.

142. Built half model of brig "Liberty and Property." (Scale 1 : 48.) Lent by James Young, Esq., 1883. N. 1590.

This sailing vessel was built of wood at Whitby in 1754. She was employed in the Shields and London coasting trade; but her ports and some other details suggest that she was intended for use as a war-vessel if required.

Tonnage, 274 tons; length, 120 ft.; breadth, 28 ft.; depth at side, 20 ft.

143. Rigged model of brig "Brotherly Love." (Scale 1 : 96.) Lent by James Young, Esq., 1876. N. 1421.

This merchant sailing vessel was built of wood at Ipswich in 1764 and in 1876 was said to be still employed as a coasting collier. Many of these small brigs were engaged in this coasting trade, until the general introduction of steam colliers rendered them almost obsolete.

Gross register, 214 tons; length, 86·5 ft.; breadth, 24 ft.; depth at side, 27 ft.

A photograph is also shown.

144. Rigged model of brig "Antelope." (Scale 1 : 96.) Lent by James Young, Esq., 1876. N. 1420.

This vessel, built of wood at Sunderland in 1766, is shown with topsail, courses, foretopmast, staysail, and jib set.

Tonnage, 195 tons; length, 80 ft.; breadth, 24 ft.; depth at side, 20 ft.

145. Oil painting of S. "Swallow." Lent by the Peninsular and Oriental Steam Navigation Co., 1903. N. 2342.

This shipbuilders' picture, painted in 1788 by T. Luny, represents a ship of 18 guns and about 700 tons burden, belonging to the Hon. East India Company. About that time their ships were well armed and more strongly built than ordinary merchantmen and the crews regularly drilled for naval warfare.

The vessel is shown in three different positions:—Bow View—"Hove to" for picking up a pilot; Broadside View—Under plain sail; Stern View—Before the wind and under all possible sail.

146. Lithograph of S. "The Earl Balcarres." Received 1908. N. 2505.

This lithograph, by T. G. Dutton, represents one of the latest and largest of the vessels belonging to the Hon. East India Company and known as "East Indiamen." These vessels were superior in general construction and equipment to ordinary trading vessels while their crews were much in excess of trading requirements and were trained similarly to those of the Royal Navy. They performed the duties of both man-of-war and merchantman and often took a successful part in naval engagements. "The Earl Balcarres" was built at Bombay in 1815 and was sold out of the Service in 1834 when the Company ceased their trading operations. She carried 130 men, 26 18-pr. guns and was of 1,417 tons burden. The vessel is here shown sailing "free"—under plain sail and weather studding-sails. Although carrying but one tier of guns she is painted to represent a two-decked man-of-war.

147. Rigged model of S. "Merlin." (Scale 1 : 96.) Presented by H. Davis, Esq., 1901. N. 2263.

This is a built model of a wooden ship constructed at St. John, New Brunswick, in 1851 and a sister ship to the "Eagle"—a well known clipper ship of the period. They were both originally intended for sailing between Liverpool and New Orleans, but afterwards made voyages between England, Australia and the East and West Indies. Such vessels have now almost disappeared, being replaced by the "tramp" steamer which, not confining itself to any route, goes wherever cargo is to be conveyed or procured.

Gross register, 1,030 tons; length, 176 ft.; breadth, 40 ft.; depth, 24 ft.

148. Rigged model of Bengal pilot brig. (Scale 1 : 48.) Received 1908. Plate IV., No. 1. N. 2454.

This represents some six similar brigs built of iron in this country from the designs of Mr. J. Thompson between 1850 and 1870 for the pilot service at the mouth of the river Hooghly, Bengal. This day and night service is carried on by three brigs: one brig cruises at or near the Western Channel of the Hooghly to supply pilots to ships inward-bound to Calcutta; another is stationed near the Eastern Channel to receive the pilots leaving outward-bound ships, while the third brig conveys pilots between the Eastern and the Western Channels, a distance of about 50 miles.

These vessels are fast, easily-manœuvred craft with excellent sea-going qualities. A large windlass, shown forward, is provided for use with coir hawsers.

Gross register, 250 tons; length (b.p.), 105 ft.; breadth, 25 ft.

Steam vessels are now being introduced for this work.

149. Rigged model of a barque (1850). (Scale 1 : 48.) Received 1908. Plate IV., No. 2. N. 2463.

This model was originally the property of the late W. H. Overend, marine artist (1851–1898), and represents a wood-built, barque-rigged sailing vessel of about the middle of the 19th century. The model was re-rigged in the Museum in 1909.

The barque rig differs from the ship rig in having the sails on the mizen mast fitted in a fore-and-aft direction, instead of being carried transversely on yards. It was much in vogue in merchant craft of the 14th and 15th centuries, but afterwards fell into disuse, until it was revived about 50 years ago. As fewer hands are required to manage the sails, this form of rig reduces to some extent the working expenses of a vessel, and it is now largely adopted both by steamers and sailing vessels. It may be noted that on recent vessels there has been a tendency to use relatively shorter masts and longer yards to obtain the necessary sail area.

Gross register, 900 tons: length, 170 ft.; breadth, 32·5 ft.

150. Half block model of S. "Fiery Cross." (Scale 1 : 48.) Lent by J. Campbell, Esq., 1869. N. 1305.

This wooden-built clipper ship was constructed by Messrs. Rennie and Rankine at Liverpool in 1855 for the Liverpool and China trade. She was built partly of fir, and was sheathed with yellow metal below the water-line.

Tonnage, b.o.m., 810; register, 686; length, 173 ft.; breadth, 31·5 ft.: depth, 18·75 ft.

151. Whole model of S. "Fiery Cross." (Scale 1 : 48.) Lent by J. Campbell, Esq., 1869. N. 1304.

This clipper sailing ship was designed by Mr. Rennie, and built of wood at Liverpool in 1860 by Messrs. Chaloner, Hart, & Co., for the China tea trade. She was sheathed with yellow metal and copper fastened.

Displacement at load water-line, 1,615 tons; displacement per inch of immersion at water-line, 10·46 tons; register, 702 tons; length between perps., 185 ft.; length on load line, 181 ft.; breadth, 31·25 ft.; depth of hold, 19·5 ft.; area of midship section to load water-line, 424 sq. ft.; area of load water-line, 4,395 sq. ft.

152. Lithograph of S. "Malabar." Received 1905. N. 2404.

This full-rigged clipper ship, here represented under all plain sail, close hauled on the port tack, was built of wood at Sunderland, in 1860, by Mr. Wm. Pile, for Mr. Richard Green, for the East Indian trade. She was copper fastened, and her bottom was sheathed with felt and yellow metal.

Tonnage, 1,350 tons; length, 207·2 ft.; breadth, 36·6 ft.; depth, 22·5 ft.

153. Half block model of centre-board schooner. (Scale 1 : 24.) Presented by the Kew Museum of Economic Botany, 1876. N. 1406.

This vessel was built about 1860 at Victoria, British Columbia, for the coasting trade.

Displacement, 40 tons; length between perps., 51 ft.; breadth, 15 ft.; depth, 5 ft.; draught, 3·5 ft.

154. Half block model of S. "Victory." (Scale 1 : 48.) Presented by Messrs. Laurence Hill & Co., 1865. N. 1085.

This wooden sailing ship was built at Port Glasgow in 1863 by Messrs. Hill & Co. for the Australian trade; on her first voyage she ran from the Clyde to New Zealand in seventy-two days.

Gross register, 1,199 tons; length, 205 ft.; breadth, 36 ft.; depth, 22·9 ft.

155. Lithograph of clipper race (1866). Received 1905. N. 2405.

During the years 1855–70, considerable rivalry existed between shipowners engaged in the China tea trade; rewards were offered for the first vessels arriving in London with the early teas, and as a result great improvements were made in the building, equipping, and sailing of the ships employed. Their route lay *viâ* the Cape of Good Hope, but since the opening of the Suez Canal, in 1869, they have been gradually displaced by steamships using the shorter route. The composite system of construction, illustrated by drawings and models in an adjacent gallery, was largely adopted in this class of vessel.

This lithograph shows the last phase of a race that excited unusual interest in shipping circles in 1866. Three vessels, "Ariel" (composite), "Taeping" (composite), "Serica" (wood), all built by Messrs. Steele and Son, at Greenock, and each accredited with fast homeward passages, had started from Foo-chow-foo (China) practically together, and after losing sight of each other during the whole voyage reached the English Channel on the same day, each making a record passage of 99 days. This record was reduced to 90 days by subsequent vessels. The leading clippers, "Ariel" and "Taeping," are shown carrying stay-sails, sky-sails, studding-sails and mizen course. The "Fiery Cross" (*see* No. 151) also took part in this race and completed the passage in 101 days.

"Taeping" (1863); tonnage (b.m.), 767 tons; length, 183·7 ft.; breadth, 31·1 ft.; depth, 19·6 ft.

"Ariel" (1865); tonnage (b.m.), 853 tons; length, 197·4 ft.: breadth, 33·9 ft.; depth, 19·6 ft.

156. Whole model of S. "Arundel Castle." (Scale 1 : 48.) Lent by Messrs. Donald Currie & Co., 1878. N. 1509.

This iron sailing ship was built at Greenock in 1864 for the London and Cape trade. She was ship-rigged, had two decks, and a poop deck 30 ft. long.

Register, 1,042 tons; length, 203 ft.; breadth, 33·5 ft.; depth, 21·9 ft.

157. Half block model of schooner "James Duckett." (Scale 1 : 36.) Lent by Messrs. Thomas Grendon & Co., 1888. N. 1803.

This three-masted schooner was built of iron at Drogheda in 1865.

Register tonnage, 232 tons; length, 120·3 ft.; breadth, 23 ft.; depth at side, 12·75 ft.

158. Rigged model of S. "Stonehouse." (Scale 1 : 48.) Received 1877. Plate IV., No. 3. N. 1480.

This wooden-built clipper sailing vessel was designed in 1863–4 by Mr. Gilbert Row and built at Pallion in 1866 by Mr. John Smurthwaite, for the Australian trade. She had a topgallant forecastle 43 ft. long, and a full poop 66 ft. long, where there was cabin accommodation for about 40 first-class passengers; she had also large cargo carrying capacity. The vessel had double topsails and was sheathed with yellow metal and copper fastened; in service she proved herself to be one of the fastest ships of her day. In 1875 she was transferred to French owners and re-named "Fanny."

The model was made by Mr. Row in 1871; the starboard side shows the horizontal section lines, and the port side the vertical longitudinal ones. The masting, rigging, and sails were added in the Museum in 1906. A complete sheer draught or line drawing of this vessel is shown on an adjacent wall.

Gross register tonnage, 1,153; length, 209 ft.; breadth, 36·2 ft.; depth, 21·9 ft.

159. Rigged model of S. "Carmarthenshire." (Scale 1 : 96.) Received 1909. N. 2533.

This represents a ship-rigged vessel built at Pembroke Dock in 1865; she was of wood construction with iron beams.

Double topsail yards and studding sail booms are shown on the model.

The principal dimensions of the vessel were:—Net register tonnage, 812; length, 174·6 ft.; breadth, 32·7 ft.; depth, 20·5 ft. She was omitted from Lloyd's Registers after 1884.

160. Whole model of S. "Durham." (Scale 1 : 48.) Lent by Messrs. Oswald & Co., 1867. N. 1160.

This sailing ship was built of iron at Sunderland in 1866.

Displacement at load line, 1,378 tons; register, 998 tons; length, 209·5 ft.; breadth, 34·75 ft.; depth, moulded, 21·3 ft.

161. Lithograph of S. "Lahloo" (1867). Received 1910. N. 2539.

This lithograph by T. G. Dutton represents one of the fastest of the famous China tea clippers; she is shown outward bound and preparing to land her pilot. Her quickest passage from Foo-chow-foo to London was 97 days in October–January 1870–1. She was wrecked in 1872.

The vessel was of composite construction (*see* sectional models and drawings) and was built by Messrs. Steele and Sons, Greenock, in 1867.

Her principal dimensions were:—Register, 799 tons; length, 191·6 ft.; breadth, 32·9 ft.; depth, 19·9 ft.

162. Rigged model of clipper schooner "John Wesley." (Scale 1 : 32.) Received 1908. Plate IV., No. 4. N. 2502.

This schooner-rigged clipper, of composite construction, was built at Aberdeen in 1867 by Messrs. Hall and Sons, for the London and Australian trade. In 1873 she was brig-rigged and passed into the employ of the Wesleyan Missionary Society, with whom she remained until 1881, when she again became a trading vessel. The model was rigged in the Museum in 1910 from particulars supplied by Messrs. Hall, Alexander & Co., and shows the vessel as originally fitted out.

Like all composite-built vessels (*see* Nos. 643 and 646) her principal internal framing was of iron; her outside planking was partly of American elm and partly teak; it was also copper-fastened and sheathed with yellow metal below the water-line. There were two decks, with a raised quarter-deck 35 ft. long, which were mainly planked with yellow pine.

Her principal dimensions are:—Register tonnage, 238; length, 118 ft.; breadth, 23·9 ft.; depth, 13·5 ft.

163. Half block model of clipper ship. (Scale 1 : 48.) Lent by J. Campbell, Esq., 1869. N. 1306.

This represents a British sailing clipper of the following dimensions:—Length, 170 ft.; breadth, 28 ft.; depth, 21 ft.

164. Rigged model of American schooner "E. W. Morrison." (Scale 1 : 24.) Presented by Phillips Melville, Esq., 1909. N. 2522.

This represents a wood-built three-masted fore-and-aft schooner which was employed, about 1870, in the transport trade on the North American lakes. She belonged to the port of Chicago and had the following approximate dimensions: Length, between perps., 85 ft.; breadth, 22 ft.; register tonnage, 150.

Vessels of the "schooner" rig carry all their sails in a fore-and-aft direction or if of the "topsail schooner" class carry, in addition, yards and upper sails on the foremast. (*See* Yachts and No. 162). Fore-and-aft schooners have been largely developed in the coasting and lake trades of North America since about 1860; they are well adapted for use in smooth waters with off-shore winds and require a comparatively small crew to manage them. Their usual characteristics are, high bow, full beam, wide quarters and tall lower masts. They are principally engaged in coal, lumber, ice and fish transport, and sometimes make oversea voyages. Recent examples of this type of sea-going American sailing vessel show a remarkable increase in size; they are over 300 ft. in length, 3,000 to 5,000 register tons and carry six to seven masts.

165. Half block model of schooner "Saint." (Scale 1 : 36.) Lent by Messrs. Thomas Grendon & Co., 1888. N. 1802.

This three-masted schooner was built of wood at Drogheda in 1870.

Gross register, 118·12 tons; carrying capacity, 204 tons; length (b.p.), 87·16 ft.; breadth, 21·25 ft.; depth at side, 10·6 ft.

166. Whole model of S. "Cygnet." (Scale 1 : 48.) Lent by A. T. Rowe, Esq., 1870. N. 1326.

This represents a wooden sailing ship on launching ways. The starboard side shows the framing and disposition of the timbers, the port side the planking. Her poop was 40 ft., and forecastle 28 ft. in length; in addition she was provided with a deck-house, 24 ft. long by 12 ft. broad.

Tonnage (b.o.m.), 446 tons; length, 144 ft.; breadth, 26 ft.; depth, 12 ft.

167. Half block model of Ss. "Lammermoor" and "Cedric the Saxon." (Scale 1 : 48.) Lent by Messrs. John Reid & Co., 1881. N. 1558.

These full-rigged sailing ships were built of iron at Glasgow in 1874–5. Register, 1,704 tons; length, 249·5 ft.; breadth, 40 ft.; depth, 23·6 ft.

168. Half model of S. "Japanese." (Scale 1 : 48.) Lent by T. Royden, Esq., 1866. N. 1427.

This represents a wooden sailing vessel, for both passenger and cargo service. The poop is 48 ft. long and the forecastle 38·3 ft.

Gross register, 905 tons: length, extreme, 193 ft.; breadth, 29 ft.; depth, 20 ft.

169. Half block model of S. "County of Selkirk." (Scale 1 : 48.) Lent by Messrs. Barclay, Curle & Co., 1881. N. 1555.

This four-masted sailing ship was built of iron at Glasgow in 1878 for the "Counties" East Indian line.

Register, 1,942 tons; length, 281 ft.; breadth, 40·5 ft.; depth, 24 ft.

170. Rigged model of S. "Sudbourn." (Scale 1 : 48.) Lent by Messrs. Richardson, Duck & Co., 1896. N. 2100.

This full-rigged sailing ship was built of iron at Stockton-on-Tees in 1881. She has two steel decks; her poop is 42 ft. and forecastle 33 ft. long. Her bar keel is 9·5 in. deep, and she has one collision bulkhead.

Gross register, 1,750 tons; net register, 1,700 tons; length, 265 ft.; breadth, 39 ft.; depth, 24·25 ft.

171. Half block model of S. "Palgrave." (Scale 1 : 64.) Lent by Messrs. Wm. Hamilton & Co., 1884. N. 1671.

This four-masted sailing ship was built of iron at Glasgow in 1884. When launched she was the largest sailing ship afloat. Her masts and lower yards are of steel, and she is fitted with a donkey boiler to supply steam to the engines of the cranes, winches, pumps, &c.

Register, 3,111 tons; length, 309·5 ft.; breadth, 48 ft.; depth of hold, 25·6 ft.

172. Half block model of S. "Falls of Earn." (Scale 1 : 48.) Lent by Messrs. Russell & Co., 1888. N. 1819.

This four-masted sailing ship was built of iron at Greenock in 1884. She had three tiers of beams, two decks, and one bulkhead. She was fitted with steam appliances for the general heavy work of the vessel.

Gross register, 2,386 tons; length, 300 ft.; breadth, 42 ft.; depth, 24·5 ft.

173. Half block model of barque "Maiden City." (Scale 1 : 48.) Lent by Charles J. Bigger, Esq., 1888. N. 1812.

This barque was built of steel at Londonderry in 1887.

Gross register, 1,242 tons; dead weight capacity, 1,950 tons; length, 223·25 ft.; breadth, 35 ft.; depth, 20·6 ft.

174. Half block model of barque "Cupica." (Scale 1 : 48.) Lent by Charles J. Bigger, Esq., 1888. N. 1813.

This barque was built of steel at Londonderry in 1888, and has two decks and one bulkhead.

Gross register, 1,210 tons; dead-weight capacity, 1,650 tons; length, 226 ft.; breadth, 36·4 ft.; depth, 21·9 ft.

175. Photogravure of barque "France." Presented by Messrs. D. and W. Henderson & Co., 1891. N. 1855.

This five-masted, barque-rigged sailing vessel was built of steel at Glasgow in 1890 by Messrs. Henderson & Co. for the French mercantile marine.

Gross register, 3,784 tons; dead weight of cargo, 6,150 tons; length, 361 ft.; breadth, 48·8 ft.: depth, 25·9 ft.; water ballast capacity, 2,200 tons.

176. Rigged model of barque "Pass of Melfort." (Scale 1 : 48.) Lent by the Fairfield Shipbuilding and Engineering Co., 1896. Plate IV., No. 5. N. 2097.

This four-masted barque-rigged sailing vessel was built of steel at Glasgow in 1891. She has one deck of steel, sheathed with wood; her poop is 50 ft. long, forecastle 42 ft., and her bar keel is 10·5 in. deep. The lower and topmasts are in one, and she has double topsail and topgallant yards. Steam power is used for the heavy work of the ship.

Gross register, 2,346 tons; net, 2,195 tons; dead weight cargo, 3,850 tons; length, 298·7 ft.; breadth, 44 ft.; depth, 24·5 ft.

STEAM PROPELLED MERCHANT VESSELS.

177. Water-colour drawing of P.S. "James Watt." Received 1905. N. 2398.

This three-masted schooner-rigged paddle-wheel steamer was built of wood, at Glasgow, in 1822, by Messrs. J. and C. Wood, to ply between Leith and London; she was the largest steamship that at that time had been built, and the first steamer entered at Lloyd's.

She was fitted with two engines of 50 h.p. each, by Messrs. James Watt & Co. The paddle-wheels were 18 ft. diam., with 16 floats 9 ft. long by 2 ft. broad.

At 10·5 ft. draught of water her speed was 8·7 knots.

Tonnage, 448 tons; length, 141·75 ft.; breadth, 25·5 ft.; depth, 16·5 ft.

178. Rigged model of P.S. "William Fawcett." (Scale 1 : 48.) Lent by the Peninsular and Oriental Steam Navigation Co., 1903. N. 2341.

The Peninsular Steam Navigation Co. was founded in 1837, and their sailings were at first limited to a weekly mail and general service between Falmouth and Gibraltar, calling at intermediate ports on the Atlantic seaboard of Spain and Portugal. In 1840 they extended their service to Egypt and, since that time, to India, China, Japan, and Australia.

The small paddle-steamer shown was built of wood in 1829 and was acquired by the Company in 1837 to commence their contract mail service to the Peninsular ports. Length, on deck, 74·3 ft.; breadth, 15·1 ft.; depth, 8·4 ft.; tonnage, (old measurement), 206 tons; horse-power, 60.

179. Whole block model of the first iron steamers built on the Thames. (Scale 1 : 48.) Presented by Messrs. Maudslay, Sons and Field, 1866. N. 1093.

This represents the paddle steamers "Lord W. Bentinck," "Thames," "Megna," and "Jumna," built of iron in 1832 for the Hon. East India Co., for the navigation of the River Ganges. They were designed and constructed by Messrs. Maudslay, Sons and Field, and fitted with oscillating cylinder engines of 30 nominal h.p. The hulls were flat-bottomed, and the vessels were shipped to India in pieces. Ten in all were ultimately supplied for this river service.

Tonnage (b.o.m.), 275 tons; length, 120 ft.; breadth, 22 ft.; draught, 2 ft.

180. Lithograph of Woolwich steam packets. Received 1905. N. 2406.

These early paddle steamers were the first vessels built for the Woolwich Steam Packet Company, which established a regular day service between London and Woolwich in 1834, and was absorbed in 1875. The boats ran between Hungerford Market (now Charing Cross Pier) and Strother's Wharf, High Street, Woolwich, calling at Greenwich and Queenhithe.

181. Lithograph of P.S. "Sirius." Presented by the City of Cork Steam Packet Co., 1906. N. 2414.

Although several passages across the Atlantic were made by steamships between 1819 and 1838, it was not until the latter year that the practicability of transatlantic navigation by such vessels was fully demonstrated. In April of that year interesting passages were made by the P.Ss. "Sirius" and "Great Western" (*see* No. 182), which represented rival companies. The "Sirius" had previously run between London and Cork, and was chartered by the British and American Steam Navigation Company from the St. George's Steam Packet Company, which afterwards became the Cork Steamship Company and the City of Cork Steam Packet Company. Under the command of Lieut. R. Roberts, R.N., she left Cork Harbour on the morning of April 4th, 1838, with 94 passengers, and was followed across the Atlantic by the "Great Western," which departed from Bristol three days later. Both vessels arrived at New York on April 23rd, the "Sirius" in the morning and the "Great Western" in the afternoon. The "Sirius" made only one voyage to America, and on her return was employed for home and continental services until wrecked in 1847.

The "Sirius" was built of wood, in 1837, by Messrs. Menzies & Co., Leith. Her engines, of the side lever type, with cylinders 60 in. diameter and 6 ft. stroke, were made by Messrs. Wingate & Co., Glasgow, and indicated 320 h.p. The paddle-wheels were 24 ft. diam. and the steam pressure was 15 lb.

Tonnage, gross, 703; length, 178 ft.; breadth, 25·6 ft.; depth, 18 ft.

182. Lithograph of P.S. "Great Western." Received 1905. N. 2399.

This four-masted schooner-rigged paddle-wheel steamer was designed by I. K. Brunel, and built of wood at Bristol, in 1837, by Mr. Patterson, for the Great Western Steamship Co.; she was the first steamer especially constructed to cross the Atlantic.

Her engines, by Messrs. Maudslay, Sons and Field, were of the side lever type, with two cylinders 73·5 in. diam. and 84 in. stroke, indicating 750 h.p. Steam at 15 lb. pressure was supplied by four return flue boilers, and the paddles, which were 28·5 ft. diam. with floats 10 ft. wide, made about 15 revs. per min.

On her first passage across the Atlantic she left Bristol on April 7th, 1838, and arrived in New York Harbour on April 23rd (*see* No. 181), and she continued to ply between those ports for over eight years. In 1847 she was sold to the Royal Mail Co. for 25,000*l.*, and in 1856 was broken up.

Tonnage, 1,320 tons; length, 236 ft.; breadth, 35·3 ft.; breadth over paddle-boxes, 59 ft.; depth, 23·25 ft.

183. Rigged model of P.S. "Britannia." (Scale 1 : 48.) Lent by the Cunard Steamship Co., Liverpool, 1894. N. 2046.

This barque-rigged paddle steamer was built of wood at Greenock in 1840 by Mr. R. Duncan for the Cunard Steamship Co., and was the first vessel of that line. She left England on July 4th, 1840, on her maiden voyage to Boston, and accomplished the passage in 14 days 8 hours, at an average speed of 8·5 knots, and a coal consumption of 38 tons per day. She was the first steamer to carry the mails between England and America.

Her cargo capacity was 225 tons, and she was fitted for the accommodation of 115 cabin passengers only.

Her engines were of the side lever type by Mr. R. Napier, and indicated 740 h.p. (*See* No. 797).

Burden, 1,154 tons; length, 207 ft.; breadth, 34·3 ft.; depth 24·3 ft.

184. Lithograph of S.S. "Princess Royal." Received 1905. N. 2408.

This early screw steamer was built of wood, in 1841, at Newcastle-on-Tyne for a firm at Brighton, and was one of the first vessels to which Sir F. P. Smith's propeller was fitted after the successful experiments with the S.S. "Archimedes." The "Princess Royal" performed the voyage from Newcastle to Brighton, about 400 miles, in 48·5 hours and afterwards proved very satisfactory both as an excursion steamer and tug-boat at South Coast ports. Her screw propeller was two-bladed, 5 ft. diam. and 6 ft. pitch, each blade having half a turn; it was driven by two sets of engines which gave an average speed of about 8 knots.

Register, 101 tons; length on keel, 81 ft.; breadth, 17·5 ft.; depth of hold, 10 ft.; draught, 6·5 ft.

185. Oil painting of Royal Mail steamers. Lent by J. Scott Russell, F.R.S., 1868. N. 1224.

This represents some of the West India Mail Co.'s fleet at anchor in Southampton Water at the time when such vessels were paddle steamers built of wood.

The two most prominent ships in the picture are the "Teviot" and "Clyde," built in 1841, and of the following dimensions:—"Teviot": Length, 214·25 ft.; breadth, 33·6 ft.; depth, 30·5 ft.; tonnage, 1,793 tons. "Clyde": Length, 208·5 ft.; breadth, 32·2 ft.; depth, 24·7 ft.; tonnage, 1,371 tons.

186. Rigged model of P.S. "Hibernia." (Scale 1 : 48.) Lent by the Cunard Steamship Co., 1894. Plate IV., No. 6. N. 2047.

This barque-rigged paddle steamer was built of wood at Greenock in 1843 by Mr. R. Steele for the Cunard Steamship Co. Her engines indicated 1,040 h.p., giving her a speed of 9·25 knots.

Burden, 1,422 tons; length, 219 ft.; breadth, 35·75 ft.; depth of hold, 24·2 ft.

187. Rigged model of S.S. "Great Britain." (Scale 1 : 48.) Presented by T. R. Guppy, Esq., 1878. Plate IV., No. 7. N. 1487.

This represents the S.S. "Great Britain," built by the Great Western Steamship Co., at Bristol, in 1839–43. She was the first large iron ship, and the first screw steamer to cross the Atlantic.

The Great Western Steamship Co. had previously built, as an extension of the G.W.R. system across the Atlantic, the P.S. "Great Western" (*see* No. 182). The quickest passage made by this steamer had been 12 days 18 hours westward and 12 days 7·5 hours eastward; the average number of passengers carried was 85, and the largest number in one voyage 152, at a charge of 35 guineas each.

The Great Western Steamship Co. considered that a larger ship would be much more profitable, and Mr. Brunel was consulted as to its construction. He reported that it was impracticable to build a wooden ship as large as was required, and advised that the ship should be of iron. Hitherto only very small iron ships had been built, so that there was nothing in the way of a precedent upon which the calculations could be based. As no contractor could be found willing to undertake either the building of the hull or the making of the engines, the Great Western Co. had themselves to lay down plant for iron shipbuilding on a large scale, and Mr. Brunel's designs being accepted, the vessel was commenced in 1839 at Bristol. It was originally intended to propel her by paddle-wheels, but before the building had proceeded far the superiority of the screw propeller was demonstrated by the arrival at Bristol of the "Archimedes" (*see* Nos. 971–2.) Brunel accordingly altered his designs for the "Great Britain" so as to adapt her for screw propulsion.

At first it was intended to call this vessel the "Mammoth," as she was 100 ft. longer than the largest line-of-battle ship then existing. She had six masts, two forward of the funnel and four abaft, and could carry 1,700 sq. yds. of canvas.

The ship was floated on July 19th, 1843, but owing to the delay in completing some alterations to the dock she did not enter the river till December, 1844, the machinery having been meanwhile put in. Next day a trial of the screw propeller was made and a speed of 11 knots was obtained with 16 revolutions per minute of the engines, while six of the boiler fires were not lighted.

On January 23rd, 1845, the ship left Bristol and arrived at London in 59·5 hours, the average speed being 9·6 knots. She afterwards steamed to Liverpool, and on the 26th July, 1845, commenced her first voyage to New York, with about sixty passengers on board and 600 tons of cargo. She arrived safely at New York after a passage occupying just over fifteen days. The average speed was 9·25 knots, but the engines only worked to 600 h.p. The return voyage to Liverpool occupied fourteen days, and the greatest run on any one day was 287 miles. On being docked her iron plates were, contrary to anticipation, found to be free from fouling. In a subsequent voyage the six-bladed propeller broke, and the vessel proceeded to Liverpool under canvas, sailing and steering exceedingly well, and making from 10 to 11 knots an hour. The ship was then fitted with a new propeller having only four blades, and Atlantic voyages were continued until 1846, when the ship was stranded in Dundrum Bay, Co. Down. When she was floated off, and taken to Liverpool, the bottom of the ship was found to be a good deal damaged, the boilers having been forced up 15 inches. The repairs were too costly an undertaking for the Great Western Steamship Co., so the vessel, which had cost nearly 100,000*l.*, was sold for about 24,000*l.* The purchasers had the engines replaced by a pair of geared oscillating cylinder engines of 500 h.p., driving a three-bladed cast-iron screw propeller, 15·5 ft. diam. and 19 ft. pitch, with which a speed of 10 knots an hour was attained without sails. The number of masts was reduced to four, while the spread of canvas was about the same as before. In 1853 the steamer was placed upon the Australian trade, where she continued until 1874; subsequently the propelling machinery was taken out and the "Great Britain" became a sailing vessel entirely.

The following is a description of the hull of the "Great Britain" given in considerable detail on account of its historical interest:—

The keel was made of flat plates ·875 in. thick and 20 in. wide, welded into lengths of from 50 ft. to 60 ft. scarf-jointed and riveted. The stem was forged 12 in. deep and 5 in. thick at the fore foot, tapering to 1·5 in. at the upper deck. The stern or screw frame was a single forging 15 ft. deep, 8 ft. wide at the lower end and 12 ft. at the upper end. The frames or ribs were angle irons 6 in. by 3·5 in. by ·625 in. thick, spaced 18 in. apart amidships, increasing to 24 in. at the ends, the angle bars at the ends being 6 in. by 2·5 in. and 4 in. by 3 in.

The outside plates were from 6 to 6·5 ft. long, 3 ft. wide, ·6875 in. thick for the garboard and three adjacent strakes, and above these to the load-line they were ·625 in. thick amidships, tapering to ·375 in. at the ends.

There was no outside keel, but to prevent undue rolling two bilge keels 110 ft. long were fitted, one on each side, so that their lower edges were level with the flat keel plate. The seams of the outside plates, which were clinker built, were double riveted, taper liners being placed between every frame and the outside plate.

The ship was divided into six watertight compartments, each being connected with the pumping engines. The forward three bulkheads were carried up to the underside of the upper deck, the two after ones going only to the under side of the saloon deck.

The deck beams were made up of angle iron 6 in. by 3·5 in. by ·5 in. thick, the end of each beam being bent down and riveted to the ship's frame. Stringer plates 3 ft. wide riveted to these beams formed horizontal ties at each deck. The upper and lower cargo decks were of plate iron, the latter being supported by longitudinal plate-iron sleepers placed on edge on the ship's frames; and the upper deck was supported by wooden pillars secured at their feet to the lower cargo deck, and the deck plates were secured to the ship's sides by struts and tie-plates running fore and aft the whole length of the ship. The upper deck was flush from end to end; there were no deck structures except the ordinary companion hatches, over the saloon, cabin, and engine-room stairways. The bulwarks consisted of a handrail supported by stanchions, running completely round the ship and carrying netting. The deck was of red pine laid lengthwise, and the stringers were iron plates 3 ft. by ·5 in. thick, a tie of Baltic pine running the whole length. The main deck was of pine, 5 in. thick, level with the deep load line of the ship.

Displacement at load-line of 18 ft., 3,618 tons; cargo capacity, by measurement, 1,200 tons; length over all, 322 ft.; length between perpendiculars, 289 ft.; breadth, extreme, 50·5 ft.; depth, 32·5 ft.; coal capacity, 1,000 tons; number of passengers that could be carried, 260.

A model of the engines is exhibited in the collection of Marine Engines (*see* No. 820).

An aquatint (Woodcroft Bequest, N. 2310) of the vessel is also shown, in addition to a nautilus shell, bearing a representation of the "Great Britain" with particulars, and a photograph of her as a coal hulk at Port Stanley, Falkland Islands, in January 1905, presented by C. D. Mackellar, Esq. (N. 2543, 1910.)

188. Oil paintings of S.S. "Great Britain." Lent by Capt. C. Claxton, R.N., 1865. N. 1074.

The upper of these two pictures, painted by J. Walter in 1847, represents this vessel on shore at Dundrum Bay, Ireland, at high water and in a gale of wind, whilst the lower shows her at low water. She ran ashore in September, 1846, and remained exposed for 11 months, nearly submerged at every high tide, the sea in south-westerly and westerly gales making a clean breach over her. The breakwater represented was designed by Brunel, and consisted of 8,000 faggots, 3 ft. in diam. and 12 ft. long, placed about the stern and exposed quarter, loaded with stones, and backed by two rows of birch logs, about 60 ft. long. This, combined with the vessel's great strength, saved her, and she was got off in August, 1847.

189. Rigged model of P.S. "Empire." (Scale 1 : 48.) Made in the Museum in 1904, from a larger model presented by D. Lapraike, Esq., 1868. Plate IV., No. 8. N. 2355.

This represents one of the early passenger boats plying between New York and Troy on the Hudson River (U.S.A.); she was built of wood at New York in 1843 by William H. Brown, was damaged in collision in 1849 and again in 1853, and dismantled shortly after the latter date. The model exhibits most of the leading features of the American river-boat, *i.e.*, fine lines, long flat floors, shallow draught, and overhanging "guards" or sponsons at the level of the main deck.

To give to the shallow hull sufficient longitudinal stiffness, trusses, usually "hog-backed" in shape, are built up from either side amidships for about two-thirds of the vessel's length. In this example the trusses were about 22 ft. deep, the booms and most of the posts were of timber 12 in. by

10 in., while the cross bracing was 9 in. sq.; the joints were secured with iron straps and the posts had through tie rods; transversely the top booms of the trusses were united by struts and tie rods. The guards or overhanging sponson decks were supported by the projecting main deck beams, assisted by inclined ties from the trusses and by wooden knees and diagonal iron struts.

Passenger accommodation was provided by two tiers of cabins and saloons upon the upper and guard decks respectively, while forward, above the cabins, was placed the steering-wheel house from which the large rudder was worked.

The engine was of the half beam type with two cylinders 4 ft. diam. by 12 ft. stroke; boilers and fuel were carried on the guards. The paddle-wheels were 32 ft. diam. and constructed of wood (*see* No. 939).

Tonnage measurement, 936·6; length on keel, 307·5 ft.; breadth, 30·5 ft.; breadth, over guards, 62·5 ft.; depth, 9·75 ft.; draught, 4·5 ft.

190. Lithograph of S.S. "Sarah Sands." Woodcroft Bequest, 1903. N. 2317.

This iron-built screw steamer was constructed by Messrs. Hodgson & Co. at Liverpool in 1845, from the design of Mr. J. Grantham. She was one of the first vessels to demonstrate the practicability of the use of auxiliary screw-power for general trading purposes between England and America; in 1847 she steamed from Liverpool to New York in 20 days, and in 1849 made regular passages in from 16·5 to 18·5 days. In 1857, while engaged as a transport and when about 400 miles from Mauritius, she was burning for 16 hours, and then experienced a severe gale which filled the engine-room with water; the bulkheads, however, remained intact, and the vessel reached Mauritius under sail without any loss of life.

The "Sarah Sands" was one of the first vessels fitted with direct-acting screw engines; they were of 200 h.p., and were made by Messrs. Bury, Curtis, and Kennedy under the patent granted to Mr. J. Grantham in 1842.

Tonnage, 1,300 tons; length (extreme), 220 ft.; breadth, 32 ft.; depth of hold, 20 ft.

191. Whole models of small steamers. (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1250 & 1253.

These represent two classes of small vessels built between 1840–50 by Mr. Russell's firm upon his system of wave lines.

The paddle vessels were for passenger service, and had the following dimensions:—Length on load water-line, 157 ft.; breadth, 18 ft.; breadth over paddle-boxes, 34 ft.; depth at side, 9 ft.

The screw vessels were for the coasting cargo trade, and their dimensions were:—Length on load water-line, 135 ft.; breadth, extreme, 24 ft.; depth at side, 12 ft.

192. Whole model of S.S. "Victor." (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1225.

This represents a small screw trader, with a cargo capacity of 100 tons, built of iron about 1845 by Messrs. Robinson and Russell, Millwall, for employment on the coast of Norway.

The engine had two cylinders 10·25 in. diam. by 18 in. stroke, and was supplied with steam at 40 lb. pressure. The screw was 5·5 ft. diam., and made 116 revs. per min., giving a speed of 8 knots.

Load displacement, 146 tons; tonnage (b.m.), 142 tons; gross register, 130·2 tons; length on load water-line, 96·5 ft.; breadth (extreme), 17·5 ft.; depth at side, 9·5 ft.; draught of water (laden), 6·75 ft.; immersed midship section (laden), 89·8 sq. ft.

193. Whole models of steamers. (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1278–9.

These represent Admiral E. G. Fishbourne's designs described in No. 65, but as modified for a steamer. The proportionate length is increased, because a steamship could be more easily turned than a sailing vessel.

Length on load water-line, 252 or 236 ft.; breadth (extreme), 39 or 32 ft.; depth at side, 28 or 21 ft.

194. Whole model of river steamer. (Scale 1 : 48.) Received 1894. N. 2033.

This represent the first paddle-wheel passenger steamer to navigate the Danube; she was built at Buda-Pesth in 1846, under the directions of Mr. Samuel Pretious. On the base is a design that shows the method of launching.

The dimensions were approximately:—Tonnage, 450 tons; length, 225 ft.; breadth, 19·5 ft.; draught, 3 ft.

195. Lithograph of P.S. "New World." Presented by T. Silver, Esq., 1861. N. 702.

The "New World" is a similar vessel to the "Empire" (*see* No. 189), and was built in 1849 to run between New York and Albany. She was rebuilt in 1855, and increased accommodation for passengers was obtained by introducing a three-decked superstructure, a practice that has since been generally followed in these river-boats. In addition to the "hog frames" the hull is strengthened by large king-posts, about 40 ft. high, stepped into the keel and having caps at the tops, to which are fastened iron tie-rods connected with the guards and with the sides.

The paddle-wheels were 45·5 ft. diam., iron-framed with wooden floats, and were driven by a typical "walking-beam" engine, with cylinders 76 in. diam. by 15 ft. stroke, developing 1,800 indicated h.p. at 20 revs. per min. During an experimental trial in 1852, from New York to Albany (145 miles), a speed of 20 knots was realised.

The dimensions of the "New World," as rebuilt, were:—Register tonnage, 1,675 tons; extreme length, 380 ft.; breadth, 50 ft.; breadth, over guards, 85 ft.; draught, 5·5 ft.

196. Lithograph of P.S. "Atlantic." Woodcroft Bequest, 1903. N. 2314.

This schooner-rigged paddle steamer was built of wood at New York in 1849–50 from the designs of Mr. E. K. Collins. She was the pioneer vessel of the "Collins" Line, established for the conveyance of the United States mails, and with her sister ships "Pacific," "Baltic," and "Arctic" began the first serious competition with the English steamships for fast trans-atlantic service. These four vessels were almost identical, and were so constructed as to admit of their being converted into war-vessels if necessary.

The "Atlantic" commenced running in 1850, and in 1852 made a record passage from New York to Queenstown—2,712 miles in 9·7 days, while in the same year the "Baltic" made a record from Queenstown to New York —3,054 miles in 9·54 days. The "Arctic" was, however, lost at sea in 1854, and the "Pacific" in 1856; which misfortunes, together with financial difficulties, caused the abandonment of the service in 1858, although a larger vessel, the "Adriatic," had then been added.

These ships were excellently fitted and the accommodation embodied improvements in ventilation and cabin heating; the ship's boats were made of galvanized iron.

Each vessel was provided with two sets of side-lever engines, with cylinders, 95 in. diam. and 9 ft. stroke, driving paddle-wheels 35 ft. diam.; with steam at 17 lb. the combined i.h.p. was about 2,000 and the speed

12·5 knots. The boilers were of rectangular shape, but the furnaces contained a large number of vertical water-tubes 2 in. diam.; the coal was carried from the bunkers to the stokeholds by mechanically driven buckets.

Displacement, 6,200 tons; length (o.a.), 300 ft., (b.p.), 282 ft.; breadth, 46 ft.; depth of hold, 32 ft.

197. Whole block model of P.S. "Her Majesty." (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868.
N. 1226.

This represents an iron paddle steamer designed for mail service in any weather for a run not exceeding 60 miles, and on which sleeping accommodation is not required; several of these boats were built about 1850, and the one represented was built and engined by Messrs. Robinson and Russell in that year for service between Portsmouth and Ryde.

The engines had two oscillating cylinders 27 in. diam. by 30 in. stroke, and made 58 revs. per min.

Steam at 20 lb. pressure was supplied by a tubular boiler 9·75 ft. long, 11·25 ft. wide, and 6 ft. high, possessing 1,234 sq. ft. of heating surface, and 50 sq. ft. of grate area. The total weight of the engines, boilers, and water was 30·5 tons, and the space occupied 24 ft. in length.

The paddle-wheels were 11·16 ft. diam. and each had nine fixed floats, 5 ft. by 2·3 ft.; there were three masts, and the sail area was 64 sq. yds. The average speed was 12·8 knots.

Load displacement, 93·5 tons; tonnage (b.m.), 119·5 tons; gross register tonnage, 90 tons; length, on load water-line, 126·75 ft.; breadth, 14 ft.; breadth, across paddle-boxes, 26 ft.; depth at the side, 7 ft.; draught of water (laden), 3·5 ft.; immersed midship section (laden), 46 sq. ft.

198. Whole models of S.S. "Victoria." (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1862 and 1868.
N. 894 and 1237.

This vessel was built of iron in 1852 for the Australian Royal Mail Steam Navigation Co., and gained the prize of 500*l.* offered by the colonies for the fastest voyage to Australia. Her time from Gravesend to Adelaide was 60 days, including two days delay at St. Vincent.

She was designed by Messrs. I. K. Brunel and J. S. Russell, for a speed of 10 knots under full steam, and to provide as much passenger accommodation and space for high-priced cargo as the coal requirements would permit.

The entrance and run of the ship were of the wave-line form, while the central 45 ft. were parallel; the bilges were round, the topsides tumbled home, and there was no external keel, so that the vessel was very easy in the sea-way. The hull was in 12 watertight compartments, and there were longitudinal bulkheads carried through the engine and boiler rooms so as to separate the coal from the machinery.

The engines were of the angular, oscillating type, with four cylinders, 48 in. diam. by 33 in. stroke, arranged in two pairs, and working on two cranks on the propeller shaft, while an intermediate crank worked the air-pumps.

Steam at 15 lb. pressure was supplied by four tubular boilers, 18 ft. wide and 12·5 ft. high, each with five furnaces. The total heating surface was 9,421 sq. ft., given largely by 3-in. tubes, and the grate area was 412 sq. ft. The boilers were arranged in one stokehold, the ventilation of which was assisted by a large hatchway enclosing the funnels to a considerable height. The weight of the boilers was 86·5 tons, the water contained in them weighed 67·8 tons, while the engines weighed 134 tons.

The screw was two-bladed, 15 ft. diam., 22 ft. pitch, and was connected with the engines by a friction coupling. The ship had also four masts and a sail area of 1,540 sq. yds.

Under steam alone, the engines at full power made 59 revs. per min. and gave a speed of 11 knots, with a coal consumption of 37 tons per 24 hours.

Under sail alone, with the screw held vertically, the speed was 5·5 knots, but when the screw was allowed to run freely the speed increased to 7·5 knots. Her average speed was 11·66 knots.

Load displacement, 3,000 tons; tonnage (b.m.), 1,852 tons; gross register, 1,350 tons; length on load water-line, 261 ft.; breadth (extreme), 38 ft.; depth at side, 27·6 ft.; draught (laden), 17·5 ft.; immersed midship section (laden), 590 sq. ft.

199. Whole models of P.S. "Wave Queen." (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868.
N. 1235–6.

This vessel, built in 1852, was intended for sea voyages of 100 to 150 miles. She was believed to be the smallest vessel capable of attaining the speed required; her dimensions were remarkable, her length being over 13 times her breadth and 25 times her depth.

The engines were of the angular oscillating type, with four cylinders 27 in. diam. by 2·5 ft. stroke, and made 50 revs. per min. Steam at 25 lb. pressure was supplied by two tubular boilers, 15·7 ft. long, 10·5 ft. wide, and 6·5 ft. high, having a total grate area of 100 sq. ft. and 2,342 sq. ft. of heating surface. The weight of the engines, boilers, and water was 55·5 tons. The paddle-wheels were 12·4 ft. diam., and each had 18 feathering floats 6 ft. by 2·5 ft. Her average speed was 15·5 knots.

Load displacement, 225 tons; tonnage (b.m.), 250 tons; gross register, 196 tons; length on load water-line, 205·7 ft.; breadth (extreme), 15·5 ft.; depth at side, 8·5 ft.; draught (laden), 5 ft.; immersed midship section, 67 sq. ft.

200. Whole models of P.S. "Rouen," 1853. (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868.
N. 1245–6.

This iron-built vessel was constructed and engined by Messrs. Scott Russell and Co. in 1853 for the London and Brighton Railway Co.'s services between Newhaven and Dieppe.

She was designed on Mr. Russell's wave principle, and was given a tumble-home bow.

Gross tonnage, 357 tons; length, 180 ft.; breadth, 20 ft.; depth, 8·8 ft.

201. Whole model and paintings of P.S. "Pacific." (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868.
N. 1238–41.

This mail steamer was built and engined by Messrs. Russell & Co. in 1853 for service in the Mediterranean. She could accommodate 80 first class and 165 second class passengers, with a certain amount of cargo, and was intended for a voyage of about 2,000 miles.

She was built of iron, on the longitudinal system, with "wave lines" and only a few feet of parallel middle body. She had nine watertight compartments; her plating rose to the top of the gunwale, and was continuous with the interior skin of the paddle-boxes, thus strengthening the centre of the vessel. Her sponsons were provided with open gratings to diminish the surface exposed to wave impact.

The engine was of the oscillating condensing type, with two cylinders 74 in. diam. by 7 ft. stroke; they indicated 1,684 h.p. and weighed 240 tons.

Steam at a pressure of 18 lb. was supplied by four tubular boilers, 14·8 ft. long, 18 ft. wide, and 12·5 ft. high, each with 5 furnaces. The total heating surface was 9,507 sq. ft., and the grate area 420 sq. ft. They weighed 91 tons, and contained 69 tons of water. The consumption of coal was 1·6 tons per hour.

The paddle-wheels were 27 ft. diam., and each had 14 floats 10 ft. long by 4 ft. wide. She had also two masts and a sail area of 883 sq. yds.; her average speed was 14·5 knots.

Load displacement, 1,378 tons; tonnage (b.m.), 1,268 tons; gross register, 1,469 tons; length on load water-line, 245·25 ft.; breadth, 32 ft.; breadth across paddle-wheel boxes, 54 ft.; draught of water (laden), 12 ft.; immersed midship section (laden), 320 sq. ft.

202. Half block model of S.S. "Colombo." (Scale 1 : 48.) Lent by the Peninsular and Oriental Steam Navigation Co., 1878. N. 1493.

This screw steamer was built of iron by Messrs. R. Napier & Sons at Glasgow in 1853 for the Peninsular and Oriental Co. In 1859 she was lengthened, making her dimensions:—Gross register, 2,127 tons; length, 320·5 ft.; breadth, 37 ft.; depth, 29 ft.

Her engines, which indicated 1,538 h.p., were of the beam type, and drove the propeller shaft through spur gearing.

203. Half block model of S.S. "Candia." (Scale 1 : 48.) Lent by the Peninsular and Oriental Steam Navigation Co., 1878. N. 1498.

This screw steamship was built of iron at Blackwall in 1854, by Messrs. C. J. Mare & Co., for the Peninsular and Oriental Co. She was lengthened in 1857 by Messrs. Laird Bros. Her leading dimensions then were:—Gross register, 1,951 tons; length, 317·4 ft.; breadth, 40·5 ft.; depth, 26·2 ft.

A coloured drawing, showing the vertical trunk engines with which this vessel was first fitted, is described under No. 829. In 1876 new two-stage expansion inverted engines were fitted to her, with cylinders 44 in. and 72 in. diam., by 42 in. stroke.

204. Half block model of S.S. "Ellora." (Scale 1 : 48.) Lent by the Peninsular and Oriental Steam Navigation Co., 1878. N. 1495.

This brig-rigged screw steamer was built of iron at Birkenhead in 1855, for the Peninsular and Oriental Co. She was altered to a sailing ship in 1876.

Her engines, constructed by Messrs. J. and G. Rennie, London, had two horizontal direct-acting cylinders, and indicated 1,005 h.p., with a boiler pressure of 20 lb.

Tons (b.m.), 1,665 tons; gross register, 1,727 tons; length, 261·2 ft.; breadth, 36·2 ft.; depth, 25·8 ft.

205. Lithographs of Mississippi river steamers. Presented by T. Silver, Esq., 1861. N. 703–4.

In one lithograph (printed 1855) the "Natchez" and "Eclipse" are represented racing at midnight on the Mississippi; the other lithograph (printed 1860) represents the "Mayflower." They may be taken as typical of the Mississippi steam-boats of that date. The hulls are flat-bottomed with fine lines, but are very shallow; the general description of the steamer in No. 189 is also applicable here.

The "Eclipse" was propelled by a high-pressure engine with a single cylinder 36 in. diam. by 12 ft. stroke, which drove paddle-wheels 40 ft. diam. by 15 ft. wide.

The two boilers are placed forward and about 3·5 ft. above the deck; they are 3·6 ft. diam. by 30 ft. long, and have internal return tubes 9 in. diameter. The fronts are supported by cast-iron plates, while the back ends rest on a tank which acts as a mud receiver; the sides are closed by sheet iron lined with firebrick, and the grates which are 4 ft. long, are at the front. Either coal or wood may be burnt, and the waste gases, after travelling under the shell the whole length, return through the tubes and escape by the funnels, which reach 50 ft. above the hurricane deck.

Length, 360 ft.; breadth, 42 ft.; depth, 8 ft.; draught, 5 ft.; immersed midship section, 200 sq. ft.

206. Whole model of coasting cargo steamer. (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1247.

This class of iron screw ship was introduced about 1855 for service in the North Sea. This design shows how Mr. Scott Russell's system could be applied, by the aid of a long parallel middle body, so as to give a capacious ship. She was rigged with three masts and had a sail area of 822 sq. yds.

The engines were of the oscillating type, with two inclined cylinders 36 in. diam. by 30 in. stroke, arranged opposite each other, and working on to a single crank on the propeller shaft. The propeller was a two-bladed screw 10 ft. diam. by 20 ft. pitch.

Load displacement, 551 tons; tonnage (b.m.), 615 tons; gross register tonnage, 677 tons; length on load water-line, 157·75 ft.; breadth, extreme, 28 ft.; draught of water, laden, 12 ft.; immersed midship section, laden, 272 sq. ft.

207. Whole model of general cargo steamer. (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1248.

This vessel has the same breadth and draught as that described in No. 206, but greater length of parallel middle body and wave-line ends. The screw propeller is abaft the rudder, which is entirely below the propeller shaft, there being a loop in the rudder stock, through which the propeller shaft passes.

The engines were of the oscillating type, with the two inclined cylinders, 36 in. diam. by 30 in. stroke, arranged opposite each other and working on to a single crank on the propeller shaft. The engines weighed 35 tons, and made 74 revs. per min.

Steam at a pressure of 12 lb. was supplied by a tubular boiler, containing 360 tubes 3 in. diam. by 5·5 ft. long, and having a total grate area of 72 sq. ft.

The propeller was three-bladed, and 10 ft. diam. by 17 ft. pitch. Three masts were also provided, which spread 1,497 sq. yds. of canvas; the average speed maintained was 9·5 knots.

Load displacement, 1,066 tons; tonnage (b.m.), 643 tons; gross register tonnage, 597 tons; length on load water-line, 166·25 ft.; breadth, extreme, 28 ft.; draught of water, laden, 12 ft.; immersed midship section (laden), 296 sq. ft.

208. Whole model of Baltic trader. (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1249.

This is another variation of the vessel described under No. 206, with long parallel middle body and wave-line ends. The beam is the same, viz., 28 ft., but the length is increased to 177 ft.

Although not shown in the model, the chief peculiarity of the design is the long forecastle, extending to the midship deckhouse, which was fitted up for first-class passengers. At the after end was a poop for the accommodation of the officers.

The engines were of the inverted oscillating type, with two cylinders 36 in. diam. by 30 in. stroke, and made 60 revs. per min.

Steam at a pressure of 12 lb. was supplied by two tubular boilers, each 10 ft. long, 7·5 ft. wide, and 12 ft. high, containing 180 tubes 3 in. diam. The total grate area was 84 sq. ft., and the heating surface 2,129 sq. ft.

She was propelled by a two-bladed screw, 10 ft. diam. by 22 ft. pitch; her sail area was 1,240 sq. yds., and her average speed 9·75 knots.

Load displacement, 750 tons; tonnage (b.m.), 713 tons; gross register tonnage, 472 tons; length on load water-line, 177 ft. breadth, extreme, 28 ft.; draught of water (laden), 10 ft.; immersed midship section (laden), 222 sq. ft.

209. Whole models of P.S. "Baron Osy." (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1862 and 1868. N. 899 and 1242.

This iron-built vessel was constructed in 1855 on "wave-lines," for the service between London and Antwerp.

She was built on the longitudinal system, with continuous fore-and-aft plate stringers between which were fitted transverse web frames.

The engine was of the oscillating condensing type, with two cylinders 56 in. diam. by 6 ft. stroke, and made 29 revs. per min.; it weighed 121 tons.

Steam, at 18 lb. pressure, was supplied by two tubular boilers, 9·75 ft. long, 18 ft. wide, and 11·75 ft. high, each with five furnaces. The total heating surface was 4,063 sq. ft., and the grate area 195 sq. ft. The weight of the boilers was 42 tons, and that of the contained water was 26·65 tons.

The paddle-wheels were 20 ft. diam., and each had 18 fixed floats, 8 ft. long by 1·75 ft wide.

Load displacement, 980 tons; tonnage (b.m.), 792 tons; gross register, 607 tons; length on load water-line, 208 ft.; breadth (extreme), 28 ft.; draught of water (laden), 10 ft.; immersed midship section (laden), 217 sq. ft.

210. Lithograph of S.S. "Pera." Received 1905. N. 2402.

This ship-rigged screw steamer was built of iron at Blackwall, in 1855, by Messrs. C. J. Mare & Co., for the Peninsular and Oriental Steam Navigation Co., and proved herself a fast boat. She is represented in the illustration under sail and steam; her topsails are fitted with Cunningham's patent self-reefing gear (*see* No. 581).

She had vertical trunk engines by Messrs. G. Rennie and Sons, with two cylinders each 70·25 in. diam. and 48 in. stroke, indicating 1,500 h.p., and driving a three-bladed propeller, 15·5 ft. diam. and 21 ft. pitch, which, at 60 revs. per min., gave a speed of 12·5 knots. There were four sheet-flue boilers, and the bunker capacity was 700 tons, the daily consumption being 44 tons. She was re-engined in 1872.

Tonnage, 2,607 tons; length (b.p.), 303·7 ft.; breadth, 42·25 ft.; depth, 27·2 ft.

211. Lithograph of S.S. "Royal Charter." Received 1905. N. 2401.

This full-rigged clipper ship was built of iron, in 1855, at Sandycroft, near Chester, from the designs of Mr. Grinrod, of Liverpool; she was laid down as a sailing ship, but, being purchased by Messrs. Gibbs, Bright & Co., she was fitted with screw engines of 200 h.p.

She sailed from Melbourne on August 26th, 1859, with a small cargo of skins and wool, 79,000 ozs. of gold, 388 passengers and a crew of 112; 13 passengers landed at Queenstown, and 11 riggers were taken on board for passage to Liverpool. On October 26th, about five miles from Point Lynas lighthouse, and within a mile of Moelfra light, Isle of Anglesea, she was wrecked in a heavy gale; of the 498 persons on board only 39 were saved.

She is represented in the illustration under all plain sail, on the port tack close hauled, taking in royals, flying jib, main, and mizen courses.

A portion of the stern bush for the propeller shaft, recovered nearly two years after the wreck of the vessel, is shown in an adjacent case (*see* No. 888).

Register tonnage, 2,719 tons; length, 320 ft.; breadth, 41·5 ft.

212. Whole and half models of P.S. "Lyons." (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1862. N. 898 and 1251–2.

This vessel was built in 1856 for the packet service between Newhaven and Dieppe. She had exceptionally long and fine hollow lines at the bow, but generally, with fine lines below, the upper ones were full.

The engines were of the angular oscillating type, with two cylinders 42·5 in. diam. by 54 in. stroke, working on a single crank; the air pump was worked from another crank on the paddle shaft. At 38 revs. per min. the indicated h.p. was 1,108.

Steam at 28 lb. pressure was supplied by two tubular boilers, each 8·5 ft. long, 16·25 ft. wide, and 11·75 ft. high, giving a total of 3,589 sq. ft. of heating surface and 170 sq. ft. of grate area.

The total weight of engines, boilers, and water was 116 tons. The paddle-wheels were 19 ft. diam., and each had 11 feathering floats, 8 ft. by 3 ft. wide. The average speed was 15·2 knots.

Load displacement, 315 tons; tonnage (b.m.), 421 tons; gross register, 279 tons; length on load water-line, 190 ft.; breadth, 21·5 ft.; breadth over paddle-boxes, 39·5 ft.; depth at side, 11 ft.; draught of water (laden), 6 ft.; immersed midship section (laden), 110 sq. ft.

213. Block models of the "Great Eastern." (Scale 1 : 48.) Contributed by Messrs. John Scott Russell & Co., 1857 and 1868. N. 901 and 1259–61.

The "Great Eastern," originally called the "Leviathan," was built at Millwall in 1853–8; the four models shown are those used during her construction, and represent the "lines," the plating of the inner and outer skins, and the stern.

About 1852, Mr. I. K. Brunel proposed to the Eastern Navigation Co. the construction of a steamship for the Indian and Australian trade, five or six times the size of any then in use. It was well known that large vessels possessed great advantages over small ones on long voyages, and that the greater the ship the higher the speed; it was estimated that a vessel of the dimensions proposed for the "Great Eastern" would maintain a speed of 15 knots, with less power per ton than ordinary vessels required at 10 knots. The size would also give superior passenger accommodation and cargo capacity, with a fuel endurance that would render coaling abroad unnecessary.

The construction of such a vessel being decided upon, arrangements were made by Messrs. Scott Russell & Co., of Millwall, to build the hull, the paddle-wheels, and their engines, while Messrs. James Watt & Co., of Birmingham, were entrusted with the construction of the screw engines and their machinery. The first plates of the great ship were laid on May 1st, 1854, and she was finally launched on January 31st, 1858.

Her model followed the lines that had for many years been adopted by Mr. Scott Russell, as embodying his "wave-line" principle, and she was given 120 ft. of parallel middle body. Mr. Brunel, however, proposed the use of the two systems of propulsion, and also the cellular construction of the hull.

The framing of the vessel was entirely longitudinal; the longitudinals were 2·8 ft. deep by ·5 in. thick, and were 2·5 ft. apart on the flat of the bottom, and 5 ft. apart from the bottom to a height of 36 ft. From the keel to the water-line the hull was double; the distance between the skins was 2·8 ft. and rendered cellular by the longitudinals. The deck of the ship was also double or cellular, so that the longitudinal strength of the hull was obtained by arrangements resembling those adopted in the girders of the Menai Tubular Bridge.

The hull was divided transversely by iron bulkheads, into compartments, each 60 ft. long, through which there was no opening whatever below the second deck. Two longitudinal bulkheads, 36 ft. apart, traversed 350 ft. of the length of the ship; but, besides the principal bulkheads, there was in each compartment a second intermediate bulkhead forming a coal bunker and carried up to the main deck. At the bow and stern were additional bulkheads. Two continuous tunnels ran through the principal bulkheads, near the water-line, along one of which the steam pipes passed.

The scantlings of the hull were fixed as follows:—The plates of the inner and outer skins, ·75 in. thick, 10 ft. long, and 2·75 ft. wide; other inner plates, all ·5 in. thick. All rivets ·875 in. diam., and 3 in. pitch; while all of the angle iron used was 4 in. by 4 in. by ·625 in

Accommodation for passengers:—1st class, 800; 2nd class, 2,000; 3rd class, 1,200; or, as a troopship, she would carry 10,000 men.

She had five funnels and six masts, which could spread 6,500 sq. yds. of canvas. She was fitted with 20 anchors, which, with their cables, &c., weighed altogether 253 tons.

The "Great Eastern" was launched sideways into the Thames three months after the first attempt. She weighed at the time 12,000 tons, and rested in two cradles, each 80 feet square, which were to slide on inclines 80 ft. wide and 200 ft. long, set at a slope of 1 in 14, but after starting a few feet the inclines failed, and the vessel was subsequently slowly got into the water by the application of extensive hydraulic machinery. These troubles caused financial difficulties, which stopped the work, so that it was only in September, 1859, that the trial trip took place. Her first voyage across the Atlantic was made in June, 1860; the greatest speed attained during the passage was 14·5 knots. Her average speed was 14 knots, and coal consumption 12·5 tons per hour. She, however, did not pay either as a passenger or a cargo steamer; but, from 1865 to 1873 was extensively engaged in laying submarine cables with considerable success. After this she did no useful work, and in 1888 was sold as old metal, and broken up in the two ensuing years.

The paddle and screw engines of the ship are shown and described in Nos. 814 and 831 respectively.

Displacement, 27,384 tons; tonnage, gross, 18,914 tons; length on the upper deck, 692 ft.; length on load water-line, 680 ft.; breadth, extreme, 82·5 ft.; breadth across the paddle-boxes, 120 ft.; depth at side, 58 ft.; depth of hold, 24·2 ft.; draught of water (laden), 30 ft.; area of immersed midship section, 2,204 sq. ft.; coal capacity, 10,000 tons; cargo capacity, 6,000 tons.

A lithograph (N. 2403), two oil paintings (N. 1265–6), and a photograph are also exhibited.

214. Rigged model of "Great Eastern." (Scale 1 : 96.) Contributed by Messrs. John Scott Russell & Co., 1862. Plate V., No. 1. N. 901.

The "Great Eastern" was built at Millwall in 1853–8, and until 1888–90, when she was dismantled and broken up, was the largest vessel afloat, nor was it until 1899 that her dimensions were exceeded.

This model, although probably commenced by the builders while the ship was under construction, was finished and the rigging added in the Museum in 1901. For detailed particulars of the history and construction of this remarkable vessel, *see* No. 213.

215. Coloured drawings of the "Great Eastern." Contributed by John Scott Russell, F.R.S., 1861. N. 700.

These eight drawings show various elevations and sections of the vessel, which help in elucidating the previous models.

216. Whole model of river steamer. (Scale 1 : 96.) Contributed by John Scott Russell, F.R.S., 1868. N. 1267.

This paddle-wheel steamer was built in 1859 for service on the Indus, where, owing to shoals, a draught of only 20 in. was permissible.

The hull was a cellular raft constructed without frames, but to carry the engines and boilers, which weighed altogether 150 tons, the walls of the deck cabins were worked into the depth, and the vessel became a girder 200 ft. in length. A run of 115 ft. of her middle length was included in a couple of plate-girders, 15 ft. deep, forming the sides of the cabins, and these girders were prolonged 35 ft. beyond the cabins, but under the deck.

In form, the vessel consisted of a middle body resembling a parallel box, while the stern was rounded and the keel turned up 2 ft. to allow the water to rise abaft; the bow had, however, wave lines.

The engines had three oscillating cylinders, 36 in. diam. by 48 in. stroke, made 38 revs. per min., and indicated 688 h.p. The engine framing was a triangular structure of plate iron, continuous with the longitudinal girders of the bottom of the vessel; the weight of the engines was 40·6 tons.

Steam at 25 lb. pressure was supplied by two tubular boilers 9·25 ft. long, 14·5 ft. wide, and 12·2 ft. high. The total heating surface was 3,300 sq. ft., their weight 37·4 tons, and that of the contained water 22 tons.

The diameter of the paddle-wheels was 14·3 ft., the floats being radial and measuring 9 ft. by 1·6 ft.; the speed on trial was 11·3 knots.

Load displacement, 331 tons; tonnage (b.m.), 136·3 tons; length on load water-line, 198·25 ft.; breadth, 38 ft.; breadth across paddle-boxes, 60 ft.; depth at side, 6 ft.; immersed midship section, 75 sq. ft.

217. Half block model of P.S. "Leinster." (Scale 1: 48.) Received 1893. N. 2021.

This schooner-rigged vessel is one of four paddle-wheel steamers, "Ulster," "Munster," "Leinster," and "Connaught," constructed for the mail service between Holyhead and Kingstown; she was built of iron at Poplar in 1860 by Messrs. Samuda Bros.

There are nine watertight bulkheads, two of which separate the engines from the boilers; the total length occupied by the machinery is 106 ft., 22 ft. in the middle being apportioned to the engines, and the remainder to the boilers.

The bulwarks are of iron plates, without any break for gangways, these not being required for landing either at Holyhead or Kingstown. To give additional strength to the centre of the vessel, where the weight of the engines, boilers, and paddle-wheels is concentrated, the insides of the paddle-boxes are formed of iron plates, continued from the sides and bulwarks of the vessel, with a strong bow girder, so as to provide ample resistance to the severe shocks which such long vessels encounter when driven at their full speed in a rough sea.

For the Irish mail service the four vessels were in 1896–7 replaced by larger ones with the same names, propelled by twin screws and three-stage expansion engines.

Displacement, 2,000 tons; gross tonnage, 1,467 tons; length, 343 ft.; breadth, 35 ft.; depth, 19 ft.; draught, 13 ft.; immersed midship section, 336 sq. ft.

For a working model of the engines and the paddle-wheels of these ships, *see* No. 816.

218. Rigged model of P.S. "Connaught." (Scale 1: 48.) Lent by Messrs. Laird Bros., 1869. M. 1303.

This schooner-rigged paddle steamer was built of iron at Birkenhead in 1860, by Messrs. Laird Bros., for the mail service between Holyhead and Kingstown.

The engines and paddles are similar to those of the "Leinster" (*see* No. 217).

Displacement, 2,039 tons; length, 348 ft.; breadth, 35 ft.; depth, 20·25 ft.

219. Half block models of Fraser river paddle steamers. (Scale 1: 48.) Presented by the Kew Museum of Economic Botany, 1876. M. 1404–5.

The "Governor Douglas" is a stern-wheel vessel, built about 1860 at Victoria, British Columbia, to the following dimensions:—Displacement, 200 tons; length, 144 ft.; breadth, 27 ft.; depth at side, 5 ft.; draught, 3 ft.

The "Caribo" is a similarly constructed vessel, arranged, however, for side wheels.

220. Half block model of P.S. "Massilia." (Scale 1 : 48.) Lent by the Peninsular and Oriental Steam Navigation Co., 1878. N. 1492.

This schooner-rigged steamer was built of iron on the Thames in 1860, for the Peninsular and Oriental Co.

She was fitted by Messrs. John Penn and Son with oscillating engines, having cylinders 72 in. diam. by 84 in. stroke, indicating 1,730 h.p., and supplied with steam at 20 lb. pressure.

Tonnage (b.m.), 1,919 tons; gross register, 1,640 tons; length, 309·9 ft.; breadth, 36·1 ft.; depth, 22·3 ft.

221. Lithograph of P.S. "Columbia." Received 1905. N. 2400.

This paddle steamer was built of iron at Hull, in 1861, by Messrs. Samuelson, for the Atlantic Royal Mail Steam Navigation Co., popularly known as the "Galway Line."

Four similar vessels were originally constructed for this line, to carry H.M. mails to Boston and New York, *viâ* Galway and St. John's, Newfoundland. Owing to accidents at sea and the inability of several of their ships to realise contract speed, the company was voluntarily wound up in 1864.

The "Columbia" was fitted with eight watertight bulkheads, and had the following principal dimensions:—Tonnage (b.m.), 2,913 tons; tonnage, net register, 1,625 tons; length, 360 ft.; breadth, 40 ft.; depth of hold, 32 ft.

222. Rigged model of P.S. "Scotia." (Scale 1 : 48.) Presented by Messrs. R. Napier and Sons, 1867. N. 1167.

This brig-rigged iron steamer, built at Glasgow in 1862 for the Cunard Co., was the last and finest paddle-driven vessel constructed for the Atlantic service. She had seven watertight compartments, and a double bottom. The masts were 30 in. diam.

The engines were of the side-lever type, with two cylinders 100 in. diam. and 144 in. stroke and indicated 4,900 h.p. (*see* No. 797). Steam at 20 lb. pressure was supplied by eight tubular boilers, and there were two funnels. The diameter of the paddle-wheels was 40 ft., and the floats were 11·5 ft. by 2 ft.

She had accommodation for 300 passengers, and stowed 1,800 tons of coals.

In 1879, after having been sold to the Telegraph Construction and Maintenance Co., she was converted into a twin-screw cable ship. On this duty, and while at sea, in 1896, she sustained a severe explosion from the ignition of vapour from a spirit paint, which blew out the bow and destroyed the collision bulkhead, but the second bulkhead, 44 ft. from the stem, resisted the inrush of water and saved the ship. In 1904 she was wrecked at Guam, Ladrone Islands.

Displacement, 6,520 tons; length, 366·5 ft.; breadth, 47·5 ft.; depth, moulded, 32 ft.

223. Whole model of S.S. "Annette." (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1862. N. 895.

This was an auxiliary screw China clipper, built by Messrs. Russell & Co. about 1862. She was intended to perform her voyage almost entirely by sails, using her steam power only in the districts of light winds and calms. When in China she was to engage in local trade during the intervals between the tea seasons.

She was constructed on the longitudinal system,

The engine was of the oscillating type, with the cylinders beneath the crank-shaft, which was inclined downwards towards the stern. There were two cylinders, 3 ft. diam. by 3 ft. stroke, the revolutions were 45 per min., and the indicated h.p. was 350. Steam at 20 lb. pressure was supplied by a tubular boiler 9·5 ft. long by 13 ft. high, presenting 2,204 sq. ft. of heating surface.

The screw was 11 ft. diam. by 22 ft. pitch, and was connected with the engine shaft by a universal joint, so that it could be raised or lowered without stopping the vessel. The average speed was 9·5 knots.

There were three masts, spreading sails of 1,418 sq. yds. area.

Load displacement, 1,461 tons; tonnage (b.m.), 871 tons; gross register, 650 tons; length on load water-line, 192·7 ft.; breadth, extreme, 30 ft.; draught of water, laden, 14 ft.; immersed midship section, 375 sq. ft.

224. Whole model of S.S. "Bolivar." (Scale 1 : 48.) Lent by the West India and Pacific Steam Ship Co., 1868. N. 1214.

This iron screw steamer was built at Stockton-on-Tees in 1862 for the West Indian and Pacific service.

The engines were simple, inverted, direct acting, with two cylinders 49 in. diam. by 30 in. stroke. In 1870 the ship was lengthened and fitted with two-stage expansion engines, the cylinders being 30 in. and 64 in. diam. by 42 in. stroke.

Gross register, 1,250 tons; length, 240 ft.; breadth, 32·5 ft.; depth, 19·6 ft.

225. Half block model of S.S. "Golconda." (Scale 1 : 48.) Presented by the Peninsular and Oriental Steam Navigation Co., 1865. N. 1061.

This barque-rigged screw steamer was built of iron at Blackwall in 1863, by the Thames Iron Works Co., for the Peninsular and Oriental service.

The engines were two-stage expansion, with cylinders 48 in. and 96 in. diam., by 36 in. stroke.

Gross register, 1,909 tons; length, 314·5 ft.; breadth, 38·3 ft.; depth, 26·6 ft.

226. Whole model of P.S. "Cheshire." (Scale 1 : 32.) Presented by G. H. Harrison, Esq., 1867. N. 2071.

This ferry steamer was built of iron at Liverpool in 1863 by Messrs. H. M. Lawrence & Co., from designs by Mr. George Harrison, M.Inst.C.E. She was employed on the Woodside (Liverpool to Birkenhead) service; the bow and stern are of similar shape, enabling her to go ahead or astern with equal facility, and a rudder is provided at each end. She was licensed to carry 1,620 passengers.

Two sets of independent oscillating engines drive the paddle-wheels. All four cylinders are 33 in. diam. by 42 in. stroke. The nominal collective h.p. is 130, and steam pressure, 19 lb.

Tonnage (b.m.), 632 tons; gross register, 421 tons; length, 150 ft.; breadth over sponsons, 48 ft.; breadth, 30 ft.; depth, 11 ft.; draught, 6 ft.

227. Half block model of S.Ss. "Lazareff," "Korniloff," and "Nachimoff." (Scale 1 : 48.) Received 1893. N. 2024.

These three screw steamers were built of iron at Poplar by Messrs. Samuda Bros., and launched in 1863–5 for the Russian Steam Navigation and Trading Co.; they had four watertight bulkheads, two decks, and three tiers of beams.

The engines were simple, with two cylinders 50 in. diam., by 33 in. stroke.

Gross register, 1,639 tons; length, 274·4 ft.; breadth, 35 ft.; depth, 24·5 ft.

228. Half block model of S.S. "Delhi." (Scale 1 : 48.) Lent by the Peninsular and Oriental Steam Navigation Co., 1878. N. 1490.

This screw steamer was built of iron at Blackwall in 1864, by Messrs. Money Wigram and Sons, for the Peninsular and Oriental service.

The engine was two-stage expansion, horizontal tandem, direct acting, and had surface condensers; the cylinders were 40 in. and 96 in. diam., by 36 in. stroke, and indicated 2,286 h.p., with a boiler pressure of 25 lb.

Gross register, 2,178 tons; length, 313·3 ft.; breadth, 38 ft.; depth, 26·3 ft.

229. Half block model of P.S. "Glengyle." (Scale 1 : 48.) Presented by Messrs. W. Denny & Bros., 1865. N. 1078.

This iron-built, barque-rigged paddle steamer was built at Dumbarton in 1864, for the China Navigation Company.

Gross register, 1,933 tons; net register, 1,266 tons; length, 290 ft.; breadth, 38 ft.; depth, 23·5 ft.

230. Rigged model of P.S. "Evelyn." (Scale 1 : 48.) Presented by Captain H. T. Burgoyne, R.N., 1865. N. 1073.

This paddle steamer, built at Glasgow in 1864, was employed in running the blockade during the American Civil War. She was capable of steaming at a speed of 17 knots.

Tonnage (new measurement), 284 tons; length, 230 ft.; breadth, 28 ft.; draught, with 1,000 bales of cotton on board, 7 ft.

231. Half block model of P.S. "Quebec." (Scale 1 : 96.) Lent by Messrs. Barclay, Curle & Co., 1881. N. 1556.

This iron saloon paddle steamer, of light draught, was built at Glasgow in 1864 for service on the river St. Lawrence, Canada.

Tonnage (b.m.), 1,069 tons; length, 282 ft.; breadth, 34 ft.; draught, 6 ft.

232. Half block model of S.S. "Dakahlieh." (Scale 1 : 48.) Lent by the Peninsular and Oriental Steam Navigation Co., 1868. N. 1211.

This brig-rigged screw steamer was built of iron at Blackwall in 1865, by Messrs. Money Wigram and Sons, for the Peninsular and Oriental service.

Her engines were two-stage expansion, with cylinders 38 in. and 70 in. diam. by 48 in. stroke.

Gross register, 1,553 tons; length, 270 ft.; breadth, 34·6 ft.; depth, 24 ft.

233. Half block model of S.S. "Charkieh." (Scale 1 : 48.) Lent by the Peninsular and Oriental Steam Navigation Co., 1868. N. 1210.

This brig-rigged screw steamer was built of iron by the Thames Iron Works Co. in 1865 for the Peninsular and Oriental service.

She was propelled by a two-stage expansion engine, with cylinders 38 in. and 70 in. diam. by 48 in. stroke.

Gross register, 1,615 tons; length, 274 ft.; breadth, 34·6 ft.; depth, 24 ft.

A lithograph of this vessel is also shown. (N. 2432.)

234. Whole model of S.S. "Medway." (Scale 1 : 64.) Lent by Messrs. Oswald & Co., 1867. N. 1162.

This screw steamer was built of iron in 1865 by Messrs. Oswald & Co., for the Mediterranean trade. She was employed in assisting the "Great

Eastern" in the third and successful attempt at laying the Atlantic cable of 1866, carrying the Newfoundland shore end of the cable after the "Great Eastern" had gone as close in as she could safely get. The "Medway" also carried 500 miles of supplementary main cable in case the 2,730 miles carried by the "Great Eastern" should not be enough to complete the connection. On this occasion the "Medway" was, in addition, provided with grappling apparatus to assist in picking up the broken cable of 1865.

The engines were simple, with two cylinders 54 in. diam. by 33 in. stroke.

Gross register, 1,823 tons; displacement, laden, 3,750 tons; dead-weight of cargo, 3,314 tons; length (b.p.), 280 ft.; breadth (extreme), 35·33 ft.; depth in hold, 28·4 ft.; draught of water (laden), 21·5 ft.

235. Whole model of S.S. "Venezuelan." (Scale 1 : 48.) Lent by the West India and Pacific Steam Ship Co., 1868. N. 1215.

This brig-rigged screw steamer was built of iron at Liverpool in 1865, by Messrs. Jones, Quiggin and Co., for the West India and Pacific service.

The engines were two-stage expansion, with four cylinders, two 21 in., and two 46 in. diam. by 42 in. stroke. She had new engines and boilers in 1874.

Gross register, 1,690 tons; length, 259·5 ft.; breadth, 32·1 ft.; depth, 28·9 ft.

236. Photograph of S.Ss. "Ville de Paris" and "Périere." Presented by Messrs. R. Napier and Sons, 1869. N. 1311.

These two barque-rigged screw steamers were built of iron at Glasgow in 1865–6 for the Compagnie Générale Transatlantique.

Their engines were two-stage expansion with four cylinders, two being 45 in. diam. and the other two 84 in. diam., while the stroke of each was 4 ft. The ships were propelled by single screws (*see* No. 997), and had a speed of 15 knots. The steering gear of these vessels is represented in No. 1054.

Gross register, 3,150 tons; length, 345 ft.; breadth, 43·4 ft.; depth, 29 ft.

237. Rigged model of S.S. "City of Paris." (Scale 1 : 48.) Presented by William Inman, Esq., 1866. N. 1094.

This ship-rigged screw steamer was built of iron at Glasgow in 1866 by Messrs. Tod and McGregor for the Inman Line Atlantic service; she had five bulkheads and a single screw.

The engines were simple, with two horizontal cylinders 82 in. diam., 42 in. stroke, supplied with steam at 30 lb. pressure.

Gross register, 3,081 tons; length, 397·7 ft.; breadth, 40·5 ft.; depth, 26·2 ft.

238. Half block model of S.S "Surat." (Scale 1 : 48.) Lent by the Peninsular and Oriental Steam Navigation Co., 1878. N. 1212.

This barque-rigged screw steamer was built of iron at Southampton in 1866, by Messrs. C. A. Day and Co., for the Peninsular and Oriental service. Her tonnage on launching was 2,578, but in 1874 she was lengthened, when her leading dimensions became :—Gross register, 3,142 tons; length, 356·6 ft.; breadth, 41·6 ft.; depth, 30·3 ft.

Her original engines were horizontal direct-acting, indicating 2,516 h.p., with a boiler pressure of 26 lb.; but, when being lengthened, she was fitted with two-stage expansion engines, with cylinders 48 in. and 96 in. diam., by 54 in. stroke, indicating 2,855 h.p., with the new boilers that worked at 75 lb. pressure.

239. Whole model of trading steamer. (Scale 1 : 48.) Lent by Messrs. Oswald & Co., 1867. N. 1161.

This is a screw steamer built of iron at Sunderland in 1867, for the Baltic, Mediterranean or coal trade.

The engines were simple, with two cylinders 36 in. diam., by 26 in. stroke.

Displacement (laden), 1,692 tons; dead-weight of cargo, 1,120 tons; length, 206 ft.; breadth, 28·8 ft.; depth, 18·3 ft.; draught (light), 7 ft.; draught (laden), 16 ft.

240. Half block model of S.S. "Deccan." (Scale 1 : 48.) Lent by the Peninsular and Oriental Steam Navigation Co., 1878. N. 1497.

This barque-rigged screw steamship was built of iron at Dumbarton in 1868, by Messrs. W. Denny and Bros., for the Peninsular and Oriental service.

In 1875 she was fitted with new engines and boilers by Messrs. R. and W. Hawthorn, Leslie & Co. The engines were two-stage expansion with cylinders 56 in. and 97 in. diam., by 54 in. stroke, indicating 2,600 h.p., with a boiler pressure of 68 lb.

Gross register, 3,429 tons; length, 368·3 ft.; breadth, 42·5 ft.; depth, 30·3 ft.

241. Half block model of S.S. "Travancore." (Scale 1 : 48.) Lent by the Peninsular and Oriental Steam Navigation Co., 1878. N. 1494.

This screw steamer was built of iron at Kinghorn in 1868, by Mr. John Key, for the Peninsular and Oriental Co.

She was re-engined in 1875 by Messrs. Humphrys, Tennant & Co. with two-stage expansion engines having cylinders 36 in. and 80 in. diam. by 48 in. stroke and indicating 1,428 h.p., with a boiler pressure of 24 lb.

Gross register, 1,903 tons; length, 281·6 ft.; breadth, 35·5 ft.; depth, 27·8 ft.

242. Half block model of P.S. "Marquis of Bute." (Scale 1 : 48.) Lent by Messrs. Barclay, Curle & Co., 1881. N. 1557.

This smack-rigged iron paddle steamer was built at Glasgow in 1868 for passenger traffic on the river Clyde.

She had a diagonal engine with a single cylinder 48 in. diam., by 60 in. stroke, driving feathering paddle-wheels 18·5 ft. diam.

Steam at a pressure of 45 lb. was supplied by one haystack boiler 12·6 ft. diam. and 13·5 ft. high.

Gross tonnage, 163 tons; length, 192 ft.; breadth, 18 ft.; depth, 7·5 ft.

243. Whole model of a double-ended paddle steamer. (Scale 1 : 96.) Lent by Messrs. A. and J. Inglis, 1877. N. 1478.

This paddle steamer was designed by Messrs. Inglis, to meet the requirements of Sir John Fowler's Channel Ferry scheme of 1870. She has an awning deck amidships, beneath which, and running nearly the whole length, in the centre of the vessel, is a single track of railway metals, with a platform on each side the length of the deck above. The idea was to run a train from the shore on to the metals, convey passengers and train across the Channel, and then run them off on to another line there.

The indicated h.p. was estimated at 7,500, and the speed 18 knots. Four funnels, and a rudder at each end were provided.

Length over all, 400 ft.; breadth, 45 ft.; depth, 20 ft.; draught, 12·5 ft.

244. Whole model of a Channel steamer. (Scale 1 : 48.) Lent by G. Mackie, Esq., 1895. N. 2058.

This model represents a vessel designed by Mr. S. J. Mackie for the Channel service. She was to be propelled by three pairs of paddle-wheels of a uniform diam. of 24 ft., working either synchronously or separately in two longitudinal channels or waterways, dividing her into three compartments; the centre compartment would carry the engines, boilers, coals, and cargo, and the two outside ones cargo and stores. Other modes of propulsion could, however, be fitted, and the waterway might be single, and placed in the centre. She was to be double-ended so as to go either ahead or astern with equal facility. The saloon was to be 300 ft. long, 60 ft. broad, and 12·5 ft. high.

Her leading dimensions were to be:—Length, 400 ft.; breadth, 80 ft.; draught, 6·5 ft.

245. Half block model of S.S. "Edinburgh Castle." (Scale 1 : 48.) Lent by Messrs. Donald Currie & Co., 1878. N. 1508.

This brig-rigged iron screw steamer was built at Glasgow in 1872 for the Cape trade.

The engines were two-stage expansion, with cylinders 44 in. and 72 in. diam., by 42 in. stroke; the boiler pressure was 63 lb.

Tonnage, 2,678 tons; length, 335 ft.; breadth, 37·6 ft.; depth, 28·16 ft.

246. Half block model of S.S. "Cathay" and "Hydaspes." (Scale 1 : 48.) Presented by Messrs. W. Denny and Bros., 1894. N. 1361.

These three-masted schooner-rigged iron screw steamers were built at Dumbarton in 1872 for the Peninsular and Oriental service.

Their engines were two-stage expansion, with cylinders 50 in. and 86 in. diam., by 54 in. stroke, indicating 2,500 h.p. with a boiler pressure of 65 lb.

Tonnage (b.m.), 2,723 tons; gross, 2,984 tons; length, 360 ft.; breadth, 39 ft.; depth, 31·25 ft.

247. Half block model of S.Ss. "Malwa" and "Bokhara." (Scale 1 : 48.) Lent by the Peninsular and Oriental Steam Navigation Co., 1878. N. 1491.

These two screw-steamships were built of iron at Greenock in 1873, for the Peninsular and Oriental Co.

The engines were inverted surface-condensing two-stage expansion with cylinders 50 in. and 86 in. diam., by 54 in. stroke, indicating 2,500 h.p. Steam was supplied at a pressure of 60 lb.

Gross register, 2,959 tons; length, 360·83 ft.; breadth, 39 ft.; depth, 31·25 ft.

248. Half block model of S.S. "Venetia." (Scale 1 : 48.) Presented by Messrs. W. Denny and Bros., 1894. N. 1360.

This is one of four barque-rigged iron screw steamers, built at Dumbarton in 1873 for the Peninsular and Oriental Co.

The engines were two-stage expansion, with cylinders 50 in. and 86 in. diam., by 54 in. stroke. The boiler pressure was 65 lb.

Gross register, 2,726 tons; length, 351·7 ft.; breadth, 38·3 ft.; depth, 27·8 ft.

249. Half block model of P.S. "Hankow." (Scale 1 : 48.) Lent by Messrs. A. and J. Inglis, 1881. N. 1553.

This paddle steamer was built of iron at Glasgow in 1873 for service on Chinese rivers. She is constructed on similar lines to the American river steamers.

The engine has a single cylinder 72 in. diam., by 168 in. stroke, indicating 1,840 h.p., and a walking beam driving the paddle shaft on which are the wheels 38 ft diam., with alternating half-floats. The speed is 13 knots per hour. The steam pressure is 35 lb. per sq. in., and the coal consumption at full power 2 tons per hour.

She has passenger accommodation for 14 Europeans, also for 188 Chinese —18 first and 170 second class.

Gross register, 3,073 tons; length, 308 ft.; breadth, 42 ft.; depth, 15·75 ft.; load draught, 11 ft.

250. Half block model of S.Ss. "Khiva" and "Kashgar." (Scale 1 : 48.) Lent by the Peninsular and Oriental Steam Navigation Co., 1878. N. 1489.

These brig-rigged steamers were built of iron at Sunderland in 1874 for the Peninsular and Oriental Co.'s service. They had five bulkheads, two decks, three tiers of beams, and a forecastle 29 ft. long.

The engines were two-stage expansion, with cylinders 50 in. and 86 in. diam., by 51 in. stroke, and indicated 2,200 h.p. with a boiler pressure of 70 lb.

Gross tonnage, 2,661 tons; length, 360 ft.; breadth, 26·5 ft.; depth, 29·25 ft.

251. Half block model of S.S. "Guadiana." (Scale 1 : 48.) Lent by the London and Glasgow Engineering and Iron Shipbuilding Co., 1881. N. 1554.

This three-masted schooner-rigged iron screw steamer was built at Glasgow in 1874, for the Royal Mail Steam Packet Co.

The engines were two-stage expansion, with inverted cylinders 46 in. and 82 in. diam., by 45 in. stroke.

Gross tonnage, 2,504 tons; length, 330 ft.; breadth, 36 ft.; depth, 28·5 ft.

252. Oil painting of S.S. "City of Richmond." Lent by S. E. Slader, Esq., 1879. N. 1526.

This was painted by Mr. Slader and represents a ship-rigged steamer built of iron at Glasgow in 1874 by Messrs. Tod and MacGregor, for the Inman Steamship Co., now the American Line.

She is propelled by a two-stage expansion engine, with cylinders 68 in. and 120 in. diam., by 60 in. stroke.

Gross register, 4,780 tons; length, 440·8 ft.; breadth, 43·5 ft.: depth, 34·1 ft.

253. Half block model of S.Ss. "Martaban" and "Irrawaddy." (Scale 1 : 48.) Presented by Messrs. W. Denny and Bros., 1894. N. 1359.

These three-masted, schooner-rigged, iron screw steamers were built at Dumbarton in 1874 for the British and Burmese Steam Navigation Co. The hulls had two decks, three tiers of beams, and five bulkheads.

Their engines were two-stage expansion, with cylinders 41 in. and 70 in. diam., by 42 in. stroke; the boiler pressure was 60 lb.

Gross register, 2,514 tons; length, 340 ft.; breadth, 36 ft.; depth, 28 ft.

254. Whole model of P.S. "Javary." (Scale 1: 48.) Lent by Messrs. Laird Bros., 1879. N. 1516.

This light draught paddle-steamer was built at Birkenhead in 1874, for the Amazon Steam Navigation Co.

The engines are two-stage expansion oscillating, with two cylinders, indicating 550 h.p.

Tonnage, 601 tons; length, 161 ft.; breadth, 28 ft.; depth, 10 ft.; draught, with 190 tons of cargo, 6 ft.

255. Whole model of Indian famine relief steamer. (Scale 1 : 24.) Presented by J. K. Rennie, Esq., 1893. N. 1412.

Six of these light-draught river steamers were built of iron and engined by Messrs. J. and G. Rennie, of Greenwich, in 1874. They were required for the conveyance of grain up shallow rivers, during the Indian Famine of 1874. They were constructed to carry 27 tons of grain on a draught of 3 ft. and were conveyed to their destinations in sections.

The first vessel was built and engined in 35 working days from the date of order, February 24th, 1874.

Each vessel had two sets of single cylinder engines, 12 in. diam. by 10 in. stroke, indicating 100 h.p., and driving twin screws, which gave a speed of 9 knots. Steam at 60 lb. pressure was supplied by a cylindrical return-tube boiler.

Tonnage (b.m.), 85 tons; length, 90 ft.; breadth, 14 ft.; depth of hold, 5·5 ft.

256. Half block model of P.S. "Aloungpyah." (Scale 1 : 48.) Lent by Messrs. R. Duncan & Co., 1876. N. 1425.

This light draught iron paddle steamer was built at Port Glasgow in 1875, to carry passengers and cargo on the Irawadi from Rangoon to Bhama, a distance of nearly 1,000 miles. This model illustrates the method of carrying a spar deck with a wooden awning; also details of the upper deck fittings.

The engines are two-stage expansion with diagonal cylinders 31 in. and 53 in. diam., by 54 in. stroke. Steam at 70 lb. pressure is supplied by two horizontal cylindrical tubular boilers. The coal bunkers carry 100 tons of coal, sufficient for a voyage from Rangoon to Mandalay and back, 1,400 miles.

Tonnage (b.m.), 825 tons; length, 245 ft.; breadth, 26 ft.; depth, 8 ft.

257. Whole model of P.Ss. "Rose" and "Shamrock." (Scale 1 : 48.) Lent by Messrs. Laird Bros., 1879. N. 1517.

These two paddle steamers were built of iron at Birkenhead in 1876 for the conveyance of passengers and mails between Holyhead and Kingstown.

The engines have two inverted cylinders 78 in. diam. by 84 in. stroke, indicating 3,000 h.p.

Gross register, 1,186 tons; length, 293·3 ft.; breadth, 32 ft.; depth, 16·6 ft.; load draught, 10·6 ft.

258. Whole model of S.S. "Han Kwang." (Scale 1 : 48.) Lent by Messrs. Laird Bros., 1879. N. 1515.

This iron screw steamer was built at Birkenhead in 1876 for the Chinese coasting trade. She has two decks and an awning deck, also five bulkheads.

Her engines are inverted two-stage expansion, with cylinders 34 in. and 57 in. diam., by 33 in. stroke, which, with a boiler pressure of 60 lb. indicate 800 h.p.

Gross tonnage, 1,233 tons; length, 230 ft.; breadth, 33 ft.; depth, 22·25 ft.; load draught, 12·5 ft.

259. Half block model of S.S. "Devonia." (Scale 1 : 48.) Lent by the Barrow Shipbuilding and Engineering Co., 1877. N. 1479.

This barque-rigged iron screw steamer was built at Barrow-in-Furness in 1876 for the Atlantic service of the Anchor line. She had two decks and a spar deck, four tiers of beams, and seven bulkheads.

Her engines were two-stage expansion, with cylinders 59 in. and 107 in. diam., by 48 in. stroke. Steam was supplied at a pressure of 65 lb.

Tonnage, 4,500 tons; length, 400 ft.; breadth, 42 ft.; depth, 25 ft.

260. Half block model of screw steamer. (Scale 1 : 48.) Woodcroft Bequest, 1903. N. 1337.

This represents an iron-built cargo steamer with a "well-deck," an arrangement that has since been generally abandoned.

Gross register, 1,006 tons; length, extreme, 216 ft.; breadth, 28 ft.; depth, 18 ft.

261. Half block model of proposed Atlantic steamer. (Scale 1 : 24.) Lent by Messrs. J. and G. Thomson, 1877. N. 1472.

This represents an iron-built passenger and cargo steamer which was to be fitted with engines indicating 4,500 h.p. and driving a single screw.

Gross register, 4,858 tons; length, 450 ft.; breadth, 45 ft.; depth, moulded, 35 ft.

262. Rigged model of P.Ss. "Brighton" and "Victoria." (Scale 1 : 48.) Lent by the London, Brighton, and South Coast Railway Co., 1878. N. 1510.

These schooner-rigged paddle steamers were built of steel at Glasgow in 1878, for the service between Newhaven and Dieppe.

The engines are inverted two-stage expansion with cylinders 48 in. and 83 in. diam., by 60 in. stroke, giving a speed of 16·8 knots, with a boiler pressure of 80 lb.

Gross register, 531 tons; length, 220 ft.; breadth, 27·5 ft.; depth, moulded, 11·6 ft.

263. Half block model of P.S. "Violet." (Scale 1 : 48.) Lent by Messrs. Laird Bros., 1879. N. 1518.

This vessel was built of steel at Birkenhead in 1879, for the Irish mail service of the London and North Western Railway Co. The quarter deck is 99 ft., the bridge deck 90 ft., and the forecastle 96 ft. in length.

The engines had a pair of oscillating cylinders 78 in. diam. by 84 in. stroke, indicating 3,200 h.p.; in 1890 they were replaced by a three-stage expansion set with cylinders 44 in., 70 in. and 108 in. diam. by 78 in. stroke. New boilers were also fitted.

Gross register, 1,035 tons; length, 300 ft.; breadth, 33·1 ft.; depth, 14·4 ft.

264. Rigged model of S.S. "Arizona." (Scale 1 : 48.) Lent by the Fairfield Shipbuilding and Engineering Co., 1901. N. 2267.

This four-masted, barque-rigged screw steamer was built of iron and engined at Glasgow in 1879, by Messrs. J. Elder & Co., for the Guion Steamship Co.'s transatlantic service; she commenced a new era by a record passage from Queenstown to Sandy Hook of 7·3 days. In November, 1879, while travelling at the speed of 14 knots in mid-ocean, she ran into an iceberg which crushed in her bow for a length of 26 ft. and to a depth of 14 ft. below water-line, but she was effectually protected from foundering by her collision bulkhead.

The vessel has four decks, the upper and main being continuous and covered with wood; the lower deck is only plated amidships, while the orlop deck extends from the machinery space to each end; there is also a bridge 34 ft. long and a forecastle of 74 ft. She is built with a bar keel 12 in. deep and a stem 9 in. by 5·5 in.; there are eleven bulkheads, eight of which are watertight.

Her original engines were an inverted two-stage expansion set, with one high-pressure cylinder, 62 in. diam., and two low-pressure cylinders of 90 in. diam. by 66 in. stroke. Steam at 90 lb. pressure was supplied by seven Scotch boilers 13·5 ft. diam. On trial with an indicated h.p. of 6,357 and 56 revs. per min., she attained a speed of 17·3 knots.

In 1898 her engines were altered by the Fairfield Company to a three-stage expansion set, with cylinders 34·5 in., 56 in., and 92 in. diam., and the original stroke of 66 in. Steam at 180 lb. pressure is supplied by three double and two single-ended boilers, having in all 24 corrugated furnaces, a grate surface of 468 sq. ft., and a heating surface of 14,578 sq. ft. With this machinery the same i.h.p. and speed are obtained with a considerably reduced coal consumption.

Gross register, 5,305 tons; length, 450·2 ft.; breadth, 45·4 ft.; depth, 35·7 ft.

265. Rigged model of S.S. "Orient." (Scale 1 : 48.) Lent by the Orient Steam Navigation Co., 1891. N. 1867.

This four-masted barque-rigged steamer was built of iron at Glasgow in 1879, for the Australian trade, by Messrs. John Elder & Co. She has four decks—two iron and one partly iron—the upper deck being sheathed with wood; the double bottom aft is 54 ft., and the midship deep tank 28 ft. long, both of which could be filled with water ballast; her bar keel is 12 in. deep, and she has eight bulkheads.

The engines are two-stage expansion, with one high pressure cylinder 60 in. and two low pressure cylinders 85 in. diam. by 60 in. stroke, indicating 5,400 h.p., driving a right-handed, four-bladed propeller 22 ft. diam., and 30 ft. pitch, at 58 to 62 revs. per min. The boss of the propeller is of annealed cast iron; the blades are of steel, cast by Messrs. Vickers, Sons & Co., of Sheffield, and are bent backwards to prevent vibration. Steam at a pressure of 75 lb. is supplied by four circular double-ended boilers, 15·5 ft. diam. by 17·25 ft. long, with six furnaces 4 ft. diam. and 6 ft. long, giving a grate area of 264 sq. ft. The bunkers hold 3,000 tons of coal, or more than sufficient for the voyage out to Australia by the long sea route, *viâ* the Cape of Good Hope. She can carry 3,600 measurement tons of 40 cub. ft. of cargo, and has accommodation for 220 saloon, 130 second, and 300 steerage passengers.

Displacement, 9,500 tons; gross register, 5,365 tons; length, 445·5 ft.; breadth, 46·25 ft.; depth, 35·08 ft.

266. Whole model of S.S. "Vindobala." (Scale 1 : 96.) Lent by Messrs. Hepple & Co., 1882. N. 1582.

This schooner-rigged screw steamer was built of iron at Newcastle in 1879. She has one iron deck, and two tiers of beams, five bulkheads, a bridge deck 96 ft. and forecastle 32 ft. long. Her double bottom aft is 62 ft., forward 72 ft., and under the engine and boiler room 32 ft. long, with a capacity of 32 tons; there is also a fore-peak tank of 35 tons, and an after-peak tank of 40 tons capacity.

Her engines are two-stage expansion with cylinders 33 in. and 62 in. diam. by 42 in. stroke. The boiler pressure is 80 lb.

Gross register, 1,744 tons; length, 261 ft.; breadth, 34·25 ft.; depth, 21·66 ft.

267. Whole model of stern wheel steamer "Inez Clarke." (Scale 1 : 12.) Presented by Messrs. Yarrow & Co., 1900. Plate V., No. 2. N. 2256.

This shallow draught steamer and a sister vessel, the "General Troquilla," were built in 1879 by Messrs. Yarrow & Co. for the United States of Colombia, to be employed in the mail service on the river Magdalena. They attained a speed of 15 miles an hour.

They were constructed of galvanised steel plates, from ·12 to ·19 in. in thickness, and divided into eighteen watertight compartments; the engines are placed aft and act directly on to the paddle-wheel shaft, while, to distribute the weights, the boiler is at the fore part of the ship. To resist hogging and generally give longitudinal strength to the structure, two deep trusses are introduced so as to supply this stiffness with a minimum of weight; these also form the supports for the two flying decks, upon which the saloon accommodation is provided. The rods of the trusses have screw adjustments, by which initial stresses can be applied, for the purpose of avoiding vibration of the members.

The engines are of the two-stage expansion type, with a high pressure cylinder, 15 in. diam., on one side, and a low pressure cylinder, of 27 in. diam., on the other; the stroke of each is 4·5 ft. Gooch's stationary link motion is used, and the engines are fitted with a detached surface condenser of cylindrical form. The air and circulating pumps are driven by an independent engine.

The boiler is of the locomotive type, with a divided fire-box and large grates suitable for burning wood; the two grates are fired alternately, and forced draught from a fan is delivered into the closed ash-pit. The fan also assists in ventilating the various saloons, and the fan engine is fitted for driving a circular saw when required for cutting up the timber used as fuel. Under ordinary conditions, with 160 lb. boiler pressure, 250 indicated h.p. is developed, but there is an arrangement by which boiler steam, lowered to 60 lb. pressure by a reducing valve, can be directly admitted into the low pressure cylinder so as to obtain additional power when rapids have to be ascended. With a draught of 15 in. these vessels have obtained a speed of over 13 knots. Owing to the very small immersion, three rudders are fitted, the centre one of which is of the balanced type.

Displacement, light, about 73 tons; length, 130 ft.; breadth, 28 ft.; draught, 12 in.; draught with a load of 90 tons, 24 in.

268. Rigged model of S.S. "Athenian." (Scale 1 : 48.)
Lent by the Union Steam Ship Co., 1897. N. 2154.

This three-masted, schooner-rigged steamer was built of iron at Glasgow in 1881 by Messrs. Aitken and Mansel, for the South African service. She has three decks, eight bulkheads, a bridge deck 102 ft. long, forecastle 42 ft., and a water ballast capacity of 370 tons in a cellular double bottom 220 ft. long.

Her engines were altered in 1886 to a three-stage expansion set, with cylinders 36 in., 58 in., and 94 in. diameter, by 54 in. stroke. Steam at 160 lb. pressure is supplied by three double-ended steel boilers, with 18 corrugated furnaces.

Gross register, 3,882 tons; length, 365 ft.; breadth, 45·8 ft.; depth of hold, 29 ft.

269. Half block model of S.S. "Austral." (Scale 1 : 48.)
Lent by the Orient Steam Navigation Co., 1882. N. 1574.

This screw steamer was built at Glasgow in 1881, for the Australian trade, by Messrs. John Elder & Co. She has four masts, schooner-rigged, and a sail area of 28,000 sq. ft. The bottom is double, with 19 watertight compartments, and there are 13 watertight bulkheads in her hull. She is built of mild steel, and has a total water ballast capacity of 1,000 tons. She has been built to suit the requirements of the Admiralty for a war cruiser, and is specially strengthened to carry guns.

The engines are two-stage expansion, with one cylinder of 63 in., and two of 86 in. diam., by 60 in. stroke. Steam is supplied at a pressure of 95 lb. by four double-ended steel boilers, 16 ft. diam. and 17 ft. long, with six furnaces in each, and a total grate area of 688 sq. ft. She indicated 7,114 h.p., giving a speed of 17·3 knots, and the coal consumed was at the rate of 1·3 lb. per indicated h.p. per hour. She could steam from England to Australia at her full speed without re-coaling or interference with her ordinary cargo and passengers.

In November 1882, the "Austral" sank in Sydney Harbour in 50 ft. of water; the ports had been left open, and the vessel filled owing to a heavy list due to unequal coaling. She was raised in March, 1883, and soon restored to her original condition. (*See* photographs, N. 1820, presented by Sir Herbert Sandford, 1888.)

Displacement at load line, 9,500 tons; gross register, 5,524 tons; length, 455 ft.; breadth, 48·25 ft.; depth, 37 ft.

270. Rigged model of S.S. "Servia." (Scale 1 : 48.) Lent by the Cunard Steamship Co., Ltd., 1907. N. 2437.

This barque-rigged steel steamer was built and engined at Glasgow in 1881–2 by Messrs. J. and G. Thomson for the Cunard Co.'s Liverpool and New York service. She was the largest vessel afloat at that date, with the exception of the "Great Eastern"; she was also the first cargo vessel constructed throughout of Siemens mild steel and the first Cunârder to be lighted electrically. Her record Atlantic passage was 7 days 1 hour 38 mins.

The lower portions of the ship were framed on the cellular system, combined with a centre-through-plate keel which was built up in five thicknesses and hydraulically riveted. The main hull was sub-divided by twelve watertight bulkheads, eight of which were extended to the main deck. Orlop, lower, main, and upper decks were fitted in addition to a promenade deck for passengers.

In a steel-protected steering house at the stern, provision was made for four separate methods of steering: (i) A steam gear; (ii) A hand screw gear; (iii) A hand double-purchase chain gear; (iv) Tackles acting directly on a large horizontal wheel instead of the usual quadrant attached to the rudder head. Cunningham's patent self-reefing sail gear was fitted to the fore and main topsail yards. Accommodation was provided for 500 to 600 first-class passengers and about 700 others.

The vessel was propelled by two-stage expansion engines having a high pressure cylinder 72 in. diam. and two low pressure cylinders each 100 in. diam. with a common stroke of 78 in. Steam was supplied by seven boilers, six of which were double-ended with six furnaces each and one single-ended with three furnaces, the whole 39 furnaces being constructed with Fox's corrugated flues. On light draught trials, with steam at 90 lb. per sq. in. and engines indicating 10,300 h.p. she realised a speed of 17·8 knots.

The "Servia" was included in the Admiralty list of auxiliary cruisers and could under war conditions carry sufficient coal to steam 16,400 miles at her normal full speed, *i.e.*, 16·7 knots.

Displacement, 12,300 tons; gross register, 7,392 tons; length (overall), 540 ft.; breadth, 52·1 ft.; depth, 37 ft.; draught (mean), 26 ft.

271. Whole model of S.S. "City of Rome." (Scale 1 : 96.) Lent by the Barrow Shipbuilding and Engineering Co., 1882. N. 1580.

This four-masted, schooner-rigged screw steamer was built of iron at Barrow in 1882 for the Anchor Line of Atlantic steamships.

She has four decks (three of iron) and is divided by ten bulkheads; the double bottom is 107 ft. long, with a capacity of 376 tons; the coal bunkers are along the sides of the ship and form part of the structure.

The engines are two-stage expansion, inverted tandem, with three pairs of cylinders 43 in. and 86 in. diam., by 72 in. stroke, indicating 11,890 h.p.

Steam at 90 lb. pressure is supplied by eight steel boilers, 19 ft. long by 14 ft. diam., giving a grate area of 1,398 sq. ft., and 29,286 sq. ft. of heating surface. The propeller is 24 ft. diam., and the speed on trial was 18·23 knots.

Displacement, 11,230 tons; gross tonnage, 8,141 tons; length, 560 ft.; breadth, 52·25 ft.; depth, 37 ft.

272. Half block model of proposed Atlantic steamer. (Scale 1 : 64.) Lent by Messrs. McMillan and Son, 1882. N. 1584.

This half block model represents a design for a large twin-screw steamer for the Atlantic service.

The hull was to be divided into 44, and the double-bottom into 22 watertight compartments, with a water-ballast capacity of 1,800 tons.

Two distinct sets of engines, each of the 4-cylinder inverted three-stage expansion type, with one cylinder 44 in., one of 66 in., and two of 100 in. diam. by 72 in. stroke were provided for. These were estimated to indicate 20,000 h.p. at 59 revs. per min., and to give the vessel a speed of 20 knots on a 23 ft. draught. The propellers were to be 22 ft. diam. and 35 ft. pitch. Steam at 125 lb. pressure was to be supplied by twelve steel boilers with six furnaces in each. The accommodation would be for 1,134 passengers with a ship's company of 300, or else for 4,000 troops.

The details of the proposed vessel are:—Displacement at 26 ft. draught, 19,835 tons; weight of vessel complete for sea, 12,500 tons; dead weight capacity at 26 ft. draught, 7,335 tons; tonnage, gross, 10,000 tons; length, 600 ft.; breadth, 70 ft.; depth, 39 feet; immersed midship section, laden, 1,537 sq. ft.; wetted surface, laden, 52,207 sq. ft.

273. Half block model of P.S. "Barrow Express." (Scale 1 : 48.) Lent by the Barrow Shipbuilding and Engineering Co., 1882. N. 1581.

This vessel was designed in 1881–2 for a high speed service between Barrow-in-Furness and Douglas, Isle of Man.

The engines were to be two two-stage expansion sets, with oscillating cylinders, 50 in. and 88 in. diam., by 72 in. stroke, indicating 5,000 h.p. Steam at 85 lb. pressure was to be supplied by four doubled-ended steel boilers. The feathering float wheels were to be 24 ft. diam., and to have each ten steel floats.

Register, 1,595 tons; length, 320 ft.; breadth, 38·25 ft.; depth, 14·42 ft.

In 1885 the paddle steamer "Mona's Queen" was built of steel on this design.

274. Rigged model of P.S. "Ho-Nam." (Scale 1 : 48.) Lent by Messrs. A. and J. Inglis, 1891. N. 1865.

This schooner-rigged paddle steamer was built of steel at Glasgow in 1882, for the conveyance of passengers and cargo, principally between Hong Kong and Canton. There are three decks 9 ft. apart, the lower one of which is of steel, for cargo, while the two above it are of wood. The sponsons, supported in the usual way by beams and stays, are carried entirely round the ship.

The engines are two-stage expansion of the overhead beam type, with cylinders 40 in. and 72 in. diam., by 120 in. stroke, and at 33 revs. per min., indicate 2,900 h.p., and give a speed of 16·25 knots. The beam is 23 ft. long, 11 ft. deep, and weighs 14 tons, while the connecting rod is 23 ft. long. The surface condenser, of 5,395 sq. ft. area, is placed alongside the cylinders, while the pumps are worked by a rod from the beam.

Steam at 75 lb. pressure is supplied by three double-ended steel boilers, placed athwartships, and fired from the wings. They are 14 ft. diam., 14 ft. long, and have in all 18 furnaces, giving a grate area of 297 sq. ft., and a heating surface of 7,939 sq. ft.

The paddle-wheels are 21 ft. diam., and are built entirely of steel, with feathering floats 15 ft. by 4 ft.

Gross register, 2,364 tons; length, 270 feet; breadth, 38 ft.; depth, 13·25 ft.

275. Rigged model of H.M. telegraph S.S. "Monarch." (Scale 1 : 48.) Lent by W. R. Culley, Esq., 1885. N. 1691.

This schooner-rigged iron screw steamer was built at Port Glasgow in 1883, for the Telegraph Department of the Post Office. She was designed for laying and repairing submarine cables, is double-bottomed, and has three cable tanks. There are cable sheaves at the bow and stern, for picking up or laying, and she is capable of carrying fuel and other stores sufficient for six weeks' work.

The engines are two-stage expansion, with inverted cylinders 30 in. and 50 in. diam. by 48 in. stroke, indicating 1,040 h.p., and driving a single propeller. The boiler pressure is 80 lb.

Displacement at 16 ft. draught, 2,135 tons; gross register, 1,122 tons; length, 240 ft.; breadth, 33 ft.; moulded depth, 20 ft.

276. Rigged model of S.S. "Clan Macarthur." (Scale 1 : 48.) Lent by Messrs. Cayzer, Irvine & Co., 1888. N. 1808.

This schooner-rigged screw steamer was built of steel at Greenock in 1883 for cargo and passenger traffic to the East. She has three steel decks, the upper sheathed with wood; the bridge deck is 144 ft. and the forecastle 48 ft. long.

Her engines were two-stage expansion, with cylinders 48 in. and 86 in. diam., by 60 in. stroke, and indicated 2,376 h.p. Steam was supplied by two boilers, having twelve corrugated furnaces.

In 1893 the engines were altered to three-stage expansion, with cylinders 30·5 in., 48 in., and 82 in. diam,, with a stroke of 60 in. Steam at 160 lb. pressure is supplied under forced draught by two single-ended steel boilers, with eight ribbed furnaces, a grate area of 160 sq. ft., and 6,411 sq. ft. of heating surface.

Gross register, 3,994 tons; length, 382 ft,; breadth, 44 ft.; depth, 28 ft.

277. Rigged model of S.S. "City of Chicago." (Scale 1 : 48.) Lent by the Inman and International Steamship Co., 1887. N. 1728.

This four-masted, barque-rigged steamer was built of iron at Glasgow in 1883 by Messrs. C. Connell & Co,, for the Atlantic service. She had four decks, two of which were iron, and seven bulkheads.

The engines were two-stage expansion with one cylinder 56 in. and two of 80 in. diam., with a stroke of 60 in., indicating 5,000 h.p., and driving a single screw. Steam at 90 lb. pressure was supplied by four double-ended and two single-ended steel boilers, having a total of 30 furnaces.

Gross register, 5,202 tons; length, 430 ft.; breadth, 45 ft.; depth, 33·5 ft.

278. Whole model of telegraph S.S. "Britannia." (Scale 1 : 48.) Lent by the Telegraph Construction and Maintenance Co., 1892. N. 2007.

This twin-screw, schooner-rigged steamer was built of steel at Birkenhead in 1885, by Messrs. Laird Bros., and was specially constructed for laying and repairing submarine telegraph cables. She has five watertight bulkheads, and a double bottom forward, 64 ft. in length, with a water ballast capacity of 205 tons, while there is a deep tank aft, 40 ft. long, with a capacity of 112 tons.

She is propelled by two sets of two-stage expansion engines, with cylinders 26 in. and 45 in. diam., by 30 in. stroke, which, with a boiler pressure of 75 lb., together indicate 1,350 h.p., and give a speed of 12 knots.

The apparatus for laying the cable is shown on the after part of the model, whilst the picking-up gear is placed forward.

Gross register, 1,525 tons; length, 247·2 ft.; breadth, 34·3 ft.; depth, 17·4 ft.

279. Whole model and drawings of S.Ss. "Crocus" and "Snowdrop." (Scale 1 : 48.) Lent by Messrs. Flannery and Fawcus, 1885. N. 1678.

These Mersey river ferry boats were built at Preston in 1885 by Messrs. W. Allsup and Sons, from designs by Messrs. Flannery and Fawcus, for the service between Liverpool and Wallasey. They are both constructed of mild steel throughout, and are divided into 18 watertight compartments; both ends are alike, so that they can go ahead or astern with equal ease.

They have each two complete sets of two-stage expansion engines, with inverted cylinders of 18 in. and 37 in. diam., by 24 in. stroke. Two steel boilers supply steam at 100 lb. pressure. They are fitted with twin-screws at each end, and their speed on trial was 11 knots.

With the model is a coloured sectional drawing of the "Crocus."

Tonnage (b.m.), 731·5 tons; length, 130 ft.; breadth, 35 ft.; depth, 11·42 ft.

280. Whole model of a ferry steamer. (Scale 1 : 48.) Lent by Messrs. William Simons & Co., 1894. N. 2036.

This shows an arrangement of ferry steamer with a raising and lowering deck, which can be maintained at the quay level whatever the state of the tide, thus facilitating the taking on board of passengers and vehicles.

The movable deck is carried between 16 square vertical guides, arranged in pairs. Between each pair is a sliding frame, fixed to the deck and having in the centre a nut through which a square-threaded screw passes. There are eight of these screws, and they are all turned simultaneously by an engine placed below the main deck and connected with the screws by worm gearing. The screws are supported by collars carried by bearings at the top of the guides, and so become adjustable suspension rods instead of columns.

The boat is flat-bottomed, to diminish the draught, and this example is propelled by paddle-wheels. The boat is designed to carry 2,000 passengers, and 20 horse vehicles.

Length, 170 ft.; breadth, 52 ft. depth, 11 ft.

281. Whole model of P.S. "Orlando." (Scale 1 : 24.) Lent by Messrs. Sir W. G. Armstrong, Mitchell & Co., 1887. N. 1725.

This river passenger steamer was built on the Tyne in 1885, for service on the Thames between Greenwich and Battersea. It differs from the earlier "penny boats" in having large and well lighted saloons aft and forward, also in having the engines controlled from the deck, under the bridge.

The engine is two-stage expansion with inclined cylinders 15 in. and 30 in. diam., by 24 in. stroke; steam at 100 lb. pressure is supplied by a cylindrical return-tube boiler with two furnaces. When driving the paddle-wheels at 44 revs. per min. the indicated h.p. was 100, the speed 10 knots, and the coal consumption about 1·25 tons in 12 hours. The wheels are 9 ft. diam., and each has seven curved feathering floats, 4·6 ft. long by 1·8 ft. deep.

The crew consists of a master, mate, two deck hands, an engineer, and a stoker. The vessel is certified to carry 300 passengers.

Displacement, light, 77 tons; gross register, 70·6 tons; net register, 34·9 tons; length, 100·5 ft.; breadth, 14·1 ft.; depth, 6·1 ft.; draught of water, loaded, 3·5 ft.

282. Rigged model of P.S. "Ozone." (Scale 1 : 48.) Lent by Messrs. Napier, Shanks and Bell, 1888. N. 1814.

This paddle steamer was built of steel at Glasgow in 1886 for the Bay Excursion Co., Melbourne. The engines are two-stage expansion, with inclined cylinders 47 in. and 85 in. diam., by 66-in. stroke, and indicate 2,680 h.p. at 47·5 revs. per min. Steam is supplied at 90 lb. pressure by six steel boilers 7·75 ft. diam. by 15 ft. long, which are fitted with forced draught. The paddle wheels are 21·8 ft. diam., and each have nine feathering floats of wood. The speed of the vessel is 18·24 knots.

She has one deck and a promenade deck.

Gross register, 572 tons; length, 260 ft.; breadth, 28 ft.; depth, 11·4 ft.

283. Half block model of S.Ss. "Glengyle" and "Glenshiel." (Scale 1 : 48.) Lent by the London and Glasgow Engineering and Iron Shipbuilding Co., 1888. N. 1810.

These three-masted schooner-rigged screw steamers were built of steel at Glasgow in 1886 for the "Glen" line, trading between India and China.

They have two steel decks, wood sheathed, three tiers of beams, poops 76 ft., bridge deck 69 ft., and forecastle 53 ft. long, bar keel 11 in. deep, and six bulkheads.

The engines are three-stage expansion, with cylinders 34 in., 53 in. and 87 in., diam. by 54 in. stroke, indicating 3,500 h.p. Steam at 140 lb. pressure is supplied by three double-ended steel boilers with eighteen furnaces, and a grate area of 318 sq. ft.

Gross register, 3,455 tons; length, 370 ft.; breadth, 45 ft.; depth, 26·75 ft.

284. Rigged model of S.S. "Orinoco." (Scale 1 : 48.) Lent by the Royal Mail Steam Packet Co., 1901. N. 2259.

This schooner-rigged steamer was built of steel and engined at Greenock in 1886, by Messrs. Caird & Co., for the West Indian Mail service. She has three decks and a spar deck, wood sheathed, while there are 10 bulkheads. The vessel is propelled, at a speed of 16 knots, by engines of the inverted three-stage expansion type (*see* No. 853).

Gross tonnage, 4,478 tons; length on main deck, 409·7 ft.; breadth inside, 45 ft.; depth to main deck, 25·4 ft.

285. Drawing of S.S. "Cambridge." (Scale 1 : 96.) Lent by the Great Eastern Railway Co., 1891. N. 1873.

This is a sectional elevation of the vessel, with plans of the upper, main, and lower decks.

The "Cambridge" was designed by Mr. W. G. Ramsden, for the G.E.R. Co.'s continental service between Harwich and the Hook of Holland. She was built of steel and engined at Hull in 1886 by Earle's Shipbuilding and Engineering Co.

There are two sets of engines, of the two-stage expansion, inverted type, with cylinders 30 in. and 57 in. diam. by 36 in. stroke, giving a total of 2,200 indicated h.p. and driving twin screws.

Accommodation is provided for 134 first-class passengers, and portable fittings for 62 more during the tourist season; second class accommodation is also provided for 56 passengers.

Gross register, 1,160 tons; net register, 519 tons; length, 280·5 ft.; breadth, 31 ft.; depth to ceiling, 15·2 ft.

286. Half block model of S.S. "Hubbuck." (Scale 1 : 48.) Lent by Messrs. Joseph L. Thompson and Sons, 1889. N. 1832.

This three-masted schooner-rigged screw steamer was built of steel at Sunderland in 1886.

She has two decks and three tiers of beams; the poop is 37 ft. long, bridge deck 90 ft., and forecastle 40 ft.; the bar keel is 11 in. deep, and the bottom is double and cellular, with a ballast capacity of 407 tons.

The engines are three-stage expansion, with cylinders 27 in., 42 in., and 69 in. diam., by 45 in. stroke, indicating 1,800 h.p., and giving a speed of 12 knots. Steam is supplied at 150 lb. pressure by two double-ended boilers, having a grate area of 168 sq. ft.

Displacement, 6,000 tons; gross register, 2,749 tons; length, 325 ft.; breadth, 40 ft.; depth, 25·75 ft.

287. Half block model of S.S. "Ormuz." (Scale 1 : 48.) Lent by the Orient Steam Navigation Co., 1887. N. 1707.

This four-masted barque-rigged steamer was built of steel at Glasgow in 1886, by the Fairfield Shipbuilding Co., for the Australian trade. She has four decks, and is built with a cellular double bottom 275 ft. long, which will hold 808 tons of water ballast, and there is a fore-peak tank with a capacity of 38 tons; the bar keel is 12 in. deep.

The engines are three-stage expansion, with three cylinders, 46 in., 73 in. and 112 in. diam., by 72 in. stroke, which with a boiler pressure of 150 lb. indicated 8,500 h.p., driving a single four-bladed propeller and giving a speed of 17·5 knots.

Steam is supplied by one single-ended and six double-ended steel boilers, having 38 corrugated furnaces, with a grate surface of 899 sq. ft.

Gross register, 6,031 tons; length, 465·5 ft.; breadth, 52 ft.; depth, 19 ft.

288. Half block model of S.S. "Twickenham." (Scale 1 : 48.) Lent by Messrs. Watts, Ward & Co., 1890. N. 1848.

This schooner-rigged steamer, of the "well-decked" type, was built of steel at West Hartlepool in 1888 for the Britain Steam Ship Co. She has a cellular double bottom 254 ft. long, with a water ballast capacity of 614 tons; her bar keel is 11 in. deep, while the poop is 27 ft., the quarter-deck 98 ft., the bridge deck 112 ft., and the forecastle 32 ft. long respectively.

The engines are three-stage expansion, with cylinders 23 in., 37·5 in. and 61·5 in. diam., by 39 in. stroke. Steam at 160 lb. pressure is supplied by two single-ended steel boilers with six corrugated furnaces giving a grate area of 91 sq. ft.

Gross tonnage, 2,463 tons; length, 300 ft.; breadth, 38·5 ft.; depth, 23·25 ft.

289. Rigged model of S.S. "Islander." (Scale 1 : 48.) Lent by Messrs. Napier, Shanks and Bell, 1888. N. 1815.

This schooner-rigged twin-screw steamer was built of steel in 1888, for the Canadian Pacific Navigation Co., Victoria, B.C.

She has two sets of three-stage expansion engines with cylinders 20 in., 31 in., and 52 in. diam., by 36 in. stroke, indicating 3,000 h.p. Steam is supplied at 160 lb. pressure, by four steel boilers.

Five adjacent photographs show the interior accommodation; the dining saloon is on deck, with the sleeping berths above, and a large promenade deck above all.

Tonnage, 1,500 tons; length, 240 ft.; breadth, 42 ft.; depth, 14·6 ft.

290. Half block model of S.S. "Arbib Brothers." (Scale 1 : 48.) Received 1907. N. 2442.

This schooner-rigged cargo steamer was built of steel at Wallsend-on-Tyne in 1888 by Messrs. Swan and Hunter and was engined by Messrs. T. Richardson and Son of Hartlepool. In 1897 her name was changed to "Benedict."

The half block model, as here shown, is usually made from the original "draught" or drawings of the vessel before building operations are commenced; the underwater portion is built up of a number of horizontal layers or sections of wood copied directly from the designer's drawings, and thus furnishes in a concrete form a clear and accurate knowledge of the vessel's lines.

This vessel was constructed with a cellular double bottom in which provision was made for about 420 tons of water ballast; her hull was further sub-divided by five main transverse watertight bulkheads and also was fitted with three tiers of deck beams carrying two completed decks.

She had three-stage expansion engines with cylinders 24 in., 39 in., and 64 in. respectively and 42 in. stroke. Steam was supplied at 160 lb. pressure by six single-ended boilers.

Displacement, 4,370 tons; gross register, 2,714 tons; length, 320 ft.; breadth, 40 ft.; depth, moulded, 27 ft.

291. Rigged model of S.S. "Taroba." (Scale 1 : 48.) Presented by Messrs. Gray, Dawes & Co., 1904. N. 2360.

This schooner-rigged steamer was built and engined by Messrs. A. and J. Inglis at Glasgow in 1888, for the London and Calcutta trade of the British India Steam Navigation Company.

In construction and equipment this vessel embodied most of the improvements of her time. She was built entirely of steel, with three complete decks and six transverse bulkheads; the forecastle was 51 ft., the boat deck amidships 162 ft., and the poop deck 50 ft. long respectively. Hydraulic cranes were used for working her main cargo hatches, and electric lighting was adopted throughout.

Her engines were three-stage expansion with cylinders 33 in., 52 in., and 86 in. diam. by 60 in. stroke. With a boiler pressure of 170 lb. a speed of 16 knots was realised on trial.

Accommodation was provided for 80 first class and 36 second class passengers.

Gross register, 4,938 tons; length, 410 ft.; breadth, 46 ft.; depth, moulded, 31 ft.

292. Half block model of Woolwich ferry steamers. (Scale 1 : 48.) Lent by the London County Council, 1910. N. 2562.

This represents the two paddle vessels "Duncan" and "Gordon," used as a free ferry for passengers and vehicles across the Thames at Woolwich; they were built for the London County Council in 1888–9, at Blackwall, by Messrs. R. and H. Green, and were engined by Messrs J. Penn and Son of Greenwich.

The hull is double-ended to give facility for steaming either ahead or astern. Watertight sub-division is obtained by six main bulkheads, and, for constructional work on these vessels, iron framing with steel plating is largely adopted.

Propelling engines of the diagonal type are used with four cylinders, each 33 in. diam. and 36 in. stroke, indicating a total of 600 h.p.; steam is supplied at 30 lb. per sq. in. by two single-ended boilers.

Gross register, 493 tons; length, 164 ft.; breadth, over paddles, 60 ft.; load draught, 4 ft.

293. Rigged model of S.S. "Philadelphia." (Scale 1 : 48.) Lent by Messrs. Ismay, Imrie & Co., 1909. N 2524

This twin-screw transatlantic steamer was built and engined at Glasgow in 1888–9 by Messrs. J. and G. Thomson for the Inman and International Steamship Co., Liverpool. She was originally named "City of Paris," which was altered to "Paris" in 1893. With her sister ship "City of New York" she was the largest vessel in service in 1889 and the earliest large ocean steamer in which twin-screw propulsion and forced-draught arrangements were adopted. She was also the first vessel to cross the Atlantic in less than six days (May, 1889). During the Spanish-American war (1898) she was chartered by the U.S.A. Government and was known as the "Yale"; a number of Q.F. guns are shown in position on the model.

She has four principal decks, including a covered upper deck for passengers and a continuous promenade deck above it; the berth accommodation provides for about 2,000 passengers. Cellular sub-division of the hull was a special feature of her design, and the arrangement of the two sets of machinery on each side of a middle-line bulkhead was an innovation in this respect; no doorways were cut in the main bulkheads below the water line. She has 14 principal transverse watertight bulkheads and the double-bottom spaces provide for a series of water-ballast tanks extending over a length of 400 ft. and having a total carrying capacity of 1,550 tons. The value of this watertight sub-division was tested by two serious accidents. In 1890, while off the Irish coast, one of her main propeller shafts broke and damage resulted to both engine rooms and the adjacent portions of the hull; the vessel, however, was safely floated into Queenstown. In 1899 she ran aground on the Manacles Rocks near Falmouth and badly injured her external plating and framing; again she was salved and was finally re-engined, lengthened and repaired by Messrs. Harland and Wolff at Belfast in 1900–1, after which she received her present name.

Her original propelling engines were of three-stage expansion type using steam at 150 lb. per. sq. in. and developing collectively 20,000 indicated h.p. Her present engines are of four-stage expansion type using steam at 200 lb. per sq. in. and having cylinders 38·5 in., 54 in., 76 in., 106 in. diam. by 60 in. stroke. She has 10 cylindrical boilers, 6 double-ended and 4 single-ended, giving a total heating surface of 39,618 sq. ft.

Gross register, 10,786 tons; length, 527·6 ft.; breadth, 63·2 ft.; depth, moulded, 41·9 ft.

Photographs of the original engines and of the vessel under construction are shown in the collection of Marine Engines.

294. Half block model of S.S. "Aska." (Scale 1 : 48.) Lent by the Ailsa Shipbuilding Co., 1890. N. 1846.

This schooner-rigged steamer was built of steel at Troon, N.B., in 1889, for the British India Steam Navigation Co. She has a single deck and five bulkheads, also a shade deck.

Her engines are three-stage expansion, with cylinders 16 in., 26 in., and 42 in. diam., by 30 in. stroke, indicating 2,200 h.p.

Steam is supplied by one double-ended boiler, with four corrugated furnaces, giving a grate area of 78 sq. ft.

Gross tonnage, 527 tons; length, 190 ft.; breadth, 29 ft.; depth, 12·25 ft.

Prints of the engines are shown in the collection of Marine Engines. (*See* No. 857.)

295. Half block model of S.Ss. "Windsor" and "Hounslow." (Scale 1 : 48.) Lent by Messrs. Watts, Ward & Co., 1890. N. 1849.

These schooner-rigged steamers were built of steel at West Hartlepool in 1890 for the Britain Steam Ship Co. They are well decked, have one iron deck, two tiers of beams, web frames, and a cellular double bottom 268 ft. long, with a water ballast capacity of 653 tons. There are five bulkheads. The poop is 29 ft. long, quarter-deck 102 ft., bridge deck 118 ft., and forecastle 31 ft.

The engines are three-stage expansion, with cylinders 23 in., 37·5 in., and 61·5 in. diam., by 39 in. stroke. Steam at 160 lb. pressure is supplied by two single-ended steel boilers with six corrugated furnaces, giving a grate area of 99 sq. ft. and 3,520 sq. ft. of heating surface.

Gross tonnage, 2,797 tons; length, 314·5 ft.; breadth, 40·5 ft.; depth, 20·4 ft.

296. Half block model and drawing of S.Ss. "Ching Ping" and "Fu Ping." (Scale 1 : 48.) Lent by the Blyth Shipbuilding Co., 1891. N. 1861.

These two schooner-rigged screw steamers were built of steel at Blyth, Northumberland, in 1890 for the Chinese Engineering and Mining Co. They are constructed with web frames, and have iron decks, with poops 33 ft., bridges 44 ft., and forecastles 29 ft. long.

Their engines are three-stage expansion, with cylinders 15 in., 25 in., and 41 in. diam., by 24 in. stroke.

Gross register, 886 tons; length, 215 ft.; breadth, 32·1 ft.; depth, 13·2 ft.

297. Rigged model of S.S. "City of Vienna." (Scale 1 : 48.) Lent by Messrs. George Smith and Sons, 1888. N. 1816.

This barque-rigged steamer was built of steel by Messrs. Workman, Clark & Co. at Belfast in 1890 for the East Indian passenger and cargo trade. She has three decks, two being of steel sheathed with wood; the poop is 40 ft. long, bridge deck 162 ft., and forecastle 42 ft.

Her engines are three-stage expansion, with cylinders 32 in., 53 in., and 87·5 in. diam., by 60 in. stroke, indicating 4,000 h.p. Her speed is 15 knots.

Steam at 160 lb. pressure is supplied by four single-ended steel boilers, each 14·5 ft. diam., by 11·5 ft. long, with 12 furnaces, giving a grate area of 210 sq. ft., and 8,570 sq. ft. of heating surface; the furnaces have forced draught on Howden's system; (*see* No. 913).

Gross register, 4,672 tons; length, 412·25 ft.; breadth, 46·6 ft.; depth, 29·25 ft.

298. Rigged model of S.S. "Dunottar Castle." (Scale 1 : 48.) Lent by the Fairfield Shipbuilding and Engineering Co., 1901. N. 2269.

This three-masted, schooner-rigged, screw steamer was built of steel and engined at Glasgow, in 1890, by the Fairfield Co. for the Union-Castle line; she established a record on her maiden voyage from Dartmouth to Cape Town (16·5 days) and has since broken it.

She has a cellular double bottom, 320 ft. long, with a water ballast capacity of 779 tons, and is subdivided internally by seven watertight bulkheads extending to the upper deck. There are two decks and a spar deck and four tiers of beams; her poop is 115 ft., bridge deck 155 ft., and forecastle 55 ft. in length. Accommodation is provided for 160 first class, 100 second class and 100 third class passengers.

The engines are a three-stage expansion set, with cylinders 38 in., 61·5 in. and 100 in. diam., by 66 in. stroke. Steam at 160 lb. pressure is supplied by four double-ended multitubular boilers, 15·25 ft. diam. and 18·7 ft. in. length, giving a total of 24 corrugated furnaces, a grate surface of 500 sq. ft., and a heating surface of 17,816 sq. ft. The engines indicate 7,000 h.p. and give a speed of 17 knots. The propeller is four-bladed, with cast steel blades and boss.

Gross register, 5,465 tons; length, 420 ft.; breadth, 49·8 ft.; moulded depth, 33·2 ft.

299. Drawing of stern-wheel S. "Kenia." (Scale 1: 64.) Lent by Messrs. Kincaid & Co., 1891. N. 1856.

This shows the plan, profile, and sections of the first vessel ordered by the Imperial British East Africa Co. for the inland navigation of their territories. She was built at Greenock in 1890 by Messrs. Kincaid & Co., and sent to Mombasa in sections. As a means of defence against natives, a perforated tube runs round the vessel under the gunwale moulding, by which boiler steam can be discharged so as to prevent boarding. A quick-firing Hotchkiss gun is also carried, mounted on the promenade deck. She is fitted with three large rudders, the centre one being balanced, and all three are connected with the same yoke on the promenade deck.

The engines are of the two-stage expansion type, with one cylinder on the port and the other on the starboard side. They are placed on the inner ends of a pair of steel beams which carry the paddle-wheel on the outer ends; the beams rest on trunnions, by which arrangement the immersion of the floats can be adjusted. The steam and exhaust passages are through the trunnions. Steam is supplied at 120 lb. pressure by a locomotive boiler with capacious fire-box for burning wood. The speed is 10 knots.

Length, 80 ft.; breadth, 21 ft.; draught of water, light, 1·5 ft.; draught of water, fully loaded, 3·25 ft.

300. Sectional half model of a petroleum steamer. (Scale 1 : 48.) Lent by Messrs. Sir W. G. Armstrong, Mitchell & Co., 1892. Plate V., No. 3. N. 2006.

This is a steamer specially designed in 1891 for the conveyance of petroleum in bulk. This oil was at first carried only by wooden sailing ships, in barrels in the hold, whereby much space was lost and a heavy cost for packages incurred. Three ships for the conveyance of oil in bulk were built at Jarrow in 1872, but were never tried, and subsequently some ordinary cargo vessels were altered to enable them to carry petroleum in tanks, but they were only partially successful. The first tank steamer used was the "Glückauf," built by Sir W. G. Armstrong, Mitchell & Co. in 1886.

Petroleum steamers, the use of which has increased considerably in recent years (*see* Nos. 320 and 674), usually have their machinery aft, with oil holds up to the main deck, and a long trunk from 10 ft. to 15 ft. wide from the main to the spar deck; this trunk acts as a feeder, and allows the oil to expand and contract without its affecting the vessel's stability by becoming a shifting cargo. The oil hold is divided into compartments, frequently by a centre line bulkhead and by transverse bulkheads about 20 ft. apart; the ordinary structural details are also modified so as to insure oil-tight joints.

The vessels carry powerful pumps, and have large oil and water mains led along the main deck, with branches into the various compartments or tanks, and connections for pipes from the shore. The tanks may contain oil of different qualities, and can be filled or emptied separately; the steamer shown has eight bulkheads, forming seven tanks 24 ft. long, while the engines, boilers, and pumps are in an after compartment.

The steamer represented is of about the following dimensions:—Gross register, 3,000 tons; length, 316 ft.; breadth, 38 ft.; depth, 30 ft.

301. Half block model of S.S. "Ophir." (Scale 1 : 48.) Lent by the Orient Steam Navigation Co., 1893. N. 1573.

This schooner-rigged twin-screw steamer was built of steel at Glasgow in 1891, by Messrs. R. Napier and Sons, for the Australian trade. She has four steel decks, two of which are sheathed with wood.

She has two sets of three-stage expansion engines, with cylinders 34 in., 51·5 in., and 85 in. diam., with a stroke of 54 in. Steam at 160 lb. pressure is supplied by five double-ended and two single-ended steel boilers, with 36 ribbed furnaces, giving a grate area of 756 sq. ft., and a heating surface of 26,000 sq. ft. The normal indicated h.p. is 9,500, and the maximum 11,400 h.p. Her speed is from 18 to 18·75 knots, and she carries a total of 892 passengers.

There are two manganese bronze three-bladed propellers, 17 ft. diam. and 23·25 ft. pitch. The propeller shafts project about 39 ft. aft from the skin of the ship, and are 23 ft. between centres.

The "Ophir" was the first vessel in the Australian trade fitted with twin screws; she has large coal capacity as her permanent bunkers, which are arranged alongside and between the boiler compartments, are sufficient to enable her to steam 15·5 days at 16 knots, equal to 6,000 miles. If the holds were also filled with fuel the vessel could steam 14,000 miles at full speed, or cruise 130 days at 10 knots.

Displacement, at 24·5 ft. draught, 10,600 tons; gross register tonnage, 6,910 tons; length, 465 ft.; breadth, 53·3 ft.; depth, 34·1 ft.

302. Rigged model of S.S. "Scot." (Scale 1 : 48.) Lent by the Union Steam Ship Co., 1898. N. 2164.

This twin-screw schooner-rigged steamer was built of steel at Dumbarton in 1891, by Messrs. W. Denny and Bros., for the Cape mail service. She is constructed with a cellular double bottom, to contain 1,000 tons of water ballast, and with 14 watertight bulkheads, ten of which are carried up to the upper deck. She has five decks, of which the upper and spar deck are of steel, wood sheathed, and a poop and forecastle each 60 ft. long, with a promenade deck 256 ft. in length.

In 1896 this vessel was lengthened by the insertion of 54 ft. immediately forward of the boiler compartment; this was performed on regular launching ways. The ship was divided by drilling out the rivets of the shell plating, frames, stringers, &c., in line with the midship watertight bulkhead; the stanchions carrying the promenade deck were then loosened so that the saloon structure remained, while the bow portion of the hull was drawn forward by winches. The additional part was then built up under the promenade deck.

She has accommodation for 204 first-class, 105 second-class, and 100 third-class passengers, but should occasion arise many more of the latter class could be provided for.

She is propelled by two sets of three-stage expansion engines, with cylinders 34·5 in., 57·5 in., and 92 in. diam., by 60 in. stroke. Steam at 170 lb. pressure is supplied by six double-ended steel boilers, 15·25 ft. diam. and 18 ft. long, having 36 corrugated furnaces 3·75 ft. diam., a grate area of 804 sq. ft. and a heating surface of 22,964 sq. ft. The funnels reach 98 ft. above the fire bars and 60 ft. above the deck. The boilers are placed in two separate watertight compartments.

The propellers are three-bladed, 17·5 ft. diam., 25 ft. pitch, with a distance of 18 ft. between their centres.

On her trial, when drawing 23 ft., the engines made 80 revs. per min. and indicated 11,656 h.p., with a boiler pressure of 170 lb. and a vacuum of 26 in.; the speed was 18·8 knots. Her maiden trip from Southampton to Cape Town was accomplished in the record time of 15d. 2h. 10m. Her coal capacity is 3,000 tons.

The following are the leading dimensions:—

	Before lengthening.	After lengthening.
Displacement	10,000 tons.	11,500 tons.
Gross register	6,844 „	7,815 „
Length	477 ft.	531 ft.
Breadth	54·7 „	54·8 „
Depth	25·9 „	25·9 „

303. Half block model of S.S. "Ibex." (Scale 1 : 48.) Lent by the Great Western Railway Co., 1891. N. 1872.

This twin-screw steamer was built of steel at Birkenhead in 1891, for the service between Weymouth and the Channel Islands.

She has one deck, also a poop 58 ft. long, and a bridge and forecastle 180 ft. long. There are eight bulkheads, and capacity for 14 tons of water ballast in a forward tank and 26 tons aft.

The two sets of engines are three-stage expansion, with cylinders 22 in., 34 in., and 51 in. diam., by 33 in. stroke. Steam at 160 lb. pressure is supplied by two double-ended steel boilers, with twelve corrugated furnaces, and a total grate surface of 250 sq. ft.

Gross register, 1,150 tons; length, 265 ft.; breadth, 32·5 ft.; depth, 14·2 ft.

304. Rigged model of S.S. "Tynwald." (Scale 1 : 48.) Lent by the Fairfield Shipbuilding and Engineering Co., 1895. N. 2357.

This twin-screw schooner-rigged passenger steamer was built of steel at Glasgow in 1891, for the Liverpool and Douglas, Isle of Man, service. She has two decks, and a shelter deck; her bar keel is 6 in. deep, and she has six bulkheads, while for water ballast a tank of 16 tons capacity is provided aft.

She is propelled by two sets of three-stage expansion engines, with cylinders 22 in., 36 in., and 57 in. diam., by 36 in. stroke. Steam at 160 lb. pressure is supplied by two double-ended steel boilers, with 16 ribbed furnaces, and a grate area of 366 sq. ft.

Gross register, 936 tons; length, 265 ft.; breadth, 34·5 ft.; moulded depth, 14·5 ft.

305. Rigged model of S.S. "Campania." (Scale 1 : 48.) Lent by the Cunard Steamship Co., 1897. N. 2054.

This twin-screw steamer and her sister ship the "Lucania" were built and engined by the Fairfield Shipbuilding Co. at Glasgow in 1892, for the Cunard Steamship Co. They are rigged with two pole masts, and were built under Admiralty supervision for use as armed cruisers if required.

They have four decks, three of which are of steel, wood sheathed, and there is a steel promenade deck 370 ft. long, also wood sheathed.

The propelling engines consist of two three-stage expansion sets, each in separate engine rooms, on either side of a dividing centre line bulkhead fitted with watertight doors for communication. Each set has five cylinders, two high pressure 37 in.; one intermediate 79 in., and two low pressure 98 in. diam., by 79 in. stroke.

Steam at 165 lb. pressure is supplied by twelve main double-ended boilers, 18 ft. diam., and 17 ft. long, each having eight corrugated furnaces; and by two smaller boilers which are chiefly used for auxiliary purposes.

The diameter of the funnels is 19 ft., and their height above the bottom of the ship 130 ft.

The twin propellers have steel bosses, and three manganese bronze blades; each blade weighs 8 tons. The propeller shafts are 24 in. diam.

On the steam trial in April 1893, with a draught of 25 ft., and a displacement of 18,000 tons, the mean speed was 23·18 knots; the engines indicated 31,050 h.p., at 84 revs. per min., with a boiler pressure of 165 lb. and a vacuum of 28 in.

The rudder, 253 sq. ft. in area, is of the centre-fin plate pattern, with special arms on either side, and strengthened by webs on the top and bottom; it can be put hard over when the ship is going at full speed, and will turn the ship in her own length. The rudder and steering gear are entirely under water.

The accommodation is for 600 first-class passengers, 400 second class, and 700 to 1,000 third class, while the ship's complement consists of 61 sailors, 195 engineers and firemen, and 159 stewards.

Displacement at load draught, 21,920 tons; gross register, 12,950 tons; length (over all), 622·5 ft.; breadth, 65·2 ft.; depth from upper deck, 43 ft.

The development of the Cunard liners is indicated by a scale diagram on the wall.

306. Whole model of S.S. "Ratcliff." (Scale 1 : 48.) Lent by Messrs. Short Bros., 1893. N. 2020.

This steam collier was built of steel at Sunderland in 1892, for the East London Steamship Co., to carry coal cargoes above the bridges on the Thames. In order to do this the funnel, masts, bridge rails, and davits are hinged so that they may lie flat on deck. She has one iron deck, web frames, raised quarter deck 63 ft., bridge deck 8 ft., and forecastle 14 ft. long. She has a cellular double bottom 126 ft. long, with a water ballast capacity of 355 tons, a fore-peak tank of 86 tons, and an aft-peak tank of 45 tons. She is schooner-rigged, has a flat keel, and four bulkheads.

Her engines are three-stage expansion, with cylinders 18 in., 29 in., and 47 in. diam., by 33 in. stroke, and drive a four-bladed propeller. Steam is supplied at 160 lb. pressure, by one single-ended steel boiler, with three plain furnaces, a grate area of 50 sq. ft., and 2,000 sq. ft. of heating surface.

Gross tonnage, 802 tons; length, 170 ft.; breadth, 36 ft.; moulded depth, 16 ft.

307. Rigged model of P.S. "Koh-i-noor." (Scale 1 : 48.) Lent by the New Palace Steamers, Ltd., 1899. N. 2203.

This paddle steamer was built of steel at Glasgow in 1892, by the Fairfield Shipbuilding and Engineering Co., from the designs of Mr. R. Saxon White. She is said to be the first swift river steamer adequately provided with watertight bulkheads.

She is divided into ten watertight compartments in accordance with the recommendations of the Bulkhead Committee. So completely has the subdivision been carried out that the 1st class dining saloon is in two portions separated by a bulkhead; communication between the two being afforded by means of a watertight door which upon an emergency can be closed from the deck above. Any person shut in the after part can escape to the upper deck by means of a trunk staircase which is always kept open.

Two rudders have been fitted; the after one, which is 9 ft. long and of large area, is worked by a steam steering gear on the engine-room platform, whilst the bow rudder, which is completely within the stem, is provided with a screw steering gear. The funnels and mast can be raised and lowered, by means of small steam winches, so that the vessel can pass under London Bridge.

The "Koh-i-noor" has two decks, and on the upper one are two deck saloons, one at each end of the machinery space, and these support the promenade deck, which is 300 ft. long and extends the full width of the ship.

The engines are two-stage expansion with cylinders 45 in. and 80 in. diam. by 66 in. stroke, indicating 3,500 h.p. and giving a speed of 19·5 knots. The cylinders are placed side by side and work on two cranks set at an angle of 90 deg. with each other. Steam at 120 lb. pressure is supplied by four Scotch boilers, with three corrugated furnaces in each.

The paddle-wheels are of steel and of the feathering type, with concave floats.

Tonnage, gross, 884 tons; tonnage, net, 275 tons; length (o.a.), 310 ft.; length (b.p.), 300·4 ft.; breadth over paddle-boxes, 58 ft.; breadth (moulded), 32·1 ft.; depth, 10·6 ft.

308. Rigged model of S.S. "Hound." (Scale 1 : 48.) Lent by Messrs. G. and J. Burns, 1901. N. 2282.

This schooner-rigged steamer was built of steel at Glasgow in 1893, by the Fairfield Shipbuilding and Engineering Co., for Messrs. G. and J. Burns' mail and general service between Ardrossan and Belfast. She is built with a bar keel, 8·5 in. deep, and has two decks; the poop is 78 ft. long, the bridge deck 80 ft. and the forecastle 48 ft. The hull is divided by four watertight bulkheads, and is provided with an after-peak tank having a water ballast capacity of 30 tons.

Her engines consist of a three-stage expansion set, with cylinders 26·5 in., 42 in. and 68 in. diam. by 42 in. stroke, indicating 2,000 h.p. and driving a single four-bladed screw which gave her a speed of 15 knots. Steam at 165 lb. pressure is supplied by a pair of double-ended boilers having a total of twelve furnaces, a grate area of 220 sq. ft. and a heating surface of 6,213 sq. ft.

Gross register, 1,061 tons; length, 250·3 ft.; breadth, 32·1 ft.; depth, 15·5 ft.

309. Rigged model of S.Ss. "Alma" and "Columbia." (Scale 1 : 48.) Lent by the London and South Western Railway Co., 1896. N. 2096.

These schooner-rigged twin-screw steamers were built of steel at Sunderland in 1894, for the mail service between Southampton and Havre, in connection with the London and South Western Railway.

In each ship the frames are of the reversed angle type, spaced about 21 in. apart. The interior is subdivided by watertight bulkheads into twelve compartments. The bulkheads are constructed of plates flanged vertically, instead of with angles, the plates themselves overlapping. Three of the compartments are occupied by machinery, one in the centre of the ship by first-class state rooms, one at the after end by second-class accommodation, while two at each end of the ship are devoted to cargo, the others being for storage, cargo, &c.; the vessel would float with any two compartments flooded. There are three decks, the promenade, upper, and main, while on the top of the bridge house on the promenade deck is a boat deck, carried out to the full width of the ship.

There are two sets of vertical three-stage expansion engines, with cylinders 19 in., 29 in., and two 33·5 in. diam. by 30 in. stroke, indicating 3,700 h.p. at 184 revs. per min., and giving a speed of 19 knots. Steam at 160 lb. pressure is supplied by two single-ended boilers, with four furnaces in each worked under forced draught, the air being supplied by two double-breasted fans, one in each stokehold.

Gross register, 1,145 tons; net register, 410 tons; length, 270 ft.; breadth, 34 ft.; depth to the promenade deck, 23 ft.

310. Half block model of S.S. "Norman Isles." (Scale 1 : 96.) Presented by Messrs. William Doxford and Sons, 1903. N. 2343.

This screw cargo steamer was built by Messrs. W. Doxford and Sons at Sunderland in 1896, for the Norwegian trade; it belongs to the "turret-decked" class of vessels originated by them in 1891 (*see* No. 673).

The characteristics of the type are:—A high navigation platform carried upon a central trunk, called a "turret," with vertical sides and curved base, extending from end to end of the vessel; rounded gunwales; and absence of sheer. These features are stated to provide the requisite strength and freeboard at a somewhat less cost than the ordinary construction, while the relatively small under-deck measurement renders the vessel economical for dead-weight cargoes, and the rounded section and considerable capacity of the turret facilitate the trimming and feeding of grain or bulk cargoes.

In addition to other details the model shows an arrangement for alternative hand and steam steering; a right-and-left-handed screw gear being used when steering by the hand wheel aft, while a quadrant arm secured to the rudder head provides the chain attachment for a steam steering engine below the deck. Stockless anchors stowing in the hawse pipes are fitted, and the main ventilating shafts amidships are utilised also as derrick posts.

The engines are a three-stage expansion set with cylinders 24·5 in., 40 in., and 65 in. diam. by 42 in. stroke.

Gross register, 3,455 tons; net register, 2,190 tons; length, 341·2 ft.; breadth, 45·6 ft.; depth, 24·7 ft.

311. Half block model of S.S. "Kamakura Maru." (Scale 1 : 48.) Lent by the Nippon Yusen Kabushiki Kaisha, 1901. N. 2271.

This twin-screw, four-masted, schooner-rigged steamer was built of steel at Belfast in 1897, by Messrs. Workman, Clark & Co., for the Nippon Yusen Kaisha (Japan Mail Steamship Co.).

She is constructed with deep framing and a cellular double bottom extending 190 ft. forward, 53 ft. under the machinery space, and 145 ft. aft, with a water ballast capacity of 1,150 tons; in addition there is a midship tank with a capacity of 480 tons, a fore-peak tank of 95 tons capacity, and an after-peak tank of 45 tons capacity. She is subdivided internally by eight watertight bulkheads.

A feature in the construction of this vessel is the almost entire absence of stem and stern castings, their place being taken by arched plating incorporated with the framing of the ship and so shaped as to greatly reduce "deadwood," while at the same time diminishing the total weight. The stern post, to which the rudder is attached, is of cellular construction, and the rudder is plated on both faces, so as to possess some buoyancy while leaving the interior accessible, an arrangement that has since been adopted in eleven vessels built for the Ocean Steamship Co.

Her engines consist of two three-stage expansion sets, built by Messrs. Barclay Curle & Co., with cylinders 20 in., 33·5 in., and 56 in., diam., with a stroke of 48 in. Steam at 200 lb. pressure is supplied by two double and two single-ended boilers, fired in 18 corrugated furnaces giving a total grate surface of 313 sq. ft., while the total heating surface is 8,271 sq. ft. The propellers are four-bladed and, through the absence of deadwood, are exceptionally clear of the stern.

Gross register, 6,123 tons; length, 445 ft.; breadth, 49·7 ft.; depth, 30·4 ft.

312. Rigged model of S.S. "Omrah." (Scale 1:48.) Lent by the Fairfield Shipbuilding and Engineering Co., Ltd., 1908. Plate V., No. 4. N. 2450.

This twin-screw steamer was built of steel and engined at Glasgow in 1898–9, by the Fairfield Co., for the Australian mail service of the Orient Steam Navigation Co.; she is also on the Admiralty list of subsidised merchant cruisers.

A cellular double bottom extends throughout the vessel, and the hold space is so subdivided by ten watertight bulkheads that the ship would keep afloat with any two of the compartments flooded. The lower, main, and spar decks are of steel, sheathed with wood. The vessel is fitted with refrigerating plant and electric light, and has accommodation for 830 passengers.

The propelling engines are of the inverted three-stage expansion type, in two sets, with cylinders 33 in., 54·5 in., and 89 in. diam., by 57 in. stroke. Steam at 180 lb. pressure is supplied by three double and two single-ended boilers with ribbed furnaces, heating surface 27,070 sq. ft., grate surface 588 sq. ft., arranged to work with Howden's forced draught. At the steam trials in 1899 a mean speed of 17·3 knots was realised with 9,200 indicated h.p. at 77·5 revs. per min., and a coal consumption of 1·4 lb. per indicated h.p. per hour.

Register tonnage, 8,291 tons; length (over all), 507 ft.; breadth (moulded), 56·7 ft.; depth, main deck, 26 ft.; do., spar deck, 37·5 ft.

313. Rigged model of S.S. "Clan Colquhoun." (Scale 1:48.) Lent by Messrs. Cayzer, Irvine & Co., 1905. N. 2371.

This cargo vessel was built of steel and engined at Sunderland in 1899, by Messrs. Wm. Doxford and Sons, for the Clan Line of steamers. She is a good example of the turret-deck type of steamer (*see* Nos. 310 and 673).

There is an enclosed forecastle 54 ft. long and a short poop deck; between these positions on the "turret" deck are placed the deck-houses, navigation bridge, hatchways, and the principal deck fittings. A number of large openings in the "turret" bulwarks ensure the rapid escape of deck water.

An elaborate system of derricks is provided for quickly loading and discharging cargo. Vertical masts are fixed midway between the large hatchways at each end of the vessel, and each serves as the common post for six radial derricks, for working which four steam winches are provided. A central hold has also two derricks pivoted on the boiler-room ventilating shafts.

A specially constructed plate rudder of the balanced type is used. The vessel is propelled by three-stage expansion engines having cylinders 27·5 in., 45·5 in. and 75 in. diam. with 60 in. stroke.

Gross register, 5,856 tons; length, 440 ft.; breadth, 51·6 ft.; depth of hold, 28·9 ft.

314. Rigged model of S.S. "Colombia." (Scale 1 : 48.) Lent by the Pacific Steam Navigation Co., 1903. N. 2328.

This twin-screw steamer was built of steel by Messrs. Caird & Co., Greenock, in 1899, for the mail and coasting service between Panama and Valparaiso.

In addition to the main and lower decks, the vessel has a shade-deck, beneath which light cargo may be carried, while above this is a long promenade deck for the use of passengers. A breakwater, formed of diagonal screens, 3 ft. high, divides the shade-deck from the anchor-deck to protect it from the effects of head seas: on the anchor-deck in the model are shown many details of the cable arrangements adopted.

On each side of the vessel are three large baggage ports, used in connection with the cargo hatches on the main deck; these hatches are each fitted with a derrick and windlass, but all heavy weights are lifted by a larger derrick on the fore-mast.

The propelling machinery consists of two sets of three-stage expansion engines, with cylinders 19·75 in., 32 in., and 52 in. diam. respectively, by 36 in. stroke, giving a total of 3,500 indicated h.p.

Length (b.p.), 359·5 ft.; breadth (moulded), 43·2 ft.; depth of hold, 19·5 ft.; tonnage (gross), 3,335 tons.

315. Rigged model of S.S. "Augusto Montenegro." (Scale 1 : 48.) Lent by the Amazon Steam Navigation Co., 1901. N. 2276.

This schooner-rigged, screw steamer was built of steel at Port Glasgow in 1900, by Messrs. A. Rodger & Co., for the Amazon Steam Navigation Co.

She has two decks and an awning deck. Her engines are a three-stage expansion set, with cylinders 12·5 in., 20 in., and 32 in. diam. respectively, by 24 in. stroke; they indicate 450 h.p. and drive a three-bladed propeller.

Gross tonnage, 318 tons; length, 140·5 ft.; breadth, 29 ft.; depth, 8·4 ft.

316. Rigged model of S.S. "Syria." (Scale 1 : 48.) Lent by Messrs. A. Stephen and Sons, Ltd., 1901. N. 2278.

This schooner-rigged, twin-screw steamer was built of steel at Glasgow, in 1901, by Messrs. A. Stephen and Sons, for the Peninsular and Oriental Steam Navigation Co., and she has been specially fitted up for the passenger and cargo service to India and China. The passengers' cabins are arranged on the poop, bridge, and boat decks, and are made exceptionally large; the "'tween decks" are fitted for the transport of troops. She has a poop 84 ft. long, a bridge deck, and a boat deck above it, each 170 ft. long, and the forecastle is 90 ft. in length.

Her engines consist of two three-stage expansion sets, with cylinders 22·5 in. diam., 36 in. diam., and 60 in. diam., by 48 in. stroke, driving three-bladed propellers, and giving a speed of 12·5 knots.

Gross tonnage, 6,900 tons; length, 450·5 ft.; breadth, 52·2 ft.; depth, 30·5 ft.

317. Half block model of S.S. "Hadley." (Scale 1 : 48.) Lent by Messrs. W. Cory and Son, Ltd., 1907. N. 2447.

This schooner-rigged, screw collier was built of steel by Messrs. S. P. Austin and Son and engined by Messrs. G. Clark at Sunderland in 1901, for Messrs. W. Cory & Son.

She is of the "well-deck" type with poop, quarter, bridge, and forecastle decks. Her hull is subdivided by four main watertight bulkheads, and, in the way of her large holds, deep transverse framing is used. A cellular double bottom extends over four-fifths of her length, and this, with the fore- and after-peak tanks, provides a total water ballast capacity of about 600 tons.

Her engines are of the three-stage expansion type, having cylinders 20·5 in., 33 in., and 54 in. diam. by 39 in. stroke. Steam, at 160 lb. pressure, is supplied by two single-ended boilers with plain furnaces.

Her principal particulars are :—Coal-carrying capacity, 2,700 tons; gross register tonnage, 1,777 tons; length, 268 ft.; breadth, 37·9 ft.; depth (moulded), 19·8 ft.

318. Rigged model of S.S. "Cedric." (Scale 1 : 64.) Lent by Messrs. Ismay, Imrie & Co., 1908. N. 2483.

This four-masted, schooner-rigged steamer was built and engined at Belfast in 1902 by Messrs. Harland and Wolff, for the White Star Line (Oceanic Steam Navigation Co.). The sister vessel "Celtic" was built for the same Company at Belfast in 1901. As regards gross tonnage and displacement, these were the largest vessels afloat at that date and were used for intermediate passenger and cargo service between Liverpool, Queenstown, and New York.

The lower portion of the hull is constructed on the cellular system with an external flat keel 4 in. thick: the ordinary frames and deck beams are of channel section and spaced 34 in. apart. The principal structural decks are known as orlop, lower, middle and upper; above these are the shade, bridge, and sun decks. Bilge keels, 18 in. deep, are fitted, one on each side, over a midship length of 250 ft. The rudder is of cast steel sections bolted together.

Stockless anchors are used with cables 3·375 in. diam.; the engines for working these were supplied by Messrs. Napier Bros., as were also the cable and warping capstans shown on the forecastle and poop decks.

The two sets of propelling engines are of four-stage expansion type with cylinders 33 in., 47·5 in., 68·5 in., and 98 in. diam. by 63 in. stroke. Steam is supplied, at 210 lb. per sq. in., by eight double-ended boilers having a total grate area of 1,014 sq. ft. and heating surface of 41,680 sq. ft.; the average speed is 16 knots. The screw propellers are 20 ft. in diam. and, as their paths closely approach the centre line of the hull, an aperture similar to that in a single-screw vessel is formed in the stern.

A special feature in both of these vessels is the large accommodation for third-class passengers, the various classes being thus provided for :—First class, 347; second class, 160; third class, 2,352.

Gross register, 21,000 tons; length, over all, 700 ft.; breadth, 75·3 ft.; depth, moulded, 48·4 ft.

319. Rigged model of S.S. "Queen Alexandra." (Scale 1 : 48.) Lent by Messrs. W. Denny and Bros., 1905. Plate V., No. 5. N. 2374.

This steel turbine-driven screw steamer was built in 1902 by Messrs. W. Denny & Bros., Dumbarton, to the order of the Turbine Steamers, Ltd., for service on the Clyde. Though of larger dimensions, she is similar generally to the S.S. "King Edward," constructed by the same builders in 1901, which was the first passenger vessel propelled by steam turbines.

She has three decks, in addition to a bridge deck extending for a considerable distance amidships.

The engines of the "Queen Alexandra" consist of three steam turbines of the parallel-flow type, developing about 4,400 h.p., and were made by the Parsons Marine Steam Turbine Co. Steam at 150 lb. pressure is admitted into a high-pressure turbine on the central line, which drives a shaft carrying one propeller, and afterwards passes into two low-pressure turbines driving wing shafts, the total ratio of expansion being 1 : 125. Each of the wing shafts originally carried two propellers which were afterwards replaced by a single propeller of larger diameter, as shown in the model. Reversal is effected by supplementary turbines placed in the exhaust ends of the low-pressure casings; when going ahead these reversing turbines revolve idly in a vacuum. For manœuvring purposes steam can be admitted independently into the low pressure or into the reversing turbine on either side. A model of engines of this type is shown in the collection of Marine Engines (*see* No. 866).

On trial this vessel attained a speed of 21·6 knots with the central turbine making 750 and the side turbines 1,100 revs. per min.

Tonnage, gross register, 665; length, 270 ft.; breadth (moulded), 32·1 ft.; depth to promenade deck, 18·75 ft.; depth to main deck, 11·5 ft.

320. Masted whole model of S.S. "Silverlip." (Scale 1 : 48.) Lent by the Shell Transport and Trading Co., 1903. N. 2337.

This three-masted, schooner-rigged, screw steamer was built of steel at Newcastle in 1903, by Messrs. Sir W. G. Armstrong, Whitworth & Co.; she was specially designed for carrying liquid fuel, or petroleum in bulk, a service which has greatly increased since the discovery in 1900 of such oil in Texas.

The vessel has two complete steel decks, and a cellular double bottom under the machinery space 73 ft. long with a capacity of 196 tons; there are also forward and after peaks and a deep tank in the fore-hold, all constructed for water ballast purposes and giving a total capacity of 1,287 tons. The machinery is placed aft, but forward of the boiler room, and there are 15 transverse bulkheads, in addition to a strong middle line bulkhead extending from keel to main deck. To insure oil-tightness the scantlings are exceptionally heavy, the rivets closely spaced, and large plates are used to reduce the number of joints, while the compartments are separately tested by water pressure. From the oil compartments trunks are carried up, to provide for the expansion of the oil. Large hatchways are fitted to each compartment to admit of loading with ordinary cargo on the outward voyage, for which reason also 16 derricks worked by steam winches are provided. Oil pipes of large diameter, fitted with controlling valves, are carried from the compartments to the shore connections fitted at the stern, and powerful pumps for discharging the oil are placed in a pump-room amidships. These pumps have also sea connections, so that they can be used to cleanse the oil tanks when other cargo has to be carried, and a fan is provided for ventilating the tanks when so employed.

The propelling machinery, built by the Wallsend Slipway Co., consists of a set of three-stage expansion engines, with cylinders 29·5 in., 48 in., and 78 in. diam. by 54 in. stroke. Steam is supplied by six single-ended boilers, working at 180 lb. pressure, and arranged for consuming either oil or coal as fuel.

Gross register, 7,492 tons; net, 4,904 tons; length, 470 ft.; breadth, 55·2 ft.; moulded depth, 35 ft.

321. Rigged model of S.S. "Regina." (Scale 1 : 48.) Lent by Messrs. A. McMillan and Son, Ltd., 1908. N. 2475.

This represents a typical Canadian lake steamer, of moderate dimensions, which was built of steel in 1907 at Dumbarton by Messrs. A. McMillan and Son.

The external characteristics of this class of vessel are:—A high forecastle and navigation platform at the extreme forward end and the propelling machinery at the extreme after end, leaving the whole intermediate portion of the hull for cargo. Closely spaced hatchways and vertical mast derricks provide for the rapid handling of the bulk cargo, generally ore, coal, or grain.

The "Regina" is propelled by three-stage expansion engines made by Messrs. Muir and Houston, Ltd., Glasgow; they have cylinders of 17 in., 28 in., and 46 in. diam. by 33 in. stroke. With steam at 180 lb. per sq. in. they develop 950 indicated h.p.

Length, 249·7 ft.; breadth, 42·6 ft.; depth of hold, 20·5 ft.; gross register, 1,957 tons.

Vessels of this class, when British built, besides fulfilling the requirements as to moderate draught necessitated by the passage of the connecting locks and rivers of the Canadian Lake system, must also be capable of successfully crossing the Atlantic Ocean.

322. Rigged model of S.S. "Sardinian Prince." (Scale 1 : 48.) Lent by the Prince Line, Ltd., 1908. N. 2491.

This design for a twin-screw cargo and passenger vessel was proposed for the Prince Line in 1908.

Large cabin and saloon spaces, with shade, promenade and boat decks, are provided amidships, while at each end are the main holds with machinery for the rapid handling of cargo. On the shade, or lower boat deck, are shown the electric fans and steam tube-heaters used in connection with the "thermo-tank" system of heating and ventilating the living-spaces on the vessel.

Displacement, 16,000 tons; gross register, 10,000 tons; length, 520 ft.; breadth, 60 ft.; depth, moulded, 40 ft.

323. Whole model of ferry steamer "Finnieston No 1." (Scale 1 : 48.) Lent by Messrs. Ferguson Bros., 1909. N. 2528.

This vessel for ferry purposes across the Clyde was built and engined by Messrs. Ferguson Bros. at Port Glasgow in 1908, for the Trustees of the Clyde Navigation.

A special feature is a movable deck or platform which provides for embarking and discharging vehicular traffic at any state of the tide; the deck has a rise and fall of 17 ft. and is capable of accommodating 16 loaded lorries or a total live load of about 105 tons; it is worked by eight elevating screws, and the weight is carried upon four arched girders each extending continuously from one side of the hull to the other.

The ferry boat is propelled by two sets of three-stage expansion engines each having cylinders 12 in., 18·5 in., and 29 in. diam. by 20 in. stroke.

The principal dimensions of the vessel are:—Gross register, 379 tons; length, 105 ft.; breadth, 45 ft.; depth (moulded), 11·75 ft.

YACHTS.

The word yacht, derived from the Dutch "jacht," was introduced into England probably in the seventeenth century; it is applied to decked vessels used for pleasure or racing purposes, and includes widely-differing types, due to the degree to which the considerations of speed or of accommodation have predominated in influencing the design.

Royal barges and similar pleasure ships are of the greatest antiquity, while in later times it is recorded that Queen Elizabeth had a pleasure vessel built at Cowes in 1588, and that Sir Phineas Pett designed and constructed racing yachts at Deptford for Charles II.

The first recorded yacht club was the Cork Harbour Water Club, now the Royal Cork Yacht Club, established in 1720; the Royal Yacht Squadron was established at Cowes in 1812. The number of such clubs in the kingdom is now over sixty, while there are over four thousand five hundred registered yachts, nearly one third of which are fitted with some form of propelling machinery.

The early yachts were small and heavily built, but as racing became more general, weight was saved by reducing the scantlings, and as there was no time allowance it was soon discovered that size was of the greatest importance in securing success. Accordingly, from the early matches at Cowes in 1780, where the vessels were of less than thirty-five tons, the dimensions increased steadily, so that in 1830 Mr. Joseph Weld's famous cutter "Alarm" (*see* No. 329) was of 193 tons, with 80 ft. on the water line and 24 ft. beam.

At first, the ballast used was in the form of stone or cast-iron blocks, with bags of shot for shifting, but in 1846 lead pigs were substituted, and in 1856 the massive external keel of lead —now universal—was adopted. The early form of hull was described as "cod's head and mackerel's tail," but in 1848 the iron cutter "Mosquito" (*see* No. 333), of 70 tons displacement, built by C. J. Mare on the Thames, to the design of T. Waterman, departed from these features by possessing a long, hollow bow and a short after body of considerable beam, conforming to a great extent to the lines advocated by Scott Russell. This innovation was much criticised, but in 1851, when the "America" (*see* No. 335), which had similar lines, had beaten the swiftest British yachts, opinion quickly changed.

The "America" was a schooner of 208 tons (b.o.m.), and in addition to new lines and rig, differed from the British yachts—which were all cutters—in having her sails as tight and flat as possible, instead of in the baggy form then in vogue. Her schooner rig soon became popular, together with the fine entrance lines and the flat cotton sails. In 1864 the yawl rig became the fashion, but after a few years the cutter again returned to favour, and it now remains the usual rig for both cruising and racing yachts, partly owing to the less labour involved in working it.

In 1875 a great change in yacht design was introduced, by Mr. E. H. Bentall of Maldon, in the "Jullanar" (*see* No. 345), a yawl of 126 tons which proved exceedingly successful, while another improvement of the period was introduced in the "Florinda."

The American yachtsmen had for many years most successfully developed the dropping-keel or centre-board system of construction, but the arrangement was never popular in this country. The modern racing yacht is, however, a combination of the two forms, the present deep keel and external ballast, possessing the advantages of both systems, except in very shallow waters.

The rules, by which the time allowances made to the smaller yachts are determined, are fixed by the Yacht Racing Association, established in 1875. At first it adopted the Thames rule, in which length and breadth were the factors, but owing to the deep and narrow hulls thus evolved the factors in 1886 were changed to length on water line and sail area, so as to favour beamy vessels which would form comfortable cruisers. The "Britannia" cutter, built in 1893 for the then Prince of Wales, was the most successful vessel designed under the 1886 rating, and she won 141 prizes in 209 starts. In 1896, however, a new formula, with length, breadth, girth, and sail area as factors, was introduced; this changed the rating basis from a "tonnage" to a "linear" measurement and encouraged a greater depth of under-water body, and hence a more commodious vessel. Changes of rating formula in 1901 and 1906 further emphasized the feature of habitability—the later rule giving a premium on freeboard.

Although at one time strongly objected to, a large number of the modern cruising yachts are now fitted with auxiliary steam or petrol-motor power, by which they are rendered far less dependent upon the state of the weather.

The earliest successful internal combustion motor launch appears to have been built in 1888, and was fitted with a Priestman oil engine. In 1902 the first serious attempt to produce a high-speed motor boat was made, and a speed of 19 knots was obtained with an engine of 66 h.p. by a boat designed by Mr. Linton Hope for Mr. S. F. Edge. The development of this class of vessel has been continuous and rapid, and has been due in a great measure to the application of the internal combustion engine.

NOTE.—*In the collection there are several models of Eastern yachts, but they have not been included in this section, as they are placed with the other examples of Oriental types.*

RACING YACHTS.

324. Rigged model of Dutch yacht. (Scale 1 : 12.) Lent by S. T. G. Evans, Esq., 1900. N. 2211.

This model represents, in general appearance, a Dutch "jacht" or sailing pleasure-boat of about 1600–50, but it is evidently not accurately to scale.

It is bluff bowed and has heavy quarters, but is provided with an exceptionally large rudder and two lee-boards. The sails consist of a foresail, jib, and mainsail, the latter being carried by a gaff instead of a sprit—an innovation that Pepys mentions as the "Bezan" rig.

The dimensions, as determined from the model, would be:—Tonnage (b.o.m.), 10 tons; length, 21 ft.; breadth, 10·5 ft.; depth, 8·5 ft.

325. Rigged model of Dutch yacht. (Scale 1 : 12.) Received 1910. N. 2546.

In 1660 the Dutch East India Company presented Charles II. with a pleasure boat or yacht known as the "Mary." This appears to have been the first vessel of the type owned in England, and its chief characteristics were embodied in most of the yachts constructed in this country during the 17th and 18th centuries.

The model here shown is said to have belonged to W. Vandevelde, junior (1633–1707), and represents a vessel similar to, but probably smaller than, the "Mary." It is of the single-masted schuyt-rig, carries lee-boards and is clincher built, with a heavy chafing or rubbing piece worked above the water-line. It has a full, round bow with prominent stem piece, a high decorated poop with lantern, and good cabin accommodation amidships.

Approximate dimensions:—Length, water-line, 27 ft.; breadth, 10 ft.

326. Rigged model of Dutch sloop and row-boat. (About 1800.) (Scale 1 : 24.) Received 1907. N. 2435.

This model probably represents a small racing or pleasure sloop as used on the canals and shallow waters of Friesland, North Holland. A sprit or single diagonal yard is sometimes adopted for the mainsail of this class of vessel instead of the long lower boom and short gaff as here shown.

Dimensions (approx.):—Length (overall), 25 ft.; breadth, 8 ft.; draught, 1·6 ft.

The six-oared row-boat is a type used for ferry purposes and is often carried or taken in tow by the larger craft.

Dimensions (approx.):—Length, 15 ft.; breadth, 5 ft.; draught, 1·25 ft.

In general features both models are representative of craft common in Dutch waters from the 17th to the 19th century.

327. Half block model of Yt. "Leopard." (Scale 1 : 24.) Received 1897. N. 2123.

This yacht was built by Mr. Linn Ratsey at Cowes, in 1807.

Length, extreme, 64 ft.; breadth, 17·5 ft.; tonnage (b.o.m.), 70 tons.

328. Half block model of Yt. "Pearl." (Scale 1 : 48.) Received 1899. N. 2189.

This cutter yacht was designed and built in 1820 by Sainty, of Colchester, for the Marquis of Anglesea, to the lines of a smuggler's clipper which the Marquis had noticed as possessing exceptional speed. In 1873 she was rebuilt by Nicholson, of Gosport, and altered to the yawl rig.

Displacement, 127·5 tons; length on water line, 65·3 ft.; breadth, extreme, 19·54 ft.; draught, forward, 6·8 ft.; aft, 11·3 ft.

329. Lithograph of Yt. "Alarm." Received 1905. N. 2407.

This successful cutter yacht was built of wood at Cowes, in 1830, from the designs of her owner, Mr. J. R. Weld. For many years in succession the "Alarm" won valuable prizes in the Solent, including the first Cup presented by Queen Victoria to the Royal Yacht Squadron in 1838. She took part in the International race won by the "America" in 1851. Shortly afterwards she was lengthened 20 ft., and converted into a fast schooner of 248 tons, beating the "America" in a match in 1861.

Original dimensions:—Tonnage (b.o.m.), 193 tons; length on water line, 80 ft.; breadth, 24 ft.

330. Half block model of Yt. "Corsair." (Scale 1 : 24.) Received 1897. N. 2122.

This yacht was built by Mr. Michael Ratsey at Cowes, in 1832. She was a good sea boat and a successful ocean racer.

Length, extreme, 74 ft.; length on keel, 57·75 ft.; breadth, 18·5 ft.; tonnage (b.o.m.), 84·9 tons.

331. Half block model of Yt. "Mystery." (1841). (Scale 1 : 48.) Received 1907. N. 2444.

This famous cutter yacht was built of iron in 1841 for Lord Alfred Paget by Messrs. Ditchburn and Mare, Blackwall, from the designs of Mr. T. J. Ditchburn.

She was the first racing yacht constructed of iron and during several seasons proved herself superior in speed, both in light and heavy weather, to all wooden yachts of similar tonnage. Her success, however, was more largely due to the adoption of finer lines, than to the new material of construction. To obtain advantages in tonnage measurement, the designer gave an unusual amount of rake to her stern-post; this feature was considered by many to have materially improved her sailing qualities and was therefore widely copied in succeeding yacht designs.

Tonnage (b.o.m.), 25 tons; length of keel, 39·9 ft.; breadth, extreme, 11·9 ft.

332. Half block model of Yt. "Fay." (Scale 1 : 24.) Received 1899. N. 2191.

This iron yacht was designed and built by the late Mr. T. J. Ditchburn, about 1845, on lines somewhat similar to those of the "Mystery" (*see* No. 331).

Tonnage (b.o.m.), 12 tons; length, extreme, 39·25 ft.; length of keel, for tonnage, 29·5 ft.; breadth, 9·7 ft.

333. Lithograph of Yt. "Mosquito." Received 1905. N. 2409.

This famous cutter yacht was built of iron at Blackwall by Messrs. Ditchburn, Mare & Co., in 1848, for Lord A. Paget, from the designs of Mr. T. Waterman; she was afterwards owned by Lord Londesborough.

In addition to the use of iron in her construction the "Mosquito" possessed the unusual features of hollow water-lines and a deep raking stern-post. A list of her successes during the period 1850–2 is given on the lithograph, and includes a victory over the "America" in the Royal Victoria Yacht Club race in 1852.

This yacht appears to have been employed as a pilot boat at Barrow-in-Furness as late as 1895.

Tonnage (Thames measurement), 59 tons; length, 63·5 ft.; breadth, 15·2 ft.; depth, 10 ft.

334. Half model of pilot boat "Mary Taylor." (Scale 1 : 48.) Lent by Henry Liggins, Esq., 1876. N. 1464.

This schooner-rigged New York pilot boat was designed and built about 1850 by Mr. George Steers, who subsequently introduced many of her features into the famous racing yacht "America," which he also designed (*see* No 335).

The novelties in the "Mary Taylor" were her extreme shallowness of floor, great depth of keel, small displacement, and the great distance at which her widest section was placed abaft the middle.

For her service she was required to be able to sail rapidly and well on all points, and yet be able to lay-to easily in all weathers, which requirements led to the design adopted.

Load displacement, 62·3 tons; length on load water-line, 61 ft.; breadth at load water-line, 17·6 ft.; mean draught, 5·2 ft.; greatest transverse section, 58·37 sq. ft.; vertical longitudinal section, 451 sq. ft.; area of load water-line, 751·8 sq. ft.; area of sails, 2,382 sq. ft.

335. Whole model of Yt. "America." (Scale 1 : 32.) Contributed by John Scott Russell, F.R.S., 1868. N. 1232.

This schooner yacht was built by Mr. Wilkes at New York, in 1851, for Mr. J. C. Stevens, Commodore of the New York Yacht Club. She was designed by Mr. G. Steers, who extended and developed in her the form he introduced in the pilot boat "Mary Taylor" (*see* No. 334).

Both vessels were remarkable for extreme shallowness of floor and great depth of keel, as well as small displacement, and the great distance at which the widest section was placed abaft the middle. Mr. Scott Russell considered, however, that their lines, as well as those of other American yachts and clippers, followed his wave-line principle.

In the year in which she was built she crossed the Atlantic and showed her superiority to English racing yachts. In August, 1851, at Cowes, she won the cup since known as the "America's cup," and a week later beat the "Titania" (*see* No. 337).

Load displacement, 146·6 tons; length on load water-line, 87·25 ft.; breadth at load water-line, 22·2 ft.; mean draught, 8·2 ft.; greatest transverse section, 102·74 sq. ft.; vertical longitudinal section, 860 sq. ft.; area of load water-line, 1,253·2 sq. ft.; area of sails, 5,263 sq. ft.

336. Lithograph of Yt. "America." Received 1904. N. 2358.

This contemporary print by T. G. Dutton, 1851, represents the yacht "America" in Cowes Roads with mainsail, foresail, and fore staysail set; under full sail, a jib and gaff topsail were also carried.

In addition to the "America" are shown: "Capricorn," schooner, 313 tons; "Gipsey Queen," schooner, 160 tons, which took part with the "America" in the historic international race; "Surprise," topsail schooner, 150 tons; "Xarifa," topsail schooner, 175 tons.

337. Whole model of Yt. "Titania" (I.), afterwards named "Themis." (Scale 1 : 32.) Contributed by John Scott Russell, F.R.S., 1868. N. 1233.

This schooner yacht was built of iron, for Mr. Robert Stephenson, by Messrs. Robinson and Russell, at Millwall, in 1851, and is the yacht that competed with the famous "America" (*see* No. 335).

She was designed by Mr. Scott Russell on his wave-line system, but after being drafted with round water and body lines she was modified to meet the rules of measurement then in force and the theories which prevailed.

This system of measurement employed the keel length as a tonnage factor, therefore the builder reduced the keel of the vessel by giving the stern-post excessive rake. To correct this he added depth to the keel, and thus gave excessive draught. He was also compelled to narrow the beam of the yacht, as if this were not done a yacht of a given displacement instead of being put down at her real tonnage of, say, 100 tons, would have to be called 200 tons, and be compelled to allow time to yachts nearly double her size. The builder of the "Titania," therefore, cut off two large slices from her sides at the load water-line, making them flat and straight where they should have had a gentle swell.

Although there was little difference in length or displacement between the two vessels, the "America" was left with broad shoulders, enabling her to stand up under press of sail, and she also retained her full length and depth of longitudinal section, enabling her to lie close on a wind. In a 20-mile run before the wind there was scarcely any difference in their speeds, the "America" beating the "Titania" by 4 min. 45 secs., which could be accounted for by the larger sail area on the "America." But when returning on the wind the "America" stood up better, and weathered the "Titania" on every tack, ultimately beating her by 45 mins.

Load displacement, 123·1 tons; length on load water-line, 81 ft.; breadth at load water-line, 18·1 ft.; mean draught, 10·16 ft.; greatest transverse section, 87·8 sq. ft.; vertical longitudinal section, 766·5 sq. ft.; area at load water-line, 1,096·8 sq. ft.; area of sails, 6,174·5 sq. ft.

338. Whole model of Yt. "Titania II." (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1234.

Soon after the alteration of the law of tonnage brought about by the race between the "America" and the "Titania" in 1851 (*see* No. 337), Mr. Stephenson decided that he would have a new yacht built on the lines which the "Titania" should have had but for the interference of the abolished law of tonnage. He determined also to increase the length of the vessel so as to secure more accommodation.

This new "Titania" was in every point more stable and more "windwardly" than the old one, and approximated more to the "America."

Load displacement, 163·63 tons; length on load water-line, 93 ft.; breadth at load water-line, 21·5 ft.; mean draught, 10·91 ft.; greatest transverse section, 92·38 sq. ft.; vertical longitudinal section, 917·4 sq. ft.; area of load water-line, 1,300 sq. ft.; area of sails, 7,537·25 sq. ft.

339. Half block model of Yt. "Aline." (Scale 1 : 32.) Lent by Messrs. Camper and Nicholsons, Ltd., 1897. N. 2139.

This schooner yacht was designed by Mr. B. Nicholson, and built by Messrs. Camper and Nicholson at Gosport in 1860, for Mr. C. S. Thelusson. She won the Queen's Cup at Cowes in her first essay, and again in 1867, and the Royal Yacht Squadron prize in 1868.

Tonnage (Thames measurement), 216 tons; length, 107·4 ft.; breadth, 21·8 ft.; depth, 11·3 ft.

340. Half block model of Yt. "Terne." (Scale 1 : 12.) Lent by Messrs. Summers and Payne, Ltd., 1908. N. 2480.

This yacht, probably cutter or sloop rigged, was built of wood at Southampton by Messrs. A. Payne and Son in 1860. She has very full lines and shows a half-deck and a transom stern; details of the external planking are also clearly indicated.

Dimensions, approximate:—Length, 20·5 ft.; breadth, 7·75 ft.; Thames measurement, 4 tons.

341. Half block model of Yt. "Egeria." (Scale 1 : 24.) Presented by Lady Dunleath, 1897. N. 2120.

This schooner yacht was built at Poole in 1865 by Mr. T. Wanhill for Mr. Mulholland. In her brilliant career she won six Queen's Cups, viz., 1865 (her first season), 1869, 1872, 1874, 1879, and 1881; in 1874 the Prince of Wales's Challenge Cup also passed into her possession.

Tonnage (Thames measurement), 157 tons; length, 98·4 ft.; breadth, 19·2 ft.; depth, 10·1 ft.

342. Half block model of Yt. "Guinevere." (Scale 1 : 32.) Lent by Messrs. Camper and Nicholsons, Ltd., 1897. N. 2140.

This schooner yacht was built at Gosport in 1868 by Mr. Nicholson, and at the time was very successful.

Tonnage (Thames measurement), 301 tons; length, 125·2 ft.; breadth, 23·6 ft.; depth, 13·3 ft.

343. Lithograph of Yt. "Cambria." Received 1905. N. 2410.

This schooner yacht was built of wood at West Cowes by Michael Ratsey, in 1868, for Mr. J. Ashbury. She was an excellent sea-boat with good speed in heavy weather, and was the first English yacht to attempt to regain the "America" cup (1870). Previous to this she had beaten the American yacht "Sappho" at Ryde, and the "Dauntless," owned by Mr. Gordon Bennett, in a transatlantic race.

Tonnage (Thames measurement), 193 tons; length, 102·6 ft.; breadth, 21·1 ft.; depth, 11·6 ft.

344. Half block model of Yt. "Muriel." (Scale 1 : 24.) Presented by A. H. Bridson, Esq., 1897. N. 2115.

This cutter yacht was built at Southampton in 1869 by Mr. Hatcher She was a famous vessel and the winner of many prizes.

Tonnage (Thames measurement), 41 tons; length, 60 ft.; breadth, 12·7 ft.; depth, 10·3 ft.

345. Rigged model of Yt. "Jullanar," lent by Sir Geo. A. Pilkington, and half block model lent by R. T. Pritchett, Esq., 1897. (Scales 1 : 24.) Plate VI., No. 1. N. 2128 and 2121.

This yawl-rigged yacht was designed and built by Mr. E. H. Bentall, an agricultural implement maker, at Maldon, in 1875. Although yacht designing had been steadily progressing, no great departure had been made by any of the leading builders until this design of Mr. Bentall's, in which there is absence of deadwood at both extremities. She soon displayed remarkable speed and became famous as a racer.

Tonnage (Thames measurement), 126 tons; length, 90·8 ft.; breadth, 16·6 ft.; depth of hold, 13·1 ft.; draught of water, 13·5 ft.

346. Half block model of Yt. "Neptune." (Scale 1 : 32.) Presented by Messrs. Wm. Fife and Son, 1897. N. 2130.

This yawl-rigged yacht was built at Fairlie, N.B., in 1875, by Messrs. Wm. Fife and Son. She won the Queen's Cup on the Thames in 1886, and at Ryde in 1888.

Tonnage (Thames measurement), 50 tons; length, 64·8 ft.; breadth, 13·5 ft.; depth, 8·9 ft.

347. Half block model of Yt. "Bonita." (Scale 1 : 12.) Lent by Messrs. Watkins & Co. 1877. N. 1474.

This yacht was designed and built as a racing cutter by Messrs. Watkins & Co. at Blackwall in 1876.

Tonnage (Thames measurement), 10 tons; length, 36 ft.; breadth, 8·2 ft.; depth, 7·5 ft.

348. Half block model of Yt. "Mersey." (Scale 1 : 24.) Lent by Messrs. Watkins & Co., 1877. N. 1473.

This yawl-rigged yacht was built at Blackwall in 1877 by Messrs. Watkins & Co., to their own design.

Tonnage (Thames measurement), 37 tons; length, 53·3 ft.; breadth, 13·2 ft.; depth, 9·0 ft.

349. Rigged model of Yt. "Formosa." (Scale 1 : 24.) Lent by A. R. Ricardo, Esq., 1883. N. 1568.

This cutter yacht was designed and built by Mr. M. E. Ratsey, at Cowes, in 1878, for the then Prince of Wales.

Gross register, 102 tons; net register, 72·37 tons; length, 84·5 ft.; length on water-line, 82·66 ft.; breadth, 16·9 ft.; depth, 12·1 ft.; draught of water, aft, 12·5 ft.; draught of water, forward, 7·75 ft.; area of mainsail, 3,150 sq. ft.; area of foresail, 750 sq. ft.; area of jib, 990 sq. ft.; total area of lower sails, 4,890 sq. ft.

In 1887 the rig was altered to that of a yawl.

350. Half block model of Yt. "Maggie." (Scale 1 : 24.) Lent by Francis Taylor, Esq., 1897. N. 2119.

This cutter yacht was built at Southampton in 1878 by Mr. D. Hatcher.

Tonnage (Thames measurement), 15 tons; length, 45 ft.; breadth, 8·8 ft.; depth, 8 ft.

351. Half block model of Yt. "Waterwitch." (Scale 1 : 12.) Lent by Messrs. Camper and Nicholsons, Ltd., 1897. N. 2142.

This schooner yacht was designed by Mr. B. Nicholson, and built at Gosport in 1880; she proved to be a very successful racer.

Tonnage (Thames measurement), 159 tons; length, 100·1 ft.; breadth, 19·2 ft.; depth, 12·3 ft.; sail area, 8,309 sq. ft.

352. Half block model of Yt. "Freda." (Scale 1 : 24.) Lent by Francis Taylor, Esq., 1897. N. 2118.

This cutter yacht was built on the Thames in 1880 by Mr. Beavor Webb, and was a well-known vessel at the time.

Tonnage (Thames measurement), 21 tons; length, 50·8 ft.; breadth, 9·8 ft.; depth, 8·2 ft.

353. Half block model of Yt. "Buttercup." (Scale 1 : 24.) Lent by R. Hewett, Esq., 1897. N. 2125.

This cutter yacht was built by Mr. T. V. Trew at Barking, Essex, in 1880. Thames measurement, 11 tons; length, 47·2 ft.; breadth, 7·3 ft.; depth, 8·5 ft.

354. Half block model of Yt. "Tara." (Scale 1 : 24.) Lent by Francis Taylor, Esq., 1897. N. 2117.

This composite cutter yacht was built at Southampton in 1883 by Mr. D. Hatcher. In 1882 the Yacht Racing Association adopted a new rule of measurement, which evolved a deep and narrow vessel, known as the "plank-on-edge" type. The "Tara" was one of the first built under this rule, and was the most extreme example, being six times as long as she was broad, and unusually deep. She had 38 tons of lead on her keel, and although only a 40-tonner, spread as much canvas as a 60; she was a fast and very successful vessel.

Tonnage (Thames measurement), 42 tons; length, 70·1 ft.; breadth, 11·5 ft.; depth, 10·15 ft.

355. Half block model of Yt. "Eclipse." (Scale 1 : 12.) Lent by A. Manning, Esq., 1897. N. 2147.

This cutter yacht was built at Southampton in 1884 by Messrs. A. Payne and Sons, to the design of Mr. C. P. Clayton. In her first year she won twenty first prizes.

Tonnage (Thames measurement), 15 tons; length, 37·1 ft.; breadth, 10·1 ft.; depth, 7·5 ft.

356. Half block model of Yt. "Minnow." (Scale 1 : 12.) Lent by Messrs. Summers and Payne, Ltd., 1908. N. 2481.

This cutter yacht, first known as "Tootsie," was built of wood at Southampton in 1885 by Messrs. A. Payne and Son to the design of Mr. A. E. Payne.

She is representative of the early "Itchen" class of racing yachts developed from Solent fishing craft. Their chief characteristics were:—Great beam in proportion to length, square stern, deep after deadwood, and raking midship section, *i.e.*, the position of maximum breadth at the load water-line was always well abaft that of the lowest water-line; this latter principle has been adopted in the designs of many modern racing yachts.

Length (b.p.), 17 ft.; breadth, 7 ft.; depth, 4 ft.; tonnage (Thames), 3 tons; Y.R.A. rating (1886 Rule), 1·39.

357. Half block model of Yt. "Thistle." (Scale 1 : 24.) Lent by John L. Watson, Esq., 1901. N. 2174.

This cutter yacht was built of steel at Glasgow in 1887 by Messrs. D. and W. Henderson & Co. She was designed by Mr. G. L. Watson to compete for the America Cup, and was the first notable vessel built under the new measurement rules which then came into operation. She won the Queen's Cup at Rothesay in 1890, and in that season gained 22 prizes; she was soon afterwards purchased by the German Emperor and renamed "Meteor," under which name she gained another Queen's Cup in 1893.

Tonnage (Thames measurement), 170 tons; length, 98·0 ft.; breadth, 20·3 ft.; depth, 14·1 ft.; sail area, 8,157·1 sq. ft.

358. Rigged model of Yt. "Volunteer." (Scale 1 : 24.)
Received 1889. N. 1821.

This centre-board cutter yacht was designed by Mr. E. Burgess, and built of steel at Wilmington, Delaware, U.S.A., in 1887, by the Pusey and Jones Co. She competed in that year for the America Cup, and retained it against the British yacht "Thistle."

Tonnage, 89 tons; length over all, 107 ft.; length on load water-line, 85·92 ft.; breadth, 23·33 ft.; draught of water, 10 ft.; draught with centre-board down, 21 ft.; length of centre-board, 25 ft. Her sail plan contained 9,000 sq. ft. of canvas.

In 1891 the "Volunteer" was lengthened, and rigged as a schooner.

A half block model, N. 2173 (Scale 1 : 32), lent by J. L. Watson, Esq., in 1899 is also exhibited.

359. Half block model of Yt. "Lady Nan." (Scale 1 : 12.)
Presented by A. E. Payne, Esq., 1897. N. 2102.

This sloop-rigged yacht was built at Southampton in 1888 by Messrs. A. Payne and Sons, to the design of Mr. A. E. Payne.

Tonnage (Thames measurement), 6 tons; length, 24·8 ft.; breadth, 8·4 ft.; depth, 4·8 ft.

360. Half block model of Yt. "Valkyrie" (I.). (Scale 1 : 48.)
Lent by the Earl of Dunraven, 1897. N. 2150.

This composite cutter yacht was built at Southampton in 1889 by Messrs. J. G. Fay & Co., to the designs of Mr. G. L. Watson. In 1890 she won 11 prizes, and in 1891 gained a Queen's Cup in a race round the Isle of Wight.

Tonnage (Thames measurement), 94 tons; length, 85 ft.; breadth, 15·9 feet; depth, 11·6 ft.

361. Half block model of Yt. "Iverna." (Scale 1 : 36.)
Lent by Messrs. J. G. Fay & Co., 1897. N. 2144.

This composite built cutter yacht was designed by Mr. A. Richardson, and constructed at Southampton in 1890. In her first season she gained 20 prizes, and in 1892 won a Queen's Cup in Dublin Bay.

Tonnage (Thames measurement), 152 tons; length, 98 ft.; breadth, 19 ft.; depth, 10·7 ft.

362. Half block model of Yt. "Yama." (Scale 1 : 24.)
Presented by Messrs. Wm. Fife and Son, 1897. N. 2131.

This cutter yacht was built in 1890 at Brooklyn, U.S.A., to the design of Mr. W. Fife, junr.

Tonnage (American), 11·4 tons; length, 52 ft.; breadth, 9·2 ft.; draught of water, 9 ft.

363. Half block model of Yt. "Creole." (Scale 1 : 24.)
Presented by Messrs. Forrestt & Son, 1897. N. 2114.

This composite cutter yacht was built at Wivenhoe in 1890 by Messrs. Forrestt and Son, to the designs of Mr. G. L. Watson. She was considered to be the prettiest example and the most consistent performer of the 40-rater type, and in her first season won 15 prizes.

Tonnage (Thames measurement), 54 tons; length, 70·5 ft.; breadth, 13·3 ft.; depth, 10·1 ft.; sail area, 3,993 sq. ft.

364. Half block model of Yt. "Reverie." (Scale 1 : 24.)
Lent by Messrs. J. G. Fay & Co., 1897. N. 2145.

This composite yawl-rigged yacht was built at Southampton in 1891 by Messrs. Fay & Co., to the design of Mr. J. M. Soper.

Tonnage (Thames measurement), 59 tons; length, 72·6 ft: breadth, 13·7 ft.; depth, 9·85 ft.; sail area, 3,994 sq. ft.

365. Half block model of Yt. "Corsair." (Scale 1 : 24.) Lent by R. T. Pritchett, Esq., 1897. N. 2113.

This cutter yacht was built at Southampton in 1892 by Messrs. Summers and Payne, to the design of Mr. A. E. Payne. In her first year she gained a sensational victory over the cutter "Meteor," formerly "Thistle."

Tonnage (Thames measurement), 60 tons; length, 67 ft.; breadth, 14·65 ft.; depth, 10·9 ft.; sail area, 4,098 sq. ft.

366. Half block model of Yt. "Satanita." (Scale 1 : 24.) Lent by Messrs. J. G. Fay & Co., 1897. N. 2146.

This composite built cutter yacht was constructed at Southampton in 1893 by Messrs. J. G. Fay & Co., to the design of Mr. J. M. Soper. In that year she won a Queen's Cup in Ireland, and in 1894 beat the "Britannia" in a reaching trial at Weymouth.

Tonnage (Thames measurement), 300 tons; length, 117·1 ft.; breadth, 24·7 ft.; depth, 12·3 ft.; sail area, 9,915 sq. ft.

367. Half block model of Yt. "Valkyrie II." (Scale 1 : 48.) Lent by the Earl of Dunraven, 1897. N. 2151.

This composite cutter yacht was built by Messrs. D. & W. Henderson & Co. at Glasgow in 1893, from the designs of Mr. G. L. Watson. She crossed the Atlantic and unsuccessfully competed for the America Cup against "Vigilant" in the same year. In 1894 she was sunk through a collision during a race on the Clyde.

Length, 85·5 ft.; breadth, 22 ft.; sail area, 10,042 sq. ft.

368. Half block model of Yt. "Vendetta." (Scale 1: 24.) Lent by Messrs. Summers and Payne, Ltd., 1908. N. 2479.

This cutter yacht was built at Southampton in 1893 by Messrs. Summers and Payne to the design of Mr. A. E. Payne; she is of wood construction with steel frames and beams amidships.

Length (b.p.), 66·5 ft.; length (w.l.), 60·4 ft.; breadth, 17 ft.; draught, 11·75 ft.; sail area, 3,962 sq. ft.; tonnage (Thames), 76 tons; Y.R.A. rating (1886 Rule), 40; (1896 Rule), 67.

369. Whole model of Yt. "Sorceress." (Scale 1 : 12.) Lent by Linton Hope, Esq., 1896. N. 2110.

This centre-board yacht was built in 1894 from the design of her owner, Mr. Hope. The shallow, dish-like underwater form, with broad overhanging ends, is typical of the small "rater" developed under the 1886–96 rating rule, in which sail area and length at the water-line were the only factors. The "Sorceress" carries no ballast, but has a deep central "fin," which gives considerable lateral resistance. She has been highly successful on the Thames in all weathers, beating most of the ballasted and bulb-fin boats.

Length, extreme, 28 ft.; length on load water-line, 19 ft.; breadth, 7·75 ft.; rating 1.

370. Half block model of Yt. "Valkyrie III." (Scale 1 : 48.) Lent by the Earl of Dunraven, 1897. N. 2152.

This composite cutter yacht was built at Glasgow in 1895, by Messrs. D. & W. Henderson & Co., from the designs of Mr. G. L. Watson. She competed unsuccessfully for the America Cup in 1895 against the "Defender."

Tonnage (Thames measurement), 263 tons; length, 88·8 ft.; breadth, 25·7 ft.; depth, 11·7 ft.; sail area, 13,028 sq. ft.

371. Half block model of Yt. "Isolde." (Scale 1 : 36.) Presented by Messrs. Wm. Fife and Son, 1897. N. 2132.

This composite cutter yacht was built at Fairlie, N.B., in 1895, by Messrs. Fife and Son, from the designs of Mr. W. Fife, jun. Her record in 1895 was: 54 starts, 31 first prizes, and 6 second; in 1896: 45 starts, 26 first prizes, and 7 second.

Tonnage (Thames measurement), 82 tons; length, 71·25 ft.; breadth, 16·8 ft; depth, 8·4 ft.; sail area, 4,006·3 sq. ft.

372. Half model of Yt. "Corolla." (Scale 1 : 12.) Lent by Messrs. Camper and Nicholsons, Ltd., 1897. N. 2143.

This lugger-rigged yacht was built by Messrs. Camper and Nicholson, at Gosport, in 1895, from the designs of Mr. C. Nicholson.

Tonnage (Thames measurement), 7 tons; length, 27·25 ft.; breadth, 7 ft.; sail area, 548·7 sq. ft.; rating, 2·5.

373. Rigged model of sailing punt "Leah." (Scale 1 : 6.) Lent by R. J. Turk, Esq., 1903. N. 2345.

This successful example of a racing punt was built at Kingston-on-Thames in 1896 by Mr. R. J. Turk; she has won the Thames Championship for her class in the five consecutive years 1896–1900 and out of a total of 40 starts, obtained 35 first places, 2 second, and 3 third.

The boat is of simple box construction, with the sides formed of single strakes inclining outwards and the whole structure held together by timber knees secured to stout floor pieces spaced 1·75 ft. apart. Two swinging leeboards are fitted, to reduce leeway, and internal housing is provided for their reception when lifted. A punting platform is constructed at the after end and the space beneath it is utilised as a locker. When sailing a large dipping lug sail is used, carried by a hollow mast and yard which are built up in wood.

Length, extreme, 25 ft.; breadth, extreme, 3·83 ft.; depth, amidships, 1·3 ft.; sail area, approximate, 200 sq. ft.; rating, (S.B.A. Rules), 0·5.

374. Half block model of Yt. "Tutty." (Scale 1 : 24.) Lent by Messrs. Summers and Payne, Ltd., 1908. N. 2482.

This cutter yacht was built of wood at Southampton in 1898 by Messrs. Summers and Payne to the designs of Mr. A. E. Payne.

Tonnage (Thames) 40 tons; length (b.p.), 60 ft.; breadth, 15·86 ft.; Y.R.A. rating (1896 Rule), 65.

375. Rigged model of Yt. "Outlook." (Scale 1 : 16.) Presented by W. Starling Burgess, Esq., 1903. Plate VI., No. 2. N. 2347.

This racing yacht was built at Boston, Massachusetts, in 1902, to the designs of Mr. Burgess to defend the "Quincy Cup," open to any sailing craft not exceeding 21 ft. at the water-line; in this she was successful and she has an unbroken record of seven victories.

Her construction illustrates the inconvenient extreme to which a rule restricting only the water-line length of competing yachts tends; nevertheless, her sail area and speed are considerably greater than have ever before been associated with so little weight or so short a water-line, results which are due to her immense beam, great overhang at bow and stern and the lightness of her construction.

The hull is of nearly uniform breadth, and gradually decreases in depth from amidships to a broad, flat entrance and run. To increase the lateral resistance there is a large central drop-keel plate, which is assisted by a deep hanging rudder.

The strength of the boat is entirely derived from a steel truss, extending from bow to stern and having six arms running athwartships from side to side. The truss section is formed by two triangles on the same base but with one inverted; the members and bracing are of angle steel. Below and around this steel frame the light wooden hull is secured, and near its centre the mast step is built, while along the top the standing rigging and sheet blocks are attached.

Displacement, 3 tons and there is no ballast; length (o. a.), 51·4 ft.; length on water-line, 21 ft.; beam, extreme, 16 ft.; beam at water-line, 13·4 ft.; draught of hull, ·66 ft.; sail area, 1,800 sq. ft. The midship sectional area is 7·54 sq. ft.; area of load water-line plane, 271 ft.; wetted surface, without board, 278 sq. ft.; and the prismatic coefficient, ·592.

376. Half block model of Yt. "Little Haste." (Scale 1 : 12.) Presented by W. Starling Burgess, Esq., 1903. N. 2346.

This centre-board yacht was built in 1902 at Manchester, Massachusetts, to the designs of Mr. Burgess, to conform with the rules of the 21-ft. cruising class of the Massachusetts Yacht Racing Association. In her first year she won the Association's championship on the open sea, and was then transferred to Lake Michigan, where she was equally successful.

The boat is a modern example of a scow of stout construction, with great beam and shallow draught, and Mr. Burgess states that her lines closely correspond with those arrived at by the theory of Mr. John Scott Russell. Despite her full overhangs she has proved to be a good sea boat and capable of beating the keel boats of her class in a heavy sea and a strong breeze.

Displacement, 3·06 tons; weight of ballast, 5·34 tons; length (o.a.), 40 ft.; length on water-line, 21 ft.; beam (extreme), 10·65 ft.; beam at water-line, 10·4 ft.; draught, 2 ft.; sail area, 941 sq. ft. Her midship sectional area, excluding keel, is 9·52 sq. ft.; area of load water-line plane, 187 sq. ft.; wetted surface, excluding centre-board, 217·3 sq. ft.; prismatic coefficient, ·532; metacentric height, 9·42 ft.; and the stability at 20 deg. is 19,000 ft. lb.

377. Half block model of Yt. "Bunnie." (Scale 1 : 8.) Lent by Messrs. Summers and Payne, Ltd., 1908. N. 2478.

This sloop-rigged yacht was built of wood at Southampton in 1906 by Messrs. Summers and Payne to the design Mr. A. E. Payne, jun.

Tonnage (Thames), 2 tons; length (w.l.), 17·15 ft.; breadth, 5 ft.; Y.R.A. rating, 18·01.

A comparison of this design with that of the "Minnow" (No. 356), a yacht of similar length at water-line, shows broadly the effect of recent rating rules upon the external appearance of racing yachts.

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378. Rigged model of ice boat. (Scale 1 : 24.) Presented by J. S. Anderson, Esq., 1865. N. 1075.

This represents a cutter-rigged ice boat such as is used on the Gulf of Finland, the North American lakes, etc., when navigation is stopped by frost.

The boat is a framed cross in plan, with the mast stepped at the intersection; it is carried on three sledge irons, one of which is aft and is fitted with a handle for steering. The dimensions vary, but in one example, the "Sokol" (*i.e.*, "Falcon"), the length was 25 ft., and the beam 12 ft.

These boats attain a very high speed; with a beam wind their velocity may exceed that of the wind by which they are propelled.

379. Rigged model of ice yacht "Swedish Arrow." (Scale 1 : 10.) Received 1909. N. 2530.

This represents a typical racing yacht as used on the frozen lakes and creeks of the Baltic; it is of lighter construction than No. 378, and has improved skids and rudder arrangements. In size and general features this vessel also resembles a 250-ft. class North American ice yacht (*i.e.*, carrying 250 sq. ft. of canvas).

The main structure consists of two wooden members arranged in the form of a horizontal cross. The fore-and-aft member or backbone extends the full length of the vessel; it is elliptical in section and tapers longitudinally in each direction from its junction with the thwartship member. It may be formed either of solid timber, scarfed where necessary, or it may be of hollow section; or, again, it may consist of a trussed frame. This member carries the mast and rudder, and also acts as a bowsprit for setting the head-sail; it likewise forms an attachment for the crew platform or cockpit at the after end. The thwartship member or runner plank is about one-half of the length of the backbone, and is of solid timber; it carries the skids or runners at the outer ends. The rudder and side runners are pivoted so as to rock freely in a fore-and-aft direction, and thus minimise the worst effects of uneven ice; further to reduce the shocks under such conditions a thick rubber cushion is usually fitted under the rudder bearing. All sliding surfaces are fitted with soft cast-iron shoe-pieces.

A single mast with a main sail and jib is the usual rig, and the vessel is manœuvred like a cutter. The spars are usually hollow, and both the standing and running rigging are of galvanised steel wire.

Length overall, 31·5 ft.; breadth, 15 ft.

CRUISING YACHTS.

380. Lithograph of H.M.Yt. "Victoria and Albert." Woodcroft Bequest, 1903. N. 2311.

This paddle-wheel yacht was built of wood at Pembroke in 1842–3 from the designs of Sir W. Symonds; she was broken up in 1868, but had then been long replaced by a larger yacht of the same name.

A somewhat unusual system was adopted in the construction of this vessel as, to reduce weight, no closely-spaced transverse ribs or frames were fitted, except to the lower or under water portions of the hull, the general transverse form above being maintained by five watertight wooden bulkheads, spaced at intervals throughout the length, and each one extending from the keel to the upper deck. To compensate for any loss of structural strength thus occasioned, the outer planking was worked in three thicknesses —the two inner layers placed diagonally across each other, at 45 deg., and the outer layer worked longitudinally. Tarred felt was laid between each thickness, and the whole finally held together by vertical and diagonal ties.

The engines, made by Messrs. Maudslay, Sons and Field, were of the twin cylinder type (*see* No. 808), and gave the vessel a speed of 10·7 knots.

Burden, 1,034 tons; length, extreme, 225 feet; length, b.p., 200 ft.; breadth, outside paddles, 59 ft.; breadth, inside paddles, 33 ft.; depth of hold, 22 ft.; draught, mean, 14·25 ft.

381. Lithograph of H.M.Yt. "Fairy." Woodcroft Bequest, 1903. N. 2312.

This iron-built screw yacht was designed and constructed by Messrs. Ditchburn and Mare at Blackwall in 1844–5, and was broken up in 1868.

She was originally intended for the conveyance of Queen Victoria between Whitehall and Woolwich, but proved so seaworthy that she subsequently became a tender to the larger yacht "Victoria and Albert" on her voyages. She was, moreover, one of the earliest vessels in the Navy designed and fitted for screw propulsion, and was considered to be the fastest vessel of her time; she was afterwards used by the Admiralty for testing various forms of propeller.

Her engines, constructed by Messrs. Penn and Son, had two oscillating cylinders, 42 in. diam. by 36 in. stroke, making 48 revs. per min., and were connected with the screw-shaft by spur gearing which gave a propeller speed of 240 revs. per min. With a boiler pressure of 10 lb. and 364 indicated h.p. a speed of 13·3 knots was obtained with a screw 5·3 ft. diam., 8 ft. pitch and 1 ft. long.

Displacement, 168 tons; length (b.p.), 144·6 ft.; breadth (extreme), 21·1 ft.; draught (mean), 5 ft.

382. Whole model of H.M.Yt. "Fairy." (Scale 1 : 48.) Lent by the Thames Iron Works and Shipbuilding Co., Ltd., 1908. N. 2486.

This was built of iron at Orchard Yard, Blackwall (now the Thames Ironworks), in 1844–5, by Messrs. Ditchburn and Mare.

For descriptive details, *see* No. 381.

383. Whole built model of Yt. "Dryad." (Scale 1 : 12.) Presented by Prof. J. W. Groves, 1893. N. 2014.

This cutter yacht was built at Cowes in 1846 by Messrs. White and Sons, for Mr. Delafield. The model was constructed by the late Mr. W. Groves, the sculptor, and is a very accurate record of the vessel and its details, even the internal fittings being faithfully represented to scale.

Tonnage, 85 tons; length, 72 ft.; breadth, 20 ft.; draught of water, 11 ft.

A half block model of the "Dryad" (Scale 1 : 24) is shown in the same case.

384. Whole block model of Yt. "Kate." (Scale 1 : 12.) Lent by Messrs. Forrestt and Son, 1873. N. 1354.

This yawl-rigged yacht was built by Messrs. Forrestt and Son for Mr. E. E. Middleton. She is decked over, but has a well with sliding hatch amidships. In 1869 the owner sailed her alone round the English coast.

Length, 23 ft.; breadth, 7 ft.; depth, 2·5 ft.

385. Rigged model of schooner yacht. (Scale 1 : 8.) Presented by A. Humphreys, Esq., 1878. N. 1503.

This represents a full-rigged fore-and-aft schooner, with mainsail, boom foresail, fore staysail, jib, fore and main gaff-topsails set.

Length, 105 ft.; breadth, 27·5 ft.; depth, 15 ft.

386. Rigged model of cutter yacht. (Scale 1 : 24.) Lent by H. L. Hooper, Esq., 1877. N. 1483.

This yacht has her mainsail and foresail set, and it represents a vessel of the following dimensions:—Tonnage (b.m.), 40·4 tons; length, 60 ft.; breadth, 12 ft.; depth of hold, 8 ft.

387. Whole block model of schooner yacht. (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1255.

This shows a proposed fast schooner designed with "wave-lines." For a speed of 12 knots the sail area was to be 12,600 sq. yds., or else a screw was to be fitted, driven by engines of 500 indicated h.p.

Tonnage (b.o.m.), 512 tons; length on load water-line, 150 ft.; breadth extreme, 27 ft.; mean draught, 10·8 ft.; immersed midship section, 175 sq. ft.

388. Whole model S.Yt. "Undine." (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1254.

This three-masted, schooner-rigged, auxiliary-screw yacht was constructed of iron in 1856 to lines determined entirely by Mr. Scott Russell's wave system.

Her keel was formed by turning down the adjacent skin plates and then riveting them together through two intervening plates ·75 in. thick, thus forming a continuous keel which terminated in a horizontal plate on the top of the floors.

The engines were of the angular direct-acting type, with two cylinders 24 in. diam. by 15 in. stroke, and indicated 160 h.p. at 100 revs. per minute. Steam at 15 lb. pressure was supplied by a tubular boiler, 8 ft. long, 12·25 ft. wide, and 8·75 ft. high, having four furnaces and 1,026 sq. ft, of heating surface. The consumption of coal per 24 hours was 6 tons, and 3·5 lb. per indicated h.p. per hour. She was fitted with a 2-bladed lifting screw, 7·75 ft. diam. by 11·3 ft. pitch, weighing ·6 ton. Her speed was 9·5 knots.

Tonnage (b.m.), 363 tons; length on load water-line, 125 ft.; breadth, extreme, 25 ft.; depth at the side, 11·5 ft.; draught, 10·5 ft.; immersed midship section, 159 sq. ft.; area of load water-line, 1,997 sq. ft.

389. Half models of S.Yt. "Cleopatra." (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1243.

This was a paddle vessel built on the longitudinal system for the Egyptian Government in 1858. Her greatest breadth was on the water-line amidships, "flare" being given to the extremities so as to ease the motion at sea; the whole of the machinery space was placed forward so as leave ample accommodation aft. She carried two masts, and had a sail area of 490 sq. yds.

Her engines had three oscillating cylinders and weighed 103 tons; they are represented and described in No. 812; her average speed was 14·7 knots.

Steam at 25 lb. pressure was supplied by two tubular boilers 15 ft. long, 9 ft. wide, and 8·5 high. The total grate area was 150 sq. ft., and the heating surface 3,251 sq. ft. They weighed 17 tons and carried 20 tons of water.

Load displacement, 435 tons; tonnage (b.m), 453 tons; gross register, 262 tons; length on load water-line, 202 ft.; breadth, extreme, 21 ft.; depth at side, 10·4 ft.; draught of water, laden, 6·25 ft.; immersed midship section, 122 sq. ft.

390. Half block model of Austrian state Yt. "Miramar." (Scale 1 : 48.) Received 1893. N. 2023.

This schooner-rigged paddle yacht was built by Messrs. Samuda Bros. in 1872 for H.I.M. the Emperor of Austria.

The engines indicate 2,500 h.p., and give a speed of 17·2 knots; the coal capacity is 300 tons.

Length (b.p.), 269 ft.; breadth, 32·8 ft.; draught, 14 ft.; displacement, 1,810 tons.

391. Half block model of S.Yt. "Sunbeam." (Scale 1 : 48.) Lent by the Rt. Hon. Earl Brassey, K.C.B., 1897. N. 2134.

This auxiliary-screw, three-masted, topsail schooner was designed by Mr. St. Clare Byrne, and composite built by Messrs. Bowdler, Chaffer & Co., at Seacombe, on the Mersey, in 1874. She is a well-known cruising yacht, having made several voyages round the world.

Her engines, by Messrs. Laird Bros., are of the two-stage expansion inverted type, with cylinders 24 and 42 in. diam. by 21 in. stroke. Steam, at 55 lb. pressure, is supplied by a boiler with three plain furnaces having

54 sq. ft. of grate surface. The engines indicated 350 h.p. and developed a speed of 10·13 knots on the measured mile. The cruising speed is 8 knots, with a daily consumption of 4 tons of coal, the endurance at this rate being 20 days.

Tonnage (Thames measurement), 532 tons; length, between perps., 159 ft.; breadth, 27·6 ft.; depth, 13·9 ft.; area of midship section, 202 sq. ft.

392. Half block model of S.Yt. "Chazalie." (Scale 1 : 32.) Lent by Messrs. Camper and Nicholsons, Ltd., 1897. N. 2141.

This schooner-rigged screw steam yacht, designed by Mr. B. Nicholson, was built at Gosport in 1875.

Her engines were inverted two-stage expansion, with cylinders 20 in. and 40 in. diam., by 24 in. stroke.

Tonnage (Thames measurement), 514 tons; length, 157·1 ft.; breadth, 27·3 ft.; depth, 15·4 ft.

393. Half block model of S.Yt. "Wanderer." (Scale 1 : 48.) Lent by Mrs. S. Lambert, 1894. N. 2032.

This composite, three-masted, schooner-rigged, screw yacht was built at Greenock in 1878 by Messrs. R. Steele & Co. She was then one of the largest yachts afloat, and so elegantly fitted that it is said her total cost was 100,000*l*.

Her engines were originally three-stage expansion, with cylinders 17 in., 34 in., and 48 in. diam., by 30 in. stroke, which at 92 revs. per min. indicated 200 h.p. Steam at 400 lb. pressure was supplied by four boilers 9·6 ft. long and 5·25 ft. broad, each with a grate surface of 19 sq. ft. and a heating surface of 760 sq. ft. The engines and boilers were on the Perkins's system and designed by Mr. J. F. Spencer. The exceptional pressure gave rise to practical difficulties that ended in the engines being replaced by a two-stage expansion set, with cylinders 25 in. and 50 in. diam., by 30 in. stroke, supplied with steam at 80 lb. pressure, and indicating 100 h.p.

Tonnage (Thames measurement), 708 tons; length, 185·4 ft.; breadth, 29·2 ft.; depth, 16·1 ft.; draught of water, 13·5 ft.

394. Whole model of the Russian Imperial S.Yt. "Livadia." (Scale 1 : 48.) Received 1883. Plate VI., No. 3. N. 1593.

This immense steam yacht was built of steel at Glasgow in 1880, by Messrs. John Elder & Co., to designs prepared by the Russian Admiralty.

The lower part of the hull is of turbot shape, and contains the machinery, coal, and stores. It is built with a double bottom 3·5 ft. deep in the centre, and nearly flat, but is stiffened by webs that divide it into 40 watertight compartments. The sides are strengthened by two continuous inner bulkheads, with cross webs, so that the intervening space is divided into 40 more compartments; these, with the rounded deck above and the bottom plates, constitute a strong annular structure that is further stiffened by radial girders.

Above this hull is a superstructure of more usual shape, which provides accommodation for the crew forward and the officers aft; above it is the upper deck, upon which are the quarters of the Emperor and his suite, while above this is an awning deck provided with state saloons.

Her three main engines are two-stage expansion, each having three cylinders, one of 60 in. and two of 78 in. diam., by 39 in. stroke; each set indicates 3,500 h.p,, and drives a four-bladed propeller 16 ft. diam., spaced 18·25 ft. apart. On her trial she attained a speed of 15·8 knots with 10,500 indicated h.p. The form of hull is not conducive to high speeds, and while crossing the Bay of Biscay the flat bottom showed itself unsuitable for rough water.

Tonnage (yacht measurement), 11,802 tons; displacement, 3,900 tons; length, 235 ft.; breadth, 153 ft.; depth from awning deck, 36·6 ft.; draught of water, 6·6 ft.

395. Half block model of S.Yt. "Puck." (Scale 1 : 24.) Lent by Messrs. Thomas Grendon & Co., 1888. N. 1801.

This steam yacht was built of steel at Drogheda in 1880. Steam at 75 lb. pressure was supplied by a steel boiler 8·25 ft. long and 5·5 ft. diam. Her speed was 13·9 knots.

Register tonnage, 25 tons; length, 61·25 ft.; breadth, 9·5 ft.

396. Rigged model of S.Yt. "Lady Torfrida." (Scale 1 : 48.) Lent by the Fairfield Shipbuilding and Engineering Co., 1901. N. 2270.

This schooner-rigged screw yacht was designed and built of steel in 1886 at Govan, by the Fairfield Company, for the late Sir William Pearce, Bart., chairman of the company.

The vessel has two decks and four bulkheads; she is completely fitted as a pleasure yacht, and is lighted throughout by electricity, which, when the dynamo is not running, is supplied by accumulator cells.

The engines are a three-stage expansion surface-condensing set, with two high-pressure cylinders, 14·25 in. diam., one intermediate pressure, 30·5 in. diam., and two low-pressure, 38 in. diam., all by 30 in. stroke. The high-pressure cylinders are arranged tandem above the low pressures, on each side of the intermediate-pressure cylinder, a three-throw crank shaft being used. Piston-valves are fitted to the high-pressure cylinders and flat slide valves to the others; reversing is effected by Brown's steam and hydraulic gear. (*See* No. 873.)

Steam at 150 lb. pressure is supplied by a single-ended Scotch boiler, 15·75 ft. diam. by 9·4 ft. long, with four corrugated furnaces and a grate surface of 81 sq. ft.; the indicated h.p. is 1,400.

Thames measurement, 735 tons; gross register, 546 tons; length, 216·5 ft.; breadth, 27 ft.; depth, 16·6 ft.

397. Drawing of S.Yt. "Grace Darling." (Scale 1 : 48.) Lent by Messrs. Fleming and Ferguson, 1888. N. 1805.

This steel-built, schooner-rigged, screw yacht was built and engined at Paisley, in 1887, from designs by Mr. J. Darling. She has two decks and five bulkheads.

Her engines are two-stage expansion with four cylinders, two high-pressure 10 in. and 14 in. diam., and two low-pressure, 14 in. and 28 in. diam., all 20-in. stroke. The boiler pressure is 190 lb. per sq. in.

Length, 143 ft.; breadth, 19·5 ft.; depth, 10·3 ft.; gross register, 169·14 tons; Thames measurement, 250 tons.

398. Rigged model of S.Yt. "Safa-el-bahr." (Scale 1 : 48.) Lent by Messrs. A. and J. Inglis, 1897. N. 2127.

This schooner-rigged, steel-built yacht was designed and constructed by Messrs. A. and J. Inglis at Glasgow in 1894, for H.H. the Khedive of Egypt. She has two decks and five bulkheads.

Her engines are a three-stage expansion set, with cylinders 18 in., 29 in., and 48 in diam., by 36 in. stroke, indicating 1,200 h.p., and giving a speed of 14·1 knots. Steam at 160 lb. pressure is supplied by two boilers, having 2,300 sq. ft. of heating surface.

Thames measurement, 677 tons; length, 221 ft.; breadth, 27·1 ft.; depth at the side, 17·3 ft.; draught of water, 12 ft.; area of greatest transverse section, 248 sq. ft.; area of load water-line, 3,590 sq. ft.

399. Rigged model of S.Yt. "Ivy." (Scale 1 : 48.) Lent by H.M. Foreign Office, 1897. N. 2155.

This composite-built, schooner-rigged, twin-screw yacht was constructed at Hull in 1895 by Messrs. Earle's Shipbuilding and Engineering Co., to the design of Messrs. J. Thompson and Son, for H.B.M. Niger Coast Protectorate. She has two decks, a short forecastle, and an awning deck extending over two-thirds of the vessel; the after part is sheltered by double canvas awnings. The hull is divided by bulkheads into six watertight compartments, and she is armed with three guns.

She is propelled by two sets of three-stage expansion engines, with cylinders 13·75 in., 22·75 in., and 35 in. diam. by 27 in. stroke, indicating 1,100 h.p., and giving a speed of 13·5 knots. Steam at 150 lb. pressure is supplied by two steel boilers with six ribbed furnaces; the grate area is 117 sq. ft., and the heating surface, 3,608 sq. ft.

Tonnage (Thames measurement), 1,131 tons; register, 337 tons; gross, 870 tons; length, 220 ft.; breadth, 33·8 ft.; depth, 15·4 ft.

400. Rigged model of S.Yt. "Alberta." (Scale 1 : 48.) Lent by the Ailsa Shipbuilding Co., Ltd., 1907. N. 2446.

This twin-screw schooner-yacht was built of steel by the Ailsa Shipbuilding Co. at Troon, and engined by Messrs. D. Rowan & Co. of Glasgow in 1896. She was designed by Mr. G. L. Watson for Mr. A. J. Drexel, of Philadelphia, and was originally known as "Margarita"; her name was changed in 1898, and she was afterwards fitted out for the use of H.M. the King of the Belgians. She is constructed with two complete decks and seven transverse watertight bulkheads; electric lighting is adopted throughout.

The yacht is propelled by two sets of four-stage expansion engines, having cylinders 15·5 in., 22 in., 31 in., and 44 in. diam. by 27 in. stroke. Steam is supplied at 200 lb. pressure by two boilers fitted with forced draught arrangements; with 3,000 indicated h.p. a speed of 17 knots was realised.

Tonnage (Thames measurement), 1,322 tons; gross register, 1,143 tons; length, overall, 280 ft.; length on water-line, 240 ft.; breadth, 33·7 ft.; depth (moulded), 20 ft.

MOTOR BOATS.

401. Whole model of motor boat "Brooke II." (Scale 1 : 12.) Presented by Messrs. J. W. Brooke & Co., Ltd., 1908. N. 2470.

This represents a vessel built in 1908 by Messrs. J. W. Brooke & Co., and in general features shows a typical high-speed motor boat. The flattening and widening of the afterbody sections, and the consequent cutting away of all the deadwood aft, is common to all high-speed motor craft, and is designed to prevent excessive change of trim of the vessel. This change of shape is necessitated by the fact that the difference between the water-pressures fore and aft causes such boats to trim so much by the stern that the ordinary ship design is unsuitable and even dangerous. The high bow and curved deck are common to most vessels of this type. Wood is used in the construction of the vessel represented on account of its lightness and low cost; moreover, with wood fair surfaces can be produced (*see* No. 636).

"Brooke II." is built of planking ·25 in. thick, and has engine-bearers 2 in. thick running from the stern of the boat to the transom. Weight has been kept at a minimum, the vessel without machinery weighing under 610 lb., and with the machinery, only about 1,100 lb.

The vessel is propelled by a Brooke petrol motor having six cylinders, each 6·5 in. diam. by 6 in. stroke. The crank-shaft is of nickel steel, and is drilled for lubrication purposes, the oil draining into a sump at the bottom of the crank-chamber. A gear pump, driven by skew wheels from the cam shaft, draws the oil from the sump and forces it through an oil-cooler, from which it is re-distributed to the main bearings. Both the valve covers and the cylinders are water-jacketed to avoid pre-ignition. The engine is started by a quadrant engaging with a spur-wheel cut at the back of the fly-wheel. On trial, fitted with a 20-in. three-bladed propeller, the vessel attained a speed of 24·6 knots with 960 revs. per min.

Displacement, 1 ton; length overall, 25 ft.; breadth, 5 ft.; brake h.p., 100.

402. Built model of seagoing motor launch. (Scale 1 : 12.) Lent by Messrs. J. King & Co., 1909. N. 2512.

This represents a class of unballasted, light draught motor-boat, designed by Mr. T. D. Sandars, for cruising in the open sea; it was built by Messrs. J. King & Co. As the design provides for either single or twin-screw propulsion, no details of the machinery are shown on the model.

The vessel is carvel-built, of pitch pine, with a deck of kauri pine; the frames are of steamed American elm and spaced 6 in. apart. Most of the internal fittings are of teak, and their general character may be seen by raising the deck of the model. There is accommodation for three deck hands, one engineer, and seven passengers.

The propelling equipment may be either a single or a double set of King-Lamb marine motors, each of 24 h.p., and using petrol or gasoline. Sufficient fuel is carried to maintain 30 hours' continuous running at 11 knots (twin-screw), or 60 hours at 8 knots (single-screw). The engines and rudder are controlled from the pilot house, but arrangements can be made for steering from the cock-pit.

Length, 50 ft.; breadth, 10 ft.; draught, 3 ft.; displacement, 13 tons.

403. Whole model of "hydroplane" motor boat. (Scale 1 : 6.) Lent by Messrs. John Wilesmith & Co., 1909. N. 2514.

This represents a type of motor craft in which, at high or moderate speeds, a "gliding" or "skimming" action takes the place of the "ploughing" action in boats of ordinary form; this considerably reduces the resistance at high speed, by diminishing the displacement. The example shown was built of wood at Worcester, in 1909, from the designs of Mr. E. P. M. Robinson.

The most noticeable features of these boats are:—Great beam to length, flat floors, inclined bow, and abrupt transom stern. In early experiments, with a single, unbroken, underwater plane, such boats were found to oscillate considerably, and became almost unmanageable; by stepping the lower hull, or forming it in two or more successive surfaces, greater stability and efficiency were obtained. In some successful hydroplanes a number of separate inclined plates or planes are attached to the submerged hull. As shown by the model, the foremost plane extends over one-third of the boat's length and carries the rudder at its after termination; beyond the "step" the hull is of decreased depth and offers a broad flat gliding surface, to which is attached an inclined shaft and deeply immersed propeller. A light hood or weather screen, with wash-strakes and coamings, protects the habitable portion of the flat deck, and a long continuous rod provides for working the tiller at various positions.

The boat has an overall length of 13 ft. and breadth of 5 ft.

In boats of the "Fauber" class (attached planes) having engines of 60 h.p. and a length of 26 ft., speeds up to 32 knots have been realised.

BOATS, BARGES, LAUNCHES, TUGS, Etc.

Under this heading are included the small vessels, used as adjuncts to ships, and also the varied craft used in fishing, or for short journeys, on which extensive accommodation is not required. Boats can most easily be divided into two classes:—those that are open and therefore unsuited for rough weather, and those that are decked so as to have more protection against swamping and also furnish some shelter to the occupants.

Pleasure boats of the open type are usually of light construction and propelled by oars although auxiliary sail or motor propulsion is sometimes adopted. Rowing boats for racing purposes are built of cedar, with canvas deck-covering, at an average weight of 1 lb. per ft. run; outriggers are used to obtain suitable fulcrums for the sculls, and sliding seats to give increased length of stroke. Open fishing and ships' boats are of much heavier build, broader in the beam, and bluff bowed; the former are usually lugger, ketch, or cutter rigged, and sometimes half-decked.

Decked boats form a class that strictly includes a large proportion of the finest pleasure craft, but these have been classed together in the section devoted to yachts. The other most important decked boats are engaged in the extensive fishing industries, and, owing to the rough weather which they have to encounter, such vessels have been developed to a high degree of seaworthiness: the introduction of steam or other motive power has greatly enlarged the capabilities of these craft. Decked launches, with steam, petrol or electricity for propulsion, are also widely used for commercial and pleasure purposes.

Steam tug-boats are of the utmost value to disabled vessels generally, to large sailing vessels when nearing land and to steamships when passing through narrow or tortuous channels. Owing to their stiff build and great engine power, steam tugs are capable of encountering almost any weather, and they are the recognised means for taking out a lifeboat during a storm.

Lifeboats were introduced practically by Greathead in 1789; his boats rendered good service, but had no means of freeing themselves from water, and were not self-righting. In 1850, a prize of 100 guineas was offered by the Duke of Northumberland for a new design; out of 280 models and plans sent in, that of James Beeching of Yarmouth was considered the best, and his was the first self-righting boat. Subsequently a boat embodying features of several of the designs was adopted, and this became the standard of the National Lifeboat Institution, but it has since been somewhat modified.

The construction of a boat resembles that of a larger vessel, but is usually determined entirely in the workshop. The stem and stern posts, with the keel, are first set up, and then equi-distant moulds, to which the planking is clamped, are set transversely on the keel; the ribs, thwarts, knees, etc., are inserted afterwards. If clincher-built, the planks, about 5 inches wide and tapering in thickness, overlap the lower ones ·75 in. If carvel-built, the planks are flush-jointed, and oakum or cotton caulked, being afterwards payed with pitch or marine glue. Where the plank is too thin for this, as in racing craft, "ribbon-carvel," *i.e.*, thin cover strips of wood over the joints inside are used. Diagonal carvel planking is used in lifeboats, and generally where great strength is required, but the construction is expensive. In boatbuilding, the fastenings are generally copper nails or rivets, clinched over washers.

Till early in the 19th century, no means of launching a boat clear of the vessel, except perhaps by one of the yards, had been devised, but as the size of vessels increased, and passenger traffic developed, the provision of convenient lowering appliances became a necessity. Straight spar davits, resembling crane jibs overhanging the side, were in use in 1808; later they were pivoted at the foot (*see* the boats on No. 62) and finally the present curved iron form, turning on its own axis, was adopted, the boat being hung from them by rope tackle with hook and ring connections. Owing to the possibility of unequal lowering, and the uncertainty in disengaging, this arrangement is very dangerous, and many attempts have been made to improve it since about 1830. Clifford's arrangement, patented in 1853, was the first improved form that was extensively adopted, but many other schemes are also shown in the collection.

OPEN BOATS.

404. Welsh coracle. Presented by J. W. Willis Bund, Esq., 1883. N. 1611.

This form of boat was in use in this country at the time of Cæsar's invasion B.C. 55. They were made of wicker work, covered with skins, but had keels and gunwales of light timber. These boats were propelled by paddles, while, owing to their light construction, they could also be easily carried by one man; such boats are still used for fishing purposes in Ireland and Wales.

The modern example shown is constructed of laths of ash, placed close together and secured by similar strips that are bent to form ribs. A strengthening gunwale or rail runs round the edge, while the exterior of the boat is covered with canvas that is afterwards coated with pitch. A seat is arranged near the middle, and a leather shoulder-strap is added for carrying the boat. The coracle is propelled by a short paddle, and is of the following dimensions:—Length, 4·6 ft.; breadth, 3·7 ft.; depth, 1·2 ft.

405. Built model of Irish curragh. (Scale 1 : 8.) Lent by S. T. G. Evans, Esq., 1889. N. 2208.

This represents one of the small canvas canoes used for fishing and general purposes off the coast of Connemara and the Aran Islands. The structure is very light and simple, consisting of a wooden frame for the top sides, into which the upper ends of the bent-wood ribs are inserted. Upon these transverse ribs longitudinal battens are lashed, to serve as flooring, while the outer watertight covering is formed of well-stretched tarred canvas; the thwarts and seats, afterwards inserted, add somewhat to the strength. There is no keel, and this peculiarity, combined with the great rise given to the bow, requires the exercise of considerable skill to keep the craft in its course if there is a head wind. The canoe represented is propelled by two pairs of narrow-bladed oars, each oar working on a single thole pin, which passes through a wooden block secured to the oar. The approximate dimensions are:—Length, 14·5 ft.; breadth, 4 ft.; depth, 2 ft.

The curraghs generally used have three thwarts, and are propelled by three men and three pairs of oars; when the wind is favourable a tanned lug sail is hoisted and the steering is done by the after oars. By the addition of ballast these somewhat crank canoes are made capable of standing bad weather, while the construction is so inexpensive that a boat to carry one ton costs only about 5*l*.

406. Royal state barge. Lent by H.M. Queen Victoria, 1883. N. 1602.

This barge was built for Frederick, Prince of Wales (1729–51). It has taken part in several state processions and was last so used in 1849 to convey Prince Albert from Whitehall Stairs to the City on the occasion of the opening of the Coal Exchange.

In general design the forward portion shows the low freeboard and long fine entrance of a wherry: amidships the sections are very full and the maximum breadth is carried to the after end of the state room; abreast of this the topsides rise sharply to form an ornamental stern about 8·5 ft. above the keel-line. The covered state-room is about 7 ft. square and beyond it is an open steering platform.

The hull is clincher-built of oak with doubling-planks of fir worked externally below the turn of bilge for half the vessel's length amidships. There are 11 thwarts or rowing benches, and between each pair some fore-and-aft planking is fitted to form a continuous central gangway. A landing-stool is carried for use where no pier is available. Provision is made for using 21 oars, and the crew consisted of "Royal watermen" wearing scarlet uniforms with gold badges and black velvet caps. Elaborate decorative work in red and gold is shown on bow, stern, state-room, and topsides.

Length, overall, 63·5 ft.; breadth, 7 ft.; depth, amidships, 2·25 ft.

407. Whole model of Venetian gondola. (Scale 1 : 20.) Received 1900. N. 2210.

This is typical of the native passenger boats used on the canals of Venice.

It has flat floors amidships with sharp upturned extremities. The bow is fitted with an ornamental iron plate that is supposed to be a survival of a form of ram, but is now of use as a sighting point in determining the clearance beneath the numerous low canal bridges. Midway in the length is a closed saloon, the full width of the boat, but the earlier gondolas had only a light arched frame carrying a gaudily-coloured covering open at each end. In the 16th century an edict was issued rendering the use of black hangings and decorations compulsory.

In 1645 Evelyn wrote:—"Taking a gondola, which is their water-coach " (for land ones there are many old men in this city who never saw one, or " rarely a horse), we rode up and down the channells, which answer to our " streets. These vessels are built very long and narrow, having necks and " tails of steele, somewhat spreading at the beake like fishe's taile, and kept " so exceedingly polish'd as to give great lustre: some are adorned with " carving, others lined with velvet (commonly black) with curtains and " tassells, and the seates like couches, to lie stretch'd on, while he who " rows stands upright on the very edge of the boate, and with one oar " bending forward as if he would fall into the sea, rows and turns with " incredible dexterity. The beakes of these vessels are like the ancient " Roman rostrums."

This description applies to the gondolas at the present time, except that sometimes they are propelled by two men, one forward and one aft. Steam launches, often worked on our omnibus system, are, however, superseding these boats for general traffic in Venice.

The usual dimensions of these vessels are:—Length, 36 ft.; breadth, 5 ft.; draught, ·75 ft.

408. Built models of Maltese boats. (Scales 1 : 24 and 1 : 32.) Received 1902. N. 2293.

These two examples have the high projecting stem and stern posts, together with the bright colouring and ornamentation, so generally found on Mediterranean craft. A wash-strake is fitted above the gunwale and, internally along the sides, are special troughs or lockers for the stowage of nets, fish and merchandise, but serving also as seats.

The smaller model (green) represents a waterman's boat, used principally for the transport of passengers and native produce between ships and the shore, within the large harbours at Valetta. It is of light draught, with fine lines and considerable sheer, and is propelled by one or two men who stand at the forward end of the boat: a small sail is also sometimes used. To give protection from the weather, a canvas awning is spread over a light framework at the after end.

Length, 20 ft.; breadth, 5 ft.; draught, 1·5 ft.

The larger model (red) represents a boat with fuller lines and of greater breadth and draught, used for fishing or for general trading purposes between Malta and the neighbouring islands of Gozo and Comino. It is usually propelled by means of a large lateen sail, the mast and yard for which are shown in the model.

Length, 27 ft.; breadth, 8 ft.; draught, 2·5 ft.

409. Drawings of pleasure and racing craft. Lent by Messrs. Searle and Sons, 1873. N. 1336.

The following classes of boats are here represented; the length and breadth of each are given in feet:—

Single sculling outrigged gig, 24 by 2·66. Sailing gig, with centre-board, 20 by 4·5. Four-oared gig, 35 by 3·4. Four-oared gig, 35 by 4·5. Counter-stern canoe, 16. Single sculling gig, 18 by 3·5. Eight-oared outrigged racer, 57 by 2·16. Four-oared outrigged racer, 42 by 1·75. Pair-oared outrigger racer, 35 by 1·4. Single sculling skiff, 22 by 3·5. Randan skiff, 27 by 4·5. Sailing canoe, 15 by 3·16. Pair-oared skiff, 20 by 4·5. Double sculling gig, 28 by 2·5. Double sculling gig, 26 by 3·8. Double sculling gig (two examples), 24 by 3·66. Outrigged racer, with sliding seat, 32 by 1. Rob Roy canoe, 14 by 2·16. Four-oared outrigged gig, 38 by 2·4. Four-oared gig, 24 by 3·4. Lake boat, 20 by 4·75. Dinghey, 12 by 4·5.

410. Built model of Thames pleasure skiff. (Scale 7 : 48.) Lent by H. E. Finn, Esq., 1885. N. 1676.

This shows an accurately-fitted pair-oared pleasure skiff, for river use, to accommodate four people. These boats are usually clincher-built with ash timbers, cedar planking, and oak gunwales and thwarts; the boat represented is of the following dimensions:—

Length, 24 ft.; breadth, 3·75 ft.; depth, 1·16 ft.

411. Whole model of man-of-war's whaler gig. (Scale 1 : 12.) Lent by Capt. H.S.H. Count Gleichen, R.N. 1883. N. 1592.

This represents a boat formerly in general use in the Royal Navy as the captain's gig or galley. She was built by Mr. White at Cowes, I. of W., in 1857, for the captain of the "Racoon." She is fitted as a lifeboat, with air chambers at each end and along each side; she pulls six oars, and would have two dipping lug sails.

Length, 30 ft.; breadth, 5 ft.; depth, 2·25 ft.

412. Whole model of gun launch. (Scale 1 : 24.) Presented by J. Scott Tucker, Esq., 1865. N. 1057.

This is a design by Mr. J. Tucker for a boat of shallow draught and broad beam, probably intended to be carried on the paddle-boxes (*see* Nos. 72 and 75).

The chief peculiarity is a slide from bow to stern in which a gun can travel fore-and-aft. There are ammunition boxes and shot racks along the side and under the seats; she rows 14 oars.

413. Whole models of nested boats. (Scale 1 : 12.) Lent by G. Fawcus, Esq., 1865. N. 1083.

This construction of boat, patented by Mr. Fawcus in 1862, permits any number of identical boats to be fitted one inside another.

When stacked together the fender strakes of the upper boat rest on the gunwales of the one beneath it, and so on, each assisting in preserving the shape of its neighbour.

These boats are clincher-built, but have the three top strakes notched into the frames; the thwarts rest upon chocks between the frames and are secured by metal straps and pins. Further details of this system are shown on adjacent engravings of lifeboats and pontoons.

414. Built models of row boats. (Scales 1 : 24 and 1 : 12.) Received 1899. N. 2195.

These illustrate the general constructional features of small rowing boats for coast or sea-service. The smaller model represents a 20 ft. clincher-built gig of four oars, and the larger model a 15 ft. clincher-built dinghey of one or two pairs of oars.

415. Rigged model of Douro wine boat. (Scale 1 : 12.) Presented by Messrs. Martinez, Gassiot & Co., 1901. N. 2258.

This represents the class of boat used for the conveyance of wine in barrels, and other produce, on the river Douro. The hull is spoon-shaped and has a large amount of overhang at both bow and stern; there is considerable sheer and it is fitted with deep washboards amidships. A single mast is provided, which carries a large square sail, for use when the wind is perfectly fair; at all other times progress against the stream is made by towing, performed either by the crew or by two or three yoke of oxen. A large block is carried in the bow for use when warping up stream through the rapids, and poles are provided for propelling the boat in shallow water. Steering is accomplished by a long and peculiarly shaped sweep, working on a thole pin fitted in the stern post, and controlled by a man on a steering platform, quick manœuvring being essential on the rapid bends of the river; sleeping accommodation for the crew is provided in a covered space aft.

These boats vary considerably in size, the largest carrying about 80 pipes of wine and the smallest 10 pipes; their draught of water is from 5 ft. to 2 ft. The model represents a boat with a carrying capacity of 15 pipes, equivalent to a load of about 8 tons; its dimensions would be approximately:—

Length, 40 ft.; breadth, 11 ft.; depth, 3·75 ft.; mast, 30 ft.; yard, 23 ft.

416. Whole model of Portuguese fishing boat. (Scale 1 : 15.) Presented by Walter Child, Esq., 1908. N. 2451.

This native-made model represents a class of boat, known as "saveiro," used for sardine fishing at Leixoes (Oporto).

They are of simple box-shaped cross-section, built of pine and fitted with iron knees and rubbing pieces at the extremities and bilges. Considerable sheer is given to the topsides and a somewhat similar longitudinal curvature is repeated in the under-water portion, thus forming a peculiar "rockered" bottom which gives rapid manœuvring qualities to these craft. They are propelled and steered by two long sweeps, each pivoted, when in use, upon a fixed thole-pin amidships; a simple sail is sometimes hoisted. Like most native Portuguese boats, these are painted externally in bright colours. "Seine" or floating nets are used—as for pilchard fishing—and are worked by hand from the stern.

The boats vary in length from about 20 ft. to 33 ft., the example shown being 25 ft. long and 10 ft. broad.

417. Drawings of Portuguese fishing boat. (Scales,—profile 1 : 33, sheer plan 1 : 20.) Presented by G. C. Mackrow, Esq., 1889. N. 1823.

This type of vessel, known as a "muleta," and which for several centuries was the recognised fishing craft, has now disappeared; it was to have been seen off the mouth of the Tagus. It has a short mast, raking forward and carrying a large lateen yard and sail, also a bowsprit and two booms on which six sails are set; at the stern there is an outrigged boom, spreading two triangular sails. This peculiar arrangement of sails appears to have been adopted to enable the vessel to remain broadside to the wind, and thus slowly drift when the nets were down. The rudder reaches below the keel level.

Length, between perps., 40 ft.; breadth, extreme, 13·3 ft.; depth, 5·1 ft.; draught, 2·9 ft.

418. Rigged model of Portuguese fishing boat. (Scale 1 : 16.) Lent by H. C. Bucknall, Esq., 1905. N. 2391.

This vessel, known as a "muleta," was in use for centuries as a fishing craft off the coast of Portugal, but has finally disappeared within the last few years. It had a short mast, raking forward and carrying a large lateen yard and sail, also a bowsprit and two booms on which six sails were set; at the stern there was an outrigged boom, spreading two triangular sails. This peculiar arrangement of sails enabled the vessel to remain broadside to the wind, and thus slowly drift when dragging the nets. The rudder is shown considerably below the keel level.

Length, b.p., 45·6 ft.; breadth, extreme, 13·3 ft.; depth, 5·2 ft.

419. Rigged model of Heligoland fishing sloop. (Scale 1 : 8.) Presented by G. C. Bompas, Esq., 1883. N. 1628.

This is an open clincher-built boat of oak, with covered spaces at stern and between the thwarts; it is flat-bottomed to enable it to be readily beached, and is consequently sailed with lee-boards. There is a single mast, with a sprit mainsail, fore-sail, and jib; as it carries no bowsprit, a spar is temporarily used for setting the jib, while when running free this spar is rigged out on the beam, with the jib set as a spinnaker. If caught by bad weather the anchor is dropped and the mast lowered, in which condition the boat will ride out the heaviest gale with one man constantly bailing. Eight days' provisions are carried, two anchors, a hemp cable, and about 900 lb. of stone ballast.

Length, 31 ft.; breadth, 9 ft.; depth, 5 ft.; draught, 2·3 ft.

420. Rigged model of Faroese eight-man boat. (Scale 1 : 12.) Presented by J. R. Tudor, Esq., 1883. N. 1606.

This represents a boat fully equipped for the chase of the grindefish and the bottle-nosed whale of the Orkneys.

The eight oars are each 11·75 ft. long, and are pulled double-banked. There is a foremast, stepped either at the first or at the second thwart; in the former position, which is that most generally occupied, the boat is considered to sail very close to the wind. The mast is 16 ft. high, and carries a dipping lug on a yard 10 ft. long; the mizen mast is 13·5 ft. high, and has a sprit sail.

The whaling instruments consist of:—two lances, each 12 in. long and 4 in. broad, fixed on a wooden shaft 6 ft. long, to which a thin line is attached; two hooks with lines, for towing the whale when dead; also a fishing lead or stone, about 3 lb. weight, slung on to a long line, and used for anchoring or for diminishing the boat's way.

Length over all, 28·5 ft.; length on keel, 16·5 ft.; breadth, 6·5 ft.; depth at stem-head, 6 ft.; depth at lowest part of gunwale, 3 ft.; depth at stern-post, 5·5 ft.

421. Rigged model of North Isles yawl. (Scale 1 : 12.) Presented by J. Barnett, Esq., 1883. N. 1608.

These fishing boats are constructed of oak and white pine, with galvanised iron fastenings. They have a pair of oars 14 ft. long, and another pair 12 ft.; there are two masts and a bowsprit. The foremast is stepped 2·3 ft. from the stem, and the mainmast 9 ft. from the stern-post; the bowsprit is 5 ft. outboard and its heel butts against the foremast. The sails are: a jib, 13 ft. in the hoist, with its foot 6·5 ft. long; a lug foresail, 12 ft. in the hoist, with its foot 10 ft. and its yard 12 ft, long; also a boom mainsail with a hoist of 12 ft., a foot 10 ft., a yard 8·5 ft., and a boom 11 ft. in length. These boats are now nearly superseded by the "Firthy" boats, of the east coast of Scotland.

Length over all, 19·25 ft.; length on keel, 14 ft.; breadth, 7·5 ft.; depth at stem-head, 4·6 ft.; depth at lowest part of gunwale, 3·5 ft.; depth at stern-post, 4·4 ft.

422. Rigged model of Shetland fishing boat. (Scale 1 : 12.) Presented by J. R. Tudor, Esq., 1883. N. 1605.

These boats, or six-oared yawls, are clincher-built of pine and fastened with iron; the oars, 16 ft. long, are pulled with one thole-pin and a grummet. There is a mast 22 ft. high, carrying a yard 18 ft. long, which spreads a lug sail 18·5 ft. in the hoist, with reef points at the head and foot of the sail.

Till about 1860 all the larger Shetland boats were imported direct from Norway in boards ready for putting together; these boats rarely exceeded 18 ft. on the keel, and had a very flat midship section.

Length over all, 29 ft.; length on keel, 20 ft.; breadth, 8 ft.; depth at stem-head, 5 ft.; depth amidships, 3·25 ft.; depth at stern-post, 4·75 ft.

423. Rigged model of Shetland skiff. (Scale 1 : 12.) Presented by W. Lawrence, Esq., 1883. N. 1607.

These fishing boats are built of fir, with iron fastenings; they carry three pairs of oars, each 10·16 ft. long, and have a mast 14·5 ft. high, stepped nearly amidships; this carries a yard 11 ft. long, spreading a square sail with a 14 ft. hoist. Three men constitute the crew, and when rowing pull a short chopping stroke, sometimes at the rate of 45 to the minute.

Length over all, 22 ft.; length on keel, 15·5 ft.; breadth, 5·6 ft.; depth at stem-head, 3·5 ft.; depth at stern-post, 3·25 ft.

424. Built model of fish-carrying boat. (Scale 1 : 4.) Presented by G. C. Bompas, Esq., 1883. N. 1614.

This form of boat is used by the North Sea trawlers for conveying their "takes" of fish to the steamers sent to carry them to the markets. It is fitted with galvanised iron air tanks under the bow and stern sheets, of sufficient capacity to ensure buoyancy even if swamped; two small tanks of oil are placed aft, for use in rough weather to calm the sea astern and prevent it breaking into the boat, and a line is secured along the keel, to which the crew can cling should the boat capsize. These boats carry about two tons, and require two men to manage them.

Length, 17 ft.; breadth, 6·5 ft.; depth, 2·75 ft.

425. Built model of fish-carrying boat. (Scale 1 : 6.) Lent by J. E. Teasdel, Esq., 1896. N. 2080.

This boat is another form of the preceding. It is clincher-built, and, to prevent being swamped in heavy weather, is fitted with 84 cub. ft. of air casing, arranged at the bow, stern, and under the midship thwart; about 18 cub. ft. of cork is also placed between the knees of the thwarts and the rising and gunwale strake. Should extra space be required the midship tank is dispensed with.

Length, 18 ft.; breadth, 6·5 ft.; depth, 2·5 ft.

426. Rigged model of Cornish fishing boat. (Scale 1 : 12.) Presented by G. C. Bompas, Esq., 1883. N. 1620.

This model represents the form of boat in general use at Mevagissey for drift fishing. It is lugger-rigged and carries a jib, a fore dipping lug-sail and a mizen standing lug-sail.

When engaged in mackerel fishing or in the winter pilchard and herring fishing, the crew consists of five hands, but for summer pilchard fishing only three hands are necessary.

Register, 11 tons; length, 38 ft.; breadth, 11·12 ft.; depth of hold, 6·16 ft.

427. Whole model of Cornish pilchard-fishing boats. (Scale 1 : 12.) Presented by G. C. Bompas, Esq., 1883. N. 1616.

Two boats are shown, the larger or "seine" boat being used to carry and work the large net by which the fish are first enclosed, the smaller boat, called the "follyer," carrying a lesser net, by which the fish enclosed by the "seine" are finally captured.

The boats are carvel-built, usually of English oak, fastened with galvanised iron nails. There is an iron stem and keel band, to prevent damage on the rocky shore, and a chain bridle for hauling the larger boats up the beach. The boats are sharp at the bow, but have wide sterns to accommodate the nets, which are of remarkable size, the "seine" net being often 1,080 ft. long, 72 ft. deep, and weighing 3 tons. The "seine" boat pulls six oars, which work in circular holes through the top strake, no thole-pins or rowlocks being used.

	"Seine."	"Follyer."
Length -	38 ft. -	20·6 ft.
Breadth -	9 ,, -	6 ,,
Depth -	4 ,, -	3 ,,

428. Whole model of East Coast coble. (Scale 1 : 12.) Lent by James Young, Esq., 1876. N. 1423.

These boats are used in the North Sea cod, ling, and haddock fisheries, each five-man fishing boat carrying two of them. They are clincher-built, of oak or larch, and are very sharp at the bow. The keel extends about two-thirds of the boat's length from the bow, while the after part is flat, with two side keels to facilitate beaching; the stern is square, and is provided with a rudder that projects 4 ft. below it. When under sail they have one mast and a bowsprit, carrying a lugsail and jib. The line fishing in which they are engaged is performed by three or four men, using six lines representing a total length of about two miles.

Carrying capacity, 1 ton; length, 28 ft.; breadth, 5·5 ft.; depth, 2·3 ft.

A half block model of a similar boat, lent by T. Turnbull, Esq., 1869, is also shown (N. 1301).

429. Half block model of Yorkshire "mule." (Scale 1 : 12.) Lent by T. Turnbull, Esq., 1869. N. 1302.

These boats are used in the herring fishery off the Yorkshire coast; their name is due to their being coble-form forward and yawl-shaped aft. They carry about 30 nets, each 60 yds. in length and 3 ft. deep.

Carrying capacity, about 6 tons; length, 33·75 ft.; breadth, 10 ft.; depth, 4·75 ft.

430. Rigged model of Norwegian herring boat. (Scale 1 : 48.) Presented by G. C. Bompas, Esq., 1883. N. 1627.

This is a clincher-built boat of fir, with high stem and stern posts. There are washboards amidships, and the central thwarts are boarded up underneath, so as to form compartments for receiving the fish. At the after end is a covered space, over which a long tiller, with locking-pins, is worked. She is fitted with a single mast, carrying a square sail, the yard of which is secured by a parrel; she pulls six oars. The drift nets used are shown, together with their sinkers, floats, and lines attached.

Length, 33·6 ft.; breadth, 8·8 ft.; depth, 2·8 ft.; mast, 23·3 ft. long; yard, 11 ft. long.

431. Rigged model of Norwegian fish-boat. (Scale 1 : 8.) Presented by G. C. Bompas, Esq., 1883. N. 1626.

These boats, known as "jaegts," are used for the transport of fish in the Trondhjem district. They are clincher-built of fir, have one mast with a square sail and topsail, pull ten short spade-shaped oars, and have the rudder fitted with a short horizontal arm, to which a long tiller working on a pivot is attached.

Length, 36 ft.; breadth, 8 ft.; depth amidships, 2 ft.

432. Rigged model of Swedish net-fishing boat. (Scale 1 : 5.) Presented by the Swedish Commissioners to the Fisheries Exhibition, 1883. N. 1603.

This is a clincher-built boat with sharp floors, and considerable rake of stern-post; she is provided with oars, and carries a sprit sail.

Length, 26 ft.; breadth, 9 ft.

433. Whole models of Swedish fishing boats. (Scale 1 : 12.) Lent by Dr. Oscar Dickson, 1883. N. 1596.

These three clincher-built boats are used for net-fishing. They have sharp floors with great proportional beam to length; six to eight oars are used, and also a mast and sprit-sail. Their lengths vary from 21 ft. to 30 ft.

434. Rigged models of Russian fishing boats. (Scale 1 : 8.) Presented by the Director of the Imperial Agricultural Museum, St. Petersburg, 1883. N. 1598.

These represent two classes of boats, used for cod-fishing and walrus-hunting off the coasts of Russian Lapland. They are clincher-built of fir and each carries a mast and square sail; their oars have heavy looms and long blades.

The twelve-oared boat has fine lines and considerable sheer, and the rudder is worked by a tiller and yoke-lines. The dimensions are:—Length, 29 ft.; breadth, 5·5 ft.

The six-oared boat has fuller lines and greater capacity; it is subdivided by partitions under the thwarts, and is fitted with a large pump for discharging water; the rudder is worked by a horizontal arm lashed to a side tiller. The dimensions are:—Length, 25 ft.; breadth, 7 ft.

435. Rigged model of boat for seal-hunting. (Scale 1 : 5.) Presented by G. C. Bompas, Esq., 1883. N. 1625.

This form is used on the Baltic coast. It is a light clincher-built boat and has its keel shod with iron so that it may be readily drawn over the ice. It is provided with a mast and square sail, but when proceeding under sail on the ice, two men with their hands on the lee gunwale run alongside to prevent capsizing, whilst the skipper steers and steadies the craft by a projecting cross pole.

Each boat carries one or more double-ended punts, which are so light that they can be carried by one or two men; they are used amongst broken ice. To lighten the boat, when ice sailing, a sledge is also carried, upon which can be stowed the whole of the provisions for the crew of eight men for several weeks; the sledge is hauled by some of the hands.

The model is fitted with washboards, cooking apparatus, sealing implements, etc.

Length, 33 ft.; breadth, 14 ft.

436. Whole model of Tasmanian seine boat. (Scale 1 : 12.) Presented by the Tasmanian Commissioners to the Fisheries Exhibition, 1883. N. 1612.

This represents a fishing boat used in Tasmania. It is double-ended, has fine lines, and pulls five oars; the seine net is carried on a platform across the stern, and a fair-lead is provided at the bow to facilitate the handling of the lines.

Length, extreme, 26 ft.; breadth, 5 ft.; depth, 2 ft.

437. Rigged model of Australian fishing boat. (Scale 1 : 3.) Presented by the New South Wales Commissioners to the Fisheries Exhibition, 1883. N. 1609.

This represents an open boat, clincher-built of cedar; it is fitted with a centre-board, and one mast carrying a sprit mainsail and foresail; there are also two oars and two sculls. These boats are much used in Sydney harbour.

Length, 15·75 ft.; breadth, 5·9 ft.; depth, 2·5 ft.

438. Whole model of a whaling boat. (Scale 1 : 16.) Received 1898. N. 2169.

Although not absolutely to scale, this built model shows in considerable detail the construction and equipment of the earlier boats used in the whale fisheries. As the boat must be rapidly moved astern after the whale has been struck, it is built double-ended, and is steered by a sweep. The clincher construction represented has, however, now been abandoned, as it was found that the smooth surface of the carvel build makes less noise and so reduces the chance of alarming the whale when approaching; for the same reason the boat is equipped with paddles as well as oars.

The boat has five thwarts, and in that at the bow are two recesses by which the harpooner steadies himself as he stands upon a raised floor while throwing the harpoon. Having planted the weapon, the harpooner takes charge of the line; this is composed of soft Manila hemp, well greased, and is carried in two tubs containing altogether about 1,800 ft. From a tub the line passes round a bollard or "logger-head" at the stern, then forward to a fairlead at the bow, and thence to the harpoon. There are notches in the gunwale near the bow to catch the line should it leave the fairlead, also for use in straightening a bent harpoon.

After the whale has been exhausted by the exertion of continuously towing the boat, it is killed by means of a long lance. The boat is equipped with two harpoons, two lances, and a small drogue or sea anchor; also some flags for marking whales or for signalling purposes, and two watertight receptacles for stores and provisions. A mast and sail are carried, and frequently a rudder, while in the inner skin, between the thwarts, holes are provided in which the handles of the oars can be inserted while resting or being towed by a whale.

Total displacement, 1 ton; length, 28 ft.; breadth, 6·8 ft.; depth, 2·8 ft.; weight of boat, 1,200 lb.; weight of equipment, 300 lb.

439. Whole model of a whaling boat. (Scale 1 : 12.) Lent by Messrs. Forrestt and Son, 1873. N. 1355.

This represents a later type of boat than the preceding, and, to reduce the noise made by the water against its sides, is carvel-built. It has greater sheer and finer lines than the earlier type, but would be similarly equipped.

In still later boats the introduction of a harpoon gun has led to the provision of a second bollard, upon which the gun is mounted in a swivel.

Length, 30·5 ft.; breadth, 5 ft.; depth, 2 ft.

440. Built model of American whaling boat. (Scale 1 : 12.) Lent by the Royal United Service Institution, 1903. N. 2321.

This model accurately represents the type of boat used by American whalers in the North Pacific Ocean about 1860.

The upper portion of the boat is constructed on the clincher or lapped-strake system, while the under-water portion is on the carvel or flush-strake principle, with an inside covering-strip to each seam. Additional strength is given by a stout "ceiling," or strakes of planking on the inside of the frames below the thwarts. Oak is chiefly used for the framing, cedar for the planking, and galvanised iron for the fastenings.

There is a single mast with a dipping lug-sail. Oars are provided for a crew of five men, and there is a large steering-sweep for which a projecting rowlock is fitted at the stern-post. Harpoons and a hand-lance are shown as the equipment, but bomb-lances, propelled by shoulder guns, are now very generally used; "toggle-irons" or harpoons with hinged barbs are also substituted for the simple harpoons, as they take a firmer hold of the whale.

The usual dimensions of these boats are :—Length, 27 ft.; breadth, 6 ft.; depth, amidships, 2·5 ft.

441. Whole model of surf canoe. (Scale 1 : 16.) Lent by Messrs. Forrestt and Son, 1873. N. 1351.

This boat was constructed for landing through the surf on the West Coast of Africa. She is carvel-built of whaler type with considerable sheer; air cases are formed around the sides under the thwarts, and movable air cases are provided in the bow and stern. She pulls six oars, and her dimensions are :—Length, 31 ft.; breadth, 6 ft.; depth, 2·3 ft.

442. Whole model of ambulance surf boat. (Scale 1 : 12.) Lent by Messrs. Forrestt and Son, 1873. N. 1353.

This represents one of the smaller boats built for the War Department by Messrs. Forrestt and Son for conveying the sick and wounded from the shore to the hospital ship off Cape Coast Castle, during the Ashanti campaign of 1873–4.

These boats were built sharp at both ends, with great sheer; the keel, stem, and stern-post were formed of one length, bent by steam, so as to avoid the weakness due to joints; for the same reason other parts, such as gunwales, stringers, frames, and sheer mouldings were in single pieces. The boats were copper fastened, and constructed with an inner lining forming a second skin. There were platforms forward and amidships, with fittings for ambulance stretchers, and a waterproof awning to protect the patients from the sun and spray.

The boat represented carried twenty-four passengers, and was propelled by twelve natives sitting close to the gunwales and working paddles, the coxswain steering with a sweep.

Length, 25 ft.; breadth, 5 ft.; depth, 2·25 ft.

443. Whole models of Berthon's collapsible boats. (Scale 1 : 12 and 1 : 16.) Lent by the Rev. E. L. Berthon, M.A., 1867. N. 1163.

This construction of boat was patented in 1851 by the contributor, who in 1879 and 1886 also introduced further modifications in the arrangements. Owing to the small space they occupy when not in use and their extreme portability, they have been very extensively adopted. The frames of these boats are constructed of wood or iron, and are arranged longitudinally in segments which are strongly hinged together at the ends; these frames support a flexible double covering, arranged as an outer and an inner skin, formed of tarred canvas. The space between the double skins is divided by the frames into from six to ten watertight compartments; the bottom-boards, thwarts, and seats are similar to those in an ordinary boat, and when in position give considerable rigidity to the whole construction. Oars or sails may be used, and the boats may be fitted with rudders. The two models, one of which is shown closed for stowing, represent twelve-oared boats, each capable of carrying 200 troops and having the following dimensions:—Weight, about 70 cwt.; length, 50 ft.; breadth, 14 ft.; depth, 6·25 ft.

444. Whole model of steam pinnace. (Scale 1 : 16.) Presented by Messrs. R. Napier and Sons, 1867. N. 1184.

This boat was designed for the ships of war proposed by the late Vice-Admiral E. P. Halsted. It was to be constructed of steel, to pull twenty oars, and to have two masts, carrying foresail, mainsail and jib; first-rates (*see* No. 98) were to have two of these pinnaces.

The engines were to indicate 40 h.p., and give a speed of 8 knots. One ton of fuel was to be carried, and the armament was to consist of two 10-pr. Whitworth guns, protected by a shield and mounted on a turntable.

Load displacement, 17 tons; length, 45 ft.; breadth, 10 ft.; depth, 4·5 ft.; draught, 2·8 ft.

445. Whole model of steam cutter. (Scale 1 : 16.) Presented by Messrs. R. Napier and Sons, 1867. N. 1184.

This boat was designed for the type of warship proposed by the late Vice-Admiral E. P. Halsted. It was to be constructed of steel, to pull ten oars, and under sail was to have two masts, carrying a foresail, main-sail, and jib; his first-rates were to have four of these cutters.

The engines were to indicate 25 h.p., drive a single screw, and give a speed of 7·5 knots. Steam was to be supplied by a return tube cylindrical boiler, to the end of which the vertical engine was secured. The whole of this machinery could be lifted out and be replaced by seats and thwarts for rowers. These cutters were to carry ·75 ton of fuel, and to be armed with two 2-pr. Whitworth guns, protected with an iron shield and mounted on a turntable.

Load displacement, 8 tons; length, 35 ft.; breadth, 8 ft.; depth, 23·5 ft.; draught, 2 ft.

446. Whole model of steam cutter. (Scale 1 : 16.) Presented by Messrs. R. Napier and Sons, 1867. N. 1184.

This boat resembles No. 445, but was intended for Admiral Halsted's sixth-rate vessels, each of which was to carry four of them.

The engines and armament were to be identical with those of No. 445.

Load displacement, 7 tons; length, 30 ft.; breadth, 7·5 ft.; depth, 3·25 ft.; draught, 2 ft.

447. Half block model of S.S. "Mab." (Scale 1 : 12.) Lent by Geo. Baird, Esq., 1876. N. 1462.

This screw steamer was built of brass at St. Petersburg in 1874 by Mr. Baird, and at the time was the fastest boat on the Neva. The screw is far aft, and extends considerably below the keel level.

She was propelled by a two-stage expansion engine with cylinders 7 in. and 11 in. diam., by 8 in. stroke, which with a steam pressure of 120 lb. drove the single screw at 600 revs. per min., and gave a speed of 16·5 knots.

Length, 48 ft.; breadth, 6·5 ft.; depth at side, 3·5 ft.; draught, 1·6 ft.; draught over screw, 2·75 ft.

DECKED CRAFT.

448. Rigged model of 18th century Dutch schuyt, "Four Brothers." (Scale 1: 24.) Received 1871. N. 1329.

Although not modelled absolutely to scale, this represents a vessel built about 1778 for the Dutch eel fisheries; it is also typical of craft used for a similar purpose at the present day.

These vessels are strongly built, usually of oak, with flat floors and full bow and stern; they are fitted with a central well in communication with the sea for transporting live cargo. This vessel is shown sloop-rigged with single mast and bowsprit; it carries a sprit mainsail and topsail, also a square topsail, fore staysail and jib. Lee-boards are provided and the vessel is steered by a large rudder. The topsides and deck-fittings are ornamented with wood carving. A master and two men constitute the crew.

Burden, about 50 tons; length, 70 ft.; breadth, 18 ft.; depth, 7 ft.

The Dutch have the right of mooring three of these vessels off Billingsgate Market, a privilege granted in the reign of Charles I. in recognition "of their straightforward dealings with us."

449. Rigged model of Dutch galliot (1800–50). (Scale 1: 48.) Received 1910. N. 2549.

This represents an early 19th century galliot of the Dutch or Flemish type, used both for trading and fishing purposes.

It is two-masted, and rigged somewhat similarly to an old-fashioned ketch or modern topsail schooner; on the single-pole foremast is carried a trysail, a square topsail, top-gallant sail, and usually a flying square sail on the lower yard; there is a fore stay-sail and jib, and also a mizen trysail.

Length, 65 ft.; breadth, 18 ft.

450. Rigged model of Dutch "botter." (Scale 1 : 24.) Received 1910. N. 2551.

This represents a vessel of the schuyt type used for dip-net fishing in the Zuyder Zee and adjacent inshore waters.

It is strongly built, of carvel construction, with half-deck forward. A stout all-round rubbing-strake is fitted, and above this the topsides are given considerable tumble-home. Stem and stern posts are raked, and the broad, full bow is of the "swim" or overhang form. There is a single-pole mast with gaff mainsail and stay foresail.

A davit is fitted to the stern for working the nets, and a tank is provided for carrying live fish.

Length, over all, 40 ft.; breadth, 14 ft.

451. Rigged model of Dutch "pinken." (Scale 1 : 24.) Received 1910. N. 2550.

This model of a pink or pinken was originally the property of Edwin Hayes, R.H.A., R.I., and represents a class of boat belonging to the port of Scheveningen, and used for drift-net fishing in the North Sea.

It is of the decked barge type, clincher built, with large relative beam, and a peculiar bulging of the water-line sections on each side of the stem and stern posts; capacious holds are provided for carrying fish and tackle.

The single-pole mast carries a boom mainsail, and also a flying square-sail for running; a stay foresail and flying jib are also used. A number of large wooden crutches provide for the stowage of spars, etc., above the deck level.

Portable wooden fenders and fixed guards amidships protect the hull against damage in narrow, crowded waterways or at the wharfside.

Dimensions :—Length, over all, 40 ft.; breadth, 20 ft.

452. Rigged model of Thames sailing barge (1800–50). (Scale 1 : 32.) Received 1910. N. 2547.

This shows an early form of topsail barge as used on the lower reaches of the Thames for general cargo work.

It differs from No. 455 in having a flat, overhanging bow instead of an upright stem; a raised after deck; a single central hatch; and a small mizen-mast, with sprit-sail, carried upon the rudder head instead of a fixed mizen carried farther forward. The usual lowering mainmast, large sprit mainsail and topsail, stay foresail and jib, are shown.

Length, 48 ft.; breadth, 13 ft.

453. Built model of Thames lighter (1850). (Scale 1 : 24.) Presented by Messrs. Searle and Sons, 1877. N. 1470.

This shows the details of construction and the fittings of the lighters used for the conveyance of grain, coal, and other merchandise, on the rivers in the London district. A portion of the internal planking has been omitted so as to show the frames.

The vessels are flat-bottomed and have a carrying capacity of from 60 to 80 tons; they are usually towed, but are provided with two long oars, by which they can be propelled and steered.

454. Built model of sailing barge. (Scale 1 : 24.) Received 1893. N. 2022.

The model represents what is known as a Harwich barge, a type that is in general use sailing coastwise between London and Harwich or Sittingbourne. A portion of the external planking has been removed from the port side to show the framing.

The floors are flat amidships, with fine entrance and run. There is a large hold with two hatchways, and a small forecastle for the two hands, while aft is a separate cabin for the captain. At the bow is a winch which is used both for weighing anchor and also for hauling the rigging, and a large rudder is provided which is steered by a wheel and bevel gear; lee-boards are carried, but these are only used when the barge is sailing light.

The usual rig is a sprit mainsail and foresail, and a small mizen or jigger; but some carry in addition a gaff topsail and jib. The masts are made to lower; in the case of the mainmast the heel is supported by a shore from the keelson, and the lowering is done by the fore winch.

The usual dimensions of these barges are:—Displacement, 150 tons; length, 84 ft.; breadth, 18 ft.; depth, 6 ft.

455. Rigged model of sailing barge "Thelma." (Scale 1 : 48.) Lent by Messrs. Gill and Sons, 1905. N. 2389.

This successful topsail barge was designed, built, and fitted out by Messrs. Gill and Sons, Rochester, in 1901. She is flat-bottomed with full water-lines throughout and in general features represents a modern cargo-carrying barge as used on the Lower Thames.

In her first year she won both the Thames and the Medway Championship races. The Championship course is usually from Chatham or Gravesend to the Mouse lightship and back. All competitors in these races are required to be genuine freight barges engaged in trade, using no ballast or false keels, and carrying the ordinary working sails and lee-boards.

Her register tonnage is 49·76 tons, and her approximate dimensions, taken from the model, are:—Length, 84 ft.; breadth, 20 ft.; depth, 6 ft.

This type of boat forms an interesting link between the pleasure yacht and the trading vessel, and, as speed and comfort are readily obtainable in its design, it has served to some extent as a model for pleasure craft of the "barge-yacht" and "Norfolk wherry" classes, used for cruising in tidal rivers or shallow waters.

456. Rigged model of oyster-dredging boat "Secret." (Scale 1 : 8.) Lent by F. Wiseman, Esq., 1883. N. 1600.

This represents a boat built at Wivenhoe, Essex, in 1856, for the fisheries at the mouth of the Thames. She is fitted with a deep lead keel and is cutter-rigged, with boom mainsail, gaff-topsail, foresail, and jib; the crew consists of three hands.

Register, 11 tons; length over all, 33 ft.; breadth, 10 ft.; depth, 4·5 ft.; draught forward, 3·5 ft.; draught aft, 5·75 ft.

457. Rigged model of a Yarmouth fishing vessel, "Celt." (Scale 1 : 24.) Presented by G. C. Bompas, Esq., 1883. N. 1613.

This represents a ketch-rigged fishing boat, built, in 1883, for drift fishing in the North Sea. The sails set are a foresail, jib, mainsail, and mizen; the mainmast is fitted in a tabernacle, so that when required it can be lowered till the head rests in the crutch shown on deck. The lumber irons on each side are for oars, spare spars, &c.; a steam capstan is fitted to assist in hauling in the nets, and on the deck are the sorting trays. The number of the crew is six when trawling, and nine when herring fishing.

Register, 36 tons; length, 59·5 ft.; breadth, 16·8 ft.; depth, 7·7 ft.

458. Half block model of trawler. (Scale 1 : 24.) Received 1882. N. 1579.

This represents a trawling ketch, built at Rye for the South Coast fisheries. In the rail, at about mid-length, is a hole and roller to accommodate the trawl warp.

Register, 45 tons; length, 68 ft.; breadth, 16 ft.; depth, 9 ft.

459. Whole model of a Yarmouth trawler. (Scale 1 : 48.) Lent by John Bracey, Esq., 1876. N. 1461.

This is a cutter-rigged vessel, carvel-built of oak, and carries a crew of six men. The usual fishing grounds are the Clay Deeps, Doggerbank, and the neighbourhood of Heligoland.

Register, 60 tons; length, 65 ft.; breadth, 18·5 ft.; depth, 9·5 ft.

460. Rigged model of Cornish fishing boat "Emulator." (Scale 1 : 12.) Presented by G. C. Bompas, Esq., 1883. N. 1619.

This represents a Penzance drift-net boat which is used, according to season, in the herring, mackerel, or pilchard fishery. She is carvel-built and is lugger-rigged; the foremast carries a dipping lug, and the mizen a standing lug with topsail. She carries sweeps in the lumber irons, and would have a crew of six men and a boy.

Some years ago one of these boats made the passage to Australia.

Register, 20 tons; length over all, 47 ft.; breadth, 13·5 ft.; depth, 7 ft.

461. Rigged model of Guernsey fishing boat. (Scale 1 : 12.) Presented by G. C. Bompas, Esq., 1883. N. 1617.

This represents a boat used in the mackerel fishery; it has three masts, carrying mizen, mainsail, foresail, jib, and gaff topsail. This rig permits of sail being easily and quickly shortened, while in light weather the spread of canvas is considerable; they are able to keep at sea in all weathers, and are fast sailers. The crew consists of six hands.

Register, 12 tons; length, 36 ft.; breadth, 12 ft.; depth, 8 ft.

462. Half block model of Whitby fishing boat. (Scale 1 : 24.)
Lent by T. Turnbull, Esq., 1869. N. 1300.

These vessels are used for herring and also line fishing; they each carry nine men, three for each of their two cobles, and three for the remaining crew. At one time they had three masts; the rig was afterwards altered to two lugs, and now they are dandy-rigged.

Register, 45 tons; length, 57 ft.; breadth, 17 ft.; depth, 8·3 ft.

463. Rigged model of Lancashire shrimping boat. (Scale 1: 12.) Presented by G. C. Bompas, Esq., 1883.
N. 1618.

This represents a Southport boat with its four shrimping nets. Whilst over the fishing ground the boat is allowed to drift with the wind or tide, so dragging her nets along the bottom. She is rigged as a cutter, with mainsail, foresail, jib, and gaff topsail.

Register, 10 tons; length, 28 ft.; breadth, 10 ft.; depth, 4·5 ft.

464. Rigged model of North Sea trawler "Gratitude." (Scale 1 : 12.) Lent by Edward Jex, Esq., 1882.
N. 1572.

This represents a Lowestoft trawler, manned by a crew of five. She is ketch-rigged, with mizen, mizen gaff topsail, boom mainsail, gaff topsail, foresail, and jib. The deck fittings are all shown, as well as her small boat, trawl-net and beam, etc.

Register, 89 tons; length, 72 ft.; breadth, 19·5 ft.; depth, 12 ft.

465. Rigged model of Manx fishing boat. (Scale 1: 24.)
Presented by G. C. Bompas, Esq., 1883. N. 1615.

This is a built and completely fitted model of a Castletown lugger. She has two masts, the foremast carrying a dipping lug and the mizen a standing lug; there is also a mizen gaff topsail and staysail. The crew consist of five men, and her dimensions would be:—Register, 34 tons; length, 56 ft; breadth, 14·75 ft.; depth, 8·25 feet.

466. Rigged model of Manx fishing boat. (Scale 1: 16.)
Presented by G. C. Bompas, Esq., 1883. N. 1622.

This represents a Peel boat, used in the herring and mackerel fisheries. She is dandy-rigged, with mizen, boom mainsail, gaff topsail, foresail, and jib.

Register, 50 tons; length, 50 ft.; breadth, 16 ft.; depth, 10·75 ft.

467. Rigged model of Manx fishing boat. (Scale 1: 16.)
Presented by G. C. Bompas, Esq., 1883. N. 1621.

This shows the type of boat used in the herring fishery. She is lugger-rigged, the foremast carrying a dipping lug and the mizen a standing lug; there is also a mizen gaff topsail and staysail. She is provided with sweeps, which are shown in their lumber irons.

Register, 24 tons; length, 50 ft.; breadth, 12·25 ft.; depth, 6·5 ft.

468. Rigged model of well vessel "City of London." (Scale 1: 16.) Received 1883. N. 1595.

This ketch-rigged vessel was built at Rye in 1883 by Mr. J. C. Hoad, for the North Sea and Iceland cod fisheries. The model shows on the starboard side the construction and interior of the wells, and on the other the plank fastenings and numerous circular holes for the free circulation of water through the wells, in which the fish are kept alive for the market.

A complete suit of sails for this model is also shown.

Register, 88 tons; length, 77·3 ft.; breadth, 20·3 ft.; depth, 12·2 ft.

469. Rigged model of Scotch fishing boat "Duchess of Edinburgh." (Scale 1 : 12.) Presented by G. C. Bompas, Esq., 1883. N. 1623.

The boats formerly used in herring fishing off the E. coast of Scotland were from 60 ft. to 80 ft. long, 18 ft. to 20 ft. beam, with a register tonnage of from 25 to 40 tons. They were rigged with a dipping lug and jib on the foremast and a mizen or jigger on the mizen mast. The foresail was large, containing from 300 to 350 sq. yds. of canvas, and in bad weather when wet became almost unmanageable; the boats had neither bulwarks nor rails higher than 9 in., and many of the fishermen were lost overboard.

The model shows an improved construction of boat which has been extensively adopted. It has protective rails to enable the crew to work in greater safety, and also a well for the helmsman. Instead of the lug, it has the smack rig, which two hands can work in any weather. The mast turns on a pivot about 3 ft. above deck, with stays on each side, which always remain taut, even when the mast is lowered, as is necessary while the boat is riding on the nets when fishing; the mast is lowered by two men working on a deck winch.

The crew consists of six or seven men, but these also attend to the nets and fish.

Register, 25 tons; length, 52 ft.; breadth, 18 ft.; depth, 8 ft.

470. Rigged model of Scotch fishing boat. (Scale 1 : 12.) Received 1910. N. 2552.

This represents a small example of the "fife" or "fifie" type of fishing craft belonging to the port of Leith; it is generally used for haddock or small line fishing in the Firth of Forth, and sometimes for winter herring fishing.

It is double-ended, with fine entrance and run, and nearly vertical stem and stern posts. Before 1850 most of these vessels were open and of light clincher construction, but with the development of fishing grounds farther from the coast came the need of better seagoing qualities. The model shows a partially-decked carvel-built boat with large central opening, and covered lockers placed aft below the deck level. The single mast, carried well forward, is fitted with a large dipping lug-sail; a mizen-mast is used with larger boats.

Length, over all, 25 ft.; breadth, 8·25 ft.

471. Rigged model of Swedish mackerel boat. (Scale 1 : 12.) Lent by Dr. Oscar Dickson, 1883. N. 1597.

This is a clincher-built boat, with hollow floors and a deep keel which render it a very safe craft. It carries a sprit sail on the main and mizen, with sliding-gunter gaff-topsails, foresail, and jib.

Length, 36 ft.; breadth, 17 ft.; depth, 7·5 ft.

472. Rigged model of Nordlands jaegt. (Scale 1 : 12.) Presented by G. C. Bompas, Esq., 1883. N. 1624.

This represents a Norwegian cargo vessel largely used for the conveyance of cured fish from the fisheries to Bergen. It is clincher-built of pine, and has one mast, which carries a square sail fitted with four bonnets on the foot for reefing, a topsail, and a foresail. A full cargo consists of about 100 tons of salted fish.

Register, 80 tons; length, 67·5 ft.; breadth, 28·4 ft.; depth, 10·75 ft.; draught forward, 9 ft.; aft, 10·5 ft.

473. Rigged model of Tasmanian fishing boat. (Scale 1 : 12.) Presented by the Tasmanian Commissioners to the Fisheries Exhibition, 1883. N. 1610.

This boat is fitted with a well in its centre, in which the fish taken can be kept alive, as suitable holes in the bottom of the well insure sufficient change of water. She is ketch-rigged, setting a foresail and jib, a boom mainsail, and a mizen.

Register, 27·6 tons; length, 48 ft.; breadth, 11·5 ft.; depth, 8·5 ft.

474. Rigged model of Tasmanian fishing boat. (Scale 1 : 12.) Presented by the Tasmanian Commissioners to the Fisheries Exhibition, 1883. N. 1611.

This is a carvel-built boat, with a sharp stern and two drop keels; she also has a central well in which to store live fish. One mast is provided, carrying a foresail and a sprit mainsail; the boat pulls four oars and is used for seine fishing.

Length, 35 ft.; breadth, 8·75 ft.; depth, 4 ft.

475. Rigged model of felucca. (Scale 1 : 16.) Lent by H. C. Bucknall, Esq., 1904. N. 2351.

This type of vessel, distinguished by its rig of single lateen sails on two or more masts and the addition of poles and oars for use in calms, appears to have been developed on the Mediterranean coasts.

The particular example represented, known as a falua—the Portuguese form of the word felucca—was very general on the Tagus before the introduction of steamers, but is now disappearing; such boats were, however, the only means of transport for passengers and goods between Lisbon and ports on the south bank of the river. The vessels are constructed locally, of pine; the majority are half-decked to the mainmast, and have the after part decked over for about 12 ft., but the larger ones are, as shown by the model, whole-decked. The sails are furled by means of a rope manipulated by a man at the masthead, assisted by another below. The crew consists of five men.

Carrying capacity, 12 tons; length over all, 49·4 ft.; breadth, 13·75 ft.; depth, 6·16 ft.; length of mainmast, 31·6 ft.; length of foremast, 27·8 ft.; area of mainsail, 580 sq. ft.; area of foresail, 476 sq. ft.

476. Rigged model of Spanish felucca. (Scale 1 : 32.) Received 1910. N. 2548.

This represents a two-masted Spanish coasting vessel of the felucca type. It has an elliptical stern and a high, ornamented stem-piece. The two lateen-rigged masts are placed well aft in the vessel, and a bowsprit is used for the head sails.

Length, 40 ft.; breadth, 11 ft.

Three views of feluccas on the Lake of Geneva are also shown.

477. Built model of "Rob Roy" canoe. (Scale 1 : 2.) Lent by Messrs. R. J. Turk and Sons, 1908. N. 2494.

This represents, in its principal features, a form of decked canoe which came into general use in 1865, largely as the result of a remarkable journey of about 1,000 miles, chiefly on the lakes and rivers of Central Europe, made by Mr. J. Macgregor, M.A., in a vessel of this type designed by himself. Published narratives of this, and subsequent journeys of a similar character, led to the formation of canoe clubs all over the world and the construction of large numbers of these craft.

As the original "Rob Roy" canoe was intended for easy transport on land as well as for use indifferently on sea, lake, and river, it embodied many of the characteristics of the Eskimo "kayak" (*see* Nos. 528 and 529). Wood, however, was used in its construction: English oak for the keel and sides, with cedar for the deck; an oscillating backboard was added to the deck aperture with an easily detachable waterproof cloth around the occupant when seated: a single mast, stepped on the fore side of the aperture, with a dipping-lug sail and jib, was also used; the canoe was propelled and steered by a double-bladed paddle. Modifications for racing and ordinary river work were subsequently made in the original design.

The example here shown was made by Messrs. Turk and Sons and is fitted with two masts and dipping-lug sails; it has also a rudder with double yoke and lines, by means of which the steering may be effected by the occupant's feet.

Ordinary travelling canoes of this type have the following principal particulars:—Length, 12 to 15 ft.; breadth, 2·5 ft.; draught (with 10 lb. of luggage), 5 in.; total weight, 70 to 80 lb. Double-ended paddle, 7 ft. long.

478. Rigged model of S.S. "Rob Roy." (Scale 1 : 24.) Lent by Messrs. A. G. Gifford & Co., 1882. N. 1569.

This ketch-rigged steamer was built at Leith, for line and net fishing.

She is constructed of wood, but has an iron bulkhead covered with non-conducting cement, dividing the hold from the engine and boiler space, which is placed as far aft as possible. The hold is fitted up with fish boxes; the crew are accommodated forward. The mainmast is fitted in a tabernacle, to enable it to be lowered; the sails set are jigger, mainsail, foresail, and jib.

The engines are of the two-stage expansion, inverted type, and drive a single screw which gives a speed of 8 knots. Steam at 90 lb. pressure is supplied by a vertical tubular boiler.

Gross register, 37 tons; length, 56 ft.; breadth, 12 ft.; depth, 6 ft.

479. Rigged model of S.S. "Hawk." (Scale 1 : 24.) Lent by Messrs. A. G. Gifford & Co., 1882. N. 1570.

This schooner-rigged steam trawler was built of wood at Leith in 1882. The trawl is shown on deck, with the net triced up to dry.

She is provided with two-stage expansion engines, having cylinders 13 in. and 24 in. diam., by 18 in. stroke, which are supplied with steam at 85 lb. pressure and drive a single two-bladed screw.

Gross register, 83 tons; length, 87·2 ft.; breadth, 18·1 ft.; depth, 9·5 ft.

480. Half block model of S.S. "Nyanza." (Scale 1 : 48.) Presented by Messrs. Cochrane, Cooper and Schofield, 1890. N. 1851.

This ketch-rigged screw steamer was built of iron at Beverley in 1890, for trawl fishing in the North Sea. She has three watertight bulkheads, and a quarter-deck 20 ft. long.

Her engines are three-stage expansion, with cylinders 12·5 in., 19·5 in., and 31·5 in. diam. by 22·5 in. stroke (*see* adjacent photographs). Steam is supplied at 160 lb. pressure, and the indicated h.p. is 320.

Gross register, 153 tons; length, 100·5 ft.; breadth, 21 ft.; depth, 10·8 ft.

481. Half block models of steam launches. (Scale 1 : 24.) Lent by Messrs. Watkins & Co., 1877. N. 1475–7.

"Jackdaw" is a screw steam launch of the following dimensions:—Length over all, 42 ft.; breadth, 8·5 ft.; draught, 3·25 ft.

"Sisceepe" is a twin-screw steam launch of the following dimensions:—Length over all, 51 ft.; breadth, 9 ft.; draught, 3·5 ft.

"Fly-by-Night" is a screw steam launch of the following dimensions:—Length over all, 60 ft.; breadth, 8·5 ft.; draught, 3·5 ft.

482. Half block models of steam launches. (Scale 1 : 24.) Lent by Messrs. Cochran & Co., 1885. N. 1679–84.

"Cricket" is a screw steam launch of the following dimensions:—Length over all, 40 ft.; breadth, 7 ft.; moulded depth, 4 ft.

Her engines are two-stage expansion, with cylinders 5 in. and 10 in. diam., by 8 in. stroke. She is fitted with a Cochran boiler, 3·25 ft.; diam. and 6·16 ft. high.

"Jeanne and Louise" is a twin-screw steam launch of the following dimensions:—Length over all, 62·5 ft.; breadth, 12 ft.; moulded depth, 4·16 ft.

The engines are two-stage expansion with cylinders 10. in. and 20 in. diam., by 8 in. stroke. Steam is supplied by a Cochran boiler, 4·83 ft. diam., and 8·5 ft. high.

"Midge" is a screw steam launch of the following dimensions:—Length over all, 63 ft.; breadth, 12 ft.; moulded depth, 7·25 ft.

The engines are two-stage expansion with cylinders 10 in. and 20 in. diam., by 14 in. stroke. Steam is supplied by a Cochran boiler, 6 ft. diam. and 9·75 ft. high.

"Anglo-Egyptian" is a screw steam launch of the following dimensions:—Length over all, 42·5 ft.; breadth, 9 ft.; moulded depth, 4·5 ft.

Her engine has a single cylinder 8 in. diam. by 10·5 in. stroke, which is supplied by steam from a Cochran boiler, 3·5 ft. diam. and 5 ft. high.

"Dewsbury" is a screw steam launch of the following dimensions:—Length over all, 25 ft.; breadth, 5·5 ft.; moulded depth, 2·75 ft.

Her engine has a single cylinder 4·5 in. diam. by 6 in. stroke, and is supplied with steam from a Cochran boiler, 2·75 ft. diam. and 3·5 ft. high.

"Rosalind" is a screw steam yacht built of wood at Dartmouth in 1881, by Messrs. Madocks & Co Her leading dimensions are:—Thames measurement, 34 tons; gross register, 28 tons; length, 62·9 ft.; breadth, 11·2 ft.; moulded depth, 5·5 ft.

Her engine is two-stage expansion, with cylinders 8 in. and 14 in. diam., by 12 in. stroke. Steam at 100 lb. pressure is supplied by a Cochran boiler, 5 ft. diam. and 9·75 ft. long.

483. Whole model of transport boat. (Scale 1 : 12.) Bequeathed by Miss. M. A. Peek, 1906. N. 1030.

This was designed by Mr. Wm. Ladd, of Deptford Dockyard, for the disembarkation of troops, horses, and field guns in the Crimea, 1854–6.

It consists of a platform supported on two flat-bottomed floats, and provided with stanchions carrying protecting ropes. A projecting extension of the platform is hinged, so that it can be lowered for use as an incline in disembarking. The floats are special boats, but can be used for other purposes; their dimensions are: length, 40 ft.; breadth, 12·5 ft.; and depth, 4·5 ft.

484. Whole model of the obelisk ship "Cleopatra." (Scale 1 : 24.) Presented by John Dixon, Esq., 1879. Plate VI., No. 4. N. 1520.

This vessel was built at Millwall in 1877, from the designs of Mr. Dixon and Sir B. Baker, for the conveyance to England of the obelisk known as "Cleopatra's needle," presented to the British nation by the Viceroy of Egypt, Mehemet Ali, in 1820. The cost of the vessel and its transport were defrayed by Sir Erasmus Wilson.

The "Cleopatra" was a wrought-iron cylindrical pontoon, tapered at each end to a vertical edge, and furnished with diaphragms 10 ft. apart, which with suitable elastic packing supported the obelisk. The plates comprising the pontoon were ·375 in. and ·4375 in. thick, and its weight was 60 tons. The obelisk is 66 ft. long, and 8·5 ft. square at the base, tapering towards the top; it was placed with the base about 20 ft. from the bow and the apex close to the stern, which was fitted with a rudder. On the top and near the centre was a deck-house with accommodation for three men with a wheel in the fore part. There was a long hurricane deck above the house and a short mast with two sails surmounted the whole. The vessel was perfectly watertight, and sealed, the only means of access being a man-hole door in the floor of the deck-house.

In removing the monolith, a short length of it was first cleared, by excavation of the sand (in which it had lain for over 20 centuries), and the corresponding part of the pontoon built around it, and a bearing diaphram fitted, then another length, and so on until the whole was enclosed. When completed the cylinder was lagged with 6-in. planks for a length of 12 ft. at either end, to protect the iron skin from injury, and then rolled down a slope into the water, and towed to a dry dock, where the deck-house and bilge keels were added. She was then towed by the S.S. "Olga" with a wire cable, a quarter of a mile long, at the rate of 7 knots an hour. Owing, however, to heavy weather in the Bay of Biscay, she was abandoned, but was afterwards picked up by the S.S. "Fitzmaurice," and taken into Ferrol, from whence she was towed to England.

The obelisk was placed 4·5 in. below the centre, which gave a metacentric height of 10 in. and a period, allowing for the bilge keels, of 6 seconds, or 10 double rolls per min.

Actual displacement, 270 tons; possible displacement, 405 tons; length, 92 ft.; diameter, 15 ft.; draught of water, 9 ft.; weight of obelisk, 160 tons; ballast, 30 tons.

LIFE-BOATS.

485. Whole model of life-boat (1804). (Scale 1 : 12.) Lent by James Young, Esq., 1883. N. 1589.

This represents a non-capsizable life-boat, probably built in 1804, by Messrs. H. S. Edwards and Sons, of Howden-on-Tyne. Air cases on the sides and at bow and stern are indicated, otherwise there is no detail.

486. Photographs of model of Brighton life-boat, 1841. Received 1896. N. 2098.

This life-boat was built at Hove in 1840 for the beach at Brighton by Mr. Golding. The form is that usually given to whale boats—sharp at both ends to row in either direction; she was built of elm plank and copper-fastened, the gunwales rise in a hollow curve giving a sheer of 2 ft. above the centre at either extremity. The sides were fitted with lockers, 14 in. wide at the top and sloping upwards from the thwarts to nearly the gunwales edge; these were filled with 3 to 4 cwt. of Farostone cork. The cork sides extended to within 3·5 ft. of either end; the ends were decked and fitted with bulkheads enclosing air-tight copper canisters. The boat pulled four oars, each 16 ft. long, single banked, and six, four of which were 13 ft. long, double banked, with the addition of one 17 ft. long, for steering. Thole pins and grummets were found preferable to rowlocks, as securing the oars in case of accident. An iron crutch was fitted to either end for steering, while the other side had a cleat and rollers for kedging the boat through surf. Two life-buoys, consisting of two cork globes 11 in. diameter, with 20 in. between them, were slung under the centre thwarts.

Her leading dimensions were:—Length, 22·5 ft.; breadth, 6·5 ft.; depth, 2·6 ft.

487. Whole models of life-boats. (Scale 1 : 8.) Lent by G. Turner, Esq., 1864. N. 1037.

These were designed by Mr. Turner, of Woolwich Dockyard, to compete for the premium of 100 guineas offered by the Duke of Northumberland in 1851 for the best type of life-boat.

They are constructed of wood and have flat bottoms with fine bows and sharp sterns. Both bow and stern are fitted with removable air chambers, recessed in the middle; air chambers are also formed under the thwarts. Apertures are provided to discharge any water shipped. The larger boat is fitted to pull 16 oars double banked, and has two masts on which she would probably carry two lug sails; the smaller boat pulls five oars.

	Large.	Small.
Length	36 ft.	26 ft.
Breadth	6 ,,	5 ,,
Depth	3·4 ,,	2·8 ,,
Weight of boat	18 cwt.	9 cwt.

488. Whole model of life-boat "Excelsior." (Scale 1 : 9·6.) Lent by J. E. Teasdel, Esq., 1896. N. 2077.

This form of life-boat, which has been adopted at Yarmouth and several other stations on the Norfolk and Suffolk coasts, was introduced about 1840 by William Teasdel. It differs from the more generally adopted construction in that it is not self-righting if capsized; but it is claimed that, as none of these boats have ever upset, the elevated air chambers that are necessary with a self-righting boat are an unnecessary obstruction; also, that when suitable air chambers and metal ballast are provided a wide boat cannot capsize.

In the boat represented the stability is assisted by an iron keel weighing one ton, together with a ballast tank capable of holding four tons of water. The air chambers, which extend along the side of the boat and to the bow and stern under the level of the thwarts, have a capacity of 320 cub. ft., and a buoyancy of 9 tons; an outside strake of watertight compartments, in lengths of 3 ft., built of light wood and covered with cork and canvas, gives an additional floating power of 3 tons in a position in which it greatly assists the stability. The floor is fitted with 12 delivery valves, 4 in. diam., for discharging any water shipped.

The boat carries two masts, and is fitted for 10 oars, double banked; above the gunwale is a rope rail carried in iron stanchions.

Length, 43·2 ft.; breadth, 12 ft.; depth, 5·6 ft.

489. Whole model of life-boat. (Scale 1 : 12.) Received 1896. N. 2075.

This design by Mr. William Teasdel, which represents a boat built for the heavy surf at Palling, Norfolk, was awarded a prize at the 1851 Exhibition.

The boat is clincher-built, and has considerable sheer; there are large air chambers at the bow and stern and along the sides, in addition to an outside strake of cork. The keel is of iron, and there is a central ballast well 7 ft. long, 2·5 ft. wide, and 1·5 ft. deep, with perforated iron sides. She is fitted for 12 oars and two masts.

Length, 36 ft.; breadth, 10·5 ft.; depth, 3·3 ft.

490. Whole model of life-boat. (Scale 1 : 9·6.) Lent by J. E. Teasdel, Esq., 1896. N. 2074.

This represents a boat built in 1851 by Mr. William Teasdel, for the Duke of Northumberland, who stationed it near Hauxley and Warkworth.

She is clincher-built of oak, with low air chambers along the sides and in the bow and stern, while there is also a high chamber at the bow and stern, extending, however, only part of the width, so as to leave both ends of the boat accessible. There is also an external cork strake, and stability is given by a heavy iron keel. She is fitted for 10 oars, and has two masts.

Length, 32 ft.; breadth, 10 ft.; depth, 4·5 ft.

491. Whole model of "Nautilus" life-boat. (Scale 1 : 9·6.) Lent by J. E. Teasdel, Esq., 1896. N. 2078.

This represents a design by Mr. William Teasdel, for a life-boat or surf-raft. The sides are planked, the floor is formed of open gratings, while buoyancy is given by air chambers in the bow, stern, and between the thwarts; in addition there is a large outside strake composed of cork. The air cases are of 84 cub. ft. capacity, and there are 20 cub. ft. of cork, giving a combined supporting power of 3 tons.

Length, 24 ft.; breadth, 9 ft.; depth, 2·5 ft.

492. Whole model of surf boat. (Scale 1 : 12.) Lent by J. E. Teasdel, Esq., 1896. N. 2076.

This boat is clincher-built, has an iron keel, and a cork outside strake. Low air chambers are provided throughout the length under the thwarts with others at each end above the thwarts. There would be 12 oars and two masts.

Length, 32 ft.; breadth, 11 ft.; depth, 3·5 ft.

493. Whole model of life-boat. (Scale 1 : 16.) Received 1896. N. 2073.

This represents the Lowestoft boat and its carriage, designed by Mr. William Teasdel.

The model is clincher-built, with a heavy iron keel; it is fitted with low air chambers extending from the bow to the stern along the sides under the thwarts, and there is a cork strake all round on the outside. She is fitted with 10 valves for discharging any water shipped; she carries 14 oars double banked, and three masts with dipping lug sails.

She is mounted on a two-wheel transporting carriage, which may also serve as a launching way.

Length, 34 ft.; breadth, 9·3 ft.; depth, 4·3 ft.

494. Life-boat carriage and limber. (Scale 1 : 19·2.) Lent by J. E. Teasdel, Esq., 1896. N. 2081.

These were constructed by Mr. William Teasdel for carrying to the neighbourhood of a wreck the life-boat and Manby's life-line mortar, together with various stores. The boat is carried on a slip way that is suspended from the axle of a pair of road wheels 15 ft. diam.

495. Whole model of life-boat. (Scale 1 : 18.) Lent by John Coryton, Esq., 1858. N. 200.

The features of this design were patented by Mr. Coryton in 1851 and subsequently somewhat further developed.

At one end the boat is wedge-shaped, with the edge vertical, while at the other end the shape resembles a shallow and flat stern. When ordinarily sailing the wedge or "vertical wave line" end was in front, while when running before the wind the positions are reversed, a principle that is embodied in some of the Burmese and Chinese boats.

The lower part of the boat was to have been of iron, with a metal keel, while the upper parts were to have been of wood; the seats were to have been fitted with cork, with air compartments at the narrow end. Propulsion and steering were to have been performed by two jets supplied by hand-worked pumps.

496. Rigged model of life-boat and carriage. (Scale 1 : 10.) Lent by the Royal National Life-Boat Institution, 1865. N. 1070.

This represents a fully equipped life-boat on its transporting carriage, as designed by Mr. John Prowse in 1861 and adopted by the Royal National Life-boat Institution.

The boat in general form resembles a whale boat, and is diagonally built of two thicknesses of mahogany. She has five thwarts 2·6 ft. apart, and pulls ten oars, double banked, in crutches formed on the thole pins. Extra buoyancy is obtained by compartments under the deck filled with watertight cases packed with cork, by detached air cases under the head and stern sheets and along the sides under the thwarts, and by raised air cases in the ends. This boat could hardly be capsized, but should such an accident occur, the sheer of the gunwale, the raised end cases, and an iron keel, would cause her to right herself. Large delivery valves enable the boat to free herself of all water above the deck in 20 seconds, even with 47 persons on board.

The transporting carriage consists of a fore and a main body. The latter is formed of a keelway, together with side or bilgeways resting on the main axle, the boat's weight, however, being entirely on the rollers of the keelway. On the withdrawal of a locking pin the fore and main bodies can be detached from each other, so that when the boat is launched from the rear end the keelway and main body form an inclined plane. To replace her on the carriage, she can be hauled bow foremost up the fore end or longer incline by disconnecting the fore carriage and letting the end of the keelway rest on the ground. The bilgeways are needed at the rear end in order that the boat may be launched in an upright position with her crew on board, but are not required at the fore end of the carriage.

A life-boat provided with a carriage on which she is kept, ready for transportation to the most favourable position for launching to a wreck, is available for a much greater extent of coast than would otherwise be possible, while a carriage is also of immense value in launching a boat from a beach through a high surf.

Length, 33 ft.; breadth, 8 ft.; depth amidships, 3·3 ft.

497. Built model and drawing of life-boat "Lady Daly." (Scale 1 : 16.) Lent by H.R.H. the Duke of Saxe-Coburg-Gotha, K.G., 1869. N. 1314.

This is equipped with masts, sails, oars, crutches, anchors, throwing lines, etc., and is in a cradle on a permanent launching slip. It represents a life-boat constructed at Adelaide, Australia, in 1867, from designs by Mr. W. Taylor, Government shipwright at that port. She was fitted with two standing lugs and a foresail.

The model was presented in 1868 by the Marine Board of South Australia to H.R.H. the Duke of Saxe-Coburg-Gotha when in command of H.M.S. "Galatea."

Length, 43·08 ft.; breadth, 9 ft.; depth amidships, 4·08 ft.

498. Rigged model of life-boat and carriage. (Scale 1 : 12.) Lent by the Royal National Life-Boat Institution, 1885. N. 1685.

This represents a fully equipped life-boat on a transporting carriage and is an exact representation of the life-boat which obtained the 600*l.* prize at the Fisheries Exhibition in 1883. There is very little difference between it and the earlier boat of 1861 (*see* No. 496).

A disc suspended on one of the stays of the main carriage is used as a turntable, while on the opposite side is a roller skid. The life-boat is hauled out of the water on roller skids, but when it is required to change the direction in which the boat is being hauled she is put on the turntable.

Length, extreme, 33 ft.; breadth, 8 ft.; depth amidships, 3·3 ft.

499. Whole model of a whaler gig as a life-boat. (Scale 1 : 16.) Lent by Messrs. Forrestt and Son, 1873. N. 1347.

This boat was constructed for H.M.S. "Sylvia." She has movable air chambers in the bow and stern, and air cases along the sides under the thwarts; she pulls five oars and has the usual fittings for sailing.

Length, 28 ft.; breadth, 5·6 ft.; depth, 2·5 ft.

500. Whole model of life-boat cutter. (Scale 1 : 16.) Lent by Messrs. Forrestt and Son, 1873. N. 1348.

This represents an ordinary man-of-war's cutter fitted as a life-boat by the addition of air cases along the side under the thwarts and movable air cases at the bow and stern. She would pull ten oars double-banked, and have the usual sailing appliances.

Length, 25 ft.; breadth, 7·25 ft.; depth, 2·83 ft.

501. Whole model of life-boat cutter. (Scale 1 : 16.) Lent by Messrs. Forrestt and Son, 1873. N. 1350.

This represents a life-boat built for the SS. "Vestal" of the Corporation of the Trinity House. There are movable air cases in the bow and stern, and along the sides under the thwarts. She has two bollards forward and one aft; she pulls five oars and is also fitted for sailing.

Length, 25 ft.; breadth, 6 ft.; depth, 2·3 ft.

502. Whole model of self-righting cutter life-boat. (Scale 1 : 24.) Lent by Messrs. Forrestt and Son, 1873. N. 1349.

This boat is built with bow and stern alike, air cases under the thwarts and close to the side, movable air cases in the bow and stern, and delivery valves to readily discharge any water shipped.

Length, 28 ft.; breadth, 7·5 ft.; depth, 3·16 ft.

503. Whole model of steam cutter with air chambers. (Scale 1 : 16.) Lent by Messrs. Forrestt and Son, 1873. N. 1352.

This represents a steam launch for the use of ships and yachts; it is fitted with air cases in the bow and stern and under the thwarts close to the side, so as to make it unsinkable by swamping.

Length, 26 ft.; breadth, 6·5 ft.; depth, 3·25 ft.

504. Whole model of a jet-propelled steam life-boat. (Scale 1 : 12.) Lent by Messrs. R. and H. Green, 1894. N. 2034.

This represents a life-boat designed and built by Mr. J. F. Green in 1893. The boat is fitted with engines which, on land, drive two travelling wheels placed about amidships and, at sea, work a centrifugal pump, which drives a stream of water through certain pipes placed below the water-line, the reaction of the issuing jet propelling the boat. When the boat is travelling on shore it rests upon three wheels, the one at the bow being spherical and carried freely upon a swivel axis. The boat enters the water stern first, and when afloat the two midship wheels are raised into their chambers by letting go the after tackles, and are retained there by the forward tackles, the engines then propelling the boat by the centrifugal pump.

There are four outlet pipes, two turned forward and two aft. When required to move ahead the two forward ones are closed by suitable valves and the two aft pipes are opened. The boat's speed is stated to be 8 knots. To turn the vessel to port, the forward port and the after starboard pipes are opened, and the others closed; she will then turn in her own length. She can be quickly stopped in a very short distance by closing the stern pipes and opening the forward ones. Other boats of this kind are provided with pipes at the sides leading off perpendicularly to the length of the boat; these are used for putting off, broadside-on, from a wreck.

By using water-tube boilers steam is got up in 15 minutes. The boat will travel at full speed for 30 hours, with an expenditure of 3 tons of coal.

The crew numbers 9 men, and there is room for 30 passengers in addition.

Length, 50 ft.; beam, moulded, 12 ft.; draught, loaded, 3·25 ft.

505. Rigged model of non-self-righting sailing life-boat. (Scale 1 : 12.) Lent by the Royal National Life-Boat Institution, 1903. Plate VI., No. 5. N. 2301.

Until 1882 nearly all of the life-boats in the service of the Institution were of the "self-righting" type, illustrated by the models No. 496 and No. 498. Since then, in deference to the wishes of local crews, a number of "non-self-righting" boats have been constructed, for use principally on the coasts of Norfolk, Suffolk, Essex, Cheshire, and Lancashire, with the result that at the close of 1901 about one-fifth of the total number of the Institution's life-boats were of this type.

The model represents one of the non-self-righting boats, built in 1902, to the designs of Mr. G. L. Watson, and differs from the self-righting construction in having less sheer and lower air-casings at the extremities, while the beam is increased. Air compartments are fitted at each end of the boat, as well as above and below the thwarts on each side. Relieving tubes and valves, 12 in number, provide for the automatic discharge of water from the deck, while a weather-board or " breakwater " across the foremost casing affords some protection from head seas.

A steel casting, weighing 3·5 tons, forms part of the main keel of the boat and gives the necessary stability, but water tanks are frequently added to carry additional ballast when required. Two bilge-keels on each side minimise rolling and at the same time strengthen and protect the structure.

For sailing purposes two lug-sails and a fore-sail are used, carried on masts whose heels are fitted in tabernacles for convenience in raising and lowering. Two drop-keels are provided for use in reducing leeway when sailing, and oars are carried for a crew of 12 men; there are, moreover, three large steering sweeps in addition to a rudder.

The boat is kept in a boat-house and launched by means of a slipway.

Length, over all, 40 ft.; breadth, 11 ft.; depth, amidships, 4·25 ft.

STEAM TUG BOATS.

506. Half block model of triple-screw tug boat. (Scale 1 : 48.) Lent by George Scott, Esq., 1877. N. 1484.

This iron-built tug, for river use, is fitted with twin screws at the stern and one screw at the bow in her fore-foot; each screw is driven by a separate and independent engine.

Length, over all, 80 ft.; breadth, 18 ft.; mean draught, 2·75 ft.

507. Whole model of paddle tug "Albatross." (Scale 1 : 48.) Lent by Messrs. Hepple & Co., 1882. N. 1583.

This iron paddle-wheel tug-boat was built at South Shields in 1878. Her engine is of the side-lever type, with one cylinder 40·25 in. diam. by 54-in. stroke, and her speed is 13 knots.

Gross register, 139 tons; length, 140 ft.; breadth, 19 ft.; depth, 8·25 ft.

508. Whole model of screw tug "Victor." (Scale 1 : 24.) Lent by Messrs. Duncan Bros., 1885. N. 1690.

This tug was built of steel at Glasgow in 1884 by Mr. W. S. Cumming. She has three bulkheads and a teak deck.

The engines are two-stage expansion and surface-condensing; the slide valves are driven by Bremme's valve gear (*see* No. 867). The boiler is of the single furnace, return multi-tubular type, constructed for a working pressure of 80 lb. The propeller is a three-bladed Duncan's (*see* No. 1005).

Length, 45 ft.; breadth, 10 ft.; depth, 6·5 ft.

509. Photographs of salvage and towing steamers "Kathleen" and "Narciso Deulofeu." Presented by Messrs. Cox & Co., 1890. N. 1836–7.

These small steel screw tugs, for coast and harbour service, were built and engined at Falmouth in 1888–9 by Messrs. Cox & Co.

They are fitted with three-stage expansion engines, which indicate 600 and 460 h.p. respectively, and give a speed of 12 knots.

The "Kathleen" belongs to the Rangoon Port Commissioners, and has the following particulars:—Gross register, 190 tons; length, 121 ft.; breadth, 19·5 ft.

510. Whole model of steam tug and despatch boat. (Scale 1 : 24.) Lent by Edward Hayes, Esq., 1890. N. 1840.

This twin-screw river steamer was built of steel at Stony Stratford in 1889, to the order of the Metropolitan Fire Brigade, for use as a steam tug and despatch boat. Her speed is 14 knots.

Length, 66 ft.; breadth, 11 ft.; draught, 4 ft.

511. Print of the salvage S.S. "Novorossisk." (Scale 1 : 32.) Lent by Messrs. R. S. Newall & Co., 1892. N. 2002.

The "Novorossisk" was built of steel and engined by Messrs. Newall & Co. in 1890, for use as a tug and salvage steamer in the Black Sea.

The screw propeller is driven by a two-stage expansion engine of 300 indicated h.p., with cylinders 16·25 and 32·5 in. diam., by 22-in. stroke. Steam at 100 lb. pressure is supplied by a single-ended boiler, 11 ft. diam. by 9·5 ft. long. On trial her speed was 9·5 knots.

The pumping machinery consists of a 15-in. centrifugal pumping engine, capable of throwing 4,100 gals. of water per min., and provided with five 8-in. suction branches; also a Worthington duplex fire pump, which will discharge 750 gals. of water per min. through four 3·5-in. fire hoses.

Length, between perps., 80 ft.; breadth, moulded, 17 ft.; depth, 10 ft.; gross register, 85 tons.

BOATS' FITTINGS.

512. Model of Clifford's boat-lowering apparatus. (Scale 1 : 10.) Lent by A. Batten, Esq., 1868. N. 1202.

This arrangement was patented by Mr. Charles Clifford in 1853, and improved in 1856 and 1858. The boat is hung from hooks on the davits by tapered ropes, which, after passing through friction blocks that prevent side rolling, are wound on a roller secured under a thwart; the ends of the ropes are, however, free. The boat is lowered by its own weight, controlled by a rope-brake on the roller.

This apparatus was extensively adopted in H.M. Navy and mercantile marine.

513. Model of boat-lowering apparatus. (Scale 1 : 16.) Presented by F. J. Sweeting, Esq., 1874. N. 1391.

This arrangement was patented by Mr. Sweeting in 1872. In order that the lowering should be under the control of one man, the ropes are attached to a winch barrel inside the ship. For raising, the barrel is rotated by a ratchet wheel and pawl, while for lowering there is a strap brake. The boat can also be lowered independently of this, as the davits are hinged so that they can swing downwards when released by a block and tackle attached to the mast. The disengaging gear consists of a curved bar at each end of the boat; these bars act as hooks for retaining the supporting ropes, and are locked down by two bolts, which are simultaneously withdrawn by a lever fitted amidships.

514. Iron blocks for boat disengaging gear. Presented by G. Fawcus, Esq., 1865. N. 1080.

These special forms of snatch block were introduced by Mr. Fawcus.

The first has an open jaw closed by a hook, which can be turned on its pivots by pulling a lanyard; a retaining safety-pawl is also added.

In the second the jaw is closed by a pin which is released by turning a slotted socket.

515. Boat disengaging gear. Presented by the Rev. J. M. Kilner, 1878. N. 1506.

This gear was patented by Mr. Kilner in 1867 and 1870. At each end of the boat a special shackle is fixed, which nips the lifting chains; each shackle can be released by lanyards.

516. Model of boat chocks. (Scale 1 : 8.) Lent by G. Fawcus, Esq., 1865. N. 1082.

This shows an arrangement for stowing boats inboard; the upper portions of each set of chocks, instead of being fixed or hinged, are capable of transverse adjustment by means of metal slides.

517. Iron fittings for securing boats' thwarts. Presented by G. Fawcus, Esq., 1865. N. 1080c.

These show a complete set of full-size straps and pins used for connecting the portable thwarts of nesting boats with the sides. (*See* No 413.) A ring-bolt secured through the upper part of each vertical strap provides an attachment for the boat's lifting and disengaging gear.

518. Model of boat davits. (Scale 1 : 16.) Lent by G. Fawcus, Esq., 1865. N. 1081.

The davits are tied back to fixed posts, round which they can slew; the davits of adjacent boats can be attached to a single post, thus permitting the boats to be closer together than usual.

519. Boat-detaching apparatus. Lent by Messrs. Hill and Clark, 1874. N. 1384.

This apparatus for automatically releasing a ship's boat when it reaches the water was patented in 1870–2 by Mr. E. J. Hill.

The boat is suspended from the lowering tackle by two rings, engaging with trip hooks secured in its bow and stern. These hooks are double-pointed, and the rings after being passed over the outer points, are hooked to the inner in the ordinary manner. When the boat becomes water-borne the rings fall loosely, and the outer points acting as guides so control their movements that they cannot re-engage with the inner hooks. The rings are connected by a horizontal rope which pulls them towards each other, and, by transmitting a portion of the pull on each ring to the other, ensures that neither is detached until both ends of the boat are water-borne. The hooks are provided with hinged claws for use when about to lift a boat, but these are to be turned back before lowering.

520. Model of boat disengaging gear. (Scale 1 : 32.) Lent by J. A. R. Clark, Esq., 1902. N. 2294.

This gear, for rapidly and simultaneously releasing the two ends of a lowered boat, was patented in 1898 by Lieut.-Col. G. S. A. Ranking, and subsequently improved by Mr. Clark.

The boat is supported at both ends by chains, from a pair of levers suspended from the davits and having their free ends brought together over the middle of the boat, and there retained by a slip chain secured to the keel. When the central chain is released the two levers are free to turn and thus liberate the end chain, so that the boat is cast off. To give more rigidity to the arrangement and also to prevent the released levers from causing injury they are connected where they meet by a strong knuckle-joint which prevents any downward or sideway movement.

521. Model of quadrant boat davits. (Scale 1 : 16.) Lent by A. Welin, Esq., 1905. N. 2361.

This shows a device for rapidly lowering a boat, patented by Mr. A. Welin in 1900–1.

The lower portion of each davit consists of a toothed quadrant rolling on a fixed horizontal rack, while a block pivoted to the davit at the centre of the quadrant slides on a horizontal guide bar and carries a nut through which a running screw actuating the davit passes. Owing to the screws for each pair of davits being threaded right and left handed, the men at the driving handles face each other and can see the progress of both davits as they roll outboard until the boat is sufficiently clear of the ship's side to be lowered by the falls. The rolling of the quadrants on the racks gives the davits a horizontal motion outboard, and also makes the load leverage less than it would be if davits turning on fixed centres were used.

By passing the falls over fixed pulleys before attaching them to the belaying pins on the davits, a differential motion is introduced which reduces the work required to return the boat inboard by causing it to drop relatively to the upper ends of the davits during that operation.

The inner portions of the boat's chocks are fixed to the deck, but the outer portions consist of pieces which are supported by links hinged to the deck, and are held in position by rods engaging with catches secured to the inner chocks. When the boat is fully prepared for lowering these rods are rapidly released and the driving screws started. The passing of the falls over the fixed pulleys, previously referred to, causes the boat to be eased off the inside chocks and the outside ones are pushed away by the boat itself as it moves outboard.

522. Bilge-plugs for a boat. Contributed by E. P. H. Vaughan, Esq., 1861. N. 699.

These drainage plugs, of which there are two forms, fit a seating in the bottom of the boat, and are secured in position by a bayonet joint.

523. Bilge-valve for a boat. Lent by H. Emanuel, Esq., 1885. N. 1693.

This is a rubber-faced valve, which is screwed against a grid fixed in the bottom.

SHIPS AND BOATS CHIEFLY OF ORIENTAL DESIGN.

These present many interesting peculiarities, arising from the state of the arts, the variations of climate, and the necessities or customs of the inhabitants.

The most general rig embodies the use of one or more lateen sails, but in many localities little or no standing rigging is employed, the requisite strength being given by the use of exceptionally stout masts.

The simplest craft are of the raft type, constructed of logs or bamboos lashed together, as seen in the "catamaran" of India or China, and the "jangada" of Brazil.

Dug-out canoes are met with in all parts of the world: in some localities, as in Ceylon, their depth is increased by the addition of wash-boards, while in Burmah and West Africa ribs and side planking are added in a way that suggests an origin for our present system of shipbuilding. In the Ceylon boat, however, in addition to the increased capacity and stability due to the elevated sides, the beam is virtually increased to a much greater extent by the addition of a ship-shaped log secured to the extremities of two outrigged bamboos; by this means it is rendered possible to carry a considerable area of sail, so that these boats obtain a speed of as much as 9 knots. The outrigger construction has reached its highest development in the "flying-proa" of the Ladrone Islands, in which the canoe is ship-shaped on one side and has a vertical plane for the other, so as to increase the leeway resistance; it is stated that these proas have obtained a speed of 17 knots. Outrigger canoes are found wherever the Malay race has penetrated, while the double canoes of the South Sea Islanders may perhaps be considered a modification of the same type.

Of boats wholly built up of weak material, easily obtained and worked, the birch-bark canoes of North America and those of gum-tree bark in Australia are typical examples: the sewn "masoolah" boats of India, which on account of their flexibility will stand being roughly beached by the incoming breakers, are also interesting illustrations of this system of construction.

Flat-bottomed boats constructed of planks include the "sampans" used in India and China for fishing, ferrying, etc., the house and flower boats of the Canton River, the latter being large examples of a form that with us is chiefly used for river punts. On the Irawadi and the Ganges such boats are also used, fitted with sails for use when going before the wind, but rowing and poling are also provided for by the addition of overhanging sponsons.

The Arab "dhow," used in the Red Sea and Indian Ocean, is an early type of vessel which is considered to have remained almost unchanged since the days of Alexander the Great. With one, two, or three masts and lateen sails, the type under various names is found also along the coast of the Mediterranean, so that there is considerable probability that the design was derived from the vessels of the early Phœnicians, while the construction is the probable forerunner of our own system of wooden shipbuilding.

524. Rigged models of Brazilian jangadas. (Scale 1 : 24.) Presented by W. R. Birnie, Esq., 1893, and Count Watson-Höwen, 1897. N. 2017.

These represent a species of raft, or catamaran, used in many parts of the world. It is constructed of several logs of light wood, or bamboo, pinned together, and is provided with seats and a mat-covered shelter amidship for protecting goods from the sun or spray. A single mast is fitted, and it carries a triangular sail secured to a light yard. These rafts are steered by an oar at the after end, and are used for fishing even at a considerable distance from land.

An adjacent illustration shows similar vessels at work on the Madras coast.

525. Rigged model of Chinese surf raft. (Scale 1 : 32.) Received 1896. N. 2089.

This model represents a form of surf raft or catamaran in general use on the coasts of China, Formosa, and Japan.

The body of the raft is formed of bamboos lashed together and to hardwood crosspieces, and is given considerable sheer and taper. Instead of a keel, three lee-boards are provided which can be drawn upwards when reaching the shore. The deck is wet, but passengers or goods to be kept dry are placed in a central tank and a light screen is employed to stop some of the spray. A single mat sail is used, or oars when necessary, while steering is done by an oar from the stern.

The dimensions are:—Length, 30 ft. to 35 ft.; width, 7 ft. to 10 ft.; crew, 3 men.

526. Dug-out canoe. (British Columbia.) Presented by the Canadian Commissioners to the Fisheries Exhibition, 1883. N. 1612.

This is a small example of a type of canoe used by the native Indians on the western coast of Canada: it differs fundamentally from the native birch-bark type (*see* No. 527) used in the eastern provinces of the Dominion. Owing to local decay, a portion of the after end of the boat has been removed, but the outlines of the complete canoe are shown upon the accompanying scale drawing.

The canoe consists of a single hollowed tree-trunk, usually of Canadian red cedar or other light wood, shaped externally to boat form. The lines show, (1) a short sharp entrance with the position of maximum breadth only 3 ft. from the bow, (2) a parallel fore-body to mid-length, (3) a long gradual run, terminated by a square-cut stern above the water-line. Considerable sheer is given to the top-sides and a covering board is fitted to the fore end.

The approximate weight of the complete canoe was 250 lb.; length, extreme, 29·25 ft.; breadth, extreme, 22·5 in.; depth, amidships, 10·75 in.

527. Built model of birch-bark canoe. (Scale 1 : 8.) Received 1899. N. 2193.

This represents in general form and construction the canoes used by native Indians upon the lakes and rivers of the eastern provinces of Canada. The chief characteristic of the type are: shallow draught, considerable sheer and taper, similarity of bow and stern, absence of keel, and extremely light build.

The canoe is constructed of white birch-bark laid upon frames or ribs of white cedar. The latter are first placed in position and held together by flexible wooden bands, then the outer shell, which has been carefully stripped in one piece from a suitable tree, is wrapped around them and secured by means of tarred thongs made from the roots of the cedar tree.

The boat is propelled by paddles, one of which is held by each rower who kneels or crouches upon the bottom of the boat while using it. A small sail is occasionally used.

The ordinary two-paddle canoe is from 16 to 18 ft. long, and can be carried many miles by one man without great exertion; such canoes are also made large enough to carry as many as twelve men.

528. Built model of Greenland canoe. (Scale 1 : 8.) Lent by The Royal United Service Institution, 1903. N. 2324.

This represents the one-man "kayak" used by native Eskimo for hunting and fishing.

It consists of a light framework of wood or whalebone covered above and below with tanned seal-skins, sewn together with sinew-thread, and made thoroughly tight. The only opening is a central circular hatchway, admitting the boatman to his hips, and into which he is secured by lacing the lower edge of his watertight jacket to the wooden coaming. External protective bands of whalebone are added at the stem and stern, to prevent injury when grounding.

A double-bladed paddle is used for propulsion, and all apparatus and provisions are carried on deck, in racks or straps. A harpoon and lance for seal-hunting are shown; attached to the former is a skin bag or buoy, which, when inflated, prevents the stricken seal from sinking.

As these boats are very shallow and without ballast or external keels, they are easily capsized, so that long practice is necessary to successfully manage them in a heavy sea or surf: their extreme lightness, however, permits of their being easily carried, inverted, on the bearer's head.

The usual dimensions are:—Length, 16 to 20 ft.; breadth, 1·5 to 2 ft.; depth, ·75 to 1 ft.; weight, 50 to 60 lb.

529. Greenland canoe and accessories. Presented by Mrs. Bompas, 1906. N. 2427.

This is an actual "kayak," or man's boat which, with the "umiak," or women's boat, are used by Eskimo off the coasts of Greenland for fishing, fowling, sealing, whaling and walrus-hunting.

It is constructed of light, bent-wood frames, irregularly spaced and lashed to longitudinal laths or battens; local and structural strength is also given by broad wooden beams or stretchers fitted on each side of the round hatchway amidships. The whole framework is finally covered with tanned seal-skins sewn together with sinew, while, for protection against injury by grounding or collision, external strips of bone are atttached to the raking bow and stern. The completed structure weighs about 40 lb., and is therefore easily transported overland. This extreme lightness, however, accompanied by a narrow beam, shallow draught, and lack of ballast or projecting keel, renders it liable to capsize, and long practice is required to manage it successfully in a heavy sea. The boatman sits in the hatchway with his outer skin coat secured to the coaming so as to prevent the entry of water; his double-bladed paddle is about 7 ft. long, made of red pine tipped with bone, and with this he balances and propels his craft. Leather straps, secured athwart the deck, provide for the stowage of provisions, harpoon-thongs and lines, and the various weapons used in the chase.

Length of the canoe, over all, 16·5 ft.; breadth, extreme, 1·75 ft.; depth of side, amidships, 6 ft.; weight, with implements, 50 lb.

Examples are shown of the following weapons:—

(1) Harpoon Dart. This is about 7 ft. long, and is used for big game. It is thrown, by means of "hand boards" as shown, a distance of 8 to 12 yards, and is fitted with detachable barbed head carrying a line with a bladder or an inflated sealskin; after striking its object, this outer barb with its line is automatically released from the harpoon-shaft, and the bladder at the same time is thrown overboard, where it marks the course of the wounded animal, and is finally used to buoy it on the surface when dead.

(2) Missile Dart. About 5 ft. long, with a detachable barbed iron point and a bladder fixed to the shaft; used when hunting in company.

(3) Great Lance. About 6 ft. long, with a detachable bone head and iron blade without barbs; it readily disengages itself, and is thrown frequently at the wounded animal as it rises to take breath.

(4) Little Lance. About 4 ft. long; has a sword point and is used to dispatch the animal outright.

(5) Fowling Dart. About 5 ft. long, with a fixed iron point at the head, and three projecting bone points about the middle of the shaft, these latter giving increased chances of striking a moving bird.

530. Whole model of Accra canoe. (Scale about 1 : 8.) Lent by W. H. Holloway, Esq., 1908. N. 2462.

This native-made model represents a type of surf boat used at Accra, the capital of the Gold Coast Colony, West Africa.

It is of dug-out construction, having its sides tied together with groups of short transverse poles lashed at intervals to the gunwales. It has a relatively large beam and a "rockered" bottom or convex keel line features which adapt it for use on a shelving, surf-beaten coast; two navigating paddles of special form are shown. The outside of the canoe is decorated by native characters and drawings.

Approximate dimensions:—Length, 22 ft.; breadth, 5 ft.

531. Whole model of Kroo canoe (Liberia). (Scale 1 : 12.) Lent by W. H. Holloway, Esq., 1908. N. 2496.

This shows a typical native canoe as used for general purposes by the Kroo tribes along the Liberian coast.

These craft are of simple dug-out character and vary in length from 18 ft. to 30 ft. They are propelled by two to four men, by means of a form of pronged paddle, peculiar to Kroomen, and may be successfully navigated in heavy sea or surf.

The example shown was made from particulars obtained at Monrovia, Liberia, and represents a canoe of the following overall dimensions :—Length, 28 ft.; breadth, 2·5 ft.; depth, amidships, 1·75 ft.

532. Whole model of Southern Nigeria river canoe. (Scale 1 : 12.) Lent by W. H. Holloway, Esq., 1908. N. 2497.

This shows a canoe of medium size as used for trading purposes on the Oils (Niger) and Cross Rivers in Southern Nigeria.

It is of dug-out character, but has a framework amidships which, when covered with matting or palm thatch, forms a shelter for women and children. It is propelled by paddles or a pole, and is chiefly employed in the transport of fruit and vegetables to market or of palm oil and kernels from the interior to the factories.

Its principal dimensions, obtained at Old Calabar, are :—Length, extreme, 33 ft.; breadth, 4 ft.; depth, amidships, 2 ft.

533. Whole model of Lagos fishing canoe. (Scale 1 : 12.) Lent by W. H. Holloway, Esq., 1907. N. 2438.

This native-made model represents a typical fishing canoe as used upon the large lagoons and inland waters of Lagos, West Africa.

These craft are simple dug-outs made from trunks of the fig or the silk-cotton tree; the hollowing-out is performed by burning and by cutting with an adze. The thwarts, platforms, mast-steps and other details are added as required. The ribs of palm-leaves are used for fishing rods and the fibre of the pine-apple for nets and lines.

The canoes are made of sizes to suit the requirements of from one to five persons; they are propelled by sails or paddles and steered by a paddle from the stern.

The dimensions of the boat represented are :—Length, overall, 28 ft.; breadth, 3·5 ft.

534. Whole model of Lagos market boat. (Scale 1 : 18.) Lent by W. H. Holloway, Esq., 1907. N. 2439.

This native-made model represents one of the larger types of boats as used for ferry and general transport purposes upon the lagoons and coastal waters of Lagos, West Africa.

It is an interesting example of the combination of "dug-out" with "built-up" boat construction. The lower part of the hull is of a hollowed tree trunk, while the topsides are raised by strakes of planking; timber knees and floors, about 2 ft. apart, give transverse strength to the structure.

These boats are propelled by sails or paddles—a larger steering paddle being worked from a platform at the stern.

The carrying capabilities of these craft vary from one to four tons (weight) and the dimensions are :—Length, overall, 48 ft.; breadth, 7·5 ft.

535. Rigged model of Nile cargo and ferry boat. (Scale 1 : 12.) Lent by W. H. Holloway, Esq., 1910. N. 2545.

This shows a vessel of somewhat primitive construction used in Upper Egypt and the Sudan, and but seldom found below the first cataract. Particulars for the model were obtained at Korosko, some 100 miles above Assuan.

The boat has a large relative beam and a full midship body tapering gradually to the stern. It is decked over the greater portion of its length and has a special beam amidships to give support to a single mast and lateen yard. The most noteworthy feature of the boat is the entire absence of internal ribs or frames. Some structural compensation for them is obtained by the method of forming the shell: fairly thick and roughly-hewn planking is used, and the butts of each piece are scarfed to those of adjacent pieces so as to form a continuous strake. Each strake is fastened to that immediately below by nails driven at a slight inclination; their heads are housed in small external notches. Some degree of watertightness is obtained by caulking the seams with grass or moss; no paint is used upon these craft. A large built-up rudder with a tiller is used.

It is interesting to note that Herodotus, writing about 250 B.C., describes the Nile cargo boats of his day as being built without ribs and with the planking worked in short thick pieces held together by long bolts.

Length, 25 ft.; breadth, 9·5 ft.

536. Rigged model of Nile fishing boat. (Scale 1 : 12.) Lent by W. H. Holloway, Esq., 1910. N. 2561.

This type of boat is used for fishing on the Lower Nile, below the first cataract; particulars for the model were obtained at Luxor.

In general form it resembles the cargo and ferry boat (No. 535) but differs from it structurally in being strongly framed and planked; it is also smaller, has greater relative beam, and is painted. A large single lateen sail is carried and the vessel is decked, with the exception of a portion amidships; within this open space a heavy beam or thwart is fitted, a square mast is stepped, and two oars are worked.

Dimensions:—Length, 16 ft.; breadth, 7 ft.

537. Rigged model of Nile cargo boat (gyassa). (Scale 1 : 12.) Lent by W. H. Holloway, Esq., 1909. N. 2529.

This represents the native type of cargo vessel used on the waters of the Lower Nile and occasionally in Upper Egypt.

The vessel has full lines with a peculiar upturned and decorated bow and bowsprit. It is framed and decked and has a large central hatchway. No external keel is fitted, thus reducing the draught. There is a large built-up rudder worked by a tiller. The bulwarks are set back all round the vessel, so as to admit of a narrow platform, which is used when poling is necessary. The lightest breeze is taken advantage of by two lofty lateen sails: the foremast is stepped well forward and carries a lateen yard at an angle of about 45 deg., while the mizenmast is right aft, with its yard nearly vertical and a boom lashed to the port quarter for extending the base of the sail. The number and arrangement of masts, spars, and sails is not uniform in boats of the same general type. The small canvas bag, shown suspended aft, is used for the stowage of provisions.

Length, 42 ft.; breadth, 12 ft.

538. Whole models of Lower Egypt fishing boats. (Scale 1 : 12.) Lent by W. H. Holloway, Esq., 1908. N. 2498–9.

These two boats represent examples of native fishing craft as used on the shallow waters of Lower Egypt.

They are of built-up construction, somewhat roughly put together, and watertightness is obtained by a thick coating of pitch on the underwater parts. They are propelled by paddles or a pole, and, being flat-bottomed, are able to float in a very few inches of water.

Their overall dimensions, obtained on Lake Mareotis, are as follows:—Lengths, 9 ft. and 11 ft.; breadth, 3 ft.; depth, at sides, 2 ft.

539. Rigged model of Nile sailing boat. (Scale 1 : 48.) Made and lent by the Rev. A. J. Foster, 1873. N. 1341.

This represents the typical Nile passenger vessel. It is usually built of wood, although recently larger examples have been constructed in steel. The accommodation consists of three single bed cabins, a centre saloon or dining-room, and a stern cabin used as a bed or sitting-room; there are also a bathroom, pantry, etc. The boat has two lateen sails, while oars and poles are also used as occasion may require. The crew consists of a captain, a mate, and from six to eight men.

Length, 96 ft.; breadth, 16 ft.; depth, 4 ft.

540. Rigged model of Egyptian yacht. (Scale 1 : 48.) Presented by the Egyptian Commissioner for the Paris Exhibition of 1867. Plate VI., No. 6. N. 1200.

This is a "dahabeeyah," constructed for the Khedive of Egypt, for use on the Nile. She is fitted with a large lateen sail forward, the yard of which rests on a saddle formed at the masthead, and there is a smaller lateen sail aft. In calms she is propelled by 14 oars, or in shallow water by poles.

Her approximate dimensions were:—Length, 152 ft.; breadth, 27 ft.; depth, 6 ft.

541. Rigged model of Arab dhow or baggala. (Scale 1 : 12.) Presented by J. Zohrab, Esq., 1881. N. 1550.

This is a model made by native craftsmen of the North-East African coast, and although not strictly accurate in some proportions and details, shows many characteristics of this type of vessel.

There are two masts with lateen sails, and the sheet of the large mainsail passes through the stern ports; two stout thwarts secured by horizontal wood knees give the necessary support to the mainmast.

The vessel is grab-built, *i.e.*, it has a long projecting cutwater, or prow head, and possesses considerable beam and a rise of floor which, with a raking bow and stern, combined with great sail area, afford good turning facilities and speed. The shell planking, which is secured to wooden frames, is generally worked in two thicknesses, with a layer of composition between to ensure watertightness and durability.

There is a square or transom stern, with heavy quarter chocks to form an attachment for the upper stern planking; these also form rubbing pieces to protect the overlapping plank-ends. Dunnage, or cargo battens, to keep heavy merchandise clear of the bottom of the ship, are shown nailed to the inside of the frames. There is a poop and forecastle deck, but with no enclosing bulkheads, as in the Bombay "pattamar" (*see* No. 553), a vessel of similar construction.

These dhows are chiefly used for trading purposes between the Red Sea ports and India, making annual voyages with the monsoons, and exchanging native produce for manufactured goods.

The usual dimensions are:—Register, 200 tons; length, 85 ft.; breadth, 21 ft.; depth, 12 ft.

542. Rigged model of Arab trading vessel. (Scale 1 : 16.) Presented by H.M. India Office, 1880. N. 1530.

This decked-boat is known as a "batello"; it has two masts, one raking forward, and both carrying large lateen sails; the tack of the mainsail is secured to a bowsprit. Steering is performed by a peculiar arrangement of yoke-lines to an overhanging rudder.

Register, 29 tons; length, 51·3 ft.; breadth, 10 ft.; depth, 4·6 ft.

543. Whole model of Red Sea dhow canoe. (Scale 1 : 12.) Lent by W. H. Holloway, Esq., 1908. N. 2500.

This represents a form of canoe used as a tender to native dhows in the Red Sea.

These craft have considerable sheer and are of dug-out character, sometimes strengthened by the addition of internal ribs; they usually carry two men and are propelled by paddles.

Their maximum length is about 18 ft. The overall dimensions of the example shown, taken at Port Sudan, are:—Length, 15 ft.; breadth, 2 ft.; depth, amidships, 1·5 ft.

544. Whole model of Madras surf boat (masoolah). (Scale 1 : 12.) Presented by Lieut.-Col. John Hoyes, R.A., 1878. N. 1507.

This is a type used on the Madras coast for conveying passengers and cargo between the shore and the ships in the roads. The surf is frequently from 6 ft. to 10 ft. in height, but owing to the flexibility of these boats they are seldom damaged.

In their construction no frames or thwarts are introduced, but the planks are sewn together over withes of straw; the leakage and the entering surf are kept under by two men who are constantly bailing. The boat is propelled by 12 men using paddles with blades 14 in. long by 10 in. wide, and is steered by one or two men at the stern.

The approximate dimensions are:—Length, 20 ft. to 32 ft.; breadth, 6 ft. to 10 ft.; depth, 4 ft. to 8 ft.

An adjacent sketch shows a similar type of boat in use in Somaliland (East Africa).

545. Rigged model of Maldive outrigger boat. (Scale 1 : 24.) Presented by Count Watson-Höwen, 1881. N. 1547.

This represents a decked vessel of the outrigger type as used for trading purposes by natives of the Maldive Islands; similar craft are also used at Mauritius.

It has considerable breadth and depth in proportion to length, and is of built-up construction, timber of the cocoanut palm being chiefly used. The keel, planking, and decks are held together by an elaborate system of sewing or lashing, while cross-spalls and pillars under the decks add rigidity to the structure. The outrigger poles and cross-spalls pass through the sides of the vessel.

The sail plan is peculiar. On the single mast amidships is carried the usual large fore-and-aft mainsail, but abaft of this is hoisted a small mizen sail at the end of a boom set at about an angle of 40 deg. to the mast. A jib foresail is sometimes added.

Dimensions:—Length, 32 ft.; breadth, 12 ft.; depth, 8 ft.

546. Rigged model of Cingalese outrigger canoe. (Scale 1 : 8.) Presented by T. D. E. Gibson, Esq., 1865. N. 1047.

This type of vessel is largely used in the neighbourhood of Ceylon for fishing, cruising, and similar purposes.

The main hull is of a hollowed tree-trunk, shaped externally to canoe form; above this are lashed washboards or side-planking to give additional freeboard and deck accommodation. The characteristic feature of these craft, however, is an outrigged log of solid timber carried parallel to the hull upon two projecting transverse poles from one side; this adds considerably to the "stiffness" of the vessel under sail, and its effect is often increased by one or more of the crew sitting to the windward side upon the outrigger. The single mast, lashed to one of the outrigger poles, carries an unusually large fore-and-aft sail, and this, with the small hull resistance, makes very high speeds possible in a fresh breeze. The lengths of these craft vary from 20 ft. to 40 ft.

Two other models (scale 1 : 16) of similar vessels are shown:—

(1) Lent by T. F. Dodd, Esq., 1868. (N. 1299.)

(2) Presented by Count Watson-Höwen, 1881. (N. 1546.)

547. Rigged model of Fijian double canoe. (Scale 1 : 8.) Presented by Sir D. Cooper, F.R.G.S., 1872. N. 1335.

This model was made by natives of the Fiji Islands, and it represents their usual form of canoe. There are two narrow hulls, connected together by beams and a deck, on which a hut cabin is frequently erected. A single mast, raking well forward, is provided; through a crutch at the masthead halyards are led, by which a matting sail, fitted with upper and lower yards, is carried. In calms the craft is propelled by paddles.

548. Whole models of Malay vessels. (Scale 1 : 36.) Presented by J. Pybus, Esq., 1868. N. 1197.

These five models represent craft used generally for cargo and ferry purposes in the Malay Archipelago.

The largest example is rigged with two masts and sails, and probably represents a vessel of about 50 ft. in length; she has fine lines with light overhanging platforms at both bow and stern. The provision for carrying two large guns forward suggest that this particular vessel may have been used for piratical purposes.

549. Rigged model of armed Malayan proa. (Scale 1 : 16.) Lent by R. Walters, Esq., 1902. N. 2286.

This represents a swift armed sailing vessel, of a type very generally employed by the pirates of the Malacca Straits and Chinese waters. The model, which shows a combination of Chinese and Malayan design and construction, was made at Hong Kong in 1840, when piracy was very prevalent in the seas and rivers of the district. The vessel has a fine entrance, a sharp run, and shallow floors which, together with a large rudder and the absence of deadwood, suggest speed and handiness combined with but small draught.

A deck with covered hatchways is fitted throughout the length of the vessel; a raised poop provides cabin accommodation, and at the same time makes a working platform for the rudder and after guns. Projecting platforms or galleries at the bow and stern afford additional deck area for the large crew, and also give facilities for boarding operations. Strong stanchions and bulwark rails, covered with canvas, form a wash-strake to the vessel through a greater part of the length, while, outside these, special provision is made for the stowage of shields, pikes, and lances.

There are two pole masts without shrouds or stays, fitted in the model with sails of cotton, but strips of palm leaves sewn together formed the material more generally used. A number of oars or paddles are also provided for propelling the vessel during calms or light winds. The rudder is of the Chinese type, suspended from a windlass so as to be readily lifted when the vessel is beached or in shallow water; it is pierced by several diamond-shaped holes, which are believed to reduce the effort required at the tiller without affecting the steering efficiency.

The armament consists of a heavy stern-chaser with two smooth-bore cannon and six gingals or heavy muskets carried on swivels.

Length, over all, 72 ft.; length of hull, 64 ft.; breadth, 14 ft.; draught, 4·5 ft.

550. Rigged model of Bengalese river boat. (Scale 1 : 24.) Presented by H.M. India Office, 1880. N. 1532.

This represents a "pulwar" used for the conveyance of valuable cargo in inland navigation. It is flat-bottomed, and decked over; oars are carried, and also a mast which spreads a square sail.

Register, 20 tons; length, 56 ft.; breadth, 12 ft.; depth, 6 ft.

551. Rigged model of Bengalese produce boat. (Scale 1 : 12.) Presented by H.M. India Office, 1880. N. 1533.

This is a "malar panshi"; it is carvel-built, with the planks fastened together by iron clamps, and is covered in with matting amidships to protect the cargo. There is a single mast, with square sail and topsail, carried in an elevated tabernacle. The rudder is suspended from ropes stretched between two stanchions, and oars are also carried. The usual dimensions are:—Length, 42 ft.; breadth, 14 ft.; depth, 4·5 ft.

552. Rigged model of Bengalese produce boat. (Scale 1 : 12.) Presented by H.M. India Office, 1880. N. 1531.

This is a broad clincher-built boat, called a "ulak"; the stern is decked over, and the centre covered by mat awnings to protect the cargo. It is fitted with one mast carrying a square sail, also with oars. She has a side rudder of balanced type, suspended by ropes.

Length, 36 ft.; breadth, 14 ft.; depth, 4 ft.

553. Rigged model of "pattamar." (Scale 1 : 24.) Presented by H.M. India Office, 1880. N. 1529.

This form of cargo vessel is chiefly engaged in the coasting trade of Bombay. They have one or two masts and lateen sails; the foremost rakes forward so as to keep the yard clear when it is being hoisted. They are grab-built, and are planked with teak upon jungle-wood frames. Their bottoms are sheathed with 1 in. boards, first covered with a resinous compound as a preservative; some of the smaller vessels of about 60 tons burden are sewed together with coir fibre.

The approximate dimensions of the large class are :—Burden, 200 tons; length, 76 ft.; breadth, 22 ft.; depth, 12 ft.

554. Rigged model of Bombay pleasure boat. (Scale 1 : 12.) Presented by H.R.H. the Duke of Coburg-Gotha, K.G., 1869. Plate VI., No. 7. N. 1315.

This yacht is built on similar lines to those of the Bombay fishing boats, which are the swiftest vessels of that coast, and are said to be able to compete with English yachts. It is clincher-built, decked over, and has a sharp bow with hollow lines; the stern is full and round, and the keel arched in the middle. It has two masts, raking forward and carrying large lateen sails.

Register, 8·8 tons; length, 41 ft.; breadth, 7·25 ft.; depth, 7 ft.

555. Rigged model of Burmese oil-boat. (Scale 1 : 16.) Lent by The Royal United Service Institution, 1903. N. 2322.

This represents a type of river boat peculiar to the Irawadi, upon which it is used principally for the transport in jars of the crude petroleum from Upper Burma.

The vessel is flat-bottomed with full lines throughout, and has the stem and stern posts rising considerably above the main structure. Projecting from the gunwale on each side of the boat is a long platform, about 4 ft. wide, which provides additional stowage for cargo, and also forms a convenient "poling" position for the boatmen who plant their bamboo poles into the river banks and then run the full length of the platforms. Thatched roofs are fitted over the greater portion of the cargo spaces to protect the contents. The rigging and steering arrangements are similar to those described with the adjacent model (No. 556).

Length, extreme, 50 ft.; breadth, without galleries, 7·25 ft.; depth, amidships, 4 ft.

556. Rigged model of Burmese junk. (Scale 1 : 24.) Received 1894. N. 2031.

This construction of vessel is used for carrying passengers and merchandise on the Irawadi river.

The lower portion of the hull is a single hollowed trunk, and from it the frames and planking are carried up. There is a fine entrance and run; the stern rises high above the water and is provided with an elaborately carved bench, from which the steersman controls a large paddle lashed to the port quarter and fitted with a short tiller.

The mast consists of two spars, which run together above the main yard and then form the topmast. The lower ends of these spars are bolted to two posts rising out of the keel piece so as to facilitate unshipping; wooden rungs from one spar of the mast to the other form a ladder for going aloft. The yard is a bamboo, or a line of spliced bamboos, of great length and suspended from the masthead by numerous guys; a rope runs along it, from which the mainsail is suspended by rings like a curtain and is spread both ways from the mast. There is a small topsail similarly arranged. The sails are of common light calico, and the area of the mainsail of a vessel with a yard 65 ft. long was found to be 4,000 sq. ft. From their rig these boats can only sail before the wind, which is, however, generally favourable in ascending the Irawadi; they return with the current.

The capacity of the junks is from 90 to 130 tons burden, and the dimensions of the one represented are:—Length, 66 ft.; breadth, 14 ft.; depth, 9 ft.

557. Whole models of Siamese river craft. (Scale 1 : 12.) Lent by L. H. Pritchard, Esq., 1908. N. 2457–61.

These five native-made models illustrate present-day types of water craft used on the River Menam and its tributaries.

N. 2457 is a house-boat used for pleasure, travelling or trading. There is a cabin or deck-house aft, and also a covered structure amidships under which food, merchandise, etc., are carried. The boat is rowed by four men at the bow, and is steered, by means of a long paddle, from the deck-house. The peculiar tail-shaped post at the stern is shown only when the owner of the craft is on board.

Length, extreme, 30 ft.; breadth, 6 ft.

N. 2458 is a sampan used for ferrying and passenger service generally over the many canals and waterways of Bangkok. It is of "built up" construction, in teak, having an overhanging bow and stern and a flat bottom. It is steered and propelled similarly to a Venetian gondola by means of a single oar lashed to a post near the stern; the passengers usually sit upon the bottom of the boat.

Length, extreme, 18 ft.; breadth, 3·5 ft.

N. 2459 is a travelling shop or market-boat with portable boards or platforms fitted throughout upon which the produce is piled for display. It is propelled gondola fashion, from either end.

Length, extreme, 21 ft.; breadth, 3 ft.

N. 2460 is a type used in the fishing industry and contains a large central well for carrying live fish. It is propelled gondola fashion from either end. Three native implements used for spearing fish are shown.

Length, extreme, 24 ft.; breadth, 3 ft.

N. 2461 is a rice-carrying boat of small dimensions with a semicircular thatched covering amidships. It is propelled gondola fashion from either end, and is typical of the boats used for practically the whole of the rice (paddy) transport of the country.

Length, extreme, 11 ft.; breadth, 3 ft.

558. Water-colour drawings of Chinese river boats. Received 1896. N. 2090.

These fourteen paintings, by native artists, show the different forms of craft in use. The smaller vessels are house boats, and are only occasionally moved, while the larger ones are cargo and passenger vessels, generally propelled by sails.

559. Rigged model of Chinese boat. (Scale 1 : 24.) Presented by the Chinese Commissioners to the Fisheries Exhibition, 1883. N. 1642.

Boats of this kind are in general use in Swatow, for the conveyance of passengers or for fishing. They have one mast carrying a mat sail, and are steered by an oar at the stern, which is used for propulsion when there is no wind.

Length, 27 ft.; breadth, 6 ft.

560. Whole model of Chinese fishing boat. (Scale 1 : 24.) Presented by the Chinese Commissioners to the Fisheries Exhibition, 1883. N. 1633.

This flat-bottomed boat of nearly rectangular form is used in dip-net fishing. It is decked at each end, while the open waist is divided into three compartments.

The large net is suspended from a pair of sheer-legs pivoted in side-cleats at the stern and the whole is raised and lowered manually by a long lever arm.

Length, 36 ft.; breadth, 12 ft.

561. Whole model of Chinese twin boat. (Scale 1 : 24.) Presented by the Chinese Commissioners to the Fisheries Exhibition, 1883. N. 1634.

This arrangement consists of two light boats, each 36 ft. long and 4 ft. beam, secured together. To the outer sides of each are attached boards painted white, which form a shelf 2·5 ft. wide, sloping towards the water. The boats are propelled by a man in the stern of each; on moonlight nights fish leap over the board and fall into the boat.

562. Rigged model of Chinese cargo boat. (Scale 1 : 24.) Presented by the Chinese Commissioners to the Fisheries Exhibition, 1883. N. 1667.

The decks of these boats are left open, mats being spread across to protect the cargo in wet weather; the stern space is reserved for the crew, and when no cargo offers these boats carry passengers. The boats are of light draught, and carry a single mast with a rectangular mat sail.

Length, 40 feet; breadth, 15 ft.

563. Rigged model of Chinese boat. (Scale 1 : 24.) Presented by the Chinese Commissioners to the Fisheries Exhibition, 1883. N. 1659.

This barge-like boat is used for carrying cargo to and from foreign vessels. It is divided into watertight compartments, which are, however, left open above, but are covered with mats during bad weather to protect the merchandise. It is provided with a mast carrying a mat sail, and has also oars. A wooden anchor with single arm is shown in the stern.

Length, 50 ft.; breadth, 12 ft.

564. Whole model of Chinese cargo boat. (Scale 1 : 24.) Presented by the Chinese Commissioners to the Fisheries Exhibition, 1883. N. 1658.

These river passenger boats are called "paper" boats on account of the very thin planking with which they are sheathed. The bow rises high out of the water, and amidships is a large bamboo-mat house, over which is a wooden frame for stowing the oars when not in use. The steering-oar is carried in a revolving wooden spindle supported upon special framing at the stern.

The approximate dimensions are:—Length, 60 ft.; breadth, 12 ft.

565. Rigged model of Chinese junk. (Scale about 1 : 72.) Presented by J. Pybus, Esq., 1868. N. 1196.

This example has three masts, with rectangular mat sails; the masts are made of comparatively large diameter owing to the absence of rigging. The large rudder is suspended by ropes from a windlass under the poop, and further secured by two ropes extending from the lower part of the rudder, under the bottom of the ship, and over the bows to another windlass. The burden of these vessels varies from 1,000 tons downwards.

566. Rigged model of Chinese junk. (Scale 1 : 24.) Presented by the Chinese Commissioners to the Fisheries Exhibition, 1883. N. 1646.

This model represents a passenger and cargo vessel from the province of Swatow.

It closely resembles the "Keying" which arrived in the Thames in 1848 after a passage of 477 days from Canton, *viâ* St. Helena and New York, and was the first junk that reached this country. Her dimensions were as follows :—

Register	800 tons.
Length	160 ft.
Breadth	33 ft.
Depth of hold	16 ft.

She was built of teak and her planks were pinned together with large nails before the ribs were introduced. She had three masts; the mainmast was formed of one pole 90 ft. long and 3·3 ft. diameter at the deck level, but there were no square yards or standing rigging. Each sail consisted of stout matting, ribbed at intervals of 3 ft. by strong bamboo, and was hoisted by a single heavy rope; it is stated that the mainsail weighed nearly 9 tons, and took the crew two hours to hoist.

The rudder, which was estimated to have weighed nearly 8 tons, was hung by two ropes, while two others passed from its lower end under the bottom of the ship to either bow. In deep water it was 12 ft. below the bottom of the vessel; in shallow water it was lifted by means of windlasses and the vessel was steered by a short tiller. When the rudder was down it often required 15 men to work the large tiller.

The junk carried three anchors, made of iron-wood and metal; each weighed about 1·34 tons.

567. Rigged model of Chinese life-boat (Upper Yangtze-Chiang). (Scale 1 : 24.) Lent by Lieut. E. Spicer Simson, R.N., 1909. N. 2508.

This represents a typical "red boat" as stationed at all the more dangerous rapids on the Upper Yangtze. They are under the control of the governments of the adjacent provinces of Hupeh and Szechuan and are used as water-police boats and life-boats.

These craft are stoutly built and are easily manœuvred by a large sweep aft. Their crews are also the best of the well-trained, resourceful men who navigate the dangerous portions of this river. The boats are supposed to be always in readiness to assist distressed vessels in the rapids and are instrumental in saving many lives each year. They are "tracked" up-stream by their crews, some local assistance being obtained at difficult rapids; the tracking hawser is secured to a small bollard at the fore end of the boat. There is usually a crew of five men, who live in the boat.

Length, 34 ft.; breadth, 7·5 ft.; depth, 3·5 ft.

568. Rigged model of Chinese cargo junk (Upper Yangtze-Chiang). (Scale 1 : 57.) Lent by Lieut. E. Spicer Simson, R.N., 1909. N. 2507.

This represents the usual type of house-boat or cargo-junk employed on the Yangtze rapids above Ichang.

The hull is sub-divided by watertight bulkheads, and an elastic cement is used for caulking the external planking so as to ensure a high degree of water-tightness under the severe stresses to which the structure is subjected. Some longitudinal stiffness is provided by three stout rubbing-pieces worked round the vessel just above the water-line.

Owing to dangerous rapids and currents, the progress of these craft up-stream is largely effected by means of gangs of "trackers," or towmen, on the banks. (*See* accompanying photograph.) The large sculls are used for crossing the river, and, to some extent, for coming down stream, 10 to 15 men handling each scull; a long oar at the bow assists the rudder in controlling the vessel in cross-currents. A sail is only used when running before the wind. The towing hawser is of plaited bamboo, and is ordinarily attached to the mast-head, so as to clear rocks or other obstructions; in navigating a rapid, however, it is lowered to the foot of the mast or fastened to one of the cross-timbers on the deck. A junk of the larger size, as shown, is usually accompanied by 30 to 50 trackers, but at the rapids from 100 to 150 additional men are required. The drums, shown on each side of the mast are used for signalling to the trackers when the voice of the pilot cannot be heard; the graduated pole, on the port bow, is used by the pilot for sounding and for fending off the bow where necessary.

The approximate dimensions of the vessel shown are:—Length, 145 ft.; breadth, 30 ft. An average junk carries about 76 tons on a draught of 2·75 ft.

569. Whole model of Chinese oblique-ended junk (Chien-Chiang). (Scale 1 : 24.) Lent by Lieut. E. Spicer Simson, R.N., 1909. N. 2509.

This represents a type of junk specially constructed to navigate one of the rapids of the Chien-Chiang, a tributary of the Yangtze-Chiang.

The flat bow and stern, instead of being built in exact athwartship planes, are set obliquely, the port, or left-hand side, being slightly in advance of the starboard, or right-hand side. This peculiarity is considered advantageous in taking an exceedingly sharp turn, between steep rocky banks, in the rapids. When the vessel enters this portion of the river it is controlled by three large sweeps, one forward and two aft, the ordinary oars being inboard, with the exception of the after one on the port side. Reaching a position where the fast current turns almost at right angles, the boats meet a mass of dead water which, acting against her inclined bow, turns it to port; at the same time the speed of the boat is somewhat checked, thus permitting the on-coming water against the stern to assist in a turning movement which is further augmented by the use of the sweeps. A high bridge is provided to enable the pilot to see above the heavy spray which here rises to a height of from 8 to 10 ft. above the water.

The approximate dimensions of the vessel shown are:—Length, 48 ft.; breadth, 10 ft.; depth, 6 ft. The largest vessels of this type are 80 ft. long and carry about 35 tons.

570. Whole model of Shogun's yacht (17th to 19th century). (Scale 1 : 10.) Presented by The Bureau of Mercantile Marine, Department of Communications, Japan, 1910. N. 2564.

This elaborately fitted and decorated model represents the "Tenchi maru," an armed yacht or state vessel originally built for the Shogun Iyemitsu Tokugawa in 1630, but rebuilt to smaller dimensions in 1831. A similar model is preserved in the Imperial Museum, Tokio.

The main hull shows a flat keel with angular bilges secured together by copper nails or similar fastenings. The long tapering bow terminates in a deep heavily plated ram or stem-piece, while the square, flattened stern shows the usual projecting end-boards and the characteristic opening used for gangway purposes and for housing and working the rudder. Another noteworthy feature of the construction is the protrusion of the tie-beams or horizontal timbers beyond the skin planking.

A single mast with square sail was hoisted when necessary, but the common method of propulsion was by means of a large number of closely-spaced sculls or sweeps each used in a nearly vertical position. To accommodate the scullers the upper deck was extended transversely so as to form an overhanging superstructure, which likewise provided for a commodious state-deck and awnings at a higher level.

Most of the woodwork is coloured with red lacquer. Metal plates, probably representing copper-gilt, are largely used for protective and decorative purposes on the external framing and planking; gold lacquer is used for special decoration. The circular badge of the Tokugawa family is reproduced on most of the hangings and ornamental work.

Iron anchors of the four-armed, grapnel type are carried, and examples are also shown of the primitive armament of bows, spears and matchlocks.

Dimensions (original): Length, 165 ft.; breadth, 54 ft.; depth, 11 ft.; number of sculls, 100.

Dimensions (as shown): Length, 90 ft.; breadth, 18·5 ft.; depth, 6·25 ft.; number of sculls, 76.

571. Rigged model of Japanese trading junk (about 1850). (Scale 1 : 20.) Presented by The Bureau of Mercantile Marine, Department of Communications, Japan, 1910. N. 2565–6.

Prior to 1635 the Japanese appear to have had a number of sea-going merchant vessels, but about this date the Administration prohibited the construction of large ships and limited the merchant marine to small coasting vessels chiefly of the single-masted classes.

This model gives a general representation of a type of cargo and passenger junk common about 1850; its merchant character is indicated by the closed or bound-up tassel hanging from the stem; state or war junks carried an open or spreading tassel (*see* No. 570). There is a heavy mainmast of rectangular section carrying a large square sail with bonnet and open-laced seams; in addition to this there are two square head-sails carried on separate masts right forward. An upturned, open stern shows the usual arrangements for lifting the large built-up rudder. A long central cargo hatchway, with portable covers, extends from mainmast to stern and provides facilities for housing the rudder-head when necessary. The ordinary bulwark framing ends at the small entrance-port abaft the mainmast, and the remainder of the topsides are formed of bamboo matting and framing, which latter also protects a portion of the lower side-planking; the entrance doors slide in vertical grooves. A pitched roof of bamboo construction covers the crew space amidships; abreast of this are large side-ports for stowing the ship's sailing boat or tender, an example of which is shown herewith.

The vessel represented has a capacity of 1,400 koku or about 140 register tons; length, overall, 90 ft.; breadth, 26 ft.; depth, 8·7 ft.; after 1885 no vessels were built of this type exceeding 50 register tons. Junks have now been largely superseded in the coasting trade by schooner-rigged vessels of ordinary construction.

572. Whole models of Japanese fishing craft. Presented by The Bureau of Fisheries, Department of Agriculture and Commerce, Tokio, 1910. N. 2570–84.

These thirteen small models originally formed portion of an exhibit, at the Japan-British Exhibition, illustrating the development of Japanese fishing craft. Each model represents a type of vessel in use for coast fishing at the close of the 19th century. Since 1896, however, the Government has encouraged the adoption of Western methods of shipbuilding and deep-sea fishing. Large fore-and-aft schooners are now engaged in the bonito and cod fisheries while carriers, trawlers and whalers propelled by steam or internal combustion engines are largely used.

The collection may be structurally subdivided into four groups:—(1) Rafts; (2) Dug-outs; (3) Partially built-up vessels; (4) Wholly built-up vessels. The dimensions given are those of an average example.

Rafts.—Of this primitive construction there is one example:—

Catamaran or surf-raft (N. 2570), Tai-wan district.—Used for net-fishing in shallow waters. Bamboo poles are bent, fitted and lashed together, so as to form a raft with tapered sides, upturned ends, and rounded bilges; cross-poles help to preserve the transverse curvature. For propulsion a large square-sail of matting is hoisted; its surface and edges are stiffened by bamboo rods. A rail lashed along each side of the raft, provides facilities for working oars and sail.
Length, 21 ft.

Dug-outs.—Of this class, usually formed of a single tree-trunk, three rigged examples are shown:—

Soriko (N. 2573), Simane district.—This is a sailing canoe with a peculiar broad, upturned bow and a square covered stern.
Length, 28 ft.

Sailing canoe (N. 2574), Okinawa or Liu-kiu Islands.—It has a lofty mast with long narrow sail stretched upon five separate yards or cross-spars.
Length, 28 ft.

Outrigger canoe (N. 2575), Ogasawara or Bonin Islands.—It is a double-ended boat with an outrigged log at about 8 ft. from one side (*see* No. 546). There is a single mast with sprit-sail; weatherly qualities are given by short curved decks at each end.
Length, 30 ft.

Partially built-up vessels.—The lower part of the hull is formed of one or more dug-out logs, and the topsides of strakes of thick planking. There are two examples of these:—

Mochippu (N. 2577), Hokkaido district.—Used in the herring fisheries. This is an open sculling boat of light draught. It has large relative beam, flaring sides and high ends; there is a single stretcher amidships, and no ribs.
Length, 25 ft.

Katzko (N. 2578).—A two-masted vessel carrying standing-lug sails, and also propelled by oars and sculls. It has a closed stern, rounded bilges, raised middle-hatch, and a rubbing-piece worked at the junction of topsides with the dug-out floor; a few ribs and stretchers are fitted.
Length, 30 ft.

Wholly built-up vessels.—The seven examples show most of the characteristic features of Japanese shipbuilding, *i.e.*, long fine entrance and broad open stern; angular bilges; portable decks or hatches; long sculls, made in two loosely-connected parts, which are worked from overhanging stretchers or beams. The overlapping strakes of plank are secured by large iron nails; these nails are indicated by a line of rectangular heads. The unusually wide strakes are formed by nailing together at their edges two or more narrow boards:—

Choro (N. 2576).—This is an open sculling boat with fine lines, high bow and square stern; it is fitted with internal ribs and stretchers.
Length, 20 ft.

Trawler (N. 2579), Ise-wan district.—This is an improved type of vessel rigged as a two-masted schooner; she has an upright stem and a fixed deck throughout with a raised portion aft carrying high bulwarks; it shows hand winches for working the nets.
Length, 40 ft.

Whaler (N. 2580).—This is a fast, easily-manœuvred, strongly-built sculling boat with long projecting stem and decorated sides; it has a fixed deck throughout.
Length, 25 ft.

Drifter (N. 2581).—This is a three-masted vessel of full body carrying a large dipping-lug sail aft and two small lug sails right forward; it has a fixed deck forward and a closed bulwark aft; it shows arrangements for working the rudder and has provision for using sculls.
Length, 35 ft.

Cod-fishing boat (N. 2582).—This is a two-masted vessel with dipping-lug sails and arrangements for working the rudder.
Length, 25 ft.

Oshi-okuri (N. 2583).—Fish carrier of Tokio Bay. It is a single-masted vessel with large square-sail and provision for using sculls.
Length, 30 ft.

Bonito-fishing boat (N. 2584), Kishu district.—This is a two-masted vessel carrying square-sails which are subdivided by open, vertical lacings; live fish for bait are carried in central wells; the model is externally decorated in colours.
Length, 30 ft.

MASTS, YARDS, RIGGING AND SAILS.

Masts and Yards.—As early as B.C. 6000 Egyptian river-boats are represented with a single mast and square sail. At about the commencement of the Christian era vessels with two and three masts appear, while in the 16th century the largest vessels carried four masts. At the present day the most popular types of sailing merchant ships are barque or schooner-rigged with from four to seven masts. In modern merchant steamers, the masts, when retained, are used for signalling or cargo-working purposes, while in warships they are also used as supports for elevated firing or observation platforms.

When ships were small, masts were constructed in one piece; as dimensions increased, it was found impossible to obtain trees large enough, hence recourse was had to masts built up of pieces bound together with rope or iron, while the height was most conveniently obtained by constructing them in two or more lengths. Masts are now usually built of pine, with iron hoops driven on whilst hot or made with hinges and bolted together. On the fore part these hoops are covered by a batten called the rubbing paunch, which prevents spars from catching against their edges.

Top-masts, top-gallant and royal masts are each formed out of single sticks. Bowsprits are, when possible, made out of a single stick or else four principal pieces, the upper and lower or main pieces, and two side fishes, which are dowelled, bolted and hooped together, in the same way as with a built mast. Yards are made of fir; the lower and topsail yards are formed either of one stick or of two pieces joined by scarfing.

Since the general introduction of iron and steel in ship-building all vessels constructed of these materials have their lower masts and yards made from metal plate. The lower masts are made of one, two or three plates, flush jointed; being hollow they form efficient ventilators for the hold of the ship; in war vessels the interior of the masts gives access to the military tops, etc., by a series of foot and hand grips.

Sails.—Sails have been made of materials such as skins and membranes, while with nations that could weave, the fibres of flax, cotton, papyrus, bamboo, and several kinds of grass, have been worked into sheets or mats for such use. For strengthening the edges, where the stresses are concentrated, a binding of hide, rope, or steel wire, has usually been added. The early sails were of the square type, in which a horizontal yard was used to support the upper, and frequently also the lower, edge. These were efficient only for propulsion *with* the wind; to make headway against the direction of prevailing winds, by means of tacking, the "lateen," a triangular sail with inclined yard, was introduced—probably in the Mediterranean Sea—just prior to the Christian era. Large mediæval vessels adopted the lateen sail in combination with square sail and from this period the sprit-sail, stay-sail and other elements of the modern "fore-and-aft" rig were developed.

To reduce the extent of sail exposed when the wind is of exceptional force the total area of canvas is divided into separate sails, each of which can be separately handled, while to render further adjustment possible many sails are provided with some "reefing" arrangement by which portions may be furled. Numerous methods of reefing have been tried in which the sail was wound round the yard in the same way as a window blind is closed upon its roller, but the only arrangement in general vogue requires a number of short pieces of rope called "reefing points" attached to the sail, by which it can be secured to the yard along a line some distance from its lower edge, thus reducing its depth by that amount.

Rigging.—Rigging is divided into two classes—the standing, by which the masts are supported and stayed, and the running, by which the yards and sails are moved and adjusted. In the early sailing ships there was no standing rigging, the masts being unstayed just as with our own small sailing boats; the running rigging was usually of hide or gut. Ropes of twisted vegetable fibre were subsequently introduced, while as the masts were increased in height standing rigging was added to support them, and some of it was converted into rope ladders to assist the crew in reaching the upper sails and tops.

The modern improvements in rigging consist chiefly in the extensive substitution of flexible wire rope and metal rods in place of hemp rope, and in the use of screws for tightening the shrouds instead of the earlier block purchase. The use of winches and other mechanical appliances, often driven by steam or other motive power, has tended to reduce the number of hands formerly necessary for safely working a ship.

573. Portfolio of rigging and sail plans of warships, 18th century. (Scale 1 : 72.) Received 1908. N. 2473.

This portfolio contains rigging and sail plans for (*a*) 1st rate, (*b*) 2nd rate, (*c*) 3rd rate British warships. The names of the ships are not given, but internal evidence shows that they belonged to the period 1705–20.

Details are shown of the masts and spars, the standing and running rigging, the principal sails—including the lateen and sprit sail—and the method of working them. A sheer plan and a body plan (*see* No. 589) of each vessel are also shown.

The portfolio is open to show the 2nd rate.

574. Rigging model of H.M.S. "Ganges." (Scale 1 : 24.) Presented by Capt. H. T. Burgoyne, R.N., 1865. N. 1045.

This was rigged by Capt. Burgoyne, and shows the masts, rigging, and sails of a wooden, two-decked line-of-battle ship of 84 guns. The names of the sails and of the spars are indicated by labels attached to them. The "Ganges" was built at Bombay in 1819–21 from the designs of Sir Robert Seppings. She was last commissioned September 4th, 1857, and paid off May 15th, 1861, being the last sailing line-of-battle ship in H.M. Navy.

Tonnage, 2,285 tons; length, 196·5 ft.; breadth, 52·2 ft.

575. Model of built mast. (Scale 1 : 24.) Presented by the Rev. J. Hardie, 1866. N. 1137.

Lower masts were invariably built up from several timbers, owing to the difficulty experienced in finding a single tree of the necessary size and soundness. The practice reached its highest perfection in the first quarter of the 19th century.

The model shows a design by Mr. R. Blake in which 38 pieces of timber, are introduced, in addition to the cheeks for the trestle-trees.

576. Models of built masts. (Scale 1 : 48.) Presented by J. Scott Tucker, Esq., 1865. N. 1058.

These three methods of building up a mast, for a line-of-battle ship were devised by Mr. Joseph Tucker, surveyor to H.M. Navy, 1813–31. The masts are each in eight or nine pieces, breaking joint and connected by various forms of scarfing and dowelling. The several members are distinctively coloured.

577. Model of mainmast of H.M.S. "Nelson." (Scale 1 : 32.) Lent by James Young, Esq., 1876. N. 1422.

This shows, in considerable detail, a built-up mainmast for a battleship. Seven trees were used in its construction, their timbers being dowelled together and hooped with iron bands driven on at intervals of about 3·3 ft.; in earlier days servings of rope were used in place of such hoops.

The cross-trees rest on trestle-trees, supported by cheeks secured to the mast. The leading particulars are:—Overall length, 127·2 ft.; greatest diameter, 41 in.; least diameter, 30·375 in.; total weight, 26·048 tons; total cost, 993*l.*

578. Model of Blake's fid for masts and bowsprits. (Scale 1 : 12.) Presented by the Rev. J. Hardie, 1866. N. 1100–1.

These three models show an improved fid for portable spars patented by Mr. R. F. S. Blake in 1833. The ordinary fid is an iron cotter passing through the heel of the mast and resting on the trestle-trees; to "strike" the topmast its stays must first be slacked, to allow the mast to be slightly raised before the fid can be removed. Blake's fid obviates this lifting; it is pivoted on a central pin so as to readily house itself within a mortise cut in the heel of the spar; when in position the fid bears upon two metal plates one of which may be easily removed and thus permit the free movement of the upper spar or bowsprit.

This invention was first tried on the bowsprit of H.M. revenue cutter "Badger," and was subsequently extensively adopted in the Royal Navy.

579. Model of cast iron steps for masts. (Scale 1 : 12.) Presented by the Rev. J. Hardie, 1866. N. 1105.

The squared heel of the mast fits into a shoe casting which is secured to the keelson; this arrangement takes the place of the heavy wood framing.

580. Model of Turnbull's topmast. (Scale 1 : 12.) Presented by Messrs. Laurence Hill & Co., 1865. N. 1086.

This shows an arrangement of masts patented in 1864 by Capt. James Turnbull.

The lower mast is of iron, and has a portion of the plating on the after side of its head omitted, so as to receive the heel of the topmast, which is afterwards locked in place by being lowered slightly. The mast cap is either hinged or made of the elongated form shown, to permit the topmast entering in an inclined position; a short wooden block is used as a securing wedge.

581. Model of self-reefing top-sail. (Scale 1 : 12.) Lent by H. D. P. Cunningham, Esq., R.N., 1866. N. 1095.

This method of reefing topsails and top-gallant sails was patented by Mr. Cunningham in 1850. It consists in arrangements by which the sail is automatically wound round its upper yard as this yard is lowered.

In the middle of the yard is a sprocket pulley, round which passes the bight of the halyards, which are of chain; the fixed end of the halyard is secured to the mast, so that the yard, as it is lowered, revolves, and thus winds in the canvas. To provide room for the wheel and halyards, the centre of the sail has an opening in it about the width of a "cloth," and extending from the head to the close reef: the edges of this opening are "roped" similarly to the edges of the sail, and connected by metal stretchers suitably protected. The sail is also fitted with battens, increasing in depth towards their ends so as to insure uniform rolling.

With this arrangement it is unnecessary for men to be sent aloft, except when close reefing is required. The introduction of double topsail yards has, however, greatly reduced the difficulty in working such sails by the ordinary means.

582. Rigged models with flat surface sails. (Scale 1 : 48.) Lent by Lieut. W. Congalton, R.N.R., 1865. N. 1062–3.

The sails are fitted at intervals with horizontal rods extending the full width, and each attached to the mast by a sliding ring, an arrangement similar to that used by the Chinese.

Examples of these sails shown are fitted to:

(*a*) A ship-rigged merchant sailing vessel of five masts and 1,300 tons displacement.

(*b*) A large schooner-rigged screw steamship.

583. Model of proposed deadeyes. (Scale 1 : 16.) Presented by the Rev. J. Hardie, 1866. N. 1109.

This arrangement was introduced by Mr. R. Blake to reduce the obstruction offered by the usual lanyards to the quarter-deck gun fire. The lower deadeyes, instead of being attached directly to the channels, have long rods interposed, so raising them above the gun level.

584. Model of shroud attachment. (Scale 1 : 16.) Presented by the Rev. J. Hardie, 1866. N. 1108.

This shows a plan proposed by Mr. R. Blake for securing shrouds to masts without a lower deadeye. In place of the latter there is a notched rail, fixed to the channels, round which the rope rove through the deadeye is taken.

585. Model of tightening gear for stays. (Scale 1 : 8.) Presented by the Rev. J. Hardie, 1866. N. 1138 and 1157.

In this arrangement by Mr. R. Blake the temporary tail of the stay is provided with ratchet teeth into which a shackle, acting as a pawl, engages. The tightening is performed by a lever which uses these teeth as its fulcrum, and when completed the deadeye lanyard is secured.

586. Slip hooks. Presented by the Rev. J. Hardie, 1866. N. 1102, 1111, and 1145.

These are six examples of slip-hooks, used largely for securing the working gear of sails. The hinged portion of each hook is held either by a shackle or by a forelock which may be respectively thrown back or withdrawn, by means of a lanyard, to give instant release; in one case a spring is fitted to prevent accidental tripping.

587. Model of steel mast construction and fittings. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1778.

This shows the upper portion of a steel lower mast. A strong plate-forging riveted to the sides of the mast forms the "mast-cap," in which the lower end of the topmast is supported. The various cleats, eye-plates, fair-leads, etc., shown in position, are for the attachment of mast stays and other rigging; the mast plating in this vicinity is usually doubled to ensure efficient connections.

A mast of large girth is made up of three plates of equal width and curvature; the edges and butts of these are flush-jointed, the former being secured and stiffened by vertical T-bars and cross stays, as shown by sectional view, and the latter carefully "shifted" so as to avoid lines of lateral weakness.

These steel masts are largely utilised as ventilators; the circular cover shown, supported on light brackets over the open end of the hollow mast, prevents the entrance of water while permitting the free passage of air.

588. Sail reefing gear. Lent by Roger Turner, Esq., 1896. N. 2101.

This arrangement, patented by Mr. Turner in 1896, is intended for use in any rig in which a spanker is used.

The reefing is performed by winding the sail on the boom, which is necessarily of the same diameter throughout. The boom is rotated by a ratchet gear close to the mast, and is carried on a spindle at the end, while the outer end terminates in a spike carrying the plate attached to the topping-lift. The fittings shown are of the size used for an 8-ton yacht, the sail of which, it is stated, can be reefed in 15 secs.

Framed illustrations and instruction sheets accompany the object.

SHIP DESIGN.

Among the earlier shipbuilders great skill and considerable forethought were devoted to the design and construction of the upper portion of the vessel, while the underwater form simply followed practical traditions of very uncertain value. No systematic preliminary planning or arranging of a ship to be constructed appears to have been undertaken till about the 17th century, for Pepys, in 1666, states that Sir Anthony Deane was "the first that hath come to any certainty beforehand of foretelling the draught of water of a ship before she is launched." Early in the 16th century the "top-hamper" was reduced, and during the three following centuries there was no marked change in general design or appearance. A great obstacle to progress was created in 1719 by the English Navy Board, who, satisfied with the performances of existing types of vessels, laid down a fixed scale of dimensions and tonnage for ships of each class, thus leaving no power with the designers of adapting the vessel's displacement to the increasing weight of armament and other changes. This remained in force for nearly a century, until the demonstrated superiority of French vessels of equal rating initiated a greatly improved scale of dimensions. The restrictions of each class to a fixed tonnage, however, still survived till 1831, when Sir W. Symonds became Surveyor of the Navy; he then secured the adoption of designs suited to the special requirements of the period.

Measurement.—For the purpose of estimating the comparative bulk of vessels, or of their relative carrying capacity for the adjustment of shipping dues, tonnage measurements are usually given, those in present use being known as—displacement, gross or net register tonnage.

Displacement tonnage is the total weight of a ship and its equipment in actual tons when floating at any given draught. It is usually calculated for a ship at the "light" and "load" water-lines respectively, and is equivalent to the weight of the volume of water displaced by the hull. Deadweight tonnage is the difference between the displacements at these two extreme draughts.

Gross tonnage is a measure of the total internal capacity of a vessel both below and above the tonnage deck, on the basis of 100 cubic feet of space to a "register ton." The cargo capacity of a vessel is, however, alone subjected to dues, so certain deductions from the gross tonnage are permitted for space occupied by the engine, boiler, crew, etc., the remaining or available space for merchandise, passengers, etc., determining the net register tonnage.

Several rules to compute tonnage in terms of the principal dimensions of a ship were in vogue during the 17th and 18th centuries. The most important of these, known as "builder's old measurement," received legal sanction in 1773, and continued in force until 1835; it was used officially in the Royal Navy until 1872. As it was calculated from the length and breadth, but took no account of depth, it led to the construction of short deep vessels of small nominal tonnage but considerable carrying capacity, which were, however, indifferent sea boats.

In 1836 the new measurement came in force making internal capacity the basis of tonnage, and this, modified in 1854, is now generally applied to all merchant shipping. Displacement tonnage is, however, almost universally adopted for warships.

Form, Resistance, Stability.—Within the last two centuries much successful work has been done by mathematicians and experimenters towards a solution of the problem of designing a ship that should offer the least possible resistance to propulsion and at the same time prove habitable, stable, and best fitted for the purposes required of it.

Bouguer, in 1746, published the first investigations showing the use of the "meta-centre" in determining a vessel's stability. Bernouilli in 1757 and Euler in 1759 also published treatises upon the laws relating to floating bodies, while in 1775 Frederick Chapman made public the results of his long and successful experience, and also simplified the methods of calculation by introducing into this work the use of Simpson's rules for irregular curves.

A Society for the Improvement of Naval Architecture was formed in London in 1791, and this associated itself with Col. Beaufoy's valuable experiments (1793–8) on the resistances of various shaped bodies moving in water.* The founding of a Naval College at Portsmouth in 1806, together with the formation of the Institute of Naval Architects (1860), and the School of Naval Architecture at South Kensington (1864), have done much to encourage the scientific study of ship-structure, including the strength of materials, the strains to which vessels are subjected in a seaway, and the general questions of displacement and stability.

The capsizing of H.M.S. "Captain" at sea in 1870, and of the S.S. "Daphne" on the Clyde in 1883, emphasised the need of careful investigations of stability under every possible condition, and have resulted in more elaborate calculations before launching, supplemented in all new types by experimental verification when equipped.

The important factors accepted at present in the total resistance of a ship are:—(*a*) Skin resistance or friction, depending upon the area and nature of the immersed surface; (*b*) Resistance due to eddy-making, which is usually confined to the stern and can be indefinitely reduced by providing a fine afterbody; (*c*) Resistance due to wave-making, which is chiefly influenced by the relationship between the form and proportion of the vessel and the actual speed.

Skin resistance varies enormously with the roughness of the immersed surface and increases nearly as the square of the speed. For lengths up to 50 feet its mean value diminishes as the length is increased, owing to the motion given to the water

* Robert Fulton, when designing his pioneer steam-boats of a few years later, appears to have been the first to make practical use of these results.

by the leading portions; in the case of a ship the skin friction forms from 40 to 80 per cent. of the total resistance.

Eddy-making is clearly seen round a square-sterned barge; in ordinary ships it causes only about 8 per cent. of the total resistance.

Wave-making is the serious resistance at high speeds, and on account of the curious manner in which it fluctuates with the speed and proportions of a vessel is still the most uncertain quantity. Mr. Scott Russell had suggested certain relationships between the length and speed of ships, but the experimental model system of the late Mr. W. Froude, initiated about 1874, has been the chief means by which this matter has been elucidated. By hauling a model at various speeds through still water in a suitable tank a complete series of reliable resistances is obtained, which, when plotted, show the varying natures of these values, and from these, by deducting the simpler skin resistance, the wave losses are determined. In this way Mr. Froude experimentally proved his law of "corresponding speeds," which states that "at speeds of ship and "model related to one another as the square roots of the length, "the wave-making resistances vary as the displacements."

The wave created by an advancing ship should travel with the vessel and have its crest near the stern, so as to give a forward hydrostatic pressure. When such a ship is forced beyond its suitable speed the waves diverge from the sides and waste themselves in still water at a distance; such a wave is absorbing fresh energy in its renewal, and thus causing an excessive resistance as compared with that at speeds when the wave is utilised.

Although at one time most strongly opposed, Mr. Froude's principle of experimenting has shown itself quite reliable and is now in practical use throughout the shipbuilding world. From the results obtained from models in such tanks it is now easy to predict the resistance of ships of entirely new forms travelling at unprecedented speeds.

Laying off is the operation by which, after the dimensions and shape of a ship have been fully determined and recorded upon drawings, the true size and shape of the various members of the structure are set out upon a level floor. Moulds or templates made to these lines afford the necessary guidance to workmen for fashioning the material and for fixing it in its place when finished. In some small yards where the type of vessel is uniform and the material chiefly wood, the trained eye and judgment of an experienced foreman may dispense with elaborate plans and lines, but with any extended or varied class of work such preliminaries are indispensable for accuracy and rapidity of construction. With the use of iron and steel for shipbuilding purposes, well-prepared plans have become imperative; the lesser scantlings and greater hardness of the material make alterations difficult and expensive, while most of the old "fairing" processes have become impracticable.

589. Portfolio of sheer draughts of warships, 18th century. (Scale 1 : 48.) Received 1908. N. 2472.

This portfolio contains sheer draughts of four 4th-rate British warships (1700–1719).

The sheer draught is the first set of drawings sent to the builder; it provides the necessary information for laying-off to full size the principal framing, and also gives a good external representation of the completed hull. Each sheer draught comprises:—(*a*) A sheer plan or side elevation showing positions of the decks, gun-ports, channels, masts, bow and stern decorations, etc.; (*b*) A stern elevation showing details of the transom framing and the arrangement of after galleries and decorative work; (*c*) A half-breadth plan showing horizontal projections of the top sides, the principal decks, the load water plane and of a number of equidistant level planes in the underwater body. Near this plan are also some rabatted diagonals, showing the true form of a number of planes drawn diagonally in the body plan; they are of considerable value in the "fairing" process and also indicate the lines of heads and heels of frame timbers; (*d*) A body plan showing transverse outlines of the hull taken at a number of equidistant vertical stations; the curves of centres for describing the arcs which form portions of these outlines are also drawn in.

The vessels' names, with particulars taken from the drawing, are:—

Name.	Length on Gun Deck, Feet.	Breadth extreme, Feet.	Tonnage	Guns.	Launched.
"Exeter" - -	147	38·5	950	60	About 1700.
"Strafford" - -	130	35·0	700	52	Plymouth, 1714.
"Winchester" -	130	33·5	700	52	,, 1717.
"Deptford" - -	131	35·25	700	50	Portsmouth, 1719.

The portfolio is open to show the "Winchester."

590. Portfolio of characteristic "lines" of warships, 18th century. (Scale 1 : 48.) Received 1908. N. 2471.

During the first half of the 18th century several attempts were made to standardize the design of the various classes of warships. This portfolio, which was possibly intended for comparison in this respect, contains, superposed, characteristic curves of the 60-gun ships enumerated below, and shows the great diversity of form given to vessels of this class by the master shipwrights of different Royal dockyards. The curves drawn to ordinates from a common base line, represent:—(*a*) Outlines of the transverse midship sections; (*b*) Horizontal projections of the topsides and principal decks; (*c*) Horizontal projections of the load water-plane and of several under-water planes; (*d*) Rabatted diagonals, which show the true lines of intersection with the hull of a number of diagonal planes (*see* No. 589).

The portfolio is open to show the lines of the "Dragon" (1733), "Rippon" (1730), "Tilbury" (1730), "Weymouth" (1733) and "Superbe," the latter, a 56-gun ship captured from the French in 1710, shows generally a finer entrance and run as well as sharper midship floors than the British ships.

The vessels shown on the remaining two sheets are:—"Augusta" (1733), "Canterbury" (1741), "Jersey" (1733), "Kingston" (1736), "Princess Mary" (1737), "Rupert" (1736), "Strafford" (1733), "Worcester" (1733), and "unnamed" (1742).

591. "Laying-off" models. (Scale 1 : 48.) Received 1874. N. 1396.

These half-block models of the fore and after extremities of a wood-built sailing vessel show the principal lines used in the "laying-off" process.

For the purpose of laying-off, *i.e.*, representing details of a vessel's true form upon paper or the scrive-board, the hull is supposed to be cut by three sets of planes parallel to the (*a*) transverse vertical, (*b*) longitudinal vertical, *c*) horizontal planes, respectively; lines of intersection of these planes with the outside surface of the ship are shown upon the models.

The projections of these sections are known as (*a*) square stations, (*b*) bow and buttock lines, (*c*) level lines. (*a*) Appear straight in the sheer and half-breadth plans, and curved in the body plan; (*b*) appear straight in the body and half-breadth and curved in sheer; (*c*) appear straight in body and sheer and curved in half-breadth plan. When (*c*) are parallel to the load water plane of the ship they are termed "water-lines."

Besides the lines mentioned, there are others shown which are used in the operations of fairing, framing, and planking the vessel; such are the "diagonal" and "bearding" lines, also the joints of canted frames at the bow and stern and the rebates of keel, stem, and deadwood.

The "laying-off" process for the midship portions are similar in principle to the above, but are simpler in detail.

592. Whole model of schooner, with flat bottom. (Scale 1 : 36.) Presented by J. Scott Tucker, Esq., 1865. N. 1056.

This represents a design, prepared about 1820, by Mr. J. Tucker for an 18-gun schooner.

The lines are as usual, except that the lower portions of the floors are cut horizontally leaving a deep keel, probably to prevent leeway. Another peculiarity is an outside tiller, worked by a block and tackle from a steering barrel placed athwartship.

593. Whole models with modified "cod's-head and mackerel's tail" lines. (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1220–1.

In the early part of the 19th century it was considered that a seaworthy, comfortable vessel should have a high, wide, and bluff bow, to enable it to carry sail well forward while yet rising high and dry above the sea. The bluff bow, however, was found to have a tendency to make a vessel steer badly. So to counteract this fault the steering was improved by the adoption of an extremely fine run to the stern, this commencing near where the bow terminated, the greatest breadth being much nearer the bow than the middle of the vessel. This fine run was not confined to the lower part of the vessel, so that a great deal of space was lost and the buoyancy and stability of the vessel were affected. These two block models show modifications of this principle obtained by adding a long parallel middle-body.

594. Whole model of a Dutch "galliot." (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1222.

Both bow and stern are extremely bluff, and rise a good deal, thus giving the vessel considerable sheer. Dutch vessels of this form were not designed for speed, but to be able to safely ride out the storms on the shallow and dangerous coasts of Holland, while also possessing ample cargo capacity.

595. Shipbuilders' models. (Scale 1 : 24.) Contributed by John Scott Russell, F.R.S., 1868. N. 1269–75.

After the dimensions and the general shape of a ship have been determined, and the "lines" set out on paper, it is usual to construct a model of the hull to scale, so that its finished appearance can be more clearly realised. The model is also of the greatest use while building the vessel, as from it the dimensions of the plates and planks and the best distribution of the butt joints can be most easily determined. These six examples of yachts or small vessels illustrate two alternative methods of constructing builders' models from given lines.

The usual way of making such a model is, to cut from alternate planks of yellow pine and cedar the horizontal sections or "water-lines" of the vessel, as set out on the drawing; then to glue and dowel these layers together, and finish by paring off the projecting edges. The difference in the colours of the wood assist the eye in following the lines, but any irregularity in figure is still more easily detected by passing the hand along the curved surfaces. To "fair" the curvature near the bow and at the stern the lines shown by longitudinal vertical sections, and known as "bow and buttock lines," are found most convenient; the three whole-block models here shown have their starboard sides built up of such vertical layers.

In several of these models, however, an entirely different system of construction has been followed. The transverse sections at various stations have been cut in thin wood, and these templates have been secured to a central board at the correct intervals. These frames are then connected by thin strips of wood, known as "ribbands," which, being placed fairly close together, indicate the shape of the body.

596. Models illustrating Scott Russell's system of wave-lines. Contributed by John Scott Russell, F.R.S., 1868.
N. 1216–19.

This series of four diagrammatic models was prepared by Mr. Scott Russell to illustrate his theory of ship-resistance, and the form of ship that he advocated and subsequently constructed upon his "wave-line" system.

N. 1216 is a rectangular block representing a floating object, 36 ft. wide, 28 ft. long, and drawing 15 ft. of water. If forced endways, Mr. Russell considered that the body was ploughing a channel of a sectional area of 540 sq. ft., so displacing 15 tons of water for every foot it advanced.

In N. 1217 the ends of the body have been tapered, so as to leave a flat bottom with a wedge-like bow and stern, and vertical end posts. There is no parallel middle body, but Mr. Russell considered that the addition of any length of parallel middle body only increased the resistance to the extent that it affected the skin-friction. The curves of the entrance wedge are on each side two parabolic arcs placed back to back, while those at the after end are cycloidal; the result gives very fine and hollow bows and rather fuller sterns.

In N. 1218 the vertical hollow wedge at the bow is maintained, but the bilges are rounded and, to facilitate the closing in of the water round the stern, the depth at this part is gradually diminished.

N. 1219 shows Mr. Russell's solid of least resistance, when the mid-ship section is elliptical; its form is intended to comply with the following conditions:—

(1) That it shall move the particles of water out of the way just sufficiently to let the largest section pass and no further.

(2) That the particles of water originally at rest should be at rest after the solid has passed.

(3) That the force moving the particles shall be constant, and the least possible.

The solid represented has a length 7 times its greatest breadth, and the proportion of fore body to after is as 7 : 5. The water-lines in the fore-body are sine curves, while those in the after body are cycloidal or trochoidal. Mr. Scott Russell developed several empirical geometrical constructions by which his ship lines could be easily set out.

597. Whole model of double-ended vessel. (Scale 1 : 48.) Contributed by John Scott Russell, F.R.S., 1868. N. 1223.

The bow and stern are of equal length, a design that permits the balancing of the weights in varying circumstances of lading and draught of water more easily than with an excess of length at one end. Mr. Russell constructed several vessels in this manner, with hollow wave-lines at both ends of equal length and width (*see* No. 74). Such hulls were intended for running in either direction.

598. Robertson's solid of least resistance, and a half block model of S.S. "Sir John Lawrence." (Scale 1 : 48.) Lent by Michael Scott, F.R.S., 1876. N. 1429–30.

About 1860 Mr. A. J. Robertson devised this "solid of least resistance," in which the entrance and run are concave, the middle body slightly convex, and the transverse sections circular. From this solid he deduced a form of ship which he patented in 1861, and his lines were adopted to a considerable extent in the "Sir John Lawrence," a screw steamship of about the following dimensions:—Length, load water-line, 200 ft.; beam, 26 ft.; draught, 11 ft. Well-rounded bilges were employed as an approach to the semi-circular sections preferred by Mr. Robertson.

599. Model of a double bulkhead. (Scale 1 : 96.) Presented by Prof. John Taylor, M.D., 1873. N. 1345.

This form of bulkhead for an iron ship was proposed by Dr. Taylor in 1861. The space within it is to be used as a water-ballast tank, and in this way can have its soundness readily tested; it also forms a fireproof bulkhead. This principle has been embodied in the athwart-ship coalbunkers of modern merchant and war-vessels and also in the cofferdam bulkheads of tank steamers.

600. Whole model and lithograph of proposed screw ship. (Scale 1 : 96.) Lent by A. Thomson, Esq., 1871. N. 1373.

This shows a design by Capt. Archibald Thomson for a screw-propelled vessel. On each side of the keel, and close to it, is a channel hollowed out of the floors, both to diminish rolling and also to secure a water lead to the screw, which is placed in the dead-wood as far forward as possible to prevent racing.

A somewhat similar construction, proposed by Mr. Hermann Hirsch, was adopted in the S.S. "Paouting" (*see* No. 601).

601. Block model of the "Hirsch" ship. (Scale 1 : 96.) Lent by Hermann Hirsch, Esq., 1876. N. 1450.

This shows a cargo vessel of the form and lines patented by Mr. Hirsch in 1872.

The peculiarity consists in swelling out the bilges till they reach the keel level, thus leaving two channels along the bottom. From the light water-line to the load water-line the sides flare out, and are then carried up vertically; but these features disappear on each side of the middle third of the length. The objects of these modifications were, to facilitate taking the ground, to increase the dead weight capacity, and to give greater stability.

The proposed vessel was to have been of the following dimensions:—Displacement, 8,221 tons; length, between perps., 450 ft.; breadth, extreme, 60 ft.; depth, moulded, 38 ft.; draught, 20 ft.; area of midship section, 1,091·3 sq. ft.; coefficient of fineness, ·527; metacentric height, 16·15 ft.

In 1873 the S.S. "Paouting" was built on this system, by Messrs. John Elder & Co., to the following dimensions:—Displacement, 1,520 tons; length, between perps., 210 ft.; breadth, 33 ft.; depth, 22·7 ft.; draught, 13·2 ft. On trial, with 800 i.h.p., her speed was 11 knots.

602. Photographs and objects illustrating Froude's method of determining ship resistances. Lent by W. Froude, M.A., F.R.S., 1876. N. 1453.

In 1874, at Chelston Cross near Torquay, the late Mr. Froude commenced his investigations on the resistance of ships by the aid of scale models, drawn through still water at definite velocities, while simultaneously recording their resistances and trim. He also discovered an important law that connects the speed and resistances of a model with the corresponding factors in the actual ship, thus giving the experimental results quantitative values.

The first four photographs show the means employed in preparing the scale model, which is cast in wax and afterwards finished by machine and hand-work to the exact lines of the ship. The other three photographs show the experimental tank, with the means employed for hauling the model and registering its indications.

No. 1 shows a series of adjustable templates, each formed of a thin flexible steel band adjustable by ordinates clamped in a base board; the depth of each template corresponds with the distance apart of the water-line sections, so that the stack of templates gives the appearance of an unfinished builder's model. One of the actual templates is also shown.

No. 2 shows the moulding box in which the wax model is cast, also the the core that is inserted in the mould before running in the wax. The box is 16 ft. long, 2·75 ft. wide, and 22 in. deep; the mould is prepared in clay to a series of fixed cross-sections obtained from No. 1 model. The core is built up on a similar series of sections secured to a base; these are partially planked with laths, then covered with calico and coated with plaster of paris.

Nos. 3 and 4 are views of the machine in which the cast model is cut to correct water-lines. The model is fixed, bottom upwards, to a travelling table resembling that of a planing machine; above the table stretches a framework which carries two revolving cutters rotating on vertical axes, the distance apart of which is automatically controlled, as the table travels, by a template fixed at the side of the machine, and clearly visible in No. 3. The arrangement is a form of profiling machine controlled by the templates previously set to the lines of the drawing. The terraced model thus shaped is finally finished by hand, with spoke-shaves and scrapers, in about three hours. A short length of a paraffin-wax model is also shown, one side being as left by the profiling cutters and the other finished.

No. 5 shows the hauling drum, for winding in the steel wire by which the model is pulled. The engine by which this work is done runs from 150 to 350 revs. per minute under the control of a delicate governor, and the speed of the truck can be varied from 63 to 120 ft. per minute.

Nos. 6 and 7 show the dynamometric truck, from which the model is suspended, and by which its movement is controlled. The truck has four wheels running on rails supported above the tank, and the various recording drums and pencils are arranged above the truck at a convenient height.

Owing to the ease with which models can be constructed and tried, Mr. Froude's system has proved of great value in determining the influence of various proposed alterations in the shape of vessels, and also in estimating the suitabilities of untried designs. Since 1885 similar work has been carried on at the Admiralty tank at Haslar, near Portsmouth, by Mr. R. E. Froude.

603. Diagrams of typical merchant ships. (Scale 1 : 48.) Made by the Admiralty, 1887. N. 1783.

These seven diagrams give longitudinal elevations of two and three-decked, well, raised quarter, awning, spar, anchor, and shelter-decked vessels. The position of the machinery and the cargo spaces, etc., are indicated and the general conditions necessary for classification at Lloyd's are enumerated.

604. Whole models showing bulkhead arrangements. (Scale 1 : 64.) Made by the Admiralty, 1887. N. 1794–5.

These are intended to show experimentally the efficiency of properly constructed and arranged compartments, and the absolute danger of certain other distributions of watertight bulkheads. Glass decks and local filling-plugs are provided so that the behaviour of the vessels, when floating under various conditions, may be readily observed. For the diagrams illustrating these cases, *see* No. 605.

605. Diagrams showing bulkhead arrangements. (Scale 1 : 48.) Made by the Admiralty, 1887. N. 1781–2.

Six of these diagrams show a vessel efficiently subdivided by watertight bulkheads and flooded in various compartments, both with and without a watertight main deck.

Three diagrams show a similar ship inefficiently subdivided and flooded in the bow compartment; the effect on its stability is greater than it would have been if no bulkheads had been introduced. The models illustrating these points are shown in No. 604.

606. Experimental model of water-balance chambers. Lent by the Admiralty, 1885. N. 1688.

These illustrate the effects of an athwartship compartment, partially filled with water, in moderating the rolling of a vessel. Such "water balance" chambers increase the period of roll and lessen the mean angle, so being specially adapted to vessels of considerable natural stability, which in a sea-way have a deep quick roll. They were fitted to most of the battleships of the central citadel type built between 1877–87, but in later vessels deep external bilge keels have been used instead, the space occupied by the chambers and the presence of the loose water being serious objections to the arrangement, while the efficiency of the deep keels has been surprisingly high.

The chamber consists of a closed rectangular tank extending from side to side of the vessel and arranged above the protective deck. In the experiments on H.M.S. "Edinburgh" it was found that 100 tons of balance water reduced the rolling by 30 to 40 per cent. at angles below 10 deg., but that the action diminished with increased roll.

607. "Plating" model of S.S. "Mauretania." (Scale 1 : 48.) Lent by Messrs. Swan, Hunter and Wigham-Richardson, Ltd., 1908. N. 2474.

An important detail in the production of a steel vessel is the ordering of material. To expedite this process as regards the shell or outer plating of the vessel a half-block model is made as soon as the drawings of a new design are available. Such a model should give a correct representation, to scale, of the external form of the hull, and upon it are arranged and drawn the edges, butts, and other details of the plating with sufficient accuracy to ensure the actual dimensions of each plate being obtainable.

The model here shown was prepared and used by Messrs. Swan, Hunter and Wigham-Richardson for ordering the shell plating required in the construction of the turbine steamer "Mauretania" built by them at Wallsend-on-Tyne in 1907 for the Cunard Steamship Co. Besides the general arrangement of plate edges and butts there are here indicated the thickness of each plate, width of seams, details of riveting and extent of local "doubling" in the way of coal and entrance ports, ash-doors, etc. The position and character of the transverse framing of the ship are also shown as well as the various decks, watertight bulkheads, and special "liners."

Length, over all, 790 ft.; breadth, moulded, 87 ft.; depth, moulded, 60·5 ft.; gross register tonnage, 31,940 tons; indicated horse-power, 70,000; speed, 25 knots.

Among the earliest examples of similar models shown in this collection are those prepared, about 1853, for the inner and outer skin-plating of the "Great Eastern."

SHIP CONSTRUCTION.

The simplest form of water-borne vehicle is the raft constructed of logs or brushwood connected into a platform capable of carrying heavy loads on inland streams. This was supplemented by the hollowed or "dug-out" canoe made from a single log, and by canoes formed of bark or skins secured to internal frames, thus leading to the built-up boats in which layers of wood were stitched together and also tied to internal ribs or frames.

The introduction of decked boats and ships is also of unknown antiquity, but it is certain that the ancient Egyptians, Phœnicians, Greeks and Romans used ships capable of carrying heavy merchandise or large bodies of troops, and that these vessels had wooden keels, frames, beams and decks, with shell planking secured by wooden and metal fastenings; they were also fitted with arrangements for rowing, sailing, steering, and anchoring.

Wooden Ships.—The structural details of wood-built vessels are clearly illustrated in numerous sectional models in the collection, while the changes in outward form are seen in the fully-rigged models and the various paintings, prints, etc.

Two of the earliest builders to break away from long established usage and to produce vessels of greater size and speed were the Petts, father and son, who built respectively the "Prince Royal" (1610) and the "Sovereign of the Seas" (1637); they reduced the heavy top-hamper and gave an improved under-water form to their vessels. Subsequently the following improvements in ship construction were introduced:—About 1640, a systematic arrangement of pillars, or vertical supports, from keel to upper deck, was adopted, thus greatly strengthening the body. In 1710 a considerable gain in structural strength and durability was effected by the introduction of "cross-timbers" connecting the lower portions of opposite frames, also a stout wood keelson and transverse "riders" above the floors, together with limber boards to facilitate the drainage of the bottom; copper sheathing was first used in 1761, but as it was found to cause oxidization of the iron bolts, this led to the introduction in 1783 of "metal" for the under-water fastening.

In 1796 a number of small frigates were built by Sir Samuel Bentham with transverse bulkheads which demonstrated the structural value of the arrangement.

With the additional strains, consequent on increased length and heavier armament, came the difficulty of preventing the various portions of a wood-built ship from "working." Diagonal wooden riders and trusses with large wooden knees were adopted, for a time, but the great weight of timber, together with the loss of internal capacity entailed by their use were serious disadvantages, so that from 1827 the use of iron-plate riders and forged iron knees was gradually introduced, and finally became general in large wood-built vessels.

Sir Robert Seppings in 1806–11 introduced "fillings" of solid timber between the transverse frames at the lower part of the ship, and a continuous "shelf" piece and thick "waterway" at the beam ends; these structural improvements, combined with his system of diagonal trussing and bracing of the frame-timbers, did much to resist the severe "hogging" stresses to which a vessel is liable at sea. Shortly afterwards he displaced the heavy "beak" head and square stern by a rounded form of bow and stern, which gave greater strength to the extremities and more efficient gun fire. He likewise simplified the conversion of timber by a method of scarfing and by the fitting of square heels and a coak in place of chocked butts to the timbers of a frame.

Many details of improvements in wood construction, proposed 1806–1855, by Messrs. J. S. Tucker, and R. F. S. Blake of H.M. Dockyards, are shown by a number of contemporary models.

Composite Ships.—After the general adoption of iron ships they showed certain defects that were not found in those built of wood, so with the object of combining the merits of both materials, the "composite" construction was introduced. The greater resistance of a wooden bottom to penetration in case of grounding, and the better facilities it offered for the attachment of an anti-fouling sheathing, led to many attempts towards combining such advantages with the superior strength and lightness of iron framing. Sectional models in the collection show various methods of arranging the outer skin planking and the inner longitudinal and diagonal ties so as to give increased rigidity to the composite structure. In 1867, Lloyd's Committee published Rules and Regulations for the building of composite vessels, and the twenty original drawings prepared to illustrate the most efficient arrangements are exhibited in this section. The composite system has been successfully employed in the construction of sailing vessels and small steamers in the mercantile marine, as well as in the smaller types of warship, but the loosening of bolts and the lack of rigidity has prevented its adoption for large vessels with powerful machinery. When the advantages of a wooden bottom are required in a ship of high engine power the hull is now generally built completely of iron or steel and then sheathed with wood externally.

Iron and Steel.—The superiority of iron over wood for shipbuilding purposes was demonstrated by the experimental vessels constructed by J. Laird of Birkenhead (1829–35), and by the experiences of the "Great Britain" (1843), while the demand for a structure capable of carrying heavy armour and powerful engines resulted in the building of H.M.S. "Warrior" in 1859–61 as an armoured, iron-built, sea-going man-of-war. The methods of framing iron and steel vessels may be arranged into three systems in the order of their introduction—(*a*) transverse; (*b*) longitudinal; (*c*) bracket.

The transverse system carries out the old principles of wood construction, by using closely spaced ribs crossing the keel and held together by longitudinal ties. It was adopted in all the earlier iron vessels, but was very frequently associated with wooden keels, keelsons, topsides, etc. The advantages of the system arise from the simplicity and rapidity with which it can be carried out, the result being that the majority of the largest merchant steamers are so built, unless a cellular bottom is considered necessary.

The longitudinal system consisted in the use of a large number of deep girders, extending fore and aft, combined with widely spaced complete and partial bulkheads. This arrangement left large areas of bottom plating unsupported, but in many respects was well adapted to vessels of great length. The "Great Eastern" (1858), designed by J. Scott Russell, was the finest example of this method of construction, but a number of smaller merchant vessels were afterwards similarly built. Since 1908 the longitudinal principle has been successfully embodied in the "Isherwood" construction of "tank" and ordinary cargo steamers.

The bracket system, first introduced by Sir E. J. Reed in the building of H.M.S. "Bellerophon" (1865), is a combination of the two former systems. The deep continuous longitudinals are retained, but at wider intervals, with short intermediate transverse frames or "brackets" spaced at about 4 ft. apart. These divide the lower portion of the ship into many small compartments or cells, and with the addition of a watertight inner bottom this combination became known as the "cellular" bottom. The economy and strength of the cellular construction had already been shown in the Britannia and Conway tubular bridges, but when incorporated into a vessel's structure it afforded exceptional facilities for carrying water ballast, and gave almost absolute immunity from danger in the event of grounding. This system has since, with slight variations, been almost universally adopted for all large battleships and cruisers, and in a large number of ocean-going merchantmen. Solid plate floors combined with longitudinal frames and stringers form a modification of the bracket system which has also been largely used in the construction of smaller vessels for the Royal Navy and mercantile marine, and for framing the extremities of large warships.

Steel began to be generally used for shipbuilding in 1878, and a series of tests made during 1878–9 at Chatham led to its adoption by the Admiralty. The revival of the ancient mode of attack by ramming, and the increasing demands for high speed, necessitated special structural arrangements at the bow and stern, which led to a further application of steel. Several forms of stem and stern-posts, with their connections, are among the exhibits, from which the great change made possible in this direction by the use of cast steel can be seen by contrasting the simple iron forgings of early vessels with the elaborate stern castings of later constructions.

Armour.—War-vessels are usually protected from gun attack by side and athwartship vertical armour, by horizontal or curved protective decks in the region of the water-line, and by side spaces generally packed with coal. Protection against ram and torpedo attack is largely given by efficient and extensive sub-division of the lower portions of the hull, aided in the latter case by torpedo "defence-nets" suspended outside the ship.

The French warship "La Gloire," completed in 1859, was the earliest sea-going ironclad; she was wood-built, and carried a complete belt of side armour 4·5 in. thick, secured by long bolts to a massive wooden framing 26 in. thick. The British "Warrior" of 1861 was an iron-built vessel with a partial belt of 4·5-in. iron armour, backed with 18 in. of timber and an inner iron skin. At this time many wooden ships also were cut down and fitted with side armour. In 1865, H.M.S. "Bellerophon" was built of iron with a complete belt of 6-in. armour; the "Hercules," in 1868, had 9-in. plates, and the "Dreadnought," of 1875, had 14-in. plates. The power of naval guns, however, increased more rapidly than the resistance of the armour. To provide the thickness necessary for protection, without giving abnormal dimensions to the vessels, the extremities were left comparatively unprotected and the weight so saved expended in a heavily armoured central citadel. This construction of armour-clad vessels reached its maximum in 1881, when H.M.S. "Inflexible" was fitted with side plates of iron 24 in. thick. Compound—iron and steel—armour was in general use until about 1889, and was superseded by the "Harvey," the "Krupp," and other forms of hard-faced steel armour; the increased resistance to penetration offered by these latter has been an important factor in the general reduction of maximum thickness and in the extension of the armoured area. Recent British battleships (1910) have an all-round armoured protection varying from about 11 in. amidships to about 3 in. at bow and stern. In 1897 it was concluded that 14 in. of solid wrought iron armour was equalled by 11 in. of compound, or by 6 or 7 in. of hardened nickel-steel armour. It was found, however, that the new armour required additional supporting, and this has been arranged by the introduction of specially deep web-frames and horizontal girders behind the armour.

The idea of carrying heavy guns in revolving armoured shields or turrets, thus obtaining good protection and a wide range of fire, was first adopted in the Royal Navy on the wood-built "Royal Sovereign" and iron-built "Prince Albert" in 1862. Since 1878, turrets, or their modern development, "barbettes"—with a protective ring of stationary armour—have been used to carry the main armaments of all first-class battleships. Where secondary batteries of large quick-firing guns are adopted, they are usually protected by some form of casemate or armoured redoubt; heavy armour gratings and light splinter-nets are also used to protect openings in the upper decks. Recent naval engagements have demonstrated the necessity for avoiding the use in the interior fittings of a warship of all combustible material.

WOODEN SHIP CONSTRUCTION.

608. Built models of wooden ships. (Scales 1 : 48 and 1 : 24.) Lent by T. Royden, Esq., 1876. N. 1428.

The first represents the framing of a three-masted wooden merchant-ship, with the square stern common at the beginning of the 19th century. The second shows a single-masted vessel. In both cases the frames are open-spaced and built up of two sets of timber.

609. Half block model of stern of a three-decker. (Scale 1 : 24.) Presented by the Rev. J. Hardie, 1866. N. 1123.

This shows the starboard side of the stern of a battleship, arranged according to Mr. R. Blake's proposal for obtaining a right-aft as well as a quarter line of fire.

610. Half block models of sterns of three-deckers. (Scale 1 : 48.) Presented by the Rev. J. Hardie, 1866. N. 1103.

The starboard half shows a proposal by Mr. R. Blake for fitting elliptical stern-galleries to a first-rate man-of-war; the port half shows details of the framing of a similar stern and also a method of working the external planking above the counter to add strength to this arrangement.

611. Model of bows of frigates. (Scale 1 : 24.) Presented by the Rev. J. Hardie, 1866. N. 1127.

The topsides are shown completely planked, while the lower portions illustrate two different dispositions of frame timbers with their temporary fairing battens or harpins. The starboard bow shows the foremost frames canted, snaped at the heels, and stepped into the stem piece. The port side shows the frames worked with their moulding in a fore-and-aft plane, and stepped into the foremost canted frames—a system largely adopted for bluff-bowed vessels.

612. Half block model of sterns of three-deckers. (Scale 1 : 48.) Presented by the Rev. J. Hardie, 1866. N. 1125–6.

The first shows the starboard side of a square-sterned vessel, with some of its vertical stern-timbers stepped into the fashion-piece, and some carried by means of snaped heels the full depth of the stern.

The second is an alternative arrangement, in which by the use of transom-timbers the work is simplified and the loss in timber conversion reduced.

613. Stern model of a three-decker. (Scale 1 : 24.) Presented by the Rev. J. Hardie, 1866. N. 1124.

This shows very completely the above-water stern construction of a first-rate line-of-battle ship of the beginning of the 19th century.

The port side shows the disposition of the frames, ports, wales, and framing of the galleries, while the starboard side shows the finished stern. With this design an all-round fire is obtained.

614. Drawing of framing of H.M.S. "Amethyst." (Scale 1 : 96.) Presented by J. Scott Tucker, Esq., 1865. N. 1048.

This shows the disposition of the port timbers of this 28-gun frigate, in which the frames were continuously bolted together in the manner introduced by Mr. J. Tucker. She was wrecked in Plymouth Sound in 1811, but after being 21 days on the rocks was floated off with unbroken sheer.

615. Block model of sterns of three-deckers (Scale 1 : 48.) Presented by J. Scott Tucker, Esq., 1865. N. 1051.

This shows a design proposed by Mr. J. Tucker in 1808. The starboard half shows the old arrangement of square stern, while the port side represents his slightly curved stern, which allows quarter gun-ports on each deck.

616. Built model of a merchant ship. (Scale 1 : 64.) Lent by Lloyd's Register of British and Foreign Shipping, 1876. N. 1437.

This represents a square-sterned ship pierced for 50 guns, possibly an East Indiaman. Details are given of the amidship, stern, topside and deck framing, of external planking and ribbands and of bowsprit and lower masts.

617. Models of deck and frame fastenings. (Scale 1 : 16 and 1 : 48.) Presented by J. S. Tucker, Esq., 1865. N. 1049–50.

These show proposals by Mr. J. Tucker, Surveyor of the Navy 1813–31, for fastening deck planking from the under side by wood screws. For this purpose overhanging strips are nailed to the beams and screws inserted through the projecting flanges; intermediate binding strips are also worked between each pair of beams.

The smaller scale model, of a portion of the midship framing of a vessel, illustrates a method of shifting the butts of frame-timbers and of securing them together by dowels and metal bolts; it also shows the scarfing of deck-beams, as well as the fastening of deck-planking, on the above system.

618. Model of built-up ship's knee. (Scale 1 : 8.) Presented by the Rev. J. Hardie, 1866. N. 1144.

Owing to the difficulty in obtaining sufficient naturally-bent timber knees, ships were frequently delayed during construction. This design by Mr. R. Blake shows a built-up timber knee of considerable strength. The two portions are connected by a pair of five-tongued tenons secured by pins and stayed with iron straps and bolts. Iron knees, however, displaced all such devices.

619. Models of futtock timbers. (Scale 1 : 6.) Presented by the Rev. J. Hardie, 1866. N. 1116–8 and 1132–3.

These show several of the methods introduced by Mr. R. Blake for forming the curved futtocks of wooden frames from two pieces of straight timber when, as was frequently the case, naturally bent timber was not available. To minimise waste the joint is made in the sharp turn of the ship's bilge; the two pieces are connected either by means of the "chocked butt" joint seen in one model or by scarf joints as shown in two others. Two more show details of the connections, which are secured by bolts and dowels.

620. Models of deck-beam fastenings. (Scales 1 : 8, 1 : 12 and 1 : 16.) Presented by the Rev. J. Hardie, 1866. N. 1112.

These show various methods employed for securing deck-beams to a vessel's frames. They were made between 1806–55 by Mr. R. Blake, master shipwright in H.M. Dockyards.

(*a*) Is an early arrangement in which the beam is supported on clamp strakes to which the wooden knee is bolted; the knee and beam are further secured by iron plate knees on each side, with bolts so distributed as to be in different lines of fibres, an arrangement due to Mr. Roberts, master shipwright.

(*b*) Here a "shelf" takes the place of one clamp strake, the wooden and plate iron knees being replaced by iron lodging and hanging knees.

(*c*) Shows a similar arrangement applied to orlop and lower deck beams, with the addition of Sepping's diagonal trussing.

(*d*) Is the latest and most extensively adopted arrangement. The shelf is lightened by chamfering, and a waterway is added above the beam, while horizontal lugs are provided to take the fastenings of the iron hanging knees.

621. Models of floor timbers. (Scales 1 : 16 and 1 : 8.) Presented by the Rev. J. Hardie, 1866. N. 1119–22, 1131 and 1135.

These illustrate various methods introduced by Mr. R. Blake for forming and fitting floor timbers, *i.e.*, the lower portions of wooden frames.

(*a*) This is a short angular floor as fitted to the finer extremities of the ship. The two arms are formed of a single piece of timber, provision being made at the lower part for fixing two tapering chocks one on each side of the keel; this arrangement obviates the weakness arising from the scoring or cutting away of the floor timber over the keel, the practice otherwise followed. Two of the models show similar floors with the side chocks in position.

(*b*) This is shown in place upon a wooden keel, and represents a floor of similar dimensions to the above, but formed by scarfing two straight pieces across the middle line of the ship.

(*c, d, e*) These show on a reduced scale methods of fitting floor timbers at the wide and flat portions of a vessel. Each complete floor is here composed of two sets of timbers, the joints in each being covered by the sides of the adjacent set. These models also illustrate two methods extensively adopted for securing the heads and heels of timbers, those shown with snaped ends providing for a chocked butt connection, while the other shows a plain butt-and-dowel joint.

(*f*) This is an example of a floor frame bent by mechanical means. The straight timber is rendered flexible by immersion in steam, and the outer ends turned to the required shape, a saw-cut made through the neutral plane of the timber facilitating this process. Through bolts, placed as shown, assist in retaining the curvature thus obtained.

(*g*) This is a portion of a wooden keel, showing the rebate formed to take the lower edges of shell planking, also details of the "letting down" process whereby one-half of the scoring is taken from the floor timbers, and one-half from the upper surface of the keel, thus forming a secure combination without unduly weakening either member.

622. Half block models of bows of three-deckers. (Scale 1 : 48.) Presented by the Rev. J. Hardie, 1866. N. 1128–9.

The first model represents the starboard bow of a first-rate line-of-battle ship of the period 1835–40; this has a total bow fire of 8 guns.

The second shows the port bow of a similar ship of about 1840–50, arranged on Mr. R. Blake's plan to obtain a bow fire of 12 guns.

623. Model of port-lids with inboard fittings. (Scale 1 : 8.) Presented by Rev. J. Hardie, 1866. N. 1107.

This shows a method proposed by Mr. R. Blake for fitting and fastening the upper and lower lids, or shutters, to gun-ports.

Each lid is vertically hinged inboard and both secured, when closed, by cotter pins. A circular gun-aperture in the centre of the port provides ventilation between decks in ordinary weather; this, however, is filled by a solid wooden block in rough weather, and the whole securely held by a central hinged bar.

624. Model of lower deck port. (Scale 1 : 16.) Presented by the Rev. J. Hardie, 1866. N. 1130.

This shows a method of constructing a gun port of a wooden line-of-battle ship. The several eye-bolts are for attaching the tackle used in working the guns.

625. Model of wooden protective belt. (Scale 1 : 20.) Presented by the Rev. J. Hardie, 1866. N. 1134.

This shows a lower deck port and the side of a wooden ship-of-war, fitted with a protective belt along the water-line, as proposed by Mr. R. Blake. The belt has a maximum thickness of 20 in., and tapers in each direction.

626. Model of stern framing of a merchant ship. (Scale 1 : 32.) Lent by the Nelson Dock Co., 1876. N. 1444.

This shows the method of framing the square sterns of the East Indiamen of about 1820.

627. Built models of a wooden ship. (Scale 1 : 48.) Lent by Lloyd's Register of British and Foreign Shipping, 1876. N. 1432–3.

The fore and the after body of a two-decked merchant ship are here shown separately; on the port side of each the inner and outer planking, with fastenings, are complete, while on the starboard side the frames are seen, held together by temporary ribbands. Some of the hanging iron knees are extended to the deck beams below them.

628. Model of midship section of H.M.S. "Rodney" (1833). (Scale 1 : 24.) Presented by F. W. Slade, Esq., 1903. Plate VII., No. 1. N. 2340.

The "Rodney" was originally a two-decked sailing line-of-battle ship of 92 guns, designed by Sir R. Seppings and launched at Pembroke in 1833. The model shows the various decks and the interior of the main hold of the vessel, together with the general arrangements for the stowage of water-tanks and provisions; also the principal features of the system of wooden ship construction followed at the time.

Amongst the structural details represented are some improvements introduced by Sir R. Seppings in 1813–32 while he was Surveyor of the Navy; these include:—

(1) The employment of a system of internal diagonal timber ties, crossing the frames at 45 deg. and fitted between themselves with corresponding struts; the panels thus formed were further stiffened by the insertion of longitudinal timbers, so that the whole arrangement converted the hull into a completed trussed structure. By this construction the requisite strength was obtained with considerably less weight than was necessary in the earlier system with its massive vertical riders and internal planking.

(2) The method of connecting the heads and heels of the timbers composing the transverse frames, by plain butts with circular dowels or plugs instead of by the various methods of scarfing previously in use.

(3) The introduction of thick continuous "waterways" and "shelf-pieces," placed respectively above and below the ends of the deck beams, to secure better connection of the beams with the sides of the vessel and also additional longitudinal strength.

Other details shown are:—The use of forked iron knees to the beams; the arrangement of pillars or stanchions for supporting the decks; and the varying thicknesses adopted for different portions of the external planking. A number of the strakes of planking near the water-line are shown cut on the "anchor-stock" system, which gave an increase of structural strength while reducing the waste in timber conversion. On the orlop deck are shown the hemp anchor cables, used before the introduction of chain cables; the planking of this deck is worked in short pieces between the beams.

The "Rodney" took part in some trials of sailing ships-of-the-line during 1845-6, and proved herself to be superior to her contemporaries in speed and steadiness during rough weather; in 1860 she was converted into an auxiliary screw-ship.

Her original dimensions were:—Burden, 2,626 tons; length, 205·5 ft.; breadth, 54·5 ft.; depth, 23·1 ft.

629. Half model of wooden paddle steamer. (Scale 1 : 48.)
Lent by the Nelson Dock Co., 1876. N. 1443.

This represents the framing of a square-sterned paddle steamer, designed about 1840. On each side of the paddle-wheel position the topsides are given considerable "flare," thus increasing the deck area and weatherly qualities.

630. Longitudinal section of a merchant ship. (Scale 1 : 32.)
Lent by Lloyd's Register of British and Foreign Shipping, 1876. N. 1431.

This is a square-sterned two-decked merchant ship, and has the leading details distinctively labelled. It represents the later form of wooden construction, in which the knees and most of the pillars are of iron. The lower beams are not decked over, except at the forecastle, as they are only introduced to strengthen the hull.

631. Half model of ship with radiating frames. (Scale 1 : 64.)
Lent by Lloyd's Register of British and Foreign Shipping, 1876. N. 1434.

This shows a wooden ship of about 800 tons, with poop deck and forecastle. The frames radiate to a point about amidships, so that while the frames there are vertical, the others incline on both sides more and more as the bow and stern are approached. The inclined frames assist in resisting the shearing stresses.

632. Half model of diagonally-sheathed vessel. (Scale 1 : 48.)
Lent by Lloyd's Register of British and Foreign Shipping, 1876. N. 1435.

This shows a wooden merchant vessel, sheathed with planking laid diagonally at about 45 degs. in one direction at the bow, and with the opposite inclination at the stern, the intermediate triangular space being sheathed vertically.

633. Half midship section of a wooden corvette. (Scale 1 : 24.)
Received 1874. N. 1393.

This represents the midship framing of a frigate, and shows in detail the improved method of wooden construction adopted in H.M. Dockyards after 1840.

Three tiers of deck beams are shown with their shelves and waterways, together with the wrought iron securing knees. Two complete frames, together with the intermediate filling pieces, are represented, and the model shows how, by breaking joint, the continuity of strength is secured. The butts of the timbers are dowelled together, instead of being connected by scarfs or chocks as formerly. Sections of keel and keelson are shown and also portion of the inner and outer planking.

634. Half block model of H.M.S. "Caledonia." (Scale 1 : 48.) Lent by Geo. Turner, Esq., 1864. N. 1036.

This vessel was commenced as a wooden battleship of 91 guns, 3,716 tons and 800 h.p., but before completion was changed to an armoured frigate carrying 36 guns. Several other vessels were similarly converted in 1862–4.

Diagonal iron riders are shown fitted all fore-and-aft outside the framing instead of inside as originally arranged: these gave increased structural strength to the vessel and, by being arched over each gun-port, added local strength to these positions.

The length of the battery was 280 ft., and its armour plates were 4·5 in. thick, backed with 30 in. of oak; the weight of the armour was 930 tons.

Her engines, by Messrs Maudslay, Sons and Field, were of the horizontal return-connecting-rod type, with two cylinders 92 in. diam. by 4 ft. stroke, and when making 57 revs. per min. indicated 4,092 h.p. with 20 lb. boiler pressure.

The screw propeller had four blades, and was 21 ft. diam., while the pitch could be varied from 20 ft. to 25 ft.; it could be disconnected from the engines by means of a clutch. Her trial speed was 13 knots.

Displacement, 5,800 tons: burden, 4,125 tons; length, between perps., 273 ft.; breadth, extreme, 59·2 ft.; draught forward, 23·5 ft.; draught aft, 26·7 ft.; immersed midship section, 1,050 sq. ft.

635. Gunwale of steel boat. Presented by Messrs. R. Napier and Sons, 1867. N. 1185.

This was designed by Vice-Admiral E. P. Halsted, R.N., for the boats of his proposed warships. The boat was to be of steel, but was to have a wooden fender secured by angle irons.

636. Shell planking and framing of motor boats. Lent by James A. Smith, Esq., M.I.N.A., 1906. N. 2424.

Wood, in preference to steel, has been largely adopted for the construction of high-speed motor craft under 50 ft. in length, the principal advantages claimed being less weight and cost, fairer surfaces and better combination of parts.

Five examples are here shown of various methods of forming the outer skins or shells of wood-built boats: they were made to illustrate a paper on "The Design and Construction of High-Speed Motor Boats" read by Mr. James A. Smith before the Institution of Naval Architects in April 1906.

No. 1 shows the ordinary carvel system with bent timbers or frames; this has single planking of mahogany with caulked seams and timbers of rock elm and is used for ordinary types of motor launches where weight is not of the first importance.

No. 2 shows double planking of mahogany without timbers, the outer skin being worked fore-and-aft and the inner skin diagonally; it is used for light dinghies, yachts, and racing launches up to 25 ft. in length.

No. 3 is the same as No. 2, but reinforced by timbers of rock elm. It is commonly used for high-powered racing launches.

No. 4 shows the ribband-carvel system: the single planking is of mahogany with timbers of rock elm, but the edges of the planking are covered on the inside by longitudinal ribbands which are scored over the timbers. It is occasionally used for high-powered motor craft.

No. 5 shows the sewn skin without timbers patented in 1898 by Mr. S. E. Saunders. It may be constructed of two, three, four or more thicknesses, each thickness being worked separately and the whole finally sewn together with copper wire. This makes a strong combination which is easily adaptable to difficult curves and is used for steam and motor launches of all types.

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637. Blake's screw. Presented by the Rev. J. Hardie, 1868. N. 1110.

This is a form of iron eye-bolt, introduced by Mr. R. Blake, for use in temporarily securing harpins and similar timbers to the frames of wooden vessels while under construction. A hole is bored through the harpin and frame, and then this screw inserted, the eye-end facilitating screwing-up. As originally made these screws have their shanks of smaller diameter than the threads, as shown, so that some slight adjustment of the harpin was possible after the screw had been inserted; the modern Blake's screws are, however, parallel throughout. They are made in various lengths, and the diameter varies from ·75 to 1·25 in.

638. Screw auger and dowel-engine. Presented by J. Scott Tucker, Esq., 1865. N. 1055.

These wood-boring tools were introduced by Mr. Joseph Tucker, Surveyor of the Navy, 1813–1831, as improvements on the ordinary shell auger for shipbuilding purposes. They cut a smooth and circular hole which can be accurately plugged, thus minimising the rapid decay that takes place around the treenail and dowel fastenings in wooden ships. So serious became this evil that between 1834–48 treenails in H.M. Navy were almost entirely superseded by copper bolt fastenings.

Preparatory to cutting a hole with either of these tools, it is necessary to bore a small guide or leading hole equal in diameter to the outer stem; the subsequent feeding is given by a thread on the stem that fits the hole. The dowel-engine, which is provided with brass head and adjustable steel blade and cutter, is still largely used for cutting holes to take the wood plugs or dowels fitted over the heads of deck and sheathing bolts on modern steel-built vessels.

COMPOSITE SHIP CONSTRUCTION.

639. Half midship section of a composite ship. Lent by the Nelson Dock Co., 1876. N. 1442.

This represents an experimental vessel, built about 1859, and classed at Lloyd's for 15 years.

Each frame is built up of thin timber with an angle iron on each side, a plan which resembles that patented by Mr. T. Bilbe in 1856. The beams are angle irons, with pieces welded in for connecting with the frames. The outside planking consists of two thicknesses of wood, laid diagonally at right angles to one another, and an outer sheathing arranged horizontally.

640. Midship section of a composite ship. (Scale 1 : 24.) Lent by the Nelson Dock Co., 1876. N. 1441.

This represents a vessel built experimentally and classed at Lloyd's for 11 years.

The main feature of the design consists in the general use of T-iron for frames and beams. The frames have the table of the T inside while the external spaces are packed with wood, another variation on Bilbe's construction of 1856. The keel, keelson, floors, and outer skin are of wood.

641. Model of midship section of a composite ship. (Scale 1 : 18.) Lent by Messrs. Short Bros., 1876. N. 1447.

This represents a vessel of about 400 tons, in which the frames are made of single angle-bars, except at the floors, where there is a reversed angle-bar; the keelson is a single plate girder. Deck, side and bilge stringers of iron are fitted.

642. Model of midship section of composite ship. (Scale 1 : 24.) Lent by Messrs. Short Bros., 1876. N. 1446.

This represents a proposed vessel in which the external plating is arranged between the frames, the plates being flanged on all four sides and bent to the general form of the ship, the webs of the angle-bar frames consequently point outward and external planking is fitted. The deck beams are also angle-bars, while the keel is a partly-intercostal plate.

643. Drawings showing composite ship construction. (Scales, full size, 1 : 6 and 1 : 12.) Lent by Lloyd's Register of British and Foreign Shipping, 1876. N. 1440.

This series of drawings was prepared in 1866 by Mr. H. J. Cornish, of Lloyd's, to illustrate the suggestions made by Lloyd's Committee for the construction and classification of vessels on the composite system, then coming into extended use. The general idea is to brace the transverse frames by outside iron ties or riders before planking; the other details are varied as in iron ships.

Eight drawings show half midship sections of vessels from 100 to 2,500 tons register, with the lower planking of elm.

Five drawings show modifications of the upper deck waterway and bulwark stanchions for vessels of 900 tons register.

Two drawings show respectively inside and outside views of iron sheer and bilge strakes, with the method of connecting the diagonal ties; they also show the outside planking.

Two drawings show various forms of keelson, while a section of the stem and full-size details of the rivets and joints are shown on two others.

644. Drawing of a composite ship. (Scale 1 : 24.) Lent by Lloyd's Registry of British and Foreign Shipping, 1876. N. 1439.

This represents a three-masted sailing vessel of about 1,000 tons register, built to conform with Lloyd's rules of 1866 for composite vessels.

The transverse frames are of reversed angle-bars; outside these is riveted an iron sheer strake 1 in. in breadth for every 6 ft. of the vessel's length and a bilge strake ·66 of the breadth of the sheer strake; both are joined by butt straps between frames. Riveted to the frames between these strakes are diagonal ties or riders, making a structure resembling a diagonal truss. The planking is bolted to these ties and angle-irons, the butts coming midway between adjacent frames, on plates riveted to them.

645. Model of midship section of a composite ship. (Scale 1 : 24.) Lent by Messrs. Short Bros., 1876. N. 1445.

This represents a vessel conforming with the recommendations of Lloyd's Committee of 1866 (*see* No. 643).

The main frames are formed of continuous reversed angle-bars, the alternate ones having reversed angles fitted to the turn of the bilge only; fore-and-aft stringers and diagonal tie-plates bind these together and also the upper-deck beams in the way of mast stresses. The deck beams are of plates, with double angle-bars along the top edges and the keelson is a continuous plate girder.

646. Model of midship section of a composite ship. (Scale 1 : 24.) Lent by Lloyd's Registry of British and Foreign Shipping, 1876. N. 1436.

This illustrates a system of combined wood and iron construction which differs somewhat from that approved by Lloyd's Registry in 1866.

The iron floors, together with the intermediate wood filling-floors, are combined with a wood keel and keelson similarly disposed to those of a wooden-built vessel. Single and double longitudinal angle-bars above the floors, with a closely-fitted wooden ceiling, take the place of side plate-keelsons, bilge keelsons, and bilge strakes; the outer frame angle-bar is cut off at the garboard strake of shell planking. Iron beams, pillars, and deck stringers are fitted, but there is no iron sheer strake. There is a light diagonal bracing riveted inside the frames between the upper and main decks, and also a thin outer sheathing of wood worked diagonally from the level of the main deck beams to the garboard strakes.

647. Models showing planking on composite vessels. (Scales, 1 : 4 and 1 : 12.) Made by the Admiralty, 1887. N. 1769–71.

These represent in detail the usual method of attaching the shell planking to vessels built with iron frames. The planking is in two layers, so disposed that each strake in either layer acts as an edge-strip to strakes in the other, thus providing a good edge connection for both. Each strake of the inner planking is attached to each frame by two bolts, screwed into the outer flange and locked by an internal nut. The outer planking is secured to the inner by through copper bolts, disposed as shown, and clinched upon a brass washer at each end.

(*a*) shows how the butt joints at the ends of the planks are distributed.

(*b*) shows how the edge joints are distributed and fastened.

(*c*) shows in detail the method of making the end joints of the inner planking, by scarfing and connecting them together at a frame. The planks of the outer thickness are plain-butted and secured by two through-bolts on each side of the butt.

For models showing experimental methods of working the outside planking of composite vessels (*see* Nos. 639, 640 and 646).

648. Models of sections of a composite gun vessel. (Scale 1 : 24.) Made by the Admiralty, 1887. N. 1790–1.

A half midship section and a forward longitudinal vertical section are shown of a small composite warship, similar to H.M.S. "Avon," 467 tons displacement, built 1867.

The details of the transverse framing, intercostal keelson, bilge, side and deck stringers, together with the deck and outer bottom planking are represented.

There is no middle-line wooden keel, but a flat keel-plate and a vertical intercostal iron keelson takes its place. There is a "collision" bulkhead carried to the upper deck, and the keelson is shaped to the contour of the bow and connected with the upper deck so as to strengthen the wooden stem.

649. Half block model showing composite ship construction. (Scale 1 : 48.) Lent by Messrs. Robert Duncan & Co., 1876. N. 1426.

This represents the construction of the sailing ships "Napier" (formerly the "James Nicol Fleming") and "Otago," built in 1869 by Messrs. Duncan & Co.

There are two decks, with a poop 54 ft. long and a forecastle 33 ft.

The frames, deck beams, floors and keelsons, are of iron; the longitudinal ties, with cross ties or riders (coloured blue), are to give additional rigidity. Longitudinal black lines show the seams of the wood planking, which is secured to the frames and riders by brass bolts. The keel, stem, sternpost, and rudder are of wood. Yellow metal sheathing was attached to the shell planking.

Length, 207·3 ft.; breadth, 34·5 ft.; depth, 20·25 ft.; gross register, 1,050 tons.

650. Sections showing composite ship construction. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1766–7.

These show, in transverse and side elevations respectively, details of the usual structural arrangements at the lower portions of a composite cruiser for the Royal Navy.

The transverse floors are continuous from bilge to bilge, the vertical keel plates being fitted intercostally. These latter are connected to the reversed frame bars by double continuous angles on their upper edges, and to the floor plates and flat-plate keel by half-staple angles on each side. The wooden keel and the two thicknesses of external planking are secured together and to the steel framing of the ship by means of bolts disposed as shown. A method of fitting false keels in two layers to prevent damage to the main wooden keel and its fastenings in the event of grounding is also illustrated. The longitudinal girders at each side of the middle line are constructed of intercostal plates, secured to the floors and to inner and outer continuous stringer plates by short connecting angle-bars.

651. Half midship section of a composite cruiser. (Scale 1 : 24.) Made by the Admiralty, 1887. N. 1792.

This represents a cruiser similar to H.M.S. "Hyacinth," of 1,420 tons displacement, built 1881–3.

It shows a wood keel, intercostal side and middle-line keelsons, bilge keel, and bilge stringer. A "turtle-back" watertight deck, combined with a longitudinal coal-bunker bulkhead, extends from the outer planking to the upper deck, for the protection of engines and boilers.

With the large increase in size and engine-power of cruisers of the Royal Navy, the composite construction has been generally abandoned in favour of steel-built hulls—wood-sheathed if necessary.

652. Model of a "tabled scarf" joint. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1764.

This is generally used for connecting the timbers composing the keel of a wood or composite vessel.

The "tabling" serves the two-fold purpose of a dowel and of a stop for the caulking; its raised portion is one-half the length and one-third the breadth of the scarf. Vertical through-bolts, carefully clinched in position, bind the two parts of the scarf closely together. The model shows also the rebates on the keel, formed to receive the lower edges of the bottom planking.

653. Model of a "hooked scarf" joint. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1765.

This shows a vertical scarf used to connect the lengths of a wood ribband or harpin.

A small square hole or key-way in the centre receives two keys, one from either side, which when driven tightly in place force the lip ends into recesses on the adjoining pieces. The joint is further secured by treenails or bolts, so that it shall withstand the stresses due to the harpin being bent to the curvature of the ship's side.

IRON AND STEEL SHIP CONSTRUCTION.

654. Model of side of H.M.S. "Warrior," showing armour-plating. (Scale 1 : 24.) Contributed by John Scott Russell, F.R.S., 1868. N. 1268.

This shows the original method proposed for securing the armour to the "Warrior" (1861), the first armoured iron ship. Wherever armour was to be fixed, the shell plating was to be provided externally with vertical and horizontal girders attached to it by angle-irons. Into the rectangular recesses thus formed the armour plates were to be secured.

This idea was abandoned in favour of closely-spaced vertical frames inside the shell plating, leaving a shelf for the 4·5-in. armour and 18-in. wood backing. The armour plates were held in position by flush conical-headed through-bolts secured by nuts inside.

655. Sectional model of a warship. (Scale 1 : 24.) Contributed by H. Caudwell, Esq., 1863. N. 947.

This represents a design for an armoured war-vessel of light draught, patented by Mr. Caudwell in 1863.

A projecting belt of wrought iron near the water-line is provided as a protection against ramming and penetration by shot in this locality. A sloping roof of thin armour gives further protection from gun fire and also prevents "boarding." Apertures in this roof are provided for ventilation and as gun ports, but they are fitted with sliding shutters. Above this protective roof a light temporary promenade deck can be carried.

The United States coast defence ironclads "Dunderberg" and "Onondaga," of 7,060 tons displacement, built during the Civil War of 1861–5, resembled this design in several respects.

656. Midship section of Halsted's warships. (Scale 1 : 24.) Presented by Messrs. R. Napier and Sons, 1867. N. 1178 and 1186.

This shows the internal construction of the combined broadside and turret vessels proposed by Vice-Admiral E. P. Halsted in 1866.

The spar or flying deck has the diagonal trussing patented by Mr. R. Napier. On the upper decks are the turrets, the ship's rail being fitted to hinge overboard when in action. On the main deck, which is 9 ft. high, are the turret communications and supports; also the broadside batteries and a gangway port on each side. The lower deck, which is 7·5 ft. high shows the turret supports and wing passages. The hold is 19 ft. deep, and through it the turret supports are carried down to the double bottom, which is 4 ft. deep. Further details of the turret are given in an adjacent model (*see* No. 711).

The armour belt extends 6 ft. below the water-line and 6 ft. above, with plates 6 in. thick; it has a backing of 6 in. of oak supported by Hughes's patent hollow stringers and an inner skin, giving a total thickness of 18 in. A short length of an actual stringer is shown; the section is similar to that of a bridge rail, but weighs 213 lb. per yard.

657. Fore deck of Halsted's warships. (Scale 1 : 48.) Presented by Messrs. R. Napier and Sons, 1867. N. 1179.

This shows the arrangement made to permit of an end-on fire from the forward turret, and the modifications thereby required in the support of the spar deck.

658. Half midship section of a battleship. (Scale 1 : 24.) Received 1874. N. 1394.

This midship framing of an iron-built armoured battleship of the "Minotaur" class illustrates a transition stage in iron ship-construction during the period 1861–5. Here, the lightened-plate frames, partly intercostal and partly continuous, foreshadow the modern "bracket" frames: the longitudinals are continuous. There is a watertight floor to the boiler-room space, but no inner-bottom plating is fitted and no complete cellular sub-division is attempted. A reduction in the ordinary spacing of the transverse framing was made at intervals so as to permit a pair of frames to form the sides of each broadside gun-port. No special framing to support the armoured side is shown. The influence of wood traditions is evidenced by the rough-tree bulwark stanchions; these were subsequently displaced by the lighter and more economical iron-built combination of topsides and hammock berthing.

A comparison with No. 659 will emphasize the many improvements in constructional details.

659. Half midship section of H.M.S. "Bellerophon." (Scale 1 : 24.) Made by the Admiralty, 1887. N. 1784.

This vessel was constructed of iron at Chatham in 1865 from the designs of Sir E. J. Reed: she is 300 ft. in length, 56 ft. in breadth, and 7,550 tons displacement. In general structural features the "Bellerophon" shows an advance in all preceding iron-built war-vessels. The "bracket" system of framing and also the complete cellular double-bottom for two-thirds the length amidships were here successfully introduced; these features have been retained, with slight modifications, in recent practice. Each bracket-frame is formed of two small end-plates joined by short unforged frame-bars at top and bottom and provided with short vertical bars at each end for connection with adjacent longitudinals: this displaced the earlier single-plate frame with joggled and stapled angle-bar connections. Weight and cost were thus considerably reduced by the new system.

Another important improvement was made by increasing the vertical depth of all bottom framing. This added to structural strength and gave easier access for cleaning and painting the enclosed compartments; it likewise provided extended facilities for the use of water-ballast.

Her armour is of wrought iron 6 in. thick, and it extends from 5 ft. below the water-line to 15 ft. above, while amidships it is carried upwards to the spar deck, so that it shields all of the guns. This model also illustrates an early method of stiffening the framing of the vessel behind the armour by means of longitudinal girders, a departure that eventually developed the deep web-frames with intercostal girders, afterwards adopted in battleships. In subsequent vessels, owing to the increased penetration of gun fire, this large area of broadside armour could not be carried, and the thicker protection necessary was arranged as a narrower belt about the water-line and around the vital portions of the ship (*see* Nos. 664 and 668).

A water-colour drawing of this vessel under sail is shown in the Ship Gallery (No. 91) and additional particulars are given on the descriptive label.

660. Attachments for sheathing. Presented by T. B. Daft, Esq., 1864–5. N. 1038.

These three specimens show means of protecting iron ships from fouling by attaching sheathing of some other metal, at the same time avoiding the rapid destruction of the iron skin through electrolytic action.

The first specimen shows a modification of methods patented in 1859–60. The iron skin is drilled with small holes which almost penetrate it, and into these plugs of vulcanite are driven. The yellow metal sheathing, ·04 in. thick, is insulated from the skin by a layer of felt and rubber, and is attached by nails driven into the vulcanite plugs.

The second specimen has zinc sheathing ·045 in. thick fixed in the same way, except that no insulating sheeting is inserted. The galvanic action oxidises the zinc and causes it to flake off, carrying the barnacles with it.

A third specimen with drawing shows Mr. Daft's last patent of 1863. The butts and edges of the shell plates are kept apart a distance of ·5 in. and covered by internal straps; into these open joints teak or vulcanite is fitted and caulked, the plates being left rough from the shears or else bevelled. The zinc sheathing is nailed on through these strips.

661. Half midship section of a sheathed corvette. (Scale 1 : 24.) Made by the Admiralty, 1887. N. 1793.

This represents the framing of an iron-built unarmoured war-vessel similar to H.M.S. "Inconstant," of 1868. Two thicknesses of wooden sheathing are attached to the outside plating.

The transverse framing consists of deep intercostal floor-plates, alternated with shallow frames of reversed angle-bars continuous through the keel and longitudinals. The vertical keel and all longitudinal frames have also their lower portions intercostal and upper portions continuous throughout the ship.

The external planking, though greatly stiffening the shell plating of the vessel, is chiefly for the purpose of securing the copper sheathing, the anti-fouling properties of which enable this class of ship to make lengthened cruises in foreign waters without necessitating "dry docking" and cleaning. (*See* No 662.)

662. Sections showing wooden sheathing. (Scales 1 : 4 and 1 : 12.) Made by the Admiralty, 1887. N. 1772–5.

These show portions of the outside planking, plating, and framing of a steel vessel, sheathed with wood in one or two thicknesses.

The bolts securing the wooden planking to the hull are disposed as shown, and they are screwed into the skin plating until their heads are well below the surface of the exterior plank; a wooden plug is then fitted over the head and a nut and washer are added inside the ship. The practice of fastening both thicknesses of plank by means of through-bolts is not universal, the outer thickness in many vessels being secured to the inner thickness of plank by wood screws of naval brass.

The primary purpose of planking outside the steel hull is to give an efficient attachment to thin copper sheathing, the poisonous properties of the salts formed by which, in sea water, make it a valuable under-water covering to vessels, particularly if designed for lengthened cruises abroad. Copper and steel when in metallic connection in the same water produce an electrolytic action that injuriously affects the hull of the ship, and as a special precaution against accidental contacts a double thickness of plank was fitted as shown. Recent tests, however, having demonstrated that metallic contact might exist even under these circumstances, a return has been made to the original practice of a well-caulked single thickness of planking.

For illustrations of proposed methods for securing zinc and brass, as anti-fouling sheathing, to the hulls of iron ships, *see* Nos. 660 and 663.

663. Model of attachment for sheathing. (Scale 1 : 6.) Lent by Messrs. Hooper and Nickson, 1870. N. 1322.

This method of fixing metal sheathing to iron ships was patented by Messrs. Hooper and Nickson in 1869.

Iron eye-bolts are first riveted or screwed through the iron skin; then planking is fitted over these bolts and secured by pins, driven in the thickness of the wood and each passing through one of the eyes. This planking is given a coat of preservative paint and then covered by nailing upon it usual brass sheathing, care being taken that the nails do not touch the iron skin or the bolts.

664. Half midship section of a battleship. (Scale 1 : 24.) Made by the Admiralty, 1887. N. 1785.

This represents the midship framing of a central citadel battleship of the "Collingwood" class, 1882.

The combination here shown of continuous longitudinal frames with short transverse "brackets" between, has been generally adopted for the construction and sub-division of the cellular bottoms of warships since 1865; the modifications since introduced being mainly for the purpose of securing greater rigidity. The model shows also the arrangement of the shell plating, topside framing, armour-shelf, armour, and wood backing, as well as the general construction of—(*a*) the transverse watertight bulkhead, (*b*) the fore-and-aft, middle-line watertight bulkhead, (*c*) the fore-and-aft, wing watertight bulkhead.

In later vessels, longitudinal coal-bunker bulkheads were fitted, thus giving the extra protection afforded by about 10 ft. of coal around the boilers and engines (*see* No. 667).

665. Half section of a battleship. (Scale 1 : 24.) Made by the Admiralty, 1887. N. 1786.

This section, taken either before or abaft the double-bottom, shows the general construction of the unarmoured ends of the central-citadel battleship of the "Collingwood" class, 1882.

Continuous Z-bar frames, extending from vertical keel to lower deck, take the place of the bracket-framing used amidships. The positions, and details of connections, of the longitudinal girders and bulkheads, also of the lower, protective, main, and upper decks are shown.

666. Section of bow framing of a battleship. (Section 1 : 24.) Made by the Admiralty, 1887. N. 1789.

This is a longitudinal, middle-line section of the fore end of a battleship of the "Admiral" class, 1882.

The stem piece is a solid forging (*see* No. 695) with a projecting spur or ram, and is supported against the severe stresses to which it may be subjected by: (*a*) the abutments of main and upper decks; (*b*) the horizontal frames or breast-hooks, six in number; (*c*) the horizontal ram plate 5 in. thick, riveted to the protective deck, and projecting outside the general surface of shell plating, to which it is secured by stout angle-bars inside and outside the ship; (*d*) the vertical armour plate, 2 in. thick, riveted to the stem and to the bottom plating on each side.

To prevent the fouling of anchors, the angular spaces between the ram plate and the bow plating are filled with wood and protected by thin steel plates.

The model also shows a "collision" bulkhead extending from the vertical keel to the upper deck across the vessel. All water gaining access below or between any of the horizontal platforms is by this means confined to the cellular spaces before this watertight screen. In some later vessels these spaces were tightly packed with cork, which gave some elasticity and also prevented the entrance of any considerable weight of water.

667. Half midship section of H.M.S. "Royal Sovereign." (Scale 1 : 24.) Made by the Admiralty, 1893. Plate VII., No. 2. N. 2016.

This shows the structural arrangements amidships of the "R" class of battleship.

The flat keel is built up of two thicknesses of steel plates, and upon this is secured by angle-bars a vertical keel plate, to which is attached the main transverse framing of the ship. These plate frames are of steel, generally ·375 in. thick: they are about 5 ft. deep at the centre line of the ship, decreasing to about 2·5 ft. at the bilge, and again increasing to about 3·5 ft. below the armour shelf: at intervals of 24 ft. watertight frames are employed. The longitudinal framing of the ship consists of six continuous fore-and-aft plate girders. The lower portion of the hull is rendered cellular by the addition of a watertight inner-bottom of steel reaching to the third longitudinal girder on each side.

The first longitudinal girder, or armour shelf, is 6 ft. wide amidships, and upon it rest the heavy transverse plate frames, about 4·5 ft. wide, which, combined with longitudinal intercostal girders, support the 18-in. steel armour plates. The shell of the ship behind the vertical armour is formed of two thicknesses of steel plate, and to this a teak backing is bolted. Horizontal protection is given by a steel deck, formed of two thicknesses of 1·5-in. plates, which is secured to the top of the armour belt by tap bolts.

An important feature in this type of vessel is the secondary armour plating, 5 in. thick and 6 ft. deep, which extends for a length of 150 ft. amidships and gives with the primary armour a protected freeboard 9·5 ft. high. The machinery and vitals of the ship are further protected by coal spaces above and below the 3-in. protective deck.

At the level of the top of the secondary belt is the main deck, which extends unbroken for the whole length of the ship, and upon which the officers and men are berthed. On this deck are placed four of the ten 6-in. guns which form the principal part of the secondary armament of the ship.

668. Sections of armoured side of H.M.S. "Royal Sovereign." (Scales 1 : 8 and 1 : 12.) Made by the Admiralty, 1893. N. 2016.

These show in detail the principal protective arrangements adopted in the nine battleships of the "Royal Sovereign" class built 1890–4.

The lower belt of side armour extends for two-thirds the vessel's length amidships and is terminated by transverse armour bulkheads; it is 8·5 ft. in width (5 ft. below water-line and 3·5 ft. above) and has 18-in. maximum thickness. It is of the "compound" type, *i.e.*, the outer face of hardened steel and the inner portion of softer and more ductile material to obviate the whole plate cracking under the impact of projectiles. Each plate weighs about 30 tons and is fastened by bolts—5·5 in. diam. and 2·7 ft. long—screwed into the back of the plate and thus avoiding the drilling of the hardened face. Details of these bolts are shown; a long steel sleeve passes over the inner end and bears against the 1-in. skin plating; outside of this are two plate washers with india-rubber between them, forming an elastic bed upon which the securing nut is screwed.

The upper belt of 5-in. armour extends over nearly one-half the amidships length of the ship and is 6 ft. in width.

Between the two armour belts is the 3-in. horizontal deck-plating, worked in two thicknesses; this affords additional protection to machinery spaces and magazines from gun-fire and the splintering of explosive shells. Upon this deck is also fitted a cofferdam, or double-bulkhead, to prevent the rapid spreading of loose water to the central hatchways.

669. Half midship section of an iron ship. (Scale 1 : 16.) Lent by Lloyd's Register of British and Foreign Shipping, 1876. N. 1438.

This represents a typical iron-built merchant vessel of about 2,000 tons register, conforming with Lloyd's rules for the highest class.

The keel is a vertical solid bar; the keelson a plate girder above the floors and carrying the heels of the pillars. The frames are of two angle-bars reversed, while the beams are of bulb-bars with two angle-bars riveted to them. The shell plating is in longitudinal strakes alternately raised and sunken. Details are shown of a watertight bulkhead, of bilge and side-stringers and of tie-plates to the deck beams. Further information is given by a drawing on the wall.

670. Half midship section of a merchant vessel. (Scale 1 : 12.) Made by the Admiralty, 1887. N. 1743.

This shows the framing of a large merchantman fitted with a bar keel, a deep middle-line keelson, and three tiers of beams.

It shows a complete transverse frame, built on the reversed angle-bar and solid floor-plate system, with details of the connections to shell plating, decks, side and bilge keelsons, also to the stringers in the hold.

671. Midship sections of merchant vessel with cellular bottom. (Scale 1 : 12.) Made by the Admiralty, 1887. N. 1744–5.

These show a merchant ship of moderate dimensions, built with a double bottom and a centre-through-plate keel.

The portion of double-bottom space shown in the completed section includes a typical transverse frame formed upon the "bracket" system, each part between the continuous longitudinal girders being built up of short plates and angle bars. This model shows also the construction of a strong web-frame fitted above the "margin" plate or outside boundary of the cellular bottom. It consists of a vertical plate or web, stiffened by double angle-bars on the inner edge, and supported by side stringers and diamond plates. Such frames take the place of the ordinary frames and compensate for the loss of deck beams in the way of the hold and machinery spaces.

The other model shows a section of the double-bottom space at a position intermediate to that described above. Here the upper frame bar is worked intercostally, while the lower frame extends continuously from the margin plates across the keel, piercing the longitudinal girders but giving transverse support to the shell plating.

Both of these sections are taken at non-watertight stations. To subdivide the double bottom into the requisite number of cells, transverse and longitudinal watertight frames are fitted at intervals of from four to eight frame-spaces apart. Each bracket composing the former has a solid web and is connected by closely-spaced rivets to the inner and outer skins and to the adjoining longitudinals. Solid plate frames, lightened by means of manholes, are introduced to give increased rigidity beneath the engines and boilers in all ships, and also beneath the barbettes and heavy armament in war-vessels.

The Admiralty system of "bracket" framing and watertight frames is shown in Nos. 677–80.

672. Model of bow and stern framing of a merchant vessel. (Scale 1 : 24.) Made by the Admiralty, 1887. N. 1787.

These are sectional elevations of the extremities of a single screw steel-built merchant ship of the largest type.

In the fore part is shown the collision bulkhead, extending from keel to upper deck, together with the watertight decks and flats for localising the effects of damage to this end of the vessel. The full details are shown of the ordinary transverse frames and of the specially deep transverse floors, which, in conjunction with the "panting stringers" (shown longitudinally between decks), are fitted to stiffen the shell plating of ships with these long fine bows.

In the after part similar details of construction are shown, together with the method of framing and plating the hull in the neighbourhood of the single propeller shaft.

The rudder with its attachments to the stern frame is also represented. This stern post is of the forged solid-bar type, as is also the stern post; the modified sections obtainable when steel castings are used are shown in several other models.

673. Model of "turret-deck" vessel. (Scale 1 : 24.) Made in the Museum, from particulars supplied by Messrs. W. Doxford and Sons, 1900. Plate VII., No. 3. N. 2183.

This sectional model shows in detail the midship length of a cargo steamer of the "turret-deck" type patented in 1891 by Mr. C. D. Doxford. The ship represented, moreover, besides differing in its above-water form from the usual "tramp" steamer, exhibits several interesting innovations in shipbuilding practice introduced to secure strength while economising labour and materials.

The leading detail in the construction is the general adoption of the Bell-Rockliffe system of "joggle" plating, patented in 1887, whereby the use of "liners," or packing pieces, between the frames and the plating is avoided, and a direct saving in the weight of hull effected. This system has now been followed to some extent in the plating of ordinary merchant vessels and in modern warships, the edges of the plates being either pressed to the required form, or rolled in a special machine patented by Mr. C. D. Doxford in 1894 and shown in an adjacent photograph.

Another detail in which the construction differs from general practice is in the use of "plate flanges," instead of rolled sections, for stiffening the main watertight bulkheads and for connecting the framing of the cellular bottom.

For the main transverse framing of the ship, "Z" sections are used throughout, with bulb angle-bars forming the upper parts: the curvature of this "harbour"-deck framing, in conjunction with the thick shell-plating, offers considerable resistance to the stresses to which this portion of a ship is subjected in a sea-way. At intervals of about 20 ft. throughout the vessel, specially strong transverse frames are fitted— as shown at the end of the hatchways; these frames are connected at the height of the harbour-deck by athwartship beams of double channel-bar supported by pillars of similar construction.

The lower, or "tween," deck is intermediately supported by a combination of fore-and-aft girders and widely-spaced pillars, so arranged as not to seriously interfere with the stowage of cargo. These, together with a portion of a large cargo hatch fitted with "shifting" beams, are shown on each deck, and the model also indicates the construction of the "hold" below.

The upper or weather deck of an ordinary merchant steamer is replaced in the "turret" type by the harbour deck, from the central portion of which rises a narrower section, or "turret," extending the full length of the vessel and supporting the working platform of the ship. The constructive value of the whole turret-erection is, that it forms an integral part of the ship in a position in which the material possesses great efficiency in resisting the hogging and sagging stresses; at the same time the interior acts as a "feeder" for bulk or grain cargoes, in a similar way to Price's self-trimming hatchways (*see* No. 722).

Like the "whaleback" steamer, so successfully adopted as a freight carrier on the American lakes, the "turret" vessel has some advantages in construction and registration over a vessel of the ordinary type, arising from the absence of sheer and the reduced deadweight of the hull, while being moreover suited for ocean navigation.

674. Model of "tank" steamer "Paul Paix." (Scale 1 : 24.) Lent by Messrs. R. Craggs and Sons, Ltd., 1909. N. 2516.

This represents a portion of the midship section of an oil-carrying steamer built by Messrs. R. Craggs and Sons at Middlesboro' in 1908 upon a system of construction introduced by Mr. J. W. Isherwood.

The value of longitudinal framing in iron ships was demonstrated as early as 1834 by Mr. J. Scott Russell, who built a small steamer entirely without transverse frames—a number of fore-and-aft stringers, riveted internally along the plate edges, supplying all necessary structural strength;

the famous "Great Eastern," completed in 1859, likewise embodied this principle (*see* models and drawings in Ship Gallery). Since this time several attempts have been made to give longitudinal frames a more important place in shipbuilding, but with no great practical success.

The "Isherwood" system re-arranges on this principle the material used for the main framing of a ship. The ordinary closely-spaced transverse frames and beams are supplanted by closely-spaced longitudinal frames at the bottom, sides and decks, while the necessary transverse strength is supplied by widely-spaced plate girders or frames extending completely round the inside of the hull; an efficient spacing of the latter has been found to be 12 to 16 ft., and of the former 27 to 29 in. By this new disposition of framing, it is claimed, all structural requirements are met with less weight of material. Other advantages claimed are :—Greater simplicity in preparing and erecting the constructional parts; less liability to serious damage by collision; easier accessibility for maintenance and repair; increased hold space, in ordinary cargo steamers, owing to fewer beam knees and bilge brackets.

In a modern oil-carrying steamer, the numerous "tank" bulkheads necessary give a natural increase of transverse strength, and hence somewhat simplify the adoption of this system; two transverse plate-frames only are in this case required between consecutive bulkheads. As shown by the model, these plate-frames are divided by the centre-line bulkhead, a complete half-frame being fitted on each side. Following the usual practice in vessels of this type, all longitudinal framing is cut off at each oil-tight bulkhead, and the continuity of strength maintained by gusset or corner plates (*see* No. 300). In the "Paul Paix" the bulb-angle framing at the sides connect with the horizontal stiffeners of the bulkhead, and both the framing and stiffeners increase in dimensions with their depth below the water-line; each transverse bulkhead is further supported by vertical web-stiffeners worked on the opposite side to the horizontal stiffeners. Each strong transverse frame is built up of ·45-in. plating and varies in depth from 20 in. to 39 in.; the plating of decks and sides is ·5 in. thick. The principal scantlings have been approved by Lloyd's Register, Bureau Veritas, and the British Corporation.

The "Paul Paix" is of the single-deck type with a continuous expansion-trunk above her main cargo spaces. She has a dead-weight capacity of 6,200 tons, and can load to full draught with light motor spirit, which is carried in 16 separate tanks. Oil fuel is carried in double-bottom compartments.

The principal particulars of the vessel are :—Gross register, 4,196 tons; length, extreme, 367 ft.; breadth, 49·4 ft.; depth, moulded, 28 ft.

At the present time (1910) the "Isherwood" system has been adopted in about 45 vessels, built or building. Adjacent photographs show details of the construction of the "Craster Hall," a two-decked vessel built on this system for ordinary cargo purposes, in 1908–9. Her principal particulars are :—Dead-weight capacity, 7,300 tons; gross register, 2,759 tons; length, 392·5 ft.; breadth, 50 ft.; depth, 29 ft.

675. Section of bar keels and centre-plate keelsons. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1730–1.

These illustrate two methods of combining, in steel-built vessels, a solid bar-keel with a vertical plate keelson.

In (*a*) the floor-plates are fitted continuously across the keel, the lower portion of the vertical plate being scored through for this purpose, while the transverse (frame and reversed frame) angle-bars are butted at the middle line. The upper portion of the vertical keelson plate is formed into a continuous longitudinal girder by the addition of double angle-bars to the top and bottom edges; a horizontal rider-plate at the upper edge provides the necessary security for the lower tier of pillars. The forged lengths of bar-keel are connected together by means of well-riveted scarf joints, and the whole is secured to the general framing of the ship by flanging the garboard strakes of shell plating as shown.

In (*b*) both floor-plate and frame-angles are cut off at the middle line by a continuous centre-through-plate keelson. From the underside of keel this extends sufficiently above the top of the floors to take two continuous angle-bars and a bulb-plate; at the lower edge two side bars, one on each side, are fitted, the total thickness of the three plates being usually equal to that of a single bar-keel. When carefully riveted to the garboard strake, as shown, this is a highly efficient combination, although the cost of workmanship has militated against its general adoption by shipbuilders. The butts of upper and lower frame-angles are connected by short doubling-angles, which are scored through the keelson-plate on the opposite side of the floor-plate.

676. Section of flat keel and centre-plate keelson. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1732.

This construction is largely used for small vessels in the mercantile marine. A single flat-plate keel, double riveted to the garboard strakes of bottom plating, is combined with a continuous vertical keelson-plate provided with double angle-bars to upper and lower edges. The transverse frames extend from the middle-line to the topsides of the vessel and are connected to the keelson-plate by means of short vertical angles on each side of the floor-plate; there is also a continuous "gutter plate" riveted to the reversed frame-bars and to the upper angles of the keelson.

For large vessels, Lloyd's rules require the flat-plate keel to be doubled for one-half the vessel's length amidships.

677. Model of bracket framing. (Scale 1 : 12.) Received, 1874. N. 1395.

This illustrates the construction of the double bottoms of warships during the period 1870 to 1895.

It shows two complete "bracket" frames, at non-watertight stations, and details of their connections with the longitudinal frames; also portions of two "longitudinals," one of which serves the purpose of an ordinary lightened-plate girder, while the other, built of solid-plates with closer-spaced riveting, serves the additional purpose of a watertight boundary to the cellular spaces into which the double bottom is divided.

Owing to the greater length, speed, and armament of modern vessels, a modified form of bracket frame, giving greater strength and rigidity, has been generally adopted.

678. Model showing cellular construction. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1735.

This is a transverse section of a double-bottom at the middle-line of the vessel. It shows full details of the arrangements for connecting the inner and outer skin plating with the bracket frames and vertical keel.

Butt straps of the vertical keel and of the inner and outer flat keels are shown, also the covering straps of the butts of the upper and lower keel angles, with details of the riveting in each case. The practice of lapping the upper and lower frame angles upon the vertical keel angles is now discontinued, the former angles being cut shorter so as to avoid the expensive bending.

679. Model showing cellular construction. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1746.

This shows a portion of the framing and outer bottom plating of a vessel built on the cellular system.

It comprises one watertight and six ordinary "bracket" frames, with their adjacent longitudinal girders, and shows the method of constructing and combining the same; also the shell plating in the vicinity, with details of the riveting at the butts, edges, and frames. The model further illustrates a method of disposing the butts of shell plating, whereby two unpierced strakes are provided between butts in the same frame space.

680. Models showing cellular construction. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1733–4.

These show details of the framing and plating adopted in the construction of the cellular bottoms of warships.

(*a*) is a watertight bracket frame, extending from the middle-line of the vessel to the first longitudinal. It consists of a solid plate bounded by a complete frame of angle-bar which is connected by closely-spaced riveting with the inner and outer bottoms, as well as with the vertical keel and the longitudinals. When caulked this transverse frame forms a watertight partition between two of the many cellular spaces into which the double bottom is divided.

(*b*) shows the construction of an ordinary bracket frame, and is typical of the general structure of the frames between the watertight ones.

Each model also illustrates a method of securing a longitudinal bulkhead and its vertical stiffeners to the inner bottom plating.

Details of the more recent practice in regard to the construction and fitting of these frames are shown in model No. 667.

681. Model of outer bottom plating of a warship. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1736.

This represents a portion of a double-bottom and details of the shell plating in the neighbourhood of the keel.

The methods of fitting butt straps to the vertical keel plates, to the inner and outer flat keel plates, and to the first or garboard strakes of the outer-bottom plating are shown, together with the covering strap of a butt of the lower angle-bar to the vertical keel.

The lower portion of this cellular bottom, after being carefully caulked and tested, is covered with a layer of cement, which protects the structure from the corrosive and mechanically wearing effects of bilge-water. The cement is thickest near the keel, where it rises to the height of the circular drainage holes shown in the bracket frames, thus facilitating the complete pumping out of these compartments.

682. Model of outer bottom plating showing disposition of the butts. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1747–8.

These illustrate two systems of so arranging the butts of shell plating as to give uniform distribution of these lines of transverse weakness.

(*a*), with plates four-frame spaces in length, shows three passing strakes of plating between each pair of butts in the same frame space.

(*b*), with plates five-frame spaces in length, has four passing strakes between consecutive butts in the same vertical section.

For illustration of an arrangement in which only two passing strakes break the line of consecutive butts, *see* No. 679.

683. Model of shell plating showing "stealers." (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1749–50.

The great difference between the girth of a vessel amidships and at the extremities renders it necessary to end some of the strakes of the outer bottom plating before reaching the bow or stern; these shortened strakes are known as "stealers."

(*a*) and (*b*) show in elevation a method of working a stealer in a sunken or a raised strake respectively.

The smaller models (*c*), (*d*), (*e*), and (*f*) are transverse sections of the above, taken through the dotted lines marked "A B" and "C D." They show details of the tapered rebates and edge connections, whereby the two strakes are worked into one and then efficiently secured.

684. Models of beam, frames, and stringer connections. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1737 and 1768.

These show the usual attachment between a ship's beam, a transverse frame, and a deck stringer; also the connection between a deck stringer, a frame, and (*a*) the sheer strake of a composite-built vessel, (*b*) the shell plating of a steel-built vessel.

The latter model shows, in addition, portions of the wooden sheathing and deck planking, as well as a "gutter-way" for carrying water from the deck to the scuppers; this gutter is formed of two continuous longitudinal angle-bars. The transverse frame is here of Z-section, while (*a*) shows a deep outer frame-bar with a smaller reversed angle riveted to its inner edge.

The ends of the deck beams shown have been deepened to strengthen the joint by splitting and opening them, then inserting an additional piece in the web and welding it into position. Usually the inserted web completely fills the space and forms a solid end, but frequently the lightened arrangement shown, in which a hole is left in the web, is adopted. The connection between a frame and a beam is sometimes made by a bracket plate riveted to the two, thus saving the expensive smith-work.

685. Models of deck stringers. (Scale 1 : 4.) Made by the Admiralty, 1827. N. 1738–9.

These illustrate alternative methods of fitting a deck stringer plate to a steel-built vessel, when such plate forms a portion of a watertight or non-watertight deck respectively. In both cases the stringer plate is scored over the ship's frames, here shown of the Z-section, and is secured to the inside flanges of the same by means of a continuous longitudinal angle-bar.

Under ordinary circumstances the inner edge of a deck stringer-plate is connected to the shell plating by short angle-bars fitted between the frames as shown by model (*a*). When, however, a watertight boundary is required, a complete frame of angle-bar, carefully riveted and caulked, is fitted as shown in (*b*).

686. Model showing bulkhead construction. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1753.

This represents a portion of a watertight bulkhead jointed with flush edges and butts.

The plating is stiffened on one side by vertical angle-bars, and on the other by horizontal T-bars which also serve as cover strips for the butt joints. The distribution of the joints and the details of the riveting are also shown. The main bulkheads of modern warships in H.M. Navy have been further stiffened by the addition of vertical Z or H-bars, provided with plate brackets to their heads, heels, and sides.

687. Model of attachment of watertight bulkheads. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1754.

This shows the method of securing the lower part of a transverse watertight bulkhead to the inner bottom of a vessel built on the cellular system.

A boundary angle-bar is attached by means of closely-spaced rivets to the inner-bottom plating and to the lower edge of the bulkhead plates, a wide liner being fitted over the sunken strakes so as to level up the surface and also to compensate for the loss of transverse strength at this section (*see* No. 688). The abutments of a fore-and-aft coal-bunker or wing bulkhead are shown, also the vertical stiffeners to the transverse bulkhead, together with portions of the cellular framing below. It is now usual to fit small bracket plates to the heels of all vertical stiffeners, and also to place if possible solid-plate frames directly under all watertight bulkheads.

688. Model of attachment of watertight bulkheads. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1755.

This shows a method of securing a transverse watertight bulkhead to the ship's plating.

A continuous boundary angle-bar, well riveted and caulked on the bulkhead, is similarly connected to the shell-plating. Where there are sunken strakes of plating a wide liner is fitted, in order to simplify the work and to strengthen a section that is considerably weakened by the number of holes necessary for watertight riveting. Gusset or bracket plates are fitted between the bulkhead and the adjoining frames on each side; these stiffen the shell and help to resist the racking stresses to which the plating and framing are subjected in a sea-way.

689. Models of watertight bulkhead joints. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1756–8.

For the maintenance of structural strength in a steel-built vessel it is often necessary to continue beams and girders completely through the watertight bulkheads. To insure watertightness at such intersections, short connecting angle-bars, fashioned to a template and carefully riveted and caulked, are generally fitted around the joints.

The accompanying models show details of the arrangements when the bulkhead is pierced respectively by a bulb angle-bar, a bulb T-bar, and a box-girder.

690. Models of bulwarks. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1740–2.

These three models illustrate various modes of forming the side structure above the upper deck in steel or composite-built vessels.

(*a*) is a combination of wood and metal; a rough-tree stanchion carries the outside wooden planking and top rail, and is secured at the heel to the sheer strake and to an inner "clamp plate." It also shows the usual method of working a wooden "waterway" with the adjoining deck planking.

In (*b*) and (*c*) the topsides are formed entirely of steel, and are stiffened, in one case by means of a bulwark stay so riveted to the deck, top rail, and side plating as to afford a distributed support; in the other by a continuation of the transverse frames of the ship to the height of the top rail.

Freeing ports are fitted to the bulwark plating of all vessels, sufficient in number to discharge readily any water accumulating upon the upper deck; as their doors only open outwards they act as valves in preventing water from entering. Details of bulwark framing and plating for composite vessels are shown on diagrams No. 643.

691. Model of deck planking. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1760–1.

These models show the usual method of securing a wooden deck to iron or steel beams when no deck plating is fitted.

For deck planks over 8 in. in width, Lloyd's rules require two bolt fastenings in each beam, secured by nuts on the underside of the flange. The butts of deck plank are, if possible, supported on a beam; where the beam flanges are not of sufficient width to receive the necessary fastenings a short piece of plate is riveted to the beam, and the ends of plank secured to it as shown.

692. Model of deck plating and planking. (Scale 1 : 12.) Made by the Admiralty, 1887. N. 1759.

This is a portion of an iron or steel deck of single thickness, with an upper covering of wooden planking. The positions of the deck beams and of the butt straps and edge strips to the plating can be seen, together with full details of the riveting in each. The butts, edges, and fastenings of wooden planking are disposed as shown; the planking is secured by galvanised iron bolts, which pierce the plating between the beams and are fitted with nuts below.

693. Model of protective deck plating. (Scale 1 : 12.) Made by the Admiralty, 1887. N. 1762–3.

This deck plating, when fitted for the purpose of protecting the vital parts of a warship from gun fire, is usually laid in several thicknesses. The accompanying models illustrate an arrangement for fitting and riveting such plating when worked in two and three thicknesses respectively.

The butts and edges are generally disposed as shown, each thickness of plating being utilised as a butt strap and edge strip to others. In this way the cost of riveting is minimised, as three single rows of rivets are sufficient to secure the two edges in one case, while four rows secure three edges as shown in the other. The usual practice is to first rivet the lower thickness to the ship's beams, then to fasten the upper thicknesses to the lower by through or tap-rivets disposed between the beams.

In one model the butts of the upper thickness rivet to a beam; the more recent practice is, however, to arrange all butts clear of beams where practicable.

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694. Rudder and stern-post. Lent by Messrs. Wm. Jessop and Sons, 1884. N. 1670.

This is a duplicate of a crucible cast steel stern-frame and rudder, made in 1881, which is believed to have been the first stern-post made in the way that has now become almost universal. It weighs 2 cwt., and was designed by Mr. J. F. Hall, for a launch built by Mr. John Shuttleworth, of Hull. She was 25 ft. long, 5 ft. beam, 3·17 ft. deep to gunwales, and was fitted with two-stage expansion engines indicating 3 h.p., and giving a speed of 6 to 7 knots. She carried 3·5 tons of cargo, in addition to a supply of coal.

The earlier practice was to make the stern-post as a forging by welding up portions in iron or steel, but large steel castings in Bessemer or Siemens metal are now used in all classes of steamers.

695. Model of stem and stern frames of battleship. (Scale 1 : 12.) Made by the Admiralty, 1887. N. 1751–2.

These represent the forged iron posts for a battleship of the "Admiral" class, 1882.

The details of the connections with the shell plating and with the flat and vertical keels are shown in each case, while the particulars of the special framing associated with this type of post are represented in No. 666.

With the introduction of large steel castings into ship construction a hollowed or gulleted form of stem and stern post was rendered possible, with horizontal ribs and ledges for the more efficient attachment to the hull framing and plating.

696. Model of frame of balanced rudder. (Scale 1 : 24.) Made by the Darlington Forge Co., 1895. N. 2067.

This represents the cast-steel frame of the rudders of H.M. cruisers "Andromache" and "Apollo," built at Chatham in 1890–1.

The rudder is of the balanced type, in which the axis of turning coincides with the centre of pressure when acting, so that but little power is required in setting and retaining the rudder in any desired position. This centre of pressure is at about ·3 of the width of the rudder from its leading edge.

The rudder is completed by filling the frame with light wood, and then covering it on each side with thin steel plating, tap-riveted on; the wood packing, however, is sometimes omitted. The weight of the rudder is carried by a collar, within the ship, resting on balls or bearing rollers. The lower end of the rudder turns in a socket on the stern post (*see* No. 128).

697. Model of shaft brackets for S.S. "Empress of China." (Scale 1 : 24.) Made by the Darlington Forge Co., 1895. N. 2062.

This represents the shaft brackets of this twin screw steamer, built at Barrow-in-Furness in 1891, for the Canadian Pacific Railway Co.

They are formed in a single steel casting, which has three large vertical flanges for connecting it to the stern post and to the transverse framing of the ship.

The actual weight of this casting was 26 tons.

698. Model of stem of H.M.S. "Royal Sovereign," 1892. (Scale 1 : 16.) Made by the Admiralty, 1893. N. 2016.

This cast steel stem-piece is formed in two parts, connected together by a scarf-joint as shown; its total weight was 25 tons.

The whole is strengthened against ramming stresses by the abutments of the various decks and the shell plating, while special support is given to the spur or ram by its connection with the protective deck plating, which is 2·5 in. thick, and extends backwards from the bow through a distance of 76 ft.

699. Model of shaft bracket for H.M.S. "Royal Sovereign." (Scale 1 : 24.) Made by the Darlington Forge Co., 1895. N. 2066.

This represents one of a pair of cast-steel brackets for this twin screw battleship, built at Portsmouth in 1892.

Both arms of the casting pierce the shell plating of the ship, and the upper one is riveted to a thick "palm" plate strongly connected to the general framing of the vessel, while the lower one is joined, by means of a scarf, to the lower arm of the opposite bracket, and both are riveted to a special framing attached to the vertical keel.

700. Model of stern frame. (Scale 1 : 24.) Made by the Darlington Forge Co., 1895. N. 2064.

This is a combined stern and rudder-post of cast steel, as fitted to the Peninsular and Oriental Co.'s steamships "Australia" and "Himalaya," built at Greenock in 1892.

The frame is in three parts, scarfed together and riveted were indicated. It is provided with a boss for a single screw-propeller, and five gudgeons for carrying the rudder; there are also projecting arms for efficient connection with the hull framing.

The total weight of the three castings was 23 tons.

701. Model of stern castings. (Scale 1 : 24.) Made by the Darlington Forge Co., 1895. N. 2063.

This represents a cast steel stern-frame with shaft brackets attached, as fitted to the Union Steamship Co.'s twin-screw vessels "Gaul," "Goth," and "Greek," built at Belfast in 1893. In these steamers the screw shafts are so close together that the propeller paths would overlap were the port screw not somewhat in front of the starboard one (*see* No. 702).

The stern-post shows the arrangements for connecting it with the flat keels and to the transverse framing of the ship.

702. Models of stern castings for S.S. "Cevic." (Scale 1 : 24.) Made by the Darlington Forge Co., 1895. N. 2061.

These represent the cast steel stern-post, rudder-frame, and shaft-brackets in their correct relative positions, as fitted to this twin-screw

White Star liner, built at Belfast in 1894. The overhanging form of stern-post here shown permits of an increased immersion of the propellers and a closer arrangement of the centre lines of the propeller shafting; the reduced area of after dead-wood also gives a shorter turning radius to the vessel.

A single casting, riveted to the stern-post and adjoining framing of the ship, forms a double shaft-bracket; in its construction provision is made for placing the port propeller in advance of the starboard one. The rudder is completed by riveting a steel plate between the projecting arms of the frame casting.

Weight of stern frames, 17 tons; weight of double shaft-bracket, 12 tons; weight of rudder-frame, 11·5 tons.

703. Models of stem, stern and rudder castings of H.M.S. "Majestic." (Scale 1 : 24.) Made by the Darlington Forge Co., 1895. N. 2065.

These represent cast-steel frames as used in the construction of this first-class battleship at Portsmouth in 1894–5.

The stem and stern-posts show the rebates for the attachment of the flat keel plates and shell plating, and also the horizontal lugs or ledges for the attachment of decks, platforms and breasthooks: a projecting spur or ram with special stiffening web forms part of the stem casting. On the upper portion of the rudder-frame are shown the two wedge-shaped stops for limiting the angle of turning.

The actual weights of these castings were: stem, 27·5 tons; stern, 8 tons; rudder, 13 tons.

704. Model of stem and stern frames of a cruiser. (Scale 1 : 24.) Made by the Darlington Forge Co., 1895. N. 2068.

These frames were cast in steel for the Spanish cruiser "Princesa de Asturias," 6,648 tons displacement, built at Caraccas in 1895.

Both castings show the usual rebate for housing the shell plating, also an exceptional length of lap for securing to the flat keel plates. The stem has provision made for the ram plate and for the abutments of upper, main, and lower decks, by which it is greatly strengthened. The stern frame has on its fore end a long vertical web for attachment to the ship-structure, and on its after end a rectangular recess to receive the lower palms of the shaft-brackets.

705. Model of stern casting for double rudders. (Scale 1 : 8.) Received 1901. N. 2261.

This represents a cast-steel stern-post as fitted to H.M. ram cruisers "Arrogant," "Furious," "Gladiator" and "Vindictive," built in 1896–1900 at the Royal Dockyards. To ensure rapid manœuvring power, these vessels are provided with double rudders.

The casting weighs about 10 tons, but is made in two parts connected together at the position shown by a scarf joint and covering-plate. The upper end is riveted to the protective deck and the lower end to the flat-keel plates; additional connection with the hull of the ship is obtained by the outer, or shell, plating which is riveted into the rebate extending along the whole length of the casting. At the side are projecting palms to which the lower arms of the propeller-shaft brackets are riveted.

The rudder-posts pass through sockets, and the weight of each rudder is carried upon a horizontal flange which forms part of the main casting; a small spur, at the heel of the main rudder-post, carries a steadying pintle. For full details of the rudders and of the complete steering machinery *see* No. 1064.

706. Model of stern frame for H.M.S. "Formidable" (1898). (Scale 1 : 12.) Received 1907. N. 2440.

This represents the cast steel stern-frame as adopted for the eight battleships of the "Formidable" class.

In order to improve the turning qualities of long, fast vessels it has been a practice, since about 1894, in designs both for merchant and warships, to cut away a portion of the after dead-wood. This necessitates some modification of the after-framing and, in the example shown, has originated the peculiar arched or overhanging stern-casting, having its after-edge or rudder-post carried vertically downwards to nearly the normal keel-line; a short intermediate portion or "heel" provides a suitable bearing for the after-end of the vessel when in dry-dock. Vertical and horizontal webs are cast on the frame for the attachment of internal decks and plate frames. The weight of the actual casting was about 11 tons.

A small separate model illustrates the method of scarfing and riveting the lower "palms" of the propeller brackets for these ships.

For details of the connections of these parts with the adjacent ship-structure *see* No. 1063.

707. Models of stem, stern and rudder castings for S.S. "Ermack." (Scale 1 : 24.) Made by the Darlington Forge Co., 1902. N. 2289.

These represent the steel castings for the ice-breaking steamer "Ermack," built in 1898 at Elswick, by Messrs. Sir W. G. Armstrong, Whitworth & Co., for the Russian Government.

The stem-post above the water-line has the usual shape, but from a point near the line of maximum draught of the vessel it turns sharply backwards and continues in a gradual downward slope for a length of about 32 ft., when it again assumes a more vertical direction till it terminates in a boss for a screw propeller. The long overhanging bow thus obtained causes the vessel, after impact, to rise upon an ice-field, thus utilising the actual weight of the ship to break a passage through the ice; this action is further assisted by the V-shaped section of the underside of the casting, and also by the violent disturbance given to the water below by the bow propeller. Beyond the boss is a projecting lip or "palm" to take the foremost keel plates which here rise considerably above the normal keel line.

The stern-frame is a combined rudder and stern-post, the latter portion having a boss for one of the three after propellers, and the former the gudgeons for carrying the rudder. On each side of the screw aperture the vertical edges of the casting have bevelled faces so as to give a ready passage for any obstructing masses of floating ice; near the heel of the stern-post is an abutment and scarf for attaching the after ends of the keel plates. The fork made by the upper part of this casting forms the lower boundary of a large recess provided in the stern of the vessel, for housing the bow of a ship which may require towing into an ice-bound harbour or which may be required as an auxiliary in forcing a channel.

Both the bow and stern-frames show the usual rebates for the attachment of the shell plating, but the internal gulleting of the castings is reduced to the minimum required for efficient riveting, so as to give increased solidity to sections that may be subjected to exceptional stresses. A number of transverse and longitudinal ribs or flanges provide means for connecting the castings with the general framing of the ship.

The rudder, shown in position, is a single steel casting, and is provided with stops to limit its angle of turning. The actual weights of the castings were :—Stem, 16·2 tons; stern frame, 7·9 tons; rudder, 12·7 tons.

708. Model of stem post of H.M.S. "Vengeance." (Scale 1 : 24.) Made by the Darlington Forge Co., 1902. N. 2288.

This represents the cast steel stem-post and ram of a first-class battleship, built by Messrs. Vickers, Son and Maxim at Barrow-in-Furness in 1898–1901.

Owing to the sharp angular rise given to the fore-foot of this type of vessel, the stem casting is wholly above the level of the keel line. It is, however, scarfed to the flat keel plates in the usual manner, the latter being bent upwards for this purpose; the lower edges of the vertical keelson plates are riveted to a longitudinal web formed on the inside of the lower portion of the casting.

The ram itself is nearer the water-line of the vessel than in earlier types and is more completely supported. Just above the spur is a broad projecting ledge to which the 2-in. protective deck is riveted, and immediately below this, in the centre of the spur, provision is made for attaching a special ram plate 2 in. thick. In addition to these there is the support derived from the ordinary shell plating of the ship and also from a protective skin of 2-in. nickel steel which covers the bow on both sides to a height of 10 ft. above the water-line. Double rebates are shown for housing these two thicknesses of plating, and at the upper portion of the casting are edges for attaching the foremost ends of the main and upper decks. The actual weight of the casting was 13 tons.

709. Models of stern and rudder frames of H.M.S. "Drake." (Scale 1 : 24.) Made by the Darlington Forge Co., 1902. N. 2287.

These were cast in steel for a first-class armoured cruiser built at Pembroke in 1899–1901. (*See* No. 135.)

The stern-frame rises considerably above the normal keel line, the after dead-wood being cut away in this particular class of vessel. The after keel-plates are bent to the angle of the casting, and secured to it by a double scarf, shown at the lower end of the model; near this scarf are two large projecting palms for carrying the lower arms of the screw-propeller brackets.

A rebate for housing the ends of the outer skin plating is shown along the whole length of the stern casting; there are various lugs or ledges for attaching the decks and platforms of the ship. At the heel of the upright post is a wedge-shaped stop for limiting the turning-angle of the rudder.

The rudder-frame, shown in position, is a single casting, and when covered with thin steel plating, will form a rudder of balanced type. A steadying pintle is fitted below the heel of the stern post, but the actual weight of the rudder is carried upon a turntable which forms part of the main stern casting as in the model of steering gear No. 1064.

Weight of stern frame, 25 tons; weight of rudder, 18·6 tons.

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710. Model of portion of main deck battery. (Scale 1 : 16.) Presented by Messrs. R. Napier and Sons, 1867. N. 1180.

This model shows three broadside guns and their mountings, as arranged in the warships proposed by Vice-Admiral E. P. Halsted in 1865–7. (*See* Nos. 98 to 105.) The side armour extends up to the main deck with lighter plating over the battery; the upper work is formed with tumbling rails so that it can be placed clear of the turret guns when required. The heaviest gun shown has a winch training gear; all three guns are mounted on iron carriages and slides, designed by Capt. T. B. Heathorn, R.A., which give a muzzle-pivoting movement; the ports are, however, of the large size then usual.

711. Model of gun turret. (Scale 1 : 16.) Presented by Messrs. R. Napier and Sons, 1867. N. 1182.

This represents Mr. R. Napier's turret, for carrying two Whitworth 9-in. M.L. guns, which was introduced in the designs for the combined turret and broadside armour-plated ships-of-war proposed by Vice-Admiral E. H. Halsted in 1865–7. (*See* Nos. 98 to 105.)

The turret is 25 ft. external diameter and 21 ft. internal; the armour consists of 8 in. of solid iron in complete rings 2·5 ft. high, then a packing of vertical or diagonal beams of teak 8 in. thick, supported by Hughes' hollow stringers formed into complete rings and secured to the inner iron skin, which is 1 in. thick. The roof of the turret is formed of alternately reversed T-irons, which form a shield that leaves ample ventilation. The turret is supported on a live ring of coned rollers, which travel on a bed formed around a circular main deck hatchway, with coamings 13 ft. external diam. and 4·5 ft. high, protected by armour similar to that on the turret; the space between this armour and the turret affords ventilation for the main deck. This armoured base protects the ammunition, hoists, etc., as well as the vertical shaft by which the turret is turned by steam power from below.

Sections of this turret are shown in several of the half models of the Halsted ships.

SHIPS' FITTINGS, ETC.

712. Diagrams showing ventilation of a battleship. (Scale 1 : 48.) Made by the Admiralty, 1887. N. 1798.

These show in profile, plan and section, the general arrangements adopted for ventilating a vessel of the central citadel type.

The spaces between main and upper decks are principally ventilated by the hatchways and side scuttles; those between main and protective decks by means of vertical shafts, rising above the upper deck and fitted with adjustable cowls, so that the motion of the ship or direction of the wind can be utilised to force air into or withdraw air from the interior. This air is distributed through horizontal pipes or trunks opening into the various compartments by means of sliding shutters or louvres.

The updraught produced by heated air in the funnel casing is used to draw the foul air from the coal-bunkers through exhaust trunks, the fresh air being supplied by pipes fitted between the ship's frames and reaching to the topsides. Free circulation of air to engine and boiler-rooms is secured by the large ventilators and cowls amidships rising well above the upper deck, from which also the supply to the steam fans is drawn when the boilers are under forced draught.

As the openings in the protective deck are necessarily limited in number, most of the compartments below are ventilated artificially. Revolving fans, driven by steam or electric motors, draw fresh air from downcast shafts and force it through large trunks, provided with numerous branches and outlets, to every accessible part of the fore and after ends of the ship, including magazines, capstan, steering, shell, and provision rooms, all these compartments exhausting into a main trunk leading to the funnel-casing.

As a ventilating pipe forms a passage through the watertight bulkheads, a weighted valve is fitted which, by a trigger gear actuated by a float, closes the pipe if water enters its compartment.

Supply shafts and trunks are shown in blue; exhaust shafts and trunks are shown in red.

Since about 1900 the above system has been considerably modified by dividing each vessel into a number of separately-ventilated units, *i.e.*, between the main watertight bulkheads. Each unit is provided with one, or more, small motor fans (*see* Mechanical Engineering Collection), these draw air from the upper deck and deliver it, through a common air-chamber, to the local sub-divisions; special exhaust trunks are fitted where necessary. This arrangement obviates the piercing of watertight partitions and the use of automatic ventilation valves.

713. Model of ship ventilator. (Scale 1 : 12.) Presented by the Rev. J. Hardie, 1866. N. 1097.

This shows an octagonal wooden trunk, which communicates with the deck to be ventilated, and is surmounted by a metal cowl with a conical mouth which can be set to windward. In bad weather the cowl is removed and the trunk closed by a wooden cover. It was designed for use in troopships by Mr. R. Blake, Master Shipwright, H.M. Dockyards (1833–55).

714. Ventilators. Lent by the Carron Co., 1890. N. 1847.

These are for ventilating deck-houses and ships' cabins.

(*a*) is a circular brass plate, with radial slots and guides, for attaching to doors or bulkheads; this plate is covered by a revolving slotted disc, by which the ventilation can be regulated.

(*b*) is a more elaborate fitting for the decks above state rooms, etc. A ventilating shaft, secured by a flange to this deck, is surmounted by an adjustable cap to prevent the entry of rain or spray. Inside the cap is a strip of india-rubber, so that during rough weather when screwed down upon the bevelled rim of the ventilating tube the joint shall be watertight.

715. Model of spherical valve for ventilator. (Scale 1 : 24.) Received 1907. N. 2445.

This arrangement for controlling openings in watertight decks was patented by Mr. James Casey in 1895. It consists of a hollow spherical valve, cut with a large single passage and enclosed in watertight casings; adjustable bearings and packing are used to ensure easy working and watertightness and the valve is opened or closed by external handles or levers. It was intended for use as a general substitute for the ordinary sliding doors, hatches, scuttles, etc., and is here shown as fitted to a ventilating shaft on a vessel's deck; with slight modifications it could be attached to openings in ships' sides and bulkheads.

Some experiments were made with this device on English and French vessels, but it has not been permanently adopted.

716. Model and diagram of Boyle's ship ventilators. (Scale 1 : 12 and 1 : 120.) Presented by Messrs. R. Boyle and Son, 1898. N. 2163.

This shows a pair of Mr. R. Boyle's patent ventilators; the taller one is the "down-cast" by which air, from the above-deck level, is carried into the depths of a ship; the shorter one has an induction apparatus, or "air pump," by which vitiated air is removed from the vessel. The down-cast apparatus acts somewhat like the old wind-sail, but has four mouths, so that it does not require setting; at the side is a trap and a branch outlet closed by a flap, by which if spray is carried down it shall escape sideways into an adjacent scupper. The up-take, or air-pump ventilator, is also stationary, but has four orifices with vertical shutters and guides which so direct the passing air as to cause it to exhaust from the ship by an inductive action.

The model is fitted with glass tubes containing tufts of cotton-wool which show the direction of the current when either ventilator is blown across. An adjacent diagram shows a steamship fitted with these ventilators, so arranged that fresh air is supplied near the bottom of each deck by down-cast ventilators, while the vitiated air is carried off by up-cast ventilators drawing from the upper part of each deck.

717. Model of a hinged watertight door. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1796.

This shows the Admiralty construction and fittings of a watertight door on a bulkhead above the protective deck.

The door is carried on hinges, and is provided with a slightly-raised flange round its inner edges which when closed presses against a narrow strip of sheet india-rubber secured in a frame attached to the bulkhead. The ten clips or handles arranged round the door are forced over brass wedges on the back of the door; the powerful closing pressure thus exerted insures an efficient watertight joint.

Since 1889 the raised flange has been usually secured to the bulkhead and the india-rubber to the door.

718. Model of watertight door. (Scale 1 : 4.) Presented by Messrs. Mechan and Sons, Ltd., 1908. N. 2469.

This represents a modern form of hinged door largely used in the Royal Navy and mercantile marine for closing openings in watertight bulkheads.

The construction shown was patented in 1894 by Mr. H. Mechan. Instead of the riveted combination of plate and angle-bar shown in No. 717, the door is made of a single steel plate pressed hydraulically between dies which form a shallow recess round the edges; this recess gives the door stiffness and also provides accommodation for the renewable rubber strips that make a watertight joint with the flanged or beaded door-frame. To obtain closing pressure eight rotative handles spaced round the door in watertight bushes on the bulkhead, are used in conjunction with brass shoes or wedges on the back of the door; the holes in each door-hinge are elongated to permit of this final adjustment.

719. Model of a deck scuttle. (Scale 1 : 4.) Made by the Admiralty, 1887. N. 1797.

This shows the method of efficiently closing an opening in a watertight deck. The opening is made between two deck beams, and is provided with a coaming or frame to which the cover is hinged. The joint is made with india-rubber, similarly to that in No. 717, but is closed by seven hinged bolts fitted with butterfly nuts.

720. Side scuttles. Lent by the Carron Co., 1890. N. 1847.

These are for providing light and air to the spaces between the decks of wood or steel-built vessels.

A hole of required diameter is first cut in the shell plating or planking and to the inner side is secured the outer frame of the scuttle. To this is hinged a frame carrying the stout glass "light" and a rubber-joint ring which insures watertightness when closed upon the outer frame. Attached likewise to the outer frame, but swinging in a different direction, is a solid metal cover or shutter, similarly jointed, so that should the glass be broken it will prevent the entrance of water. The hinges are of an adjustable type, which insure tightness of the joint all round. Hinged bolts with screw nuts for securing and releasing purposes are provided for each cover.

(*a*) is an Admiralty pattern scuttle made of gun-metal throughout. A similar pattern with outer frame and inner shutter of galvanised cast steel is also used.

(*b*) is made of brass, and has a reversible outer shutter. This is fitted with india-rubber on each side, which adapts it for use with or without an intermediate glass-light.

(*c*) has an outer shutter of galvanised cast iron; the glass also is bedded upon a rubber cushion.

721. Models of hatchways and coamings. (Scale 1 : 4.) Made by the Admiralty, 1886. N. 1776–7.

Hatchways are the openings which provide light, air, and a means of access to the between-deck spaces of vessels; such openings, when in an upper deck, are fitted with raised sides or "coamings" of wood or iron to prevent the passage of surface water from the surrounding deck.

The two models show the usual method of framing a hatchway in an iron or steel deck; the construction of wood and iron coamings respectively; the method of securing coamings in position. In each example the hatchway is formed by fitting "carlings" (or short fore-and-aft beams) between the ordinary transverse beams of the ship, at the required spacing apart, and then securing them by short connecting angle-bars at each corner, riveted as shown.

(*a*) Here the coaming is of wood, dove-tailed together so as to prevent any relative movement of the four pieces composing it. Long vertical screw bolts, disposed as indicated and each secured by a nut and washer beneath the beam flange, fasten the completed frame to the deck. The transverse ends of the coaming are provided with a rebate on their inner edges, to receive a wooden grating or cover.

(*b*) This coaming is formed of two vertical iron plates bent to form, and secured to the hatchway framing by means of boundary angle-bars. Butt straps are shown connecting the two parts of the coaming plates together; welded joints are also largely used for this purpose.

Narrow strips of plating, projecting outside the lower edge of coaming in (*a*), afford security for the adjacent deck planking; in (*b*) the outer flanges of the beams and carlings are utilised for this purpose.

In ordinary cargo vessels, hatchways are closed by portable wooden covers, or hatches, provided with lifting-rings at opposite corners. These hatches are fitted to the coamings of the upper deck hatchways and are made watertight by a tarpaulin covering; flush covers are used for the openings through the lower deck. Large hatchways are usually provided with shifting-beams and carlings, which give local strength and reduce the size of the portable covers. The weather hatchways of passenger vessels are furnished with watertight hoods or covers provided with doors and glass "lights." In modern war-vessels the large openings for the machinery spaces are fitted with shell-proof iron or steel gratings, while the smaller openings in watertight decks and flats are provided with hinged covers fitted and secured as shown in No. 719.

722. Lithograph of Price's self-trimming hatchways. (Scales 1 : 16, 1 : 48 and 1 : 96.) Lent by Wm. Denton, Esq., 1876. N. 1454.

This shows longitudinal and cross sections of the S.S. "J. B. Eminson," a vessel of 1,031 tons register, 220 ft. long, 31 ft. broad, and 17·1 ft. deep, built in 1875 at Sunderland by Messrs. Short Bros. She is fitted with the hatchways and cargo-shoots patented by Mr. John Price in 1874.

Instead of the sides or coamings of the hatchways being vertical, they are inclined inboard and supported by the deck beams. The midship section shows the vessel fully laden with coal or other bulk cargo, for which the hatchway acts as a feeder, and so prevents trouble from the cargo settling and shifting. Details are shown of the construction for vessels of from 26 ft. to 32 ft. beam.

723. Diagrams showing drainage of a battleship. (Scale 1 : 48). Made by the Admiralty, 1889. N. 1799.

These show the drainage arrangements adopted for vessels of the central citadel type.

A main drain pipe, 12 in. diameter, is placed between the inner and outer bottom on each side of the vertical keel to receive water from the spaces above the inner bottom; these pipes deliver into two cisterns or sumps, from which the pumps draw. The engine and boiler floors drain into the main, through horizontal valves attached to short vertical pipes; any water from the wing spaces and from those above the third watertight longitudinal is similarly cleared. All compartments on the fore side of the water space forward drain into the bilges, which are levelled up with cement to the height of the sluice-valves of the main drains.

The "water-balance" chamber and the coal and provision spaces at each extremity drain into the large "ejector" tanks shown on the fore side of boiler-room and after side of engine-room respectively. These tanks are emptied by means of ejectors, a form of steam-jet pump capable of discharging overboard large quantities of water; these, however, on account of their excessive steam consumption, are now superseded by additional circulating pumps.

The sumps of the main drains are emptied by the suction pipes from steam and hand pumps. The double bottoms are cleared through separate "standpipes" connecting each compartment to a valve chest, which is exhausted by hand pumps. The valves regulating the passage of water from one space to another are usually actuated by rods extending above the water-line.

724. Sectional model of ice room. (Scale 1 : 4.) Lent by the Peninsular and Oriental Steam Navigation Co., 1875. N. 1400.

This represents a cold store-room, as in use before the introduction of mechanical refrigeration in 1879, and was fitted in 1875 to the P. and O. liner S.S. "Cathay," by Messrs. W. Denny and Bros. (*see* No. 246). Similar rooms were adopted in other ships, the arrangement being simply an enlarged ice safe.

The room is placed between the orlop and lower decks. The space around it is packed with flake charcoal to minimise the conduction of heat from the outside, while the room is lined with matchboarding and sheet zinc. In one corner is a tank in which collects any water that is formed by the blocks of ice melting, and is then led off to an adjoining wine-cooling cellar.

725. Model of ship's hold, showing cold storage arrangements. (Scale 1 : 16.) Lent by the New Zealand Shipping Co., Ltd., 1908. N. 2476.

This sectional model shows the arrangements for the stowage, preservation, and discharge of meat and dairy produce as adopted on the S.S. "Papanui," a typical vessel employed in the above company's New Zealand trade.

On one side of the section, in the lower hold, mutton and lamb are represented packed in bulk; this system of stowage permits of a satisfactory circulation of cold air. The freshly-killed animals are first frozen in the shore depôts and then shipped as soon as possible, the vessel having a storage capacity for about 100,000 carcasses. On the opposite side of the section are shown boxes of frozen butter and crates of cheese.

The blackened portions of the sections represent the charcoal packing placed between the frames, floors and deck-beams to ensure the necessary insulation of holds and 'tween-deck spaces.

The air-cooling and distributing arrangements are by the Linde British Refrigeration Co. Ammonia-compression machines are used and the circulated air is chilled by passing over a series of direct-expansion coils placed in specially-insulated chambers. This cold, dry air is withdrawn by large directly-driven fans and distributed to the storage spaces by means of wooden trunks constructed along the sides and floor of the vessel; by suitable openings in these air-trunks the temperature is regulated to the requirements of the cargo, *i.e.*, butter is usually kept at 10°–15° F., meat at 22° F., and cheese at 40°–45° F.

Rapid discharge of the cargo is effected by a hand or steam-driven sprocket-chain lift which is fitted with suitable carriers and is supported upon a portable, telescopic frame reaching from the bottom of the hold to the upper deck; this arrangement was patented by Capt. G. H. Noakes in 1898.

The "Papanui" was built of steel at Dumbarton in 1898 by Messrs. W. Denny and Bros., her principal dimensions are:—Gross register, 6,582 tons; length, 430 ft.; breadth, 54·1 ft.

726. Pivot for saloon seats. Lent by the Carron Co., 1890. N. 1847.

This arrangement permits a limited sliding as well as rotary movement of the seat of a saloon chair, while the base is firmly secured to the floor. It was patented in 1887 by Messrs. Cowan and Robertson, and consists of a circular frame, fixed under the seat of the chair, and fitting in an elongated frame fastened to the base.

727. Models of tables for shipboard. (Scale 1 : 4.) Lent by H. Burrell, Esq., 1898. N. 2168.

During rough weather it is necessary to fit fences to the dining tables so as to prevent plates, etc., from sliding off through the rolling motion of the ship. These fences are usually in the form of light wooden frames, or "fiddles," resting upon the tablecloth and secured by ledges and straps. To avoid the inconvenience of using such loose parts, Mr. Burrell in 1888 patented the arrangements shown, in which the fiddles when not in use are stowed within the table-top.

In (*a*) the fiddle can sink in a corresponding slot formed through the table-top, so as to leave the surface flush, while when required for use it can be raised by cams, actuated by a lever below, and then be retained in position by suitable catches.

In (*b*) the table-top is made in panels which can be turned over; one face of each panel is provided with raised ledges.

728. Model of fittings for a troopship. (Scale 1 : 8.) Presented by the Rev. J. Hardie, 1866. N. 1142.

This shows one unit of the arrangement proposed by Mr. R. Blake for the transport of troops; it resembles that still used in troop and emigrant ships.

The fittings are temporarily fixed to the deck beams, and to steps on the deck. There are upper and lower berths, each supplying sleeping accommodation for three men on boards which fit each of these tiers. In the day time, these shelves are placed on edge and secured against the sides, while the middle one is used as a table; the back and front boards of the lower berth form benches.

729. Model of horse-stalls for troopships. (Scale 1 : 24.) Bequeathed by Miss M. A. Peek, 1906. N. 1031.

This shows the original design of Mr. Wm. Ladd, of Deptford Dockyard, for fitting upper deck horse-stalls on the ships conveying troops to the Crimea in 1854.

The roofed structure is separated into stalls by loose bars padded on the inside; the animals were backed into these stalls so that the mangers were in the gangway between two sets.

730. Model of early Kingston valve. (Scale 1 : 4.) Made in the Museum, 1904. N. 2334.

Upon the application of the steam engine to marine propulsion it became necessary, for the admission of water to the condenser and feed pumps, to cut holes through the skin of a ship below the water level. The arrangement adopted on the earliest steamships for rendering such an orifice safe consisted of an open cast-iron pipe, passing through the framing and external planking and fitted with a cock on the inboard end; these fittings were, however, difficult to repair while afloat, and any serious defect in them necessitated dry-docking. About 1837, Mr. W. Kingston, of Portsmouth Dockyard, introduced the type of valve shown by the model, as a supplementary valve to boiler blow-off cocks, which had been a source of trouble, and it was so successful that it was soon generally adopted for all under-water openings in H.M. ships.

The valve represented was 4·5 in. diam., and consisted of a gun-metal pipe, with an enlarged conical end which was carefully fitted into the outer sheathing and timbers of the ship, and then drawn tightly into place by means of a large screwed flange on its inner end; to this was bolted a separate piece with a branch flange for connection with the blow-off cock. The valve itself was of gun-metal, and it was seated on the conical portion of the pipe so that it opened outward. It was actuated by hand through a copper spindle screwed into it and passing through a stuffing box. While open the valve was supported on the guard-bar below, but when it was necessary to repair the blow-off cock, the valve was drawn up and so prevented the entry of water. The valve does not project beyond the surface of the hull, and, in the event of the spindle breaking, it acts as a non-return valve. When fitted to hand pumps and injection orifices it was usually provided with a circular grating and some form of guides; it was also capable of being pinned in the open position. Kingston valves are still used in modern vessels for pumps, evaporators and some of the smaller openings below the water-line, but, for the larger orifices they are being generally displaced by the lighter and cheaper form of screw-down valves.

The model shows also a portion of the ship-structure around the valve, with the bottom planking, transverse wooden framing, valve chock, and fastenings as usually arranged; a strip of copper was placed between the lower end of the tube and the bottom planking to protect the latter against shipworms.

731. Model of Kingston valve. (Scale 1 : 4.) Made in the Museum from drawings supplied by the Admiralty, 1903.
N. 2332.

This represents a Kingston valve of 8·5 in. diam. as now fitted to the plating of a steel-built vessel at the sea-suction inlets of the hand pumps, and in some cases at the outlets of the blow-off pipes from boilers and evaporators.

Like the earlier example No. 730, the valve is conical and opens outwards, so that it can be repaired from outside the ship while, should the spindle break, it will act as a non-return valve. The valve and casing are, however, considerably lighter than in the earlier form, and the spindle and valve are made in one piece, while guides are added to steady the valve throughout its whole travel; the valve box is, moreover, provided with a flange by which it can be directly secured to the outer bottom of the vessel or, if necessary for convenience in connecting the pipes, a distance piece may be inserted as shown in the model.

The valve spindle passes through a gland in the valve-box crown and its projecting end is cut with a right-handed square-threaded screw which engages with a nut formed through the boss of a mitre wheel. This wheel is rotated by a similar one secured to a shaft which is led to some convenient position above the water line of the ship, so that the valve can be closed even when the lower decks are flooded; at this operating station is an indicator deck-plate showing the extent to which the valve is open. The mitre gear is carried by a double bracket fixed to the valve casing, and a collar secured by a set-screw retains in position the screwed boss of the wheel forming the nut, while a stop, fitting in a slot cut along the screwed portion of the spindle, prevents the rotation of the valve when the gear is turned. There are two flanged outlets from the valve box, one being for the pump suction-pipe and the other for a flooding or other pipe.

To secure the valve-box, or the distance-piece, to the ship's skin, a facing-ring is riveted round the opening in the bottom plating, and to this the lower flange is fastened by means of studs and nuts of naval brass; a grating is also provided to this opening which checks the entry of weeds, etc. and would prevent the escape of the valve should its spindle break. To avoid the galvanic action which takes place when brass and steel in metallic contact are immersed in sea-water, a renewable protective ring of zinc is fitted round the hole through the plating where the steel would otherwise rapidly corrode.

732. Model of large sea-inlet valve. (Scale 1 : 4.) Made in the Museum from drawings supplied by the Admiralty, 1903. Plate VII., No. 4. N. 2333.

The valve represented is of 20 in. diam. and is shown as arranged for closing the sea-inlet to the circulating pumps of the main engine condensers; it is, however, typical of the class of valve fitted to the larger inlets throughout the hull of a modern vessel. The valve-box, in addition to its connection with the sea and the circulating pumps, has usually an extra flange, as shown, for a pipe by which the circulating water may be taken from the bilge should a serious leak occur.

The valve is of the screw-down type, opens inwards and has four wings; it is loosely attached to its spindle by an undercut lug of horse-shoe shape cast on the crown of the valve, while the spindle has a solid collar formed on its end, so that there are no loose pieces in the connection. The spindle passes through a stuffing-box in the cover of the valve-box, and then terminates in a left-handed, square-threaded end which engages in a long nut capable of being rotated by a box key; this key is extended to any convenient position and is there supported by a bracket containing an indicator showing the extent to which the valve is open.

Rotation of the spindle is prevented by its inner end being square and fitting between guides secured to the cover, while the square-ended nut through which it works is held in position by a bracket made in halves and secured to the cover.

The valve is shown fitted to a vessel having a double bottom, the inlets through the two skins being connected by a conical steel tube riveted to both the inner and outer plating; the hole through the outer skin is fitted with a gun-metal grating, to prevent the entrance of sea-weed, etc., and it is chiefly to reduce the obstruction the grid occasions that the outer hole is made so much larger than the valve orifice.

The valve-box is directly attached, by studs and nuts of naval brass, to a steel facing-ring riveted to the inner skin of the ship, and there is a similar facing-ring on the inside of the outer skin. To prevent the steel plate suffering through galvanic action, where the brass castings are in contact with it and at the same time immersed in sea water, protective rings of zinc are inserted as indicated in the model.

SLIPWAYS, DOCKS, ETC.

The first requisites of a modern shipbuilding yard are: a slipway upon which the hull can be built, and a dock to accommodate the vessel while it is being completed and fitted, after launching. In the early days of shipbuilding, the hard, gently-rising bank of a tidal river sufficed for the former, and a small sheltered cove, with yielding bottom, for the latter. Even now it is very customary to "beach" a small vessel at high water and execute repairs during the ebbing and flowing of a tide. The increase in the size and weight of vessels, however, led to the introduction of specially-constructed inclines of wood, stone or concrete, provided with powerful hauling appliances, and upon such " slipways " most of our ships are now built and repaired.

The first Royal Dockyards were at Deptford, Woolwich and Portsmouth, all established or greatly developed early in the 16th century, while the oldest commercial docks are those at London, 1660, Liverpool, 1710, and Hull, 1778.

A "building" slip is usually provided with a row of wood blocks upon which the various portions of the ship's structure are gradually built up and secured together; shores, guys, ribbands, etc., being used temporarily to hold the parts in their correct relative positions. When complete, or in a sufficiently advanced stage, the vessel is launched by being permitted to slide with its "cradle" down the slipway into the water. The cradle is a strong wood and iron framework, built under the vessel, to carry the total weight after the building blocks are removed, just prior to launching. It is supported on each side by narrow, well-greased planes, or "ground ways," upon which the whole slides when the restraining blocks are removed.

A "repairing" slip is generally fitted with lines of rails, upon which long trolleys or carriages, fitted with a large number of wheels and shaped to fit the under-water body of the vessel, are run; when deposited on this carriage any vessel of moderate size can be quickly hauled up high and dry beyond the reach of the tide.

"Dry" or "graving" docks are used in examining and repairing the largest vessels and occasionally to retain a hull during construction. Such docks may be placed with advantage on low-lying lands where there is a considerable rise and fall of tide. They are formed by excavating a cutting to suitable dimensions and then lining it with a thick body of brick, stone, or concrete; this is provided with a number of steps or ledges, to receive the heels of the shores or props which keep the vessel upright when unsupported by the water and resting upon the blocks arranged under its keel. If the dock opens into a tidal river or basin, the vessel enters at high tide, then the entrance is closed and the water pumped out, or drained by sluices at low tide; when the repairs are completed, water is readmitted and the vessel is floated out.

"Floating" docks are employed when excavated docks are impracticable, or present great engineering difficulties; they likewise possess the advantages of rapid construction and mobility and may be adapted for lifting the largest Atlantic liners or battleships. They usually consist of floating pontoons, enclosing a space fitted similarly to an ordinary dry dock and provided with large water chambers which when filled will sink the structure sufficiently to permit of the entry of a vessel at ordinary draught; by subsequently emptying these chambers the buoyancy necessary to raise the vessel above water-level is exerted.

The entrances to docks or basins are closed by means of gates or caissons. Gates are of wood or iron, pivoted on each side of the entrance and generally arranged so as to offer, when closed, a curved or V-shaped surface to the external water. When a strong movable roadway is necessary at such openings, or when not to be frequently opened, a caisson takes the place of gates. It may be either floating or sliding; the floating construction is a large hollow chamber of somewhat ship-shape form with the ends and bottom formed so as to fit into recesses at the dock entrance; by admitting water into the caisson it sinks into position and closes the entrance. Sliding caissons are moved horizontally along rails or grooves, by means of machinery, and when opened slide back into covered spaces on one side of the dock entrance, the top-sides of the caisson being mechanically lowered to permit of this movement.

A diving-bell, or more generally a close-fitting diving dress comprising a metal helmet attached to a waterproof jacket, is used for the survey of the submerged portions of slipways, docks, caissons, etc., as well as for the inspection of ships' bottoms while afloat; complete diving dresses, together with the necessary tubing and air pumps are for this purpose carried on all of H.M. ships.

Wood and iron derricks, stationary cranes driven by steam, air, or water power, together with locomotive and floating cranes, do the bulk of the heavy lifting work of a shipyard. For articles of considerable weight or dimensions, such as engines, boilers, masts, etc., "tripod sheers" are employed. These are formed of three inclined "legs" or supports, of circular or rectangular section, widely spaced at the base but connected together at the head, from which a block-purchase worked by a steam winch is suspended. Two of the legs are pivoted near the edge of the dock or wharf, the third being adjusted by means of a horizontal screw so as to give the required overhang. The legs of the largest sheers are built up of steel plates and stiffening bars, and take the usual parabolic form applied to crane jibs, etc. In some cases the legs are given a permanent overhang by means of guys and backstays attached to a strong vertical upright at the rear; this method was also adopted on the old-fashioned floating "sheer-hulks" used for the masting of ships.

Note.—Several of the ship models are shown with launching ways (*see* Nos. 17, 40, 62 and 166), whilst others are represented on the keel blocks upon which they rest while in dry dock (*see* Nos. 64, 96, 98, 103, 105, 237 and 293).

733. Model of the floating dock at St. Thomas. (Scale 1 : 48.) Lent by E. Hodges, Esq., 1878. N. 1486.

This iron structure was built at Cardiff in 1867, from the designs of Sir F. J. Bramwell, F.R.S., for use at the island of St. Thomas in the West Indies, where it has proved of great value.

The upper portion of the deck is formed of continuous lattice girders supporting a wide roadway on each side; the necessary buoyancy is given by a number of submerged pontoons, which are made portable to facilitate their overhaul and repair. To lower the dock preparatory to receiving a ship, water is admitted into these pontoons until they sink sufficiently, and this is subsequently pumped out so as to cause the structure to rise under its burden.

Alteration in the immersion or the trim is provided for by six "floats" or rectangular tanks on each side, which can be independently raised or lowered by means of vertical screws fixed to the structure and working in nuts attached to the floats. A single float is shown in its raised position at one end of the model. A coloured drawing of this dock is also shown.

Length, 300 ft. breadth, extreme, 100 ft.; breadth at entrance, 70 ft.; height, 42 ft.; carrying capacity, 3,000 tons.

734. Model and photographs of Bermuda floating dock. (Scale 1 : 64.) Presented by A. J. Campbell, Esq., 1880. Plate VII., No. 5. N. 1468 and 1528.

In consequence of the great need of a graving dock, capable of receiving large vessels on the North American and West Indian station, it was decided to provide such accommodation at Bermuda; but, owing to the porous nature of the rock of which the island is composed, the construction of a stone dock was considered to be impracticable, and it was decided to adopt one of the floating type patented by Messrs. Campbell, Johnstone & Co. This iron structure was accordingly built at Silvertown on the Thames in 1868 and afterwards towed to Madeira by H.M. ships "Northumberland" and "Agincourt," and from thence to its destination by H.M. ships "Warrior" and "Black Prince."

The dock is of cellular construction and has nine main transverse watertight bulkheads, intersected by seven continuous longitudinal watertight frames, making a total of forty-eight watertight compartments, each of which is fitted with valves for admitting or discharging water. Several smaller additional compartments contain the pumps, mooring cables, and the steam-driven machinery for working the capstans and cranes.

When employed to dry-dock a vessel of moderate dimensions, water is first let into the lower compartments of the dock and pumped from thence to the upper chambers, the whole structure meanwhile sinking until the valves on the floor of the dock are awash; these latter are then opened and the dock sunk sufficiently to enable the vessel to enter. When the vessel is in position over the blocks, the upper chambers of the dock are gradually emptied while "breast-shores" are being placed to support the ship, water is then let out of the intermediate chambers until the bottom of the dock is dry. For vessels of larger tonnage an increased lifting power is obtained by using the caissons with which each end of the dock is fitted, the water contained in them being partly discharged through sluices and partly into the lower chambers of the dock, as shown in the accompanying diagrams. The undocking process consists in refilling the spaces in the dock until the vessel is afloat. By admitting water into compartments on one side only, the dock can be heeled over sufficiently for all necessary cleaning or repairs on the opposite side, and in this way the whole of the surface is rendered accessible for cleaning, etc.

At its station the dock floated in a specially excavated basin, and was connected to the shore by three long brows or bridges whose free ends rose and fell with the tidal or other movement of the dock. During stormy weather the safety of the dock was insured by grounding it, the structure being then almost submerged. This model was originally constructed as a working one for experimental and lecture purposes, but was finished in detail and the external fittings added at this Museum in 1902.

The leading particulars of the dock were:—Total weight of materials, 8,200 tons; length, overall, 381 ft.; length, between caissons, 330 ft.;

breadth, between sides, 84 ft.; depth, overall, 74·4 ft.; depth, inside, 53·4 ft.; thickness of plates, ·31 to ·62 in.; and the maximum lifting power, 10,000 tons. The draught of water when light is 11·17 ft. and when sunk for docking a large ironclad 50 ft.

Owing to the increased size of warships a new floating dock was built for Bermuda in 1902 of the following dimensions :—Length, overall, 545 ft.; breadth, between sides, 100 ft.; maximum lifting power, 17,500 tons.

735. Lithograph of a tubular floating dock. Presented by Messrs. Clark and Standfield, 1878. N. 1511.

This construction of floating dock was patented by Messrs. Clark and Standfield in 1874.

The floor of the structure is formed of iron cylinders laid horizontally, and the sides of similar tubes placed vertically. By this arrangement the side and shape of the dock can be modified to suit special requirements.

736. Model of double-power floating dock. (Scale 1 : 96.) Lent by Messrs. Clark and Standfield, 1878. N. 1511.

This invention of Messrs. Clark and Standfield uses the buoyancy of the sides of the dock as well as that of the bottom, the inventors considering that the high sides of the usual construction form so much unnecessary weight which has to be lifted with each ship docked. The independent sides are also used for lifting the rest of the dock when it is being cleaned or repaired.

The lower pontoon or bottom of the dock has four fixed corner towers, between which the sides can rise and fall as if in guides; provision is also made for locking these sections together in any position.

To place a vessel in such a dock, if the sides are in the usual elevating position water is admitted into them and to the body of the dock until the whole sinks to the lowest level necessary for docking the vessel, the vessel is then floated in and secured; the water is now pumped from the main pontoon, which accordingly rises, while the sides still remain at the lower level. The sides are then secured to the main pontoon and emptied, thus raising the whole structure to a still higher level and completing the operation. The model shows a vessel in position in the dock, supported by keel blocks and shores.

This general principle has been successfully applied to the largest modern floating docks.

737. Lithographs and photographs of depositing docks. (Scale 1 : 240.) Lent by Messrs. Clark and Standfield, 1878. N. 1511.

This type of dock was introduced by Messrs. Clark and Standfield, who in 1877 constructed a large dock on this system at Nicolaieff for the Russian Government, its leading feature enabling it to accommodate vessels of the exceptional beam found in the circular ironclads.

The dock consists of a number of horizontal pontoons projecting, as cantilevers, from one side of a long horizontal pontoon resembling a box girder. This girder, or "side," as it is termed, is of such a depth that it is never completely submerged, while the cantilever pontoons attached to it are sufficiently low to allow the vessel to float over them when the arrangement is at its maximum immersion, through water having been admitted to some of the pontoons.

When a vessel is to be docked she is brought over the submerged cantilevers and secured in position by ropes and shores; water is then pumped out of the pontoons until the dock rises and the vessel bears firmly on the keel blocks. Sliding bilge blocks are then hauled under the bilges of the vessel, so as to form a suitable cradle, and the pumping is proceeded with until the dock rises to such a height that the vessel is completely above water level.

As the dock has only one side, a special arrangement is employed to keep the pontoons level at all immersions and with varying loads. This consists of a large outrigger in the form of a broad shallow pontoon, projecting from the outside of the main pontoon and capable of sliding in grooves attached to the side, so that while free to rise or fall it exerts a constant righting movement on the dock.

The arrangement is thus far equivalent to a floating dock, but its chief merits consist in the means by which it is enabled to deposit the vessel raised on a suitable staging, so that the number of ships that can be simultaneously docked depends simply upon the number of stages provided. These stagings are formed of iron or timber piles, braced together and forming narrow piers, each about 5 ft. broad, and usually from 10 ft. to 15 ft. apart. The cantilevers of the floating dock are arranged at corresponding distances, so that they can pass between these piers, and thus when the pontoon is lowered will deposit the vessel on the piers. Keel and bilge blocks are used as before; in one drawing air cushions are shown fitted in the position of the bilges to facilitate the operation of docking by reducing the shoring required.

The Nicolaieff dock, of which three photographs are shown, has ten cantilever pontoons projecting from the "side," which is made in three separate lengths, which can be used independently for small vessels. The side is subdivided longitudinally into compartments, 15 ft. and 5 ft. wide alternately; in the upper portion of each length there is a 25 h.p. semi-portable steam engine driving a vertical centrifugal pump 2·3 ft. diam. for emptying it. The cantilever pontoons are divided into watertight compartments, a number of which are permanently sealed, so that it is impossible to entirely sink the dock by any mistake.

738. Model of dock entrance and caisson. (Scale 1:48.) Presented by A. J. Campbell, Esq., 1880. N. 1528.

This represents a dock entrance closed by a caisson instead of the more usual dock gates; it is sometimes from its shape called a ship-caisson.

The caisson is formed of iron plating, stiffened internally with angle irons, diagonal braces, and horizontal decks; these decks and bulkheads also divide it into several watertight compartments, some of which form air chambers which provide the necessary flotation, while others are ballasted. When the dock entrance is to be closed the caisson is floated into its place between the entrance walls, and water is admitted into the air chambers until the keel of the caisson sinks into a recess in the sill. The ends of the caisson are also provided with ribs which enter recesses in the side walls, so that when any subsequent alteration is made in the water level on either side of it the side pressure tends to keep the sill and side joints tight; wooden facings also assist in securing a good joint. The upper deck of the caisson when in position forms a wide and strong bridge; but the arrangement, being less convenient than dock gates, is not generally used for entrances that have to be frequently opened.

739. Model of apparatus for repairing dock gates. (Scale 1:12.) Contributed by W. Smith, Esq., 1860. N. 369.

This is an apparatus patented by Mr. B. Hockin in 1858 for enabling repairs to be done to the submerged portions of dock gates without removing the gates or interfering with their working. It consists of a three-sided chamber, the open side of which is intended to fit against the face of the gate with a watertight indiarubber joint. The bottom of the chamber has a projecting flange to be passed under the bottom edge of the gate; for this purpose the gate may be slightly lifted by means of the vertical timbers provided with yokes or cross bars and lifting screws. When the chamber is in position the water is pumped out of it, and the workman is able to descend and execute the necessary repairs.

740. Models of combined floating dock and wreck-raising apparatus. (Scales 1 : 384, 1 : 96 and 1 : 24.) Presented by Druitt Halpin, Esq., 1901. N. 1521.

These models were used to illustrate a paper read by Mr. Halpin before the United Service Institution in 1870, explaining an expansion of a scheme he had prepared in detail for raising H.M.S. "Vanguard," sunk by collision, 1875.

The dock consists of two ship-shaped self-propelled iron hulls, subdivided by bulkheads and joined together by cross girders so as to form a pontoon capable of lifting and transporting the largest vessels, either above or below the surface of the water. The vessel was to be raised by means of numerous 100-ton wire cables attached to its side and secured to the floating dock, by which the wreck could be raised and carried to shallow water where, after the hull had been repaired and floated off, the dock could be sufficiently immersed to receive the vessel and then lift it for completing the repairs.

A detailed model is shown of the means proposed for attaching the wire ropes to the sunken ship without the use of divers. The scheme depended upon the use of a long tube, which could be towed to the scene of the wreck and there weighted by the admission of water till it floated vertically; it was then to be sunk till its foot bedded upon the sea bottom while the upper end remained above water. From the side of the tube projects a drilling post, carrying a wire brush for cleaning the side of the ship and also a large drilling cutter driven by an air motor, and this mechanism was to be controlled by a man within the open tube who, after drilling a hole could by apparatus provided pass through it a stretcher attached to one end of a lifting cable. The vertical open shaft was then to be sufficiently floated to enable it to be taken to a fresh position ready for the attachment of another cable and so on, the depth at which the apparatus could be worked depending upon the length of shaft that could be manipulated and not upon the hydrostatic pressure as when divers are employed.

741. Lithograph of a wreck-raising pontoon. Presented by Messrs. T. Christy & Co., 1873. N. 1358.

This shows a device patented in 1871 by Messrs. Siebe, Gorman and Christy. The pontoon consists of twin hulls, self-propelled, and is provided with a number of continuous chains led over pulleys fitted to the inner deck edges. These chains are passed, by divers, under the submerged vessel and then by means of steam-hauling gear are drawn in from each side simultaneously till the wreck is lifted above the water level and supported between the twin hulls; in this position the hull may be either repaired and pumped out, or be carried into shallower waters. Exceptional lifting power may be obtained by emptying water spaces in the pontoon itself.

742. Model of wreck-raising apparatus. (Scale 1 : 48.) Presented by Druitt Halpin, Esq., 1901. N. 2264.

This shows the method successfully adopted in raising the iron paddle-ship "Edith" belonging to the London and North Western Railway Co., which in 1875 sank after collision in Holyhead harbour to a depth of 36 ft. Her registered dimensions were:—Length, 250·6 ft.; depth, 14·4 ft.; breadth, 30·1 ft.; gross tonnage, 758 tons; displacement, 1,180 tons. Submerged the total weight to be lifted was 800 tons.

Owing to the presence of paddle-boxes it was decided to use camels at the bow and stern, calculation having shown that the vessel was strong enough as a girder to be lifted in this way. The lifting apparatus employed consisted of four rectangular caissons each 59 ft. long, 15 ft. wide, and

15 ft. deep, constructed of ·375-in. plate, with three bulkheads in each caisson and the flat surfaces supported by internal timber struts. Each pair of caissons was rigidly connected by 11 lattice and plate girders, which retained them at a distance apart of 32·5 ft., and on the top of the girders were four 12-in. square timber blocks supporting 20 wrought iron lattice columns, the caps of which formed nuts and capstan heads for lifting screws.

These camels were floated into position over the vessel and sunk till the tops were awash; a hook attached by a wire rope to each of the lifting screws was then passed into the side-lights of the vessel, or into holes 5 in. diameter cut under the doubling plate by divers, and the whole of the cables screwed taut; the water was then pumped out from the caissons by centrifugal pumps and the vessel raised, beached, and towed into dry dock. It was found that though submerged for more than two years the engines were but little injured, and the vessel subsequently resumed her station. The caissons were afterwards utilised as water tanks at Holyhead.

743. Whole model of wreck-raising lighter. (Scale 1 : 48.) Made in the Museum from drawings supplied by the Conservators of the River Thames, 1908. Plate VII., No. 6. N. 2468.

This wreck-lifting vessel was built of iron at Greenwich in 1882 by Messrs. J. and G. Rennie for the use of the Thames Conservancy Board.

The hull is vertical sided and flat-bottomed; for the purpose of lifting operations, a narrow "well" or opening 60 ft. in length, is provided along the centre line of the vessel. Throughout this central portion the design is of the "double-hulled" type, each half-body being subdivided into six watertight compartments, while before and abaft this portion there are strongly constructed holds or living-spaces of ordinary form. The starboard side is sectioned to show the general character of the constructional work in the vessel.

Steel-wire lifting ropes, 7 in. to 9 in. circumference, are here used in conjunction with eight Bullivant's automatic nippers or cable compressors (*see* No. 1104), each capable of sustaining a pull of 100 tons. A series of cast-iron fair-leads secured to the edges of the well keep the ropes in position, and the adjacent bollards give them a direct lead to the nippers.

When in use the ropes pass down the well and are fastened to slings placed around the submerged wreck. At low tide the slack rope is taken in and secured; the subsequent rise of tide lifts both lighter and wreck which are then towed into shallower water. Several lighters, some of which are provided with steam pumps, winches, and other appliances, are used when large vessels have to be raised. With a freeboard of 1·5 ft., this lighter will carry 400 tons.

Length, 105 ft.; breadth, moulded, 28 ft.; depth of side, 9·5 ft.

744. Fixed masting sheers. (Scale 1 : 20.) Presented by the Admiralty, 1864. N. 1014.

This shows the jetty and sheers for erecting the masts of battleships, originally used at Sheerness Dockyard which was opened in 1823.

The sheers consist of three compression members connected at the top by extensive lashings and considerably spreading at the feet, where they fit into cast-iron sockets. These members are of built-up timber, hooped with iron bands: at intervals the three legs are tied together by iron rods. This compound jib is tied back by four chains which, after being led through an independent mast at the back, are secured to anchorages in the masonry; on the jib side this mast is separately stayed by two inclined struts. The mast is also fitted with crosstrees and a topmast for signalling purposes, etc.

The lifting tackle consists of blocks and falls worked by capstans.

745. Model of a float for discharging cargo. (Scale 1 : 64.) Contributed by Messrs. Wm. Cory and Sons, 1862. N. 829.

This represents a design patented by Mr. Wm. Cory, junr., in 1861, for a floating pontoon for discharging cargo. With tapering ends it has considerable beam, to minimise listing.

It is provided with a gantry on which are narrow-gauge rails for coal tubs, and there are six hydraulic jib cranes of 20·5 ft. radius, for unloading coal from vessels and discharging it by screens and shoots into barges lying alongside. The pontoon shown is intended for discharging vessels up to 900 tons burden.

Length, 250 ft. ; breadth, 90 ft. ; depth, 14·5 ft.

746. Model of Turnbull's derrick. (Scale 1 : 8.) Lent by Messrs. G. S. Yuill & Co., 1894. N. 2039.

This represents an arrangement of derrick introduced by Mr. J. Turnbull for taking in or discharging cargo. There are four derricks arranged round the mast, each having a steam winch on the deck. When the load is lifted by any derrick its jib swings round automatically, either towards the centre line of the ship or from there to the side, according to which of two sockets the pin forming the heel of the derrick is placed in. The jibs are each supported by an outrigger fixed to a clamp on the mast, the extremities of the outriggers being so held by guys that the eye to which the jib is tied is almost vertically over the centre of the line joining the two socket-holes, but slightly forward of the holes in the fore-socket plate and aft of the holes in the after plate. The result is that the pull of the chain acts in a direction passing between the two sockets, and thus there is a tendency for the loaded jib to turn round one way or the other according to the hole into which its heel is put.

The two hatchways and the positions of the four winches are marked upon the deck.

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747. Model of diving bell. (Scale 1 : 12.) Presented by Prof. John Taylor, M.D., 1874. N. 1346.

The diving bell in its modern form was introduced by Smeaton in 1788, although many attempts in a similar direction had previously been made. As now generally constructed it consists of a chamber built of plates about ·4 in. thick, open below, but with the bottom edge turned up so as to carry ballast and also to stiffen it. The air is supplied through a flexible pipe entering the chamber at the top.

In the modification represented the air is introduced in an upward jet near the mouth, so that should the supply pipe burst the water would not rise within the bell. The same result is usually secured by fitting the supply orifice with a non-return valve, generally made of leather.

748. The original closed diving helmet. Presented by W. A. Gorman, Esq., 1881. N. 1543.

Augustus Siebe had in 1829 invented the open helmet, which was a small diving bell surrounding the head only, and was therefore of only somewhat limited application. In 1839, however, he constructed the closed helmet shown, which enabled the diver to work in any position and to a depth of about 100 ft.; with modern apparatus of the same type the present working limit is about 200 ft., or 87 lb. pressure.

The helmet and breastplate shown are made of sheet copper, and they are connected together by a relieved screw joint. The breastplate is secured to the diving dress of waterproof material by screws and washers fitted with wing nuts. There are two windows in the helmet, and at the back is the attachment for the air supply pipe, fitted with a non-return valve. The vitiated air is discharged directly into the water through an adjustable valve, by closing which the diver can increase his buoyancy and so rise, while a small two-way valve in front allows the pressure inside to fall when reaching the surface.

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749. Model of cofferdam to screw aperture. (Scale 1 : 48.) Lent by the Royal United Service Institution, 1903. N. 2323.

This represents the stern body of H.M.S. "Royal Alfred," 1864 (*see* No. 81), and the details of a temporary wooden cofferdam used to facilitate repairs to the propeller shaft without the vessel being dry-docked.

Two strong wooden frames were first made, which fitted closely against the stern and rudder-posts respectively, on each side of the screw-aperture. These formed watertight shields, and when lowered into position became the sides and bottom of the cofferdam, access to the interior of which was obtained through the screw "well" on the main deck—a lifting propeller being usually fitted to ships-of-war at this date. Internal struts, stays and clamps, with a few external bolts and chains, placed in position by a diver, held the sides of the cofferdam to one another and to the adjacent portions of the ship. After the contained water was pumped out a clear space, 8 ft. long, 4 ft. wide, and 18 ft. high, was obtained in the vicinity of the propeller-shaft.

750. Model of plates for stopping holes in ships. (Scale 1 : 12.) Lent by John McCool, Esq., 1872. N. 1333.

These devices, for stopping leaks, shot holes, etc., in iron ships while at sea, were patented by Mr. McCool in 1871.

In one method a weighted line is dropped through the hole, grappled for, brought on deck, and a washer plate attached, which is then drawn back by the line so as to cover the hole; it is finally secured by a bolt.

The other arrangement consists of a rubber-faced metal plate, provided with a hinged bar which is pushed through the hole and then turned so as to form a bridge against which the plate can be screwed.

751. Model of mat for stopping holes in ships. (Scale 1 : 3.) Lent by Messrs. Creswell & Co., 1876. N. 1401.

This extensively-adopted mat for covering shot-holes and leaks in ships was patented in 1875 by Lieut. (afterwards Admiral) S. Makaroff, of the Russian Navy, but is only an adaptation of an old device.

It consists of two similar pieces of canvas, from 5 ft. to 20 ft. square, sewn together on a matting made of plaited rope; on one side of this is oakum or cocoanut fibre. The whole resembles a door mat bordered with rope, and is drawn over the damaged portion of the hull by lines.

LIGHTHOUSES, ETC.

Lighthouses, to serve as landmarks both by day and night, have been generally erected on conspicuous or dangerous positions in the vicinity of important navigable routes since

B.C. 331, when the famous Pharos of Alexandria was built. The Romans were particularly energetic in this matter, and the remains of one of their lighthouses still exists at Dover. The early lighthouse was a tower or beacon, carrying a brazier in which wood or coal was burnt at night so as to give an all-round illumination, which was, however, fitful and unreliable; the arrangement survived, however, till 1822 in England, and to an even later period abroad.

The modern construction of lighthouse varies according to the site. In the most exposed positions, and where founded on a tidal rock, the foundation is quarried out of the solid, and the masonry of the base is built in blocks joggled together; this solid structure rises to a height of from 20 to 30 ft., when the rooms begin and the masonry is carried up hollow to the lantern. In an estuary, a braced structure erected on screw piles of wrought iron is usually adopted, while for the top of a cliff beyond the reach of waves, a brick or stone tower is sufficiently stable.

Lightships are usually established to indicate the position of dangerous shoals and in similar situations where the foundation for a permanent structure would present exceptional difficulties. During the day, their colour and a large ball on the masthead indicate their meaning, while at night they display a light similar to that of a lighthouse, although not of the same high order. Recently the value of lightships has been further increased by placing them in telegraphic communication with the shore, by which means they are enabled to convey information of disasters that would not otherwise be known by those on shore. A lightship was placed at the Nore as early as 1731.

Considerable development has taken place in the illumination of lighthouses. The early beacons, which were estimated to have burnt about one ton of fuel per night, were followed in the 16th century by oil lamps which, with a flat torch-like wick, gave a better but still very unsatisfactory light; Smeaton, in his "Eddystone" lighthouse of 1759, lighted it by 24 candles, each weighing 4 lb. Argand invented his annular wick in 1789, and Rumford increased the illuminating power of the arrangement by placing several of these wicks concentric with each other; seven, eight, or nine wicks are thus used in some modern oil lamps for this purpose. The commercial introduction of mineral oils in 1860, and their adoption in lighthouses in 1870, considerably improved the general illumination, and also reduced the cost of oil lighting. Coal gas, when readily available, has proved itself more convenient and economical than oil. Since the close of the 19th century the use of incandescent mantles with oil or gas burners has greatly added to the efficiency of these illuminants. Acetylene gas has also been successfully adapted for lighthouse use. The electric light has, however, some of the advantages possessed by gas and far greater power, but as it is considered to have but little more penetrative effect during foggy weather and is certainly more expensive, its application has but slowly extended; it was so long ago as 1858 that the lighthouse at the South Foreland was first lit by electricity.

To concentrate the rays from the illuminant, so as to avoid loss due to all-round dispersion, reflectors built up of small pieces of mirror-glass were first used; these were replaced by spherical reflectors, and subsequently by parabolic reflectors in metal, in which the reflected rays were discharged as parallel beams: these systems, relying on reflection only, are known as "catoptric." In 1849, Thomas Stevenson reduced both the direct and reflected rays into one parallel beam, by placing a lens in front of the light and a hemispherical reflector behind it; being a combination of a refractor and a reflector, the arrangement belongs to the "catadioptric" class. In 1822, Augustus Fresnel introduced the "dioptric" system, in which refraction only is used. To avoid the losses and other defects connected with the use of large thick lenses he substituted a small one in the centre and surrounded it with annular prisms set in frames; in the original arrangement portions of the light escape above and below, but this defect has since been remedied.

The three classes of light now shown are (*a*) "fixed," the earliest and still more widely used form, but one which is hardly distinctive enough for much frequented routes; (*b*) "flashing," showing flashes or groups of flashes at short intervals, and thus telegraphing its name, also concentrating the whole energy of the light into two or three comparatively narrow beams; (*c*) "occulting," or "eclipsing" lights, which, although resembling fixed lights most of the time, have one, two, or three short eclipses, by which their identity is established without any considerable interval of darkness occurring.

For use during fog, when lighthouses would cease to be of value either by day or night, some form of acoustic apparatus is always fitted to both lighthouses and light-vessels. Bells, guns, steam or compressed air whistles, reed trumpets and sirens have all been adopted, but for the most exposed situations the compressed-air siren is resorted to, on account of the penetrating and distinctive notes it gives. Submerged bells as fog-signals have been widely adopted on lightships, shore-stations and large seagoing vessels since 1905; when fitted with suitable receiving apparatus, vessels are enabled to hear such submarine signals at far greater distances than aërial signals and also to locate them with sufficient accuracy for safe navigation.

Buoys and beacons are small signals used to define the limits of a navigable channel in a river or estuary. They vary from a bunch of brushwood on a pole to the can-buoy of boiler-plate which is often fitted with a gas light and bell; but such arrangements are only of very local value.

All of these provisions in England and Wales are arranged and controlled by the Corporation of the Trinity House, originally a semi-religious body established at Deptford, but incorporated in 1514, and which has carried out its present important duties since 1680. The corresponding department in Scotland is the Northern Lighthouse Board, constituted in 1786, while the Irish Lighthouse Board, of about the same date, performs similar duties for the Irish coast. A special tax or toll upon shipping, known as "light dues," is levied for the support of these departments.

752. Model of the Smalls lighthouse. (Scale 1 : 48.) Lent by Capt. F. C. Pickering Clarke, R.N., 1862. N. 780.

The Smalls rocks are about 17 miles off the coast of Pembrokeshire, near the entrance to Milford Haven. This model, made out of one of the oaken piles of the original lighthouse, represents the first lighthouse on these rocks, erected in 1776. It was designed and the construction superintended by Mr. Whiteside, a musical instrument maker, assisted by Cornish miners, the expense being borne by a Mr. Phillips. The lighthouse was replaced in 1861 by a granite structure.

753. Model of Maplin lighthouse. (Scale 1 : 24.) Received 1899. N. 2199.

This lighthouse is situated on the Maplin Sand at the mouth of the Thames, near Shoeburyness. It was constructed in 1837 on Alexander Mitchell's screw-pile system, patented in 1833, and was the second lighthouse erected in this way.

It is octagonal in plan with a central wrought-iron pile and eight exterior ones 5 in. diam. and 26 ft. long, each with a cast-iron screw 4 ft. diam. These piles were screwed-in about 22 ft. and then the upper lengths added, which were slightly bent so as to give a pyramidal form to the structure. The piles are braced to the central one and to one another by horizontal and diagonal tie-rods riveted to clamps on the piles.

The lantern is above the platform, and the dwelling-rooms, stores, etc., arranged below it. Beneath these is an inverted pyramidal deck provided as a wave deflector. The model shows also the sliding ladder, boat, davits and fog bell.

754. Lithograph of Fleetwood lighthouse (1840). Woodcroft Bequest, 1903. N. 2319.

This lighthouse was erected in 1839–40 on a submerged sandbank at the entrance of Morecambe Bay. It was designed and built by Mr. A. Mitchell and was the first lighthouse completely carried on screw piles.

The substructure consists of seven wrought-iron piles, 16 ft. long and 5 in. diam., with screws 3 ft. diam. driven 12 ft. below the surface, forming a hexagonal pyramid with a slope of 1 in 5. To the tops of these piles are attached wooden baulks 12 in. diam. which reach to the height of the upper platform, while diagonal tie-rods connect the outside supports with one another and with the central one. A layer of clay and stones, several feet in thickness, was placed upon the loose sandy bottom around the structure. The lantern is 10 ft. diam. and has 12 sides, while its height above the sea level is 45 ft.

755. Model of Gunfleet lighthouse. (Scale 1 : 24.) Lent by the Corporation of the Trinity House, 1874. N. 1385.

This lighthouse on the Gunfleet Sands, at the entrance to the Thames, 31 miles from the Nore Lighthouse, is erected on Mitchell's patent screw piles, of which a separate model is shown. There are one central and six exterior piles inclining inwards, supporting columns of about 12 in. diam., strongly braced; the piles are screwed 40 ft. into the sand, and have screws 4 ft. in diam. The sockets for the columns are secured to the face of the piles by bolts.

The accommodation for the two keepers is under the lantern floor, one storey in height and divided into a living room, bed room, and oil room. Below this floor is a store room in the shape of an inverted pyramid, to which access is obtained by a ladder from the gallery. The sides and roof of the structure are of corrugated iron, with wrought iron angle plates.

The lantern contains a revolving catoptric apparatus, with fifteen reflectors and Argand burners in sets of five, placed on a frame of three sides, glazed with red glass.

756. Model of the Great Basses lighthouse. (Scale 1 : 48.) Lent by the Corporation of the Trinity House, 1874. N. 1386.

This lighthouse was erected on the Great Basses rocks, Ceylon, from the design of Sir James N. Douglass. It was commenced in 1870 and completed in 1872.

The lighthouse has a cylindrical base 30 ft. high and 32 ft. diam., on which is a tower 67·5 ft. high, 23 ft. diam. at the base, and 17 ft. at the springing of the curve of the cavetto. The thickness of the wall at the base of the shaft is 5 ft., and at the top 2 ft. The accommodation within consists of six circular chambers each 13 ft. diam. There is also a room in the basement 12 ft. diam. for coals and water, and a rain-water tank below 7·5 ft. diam. From the floor of the tank to the rock, a depth of 11·5 ft., the base is solid. The stones forming the wall of the tower are dovetailed, both horizontally and vertically, and set in cement; the tower is of Scotch granite, and the stones were fitted before being sent out.

The lantern is 110 ft. above high water, and shows a revolving red flashing light at 45 seconds intervals. The illuminant is Ceylon cocoa-nut oil. There is also a 5 cwt. fog bell.

757. Model of Malacca lighthouse. (Scale 1 : 32.) Received 1899. Plate VII., No. 7. N. 2200.

This lighthouse in the Straits of Malacca was erected by Messrs. G. Wells & Co. in 1874 on Mitchell's screw-pile system. The design is light, as the situation is well sheltered, and there is a depth of 15 ft. at low water and a tidal rise of 12 ft.; the bottom is muddy.

The structure is hexagonal in plan, with one central and six exterior wrought-iron piles 6 in. diam., screwed 15 ft. into the ground at a batter of 1 in 5. The lower lengths of the piles are coupled with socket joints formed on the pile itself, while the upper lengths have cast iron sockets. The structure is braced together with 5-in. by ·625-in. T-irons at high water level, and by 4-in. by ·5-in. ones above. The tie rods are from 1·5 to 2·5 in. diam., adjustable by right and left-handed screw couplings. The platform is 28·3 ft. above high water level, and at this height the distance between the pile centres is 13 ft.

The dwelling-house has four rooms, with a kitchen and lavatory which, on account of the climate, are in a detached overhanging structure; for the the same reason, the lean-to roof is extended over the gallery. The building is of angle-bars, covered with galvanised sheets and lined with matchboarding, grooved and tongued.

The lantern surmounts the dwelling, and is 9·6 ft. diam. by 7·53 ft. high: it contains a third order holophotal light with 8 sides, giving 1 min. intervals.

758. Model of Hino-Misaki lighthouse. (Scale 1 : 50.) Presented by the Board of Lighthouses, Japan, 1910. N. 2585.

This stone structure was built in 1903 on Cape Hino in the province of Izumo (S.W. Japan). It is fitted with dioptric group-flashing apparatus of the first order, giving double white flashes and a single white flash alternately every 20 seconds; three keepers are in attendance.

It is the highest stone lighthouse in Japan; the centre of the lantern is 128 ft. above the base, and the diameter of the structure varies from 15 ft. to 25 ft.

759. Model of Tsutsu-Zaki beacon. (Scale 1 : 25.) Presented by the Board of Lighthouses, Japan, 1910. N. 2586.

This lighted beacon was erected in 1909 on a sunken rock situated on the north side of the Eastern Channel of Tsushima Strait (Southern Japan). It is fitted with dioptric illuminating apparatus of the fifth order, flashing a white light every 15 seconds; this requires attention once a fortnight.

Great difficulty was experienced in the erection of this structure owing to the rough seas in the vicinity, only 82 actual working days being possible out of a total of 735 days in progress. A native visiting-boat, fitted with a special weather-screen at the bow, is shown near the beacon.

The centre of the lantern is 76 ft. above high water, and the diameter of the structure varies from 10 ft. to 32 ft.

760. Whole model of early lightship. (Scale 1 : 36.) Lent by the Corporation of the Trinity House, 1897. N. 2158.

The first lightship was established by Robert Hamblyn and David Avery in 1731 at the Nore, to mark the entrance to the Thames and Medway. The light was maintained by a species of toll, but ultimately the Trinity Brethren paid an annuity of 100*l.* for 61 years to purchase the ship and any rights that might have been secured. The "Dudgeon" lightship off the Lincolnshire coast, was the second floating light, and was established in 1736.

These early lightships were from 80 ft. to 90 ft. in length, and from 100 to 180 tons burden; they had one mast, nearly amidship, carrying a yard. At the masthead was a large red flag, while at each extremity of the yard was a lantern lighted by candles. When these candles required trimming the yard was lowered by a winch and placed fore and aft, the rigging being so arranged as to permit of this being easily performed. During foggy weather a bell was sounded. They were moored with anchors and hemp cables.

761. Built whole model of a Goodwin lightship. (Scale 1 : 24.) Lent by the Corporation of the Trinity House, 1865. N. 1087.

This represents the North Goodwin lightship, one of four stationed around the Goodwin Sands. It exhibits three fixed white lights, at heights of 20 ft., 25 ft., and 34 ft. respectively, and is distinguished by day by three masthead globes; a gong is sounded during foggy weather. It is moored with 42 cwt. mushroom anchors and 1·5-in. chain cables.

The port side of the model shows the ship complete, while on the starboard side the timbers, waling, cabins, oil-tanks, seamen's lockers, and other fittings are left visible. The deck detail is also very accurately shown, the hand-lead, log, and drift lines, gong, pumps, boats, guns for warning vessels seen standing into danger, crab winches for hoisting and lowering the lanterns, etc., being all represented to scale.

Length, 96 ft.; breadth, 21 ft.; depth, 10·7 ft.

762. Whole model of the Sunk lightship. (Scale 1 : 48.) Lent by the Telegraph Construction and Maintenance Co., 1892. N. 2008.

This represents a lightship moored on the Sunk shoal in the North Sea, 9 miles east of Walton-on-the-Naze. It is connected by telegraph and telephone with the shore, so that during bad weather tugs or lifeboats may be called out to the assistance of vessels seen to be in distress.

In 1870 an attempt was made to establish a floating telegraph station at the entrance of the English Channel by mooring the old corvette "Brisk" in 65 fathoms, 60 miles from Lands End. This was unsuccessful owing to the breaking of the insulated cable through the motion of the ship.

In 1885 the "Sunk" lightship was fitted with electrical appliances for shore communication, but the cable soon broke down. Double mooring, as shown, was adopted to prevent the mooring chains damaging the cable, but the failure of the electrical circuit was afterwards avoided by the use of a helical conductor. The instruments used were the Wheatstone A B C, the Morse sounder, and the telephone.

The model is fitted with an electric bell and an insulated cable, by which connection is made with a battery and key outside the case and corresponding with the shore end of the cable.

763. Whole model of Outer Gabbard lightship. (Scale 1 : 24.) Lent by the Corporation of the Trinity House, 1897. N. 2157.

This composite-built vessel was constructed at Newcastle in 1888 by Messrs. Robert Stephenson & Co.; her frames are of iron, the topsides of teak, and the bottom planking of elm, sheathed with copper to a considerable height above the water-line.

The lantern is 8 ft. diam., and contains eight two-wick Douglass lamps with 21-in. reflectors: the illuminant used is heavy mineral oil. The light gives a group of four white flashes at minute intervals with an intensity of 8,000 c.p. During fog a reed horn, worked by a hot-air engine, gives four successive blasts every 45 seconds.

The vessel is moored in 16 fathoms of water, near the Gabbard Sand off Harwich, with 210 fathoms of chain cable 1·625 in. diam., and a 3-ton mushroom anchor.

Her crew on board consists of a master, two lamp-lighters, and four seamen.

Length, 105 ft.; breadth, 23·5 ft.; depth, 12·8 ft.

764. Occulting light apparatus. Presented by Major-Gen. H. P. Babbage, 1904. N. 1465.

It was in 1850–5 that the late Charles Babbage, F.R.S., introduced his system of occulting lights for lighthouses, by which the beacon is enabled continuously to signal its number; the mechanism shown is that originally made for moving the screen by which the series of eclipses is occasioned.

The apparatus consists of a train of wheels driven by a weight and regulated by a revolving fan; this train lifts and lowers an obscuring disc in an arbitrary manner determined by the position of notches cut in the edge of a wheel. The arrangement shown signals the number 587 in the following way. After the light has been steadily visible for a long interval five occultations take place; then there is a short interva followed by eight occultations, and another short interval followed by seven occultations, the first number following the long intervals and the others the short ones.

The modern flashing lights usually revolve, but concentrating their rays into several narrow beams give a flashing signal which, owing to the concentration, has greater penetration than a steady light, as well as the desired individuality.

765. Photographs of arrangements of lighthouse lenses. Lent by Messrs. Chance Bros. & Co., 1875. M. 1397.

These show the optical apparatus for lights of the first, second, third and fourth orders, both revolving and fixed; also for oil or electric illumination.

766. Marine lamp. Presented by the U.S.A. Lighthouse Board, 1880. N. 1541.

This oil lamp, patented by Messrs. Dennis and Wheeler in 1867–8, was adopted by the U.S.A. Government as an anchor light giving an all-round illumination. The protecting glass is in the form of a cylindrical lens, with corrugations on Fresnel's principle to give horizontal distribution.

The lamp is regenerative in principle, the products of combustion being used to heat the air supplied to the burner.

767. Navigation lights. Lent by Messrs. Nunn, Ridsdale & Co., 1905. N. 2392.

Since 1863, by International Agreement, all vessels have been required to carry a number of special lights in well-defined positions for preventing collisions at sea. The Board of Trade regulations governing the character and disposition of such lights for British ships may be thus summarised:—

All vessels when under sail, under steam, or in tow shall carry from sunset to sunrise a green light on the starboard or right-hand side and a red light on the port or left-hand side, each visible at a distance of 2 miles over a horizontal arc equivalent to 10 points of the compass (112·5 deg.), *i.e.*, from right-ahead to a position 2 points abaft a transverse or beam line. A fore-and-aft screen is to be placed on the inboard side and project 3 ft. forward of each lamp, in order to prevent convergence of the two beams. In addition a steam vessel shall carry on or in front of the foremast a bright white light visible at a distance of 5 miles over an arc of 20 points of the compass (225 deg.); a second light of similar character may be carried abaft this position providing it is fixed 15 ft. higher than the foremost one.

Any vessel being overtaken by another shall show from her stern a white light or a flare-up light, the former to be carried at the same level as the side lights and to be visible at a distance of 1 mile over an arc of 12 points of the compass (135 deg.). A light similar to the above may be used by a steam vessel having another vessel in tow.

A vessel at anchor, under 150 ft. in length, shall carry forward where best seen a white light visible all-round the horizon for a distance of 1 mile; when over 150 ft. in length the vessel shall carry in addition a similar light near the stern which shall not be less than 15 ft. lower than the foremost light.

The set of five oil lamps shown, in general features, comply with the above regulations; in point of size, however, they are only suitable for a motor boat. The side lights marked "Port" and "Starboard" are fitted with red and green glasses respectively, while those marked "Mast Head," "Stern" and "Anchor" are fitted with white lenses having corrugations on Fresnel's principle to give parallel beams of light; all have internal spherical reflectors. The arc of illumination is limited, except in the case of the anchor lamp which provides an all-round light. The usual fittings for suspending or securing the lamps are shown on each.

An adjacent sketch shows in plan and elevation the disposition of the various lights on a steam vessel when under way, and also indicates the respective arcs of visibility of each, as prescribed; the letters A.A. mark the position of anchor lights upon a large vessel. Further details of navigation lights and particulars relating to sound signals for fog, etc., are shown on an adjacent printed card.

768. Model of bell buoy. (Scale 1 : 8.) Presented by the U.S.A. Lighthouse Board, 1880. N. 1540.

This is an improved form of the early signal buoy in which the swaying motion due to the waves caused a bell on the buoy to ring. Unfortunately such simple appliances are silent in calm weather when fog is most prevalent.

The arrangement shown consists of a moored buoy supporting an iron frame in which a bell is fixed. The clapper of the bell is in the form of a spherical shot which rests on a plate, with radial corrugations supported by the frame; the grooves cause the shot to strike against the bell as the buoy swings, instead of simply rolling around within it.

769. Steam siren. Lent by Messrs. Steven and Struthers, 1887. N. 1729.

This signalling apparatus, for use at sea as a foghorn, etc., was patented by Messrs. John Steven and Thomas Burt in 1882. It is a modification of the instrument for the production and analysis of musical notes invented in 1819 by Cagnard de Latour.

In the fog-siren shown steam or compressed air is, by a simple valve, admitted into an annular casing provided with twelve vertical tangential slots through which the fluid can issue in jets. Inside this is a cylinder with similar slots oppositely inclined, and this cylinder is carried on a central axis so that it can freely turn, the arrangement resembling an inward-flow turbine except that the flow is interrupted while the wide vanes blind the orifices.

To start the inner cylinder when the slots are not coincident, extra vanes on the inside are provided for six jets of steam to impinge against. To direct the sound a cowl or bell-mouth is added, which can be clamped in any desired position.

The note sounded, depending upon the velocity of rotation of the fan, has a changing pitch which is very characteristic of such signalling appliances.

LIFE-SAVING APPLIANCES.

Until the 19th century vessels were usually totally unprovided with any special arrangements for preserving the lives of those on board in the event of the vessel sinking, and it was not till 1888 that the "Merchant Shipping Life-Saving Appliances Act" rendered the adequate provision of such emergency fittings compulsory.

In cases of foundering, the usual expedient was to construct rafts from empty water-casks, spare spars, etc.; but this required time, and became increasingly difficult as the employment of iron steamers extended. The idea, however, survives in the special pontoons sometimes stowed along the bulwarks or amidships, ready fitted for use, on some vessels, while in many passenger steamers the deck seats are so constructed as to become rafts when placed in the water.

Life-belts made of cork covered with canvas and sufficient to float another adult besides the wearer form part of the equipment of all passenger vessels, while similarly constructed life-buoys of annular shape are carried on the bulwarks, bridge, and other accessible parts of the ship. Copper life-buoys of various forms are usually carried astern in ships of the Royal Navy; these are adapted for night use by fitting some system of automatic illumination.

Life-boats are the most reliable and generally successful means of saving shipwrecked crews; but such appliances have been placed in this collection with the other numerous forms of boats.

When a vessel was wrecked on a rocky coast where a life-boat was not available, the earliest method of establishing connection with those on shore was by throwing a line from the ship. In 1807, Capt. G. W. Manby, F.R.S., reversed this by firing a grapnel with rope attached from a mortar on shore. Messrs. Trengrouse and Dennett, used a rocket to propel the light line, and this idea is embodied in the apparatus adopted by the Board of Trade in 1855, and now used at all coast stations. In the United States Capt. D. A. Lyle's gun is used, in which the rope is attached to the shot and is within the cartridge. In all cases a hawser is eventually hauled on board and made fast to the stump of a mast; it then serves to support a life-buoy, cradle, or life-car, by which one to seven persons may be hauled ashore at each trip, the arrangement becoming a form of aerial ropeway.

In the neighbourhood of steep cliffs it is customary to provide ladders or cliff cranes for use in the event of a vessel being driven on to the rocks at the base.

770. Photograph of model of cliff crane. Received, 1896.
N. 2099.

This shows the original crane as used by the Royal Humane Society at Brighton in 1841. It is designed for the rescue of people wrecked in inaccessible places, such as the base of precipitous cliffs. The crane is drawn to the edge of the cliff, until the derrick overhangs the base, a weight forming a counterpoise being placed at the inner end. The people are then hoisted in a car or basket. Captain Manby's mortar apparatus was fitted to this example.

771. Model of vessel's upper deck with canting bridge and life-boat. (Scale 1 : 24.) Contributed by William Smith, Esq., 1870. N. 1320.

This life-saving arrangement was patented by Capt. H. W. Hire, R.N., and Mr. J. White, of Cowes, in 1886; it was adopted in H.M. Indian troop-ships and in the merchant service.

There is a see-saw bridge athwartship, rather longer than the ship's beam, and hinged on a metal support amidships; it is also supported at the ends by adjustable metal stanchions. The bulwarks and stanchions are hinged so that they can be swung outboard, thus lowering either end of the bridge and converting it into a launching way.

The life-boat was patented by Messrs. A. Lamb and J. White in 1862; it has bow, stern and side air cases and is fitted with three strong external keels to act as launching guides. Provision is made for carrying light guns.

772. Whole models of pontoon life-rafts. (Scale 1 : 12.) Lent by Capt. J. W. Hurst, 1868. N. 1198–9.

This construction, patented by Capt. Hurst in 1865, consists of two iron pontoons stayed apart diagonally by rods and formed into a raft by cross beams secured by clamps, so that the whole can easily be put together. There is a raised gunwale round the raft, with rowlocks for twelve oars, and it is also fitted with masts and sails.

Length, 27·5 ft ; breadth, 3 ft.; depth, 3·5 ft.

A separate model shows this raft stowed as a portion of a vessel's bulwarks.

773. Model of life-saving apparatus. (Scale 1 : 6.) Presented by H. S. Harland, Esq., 1874. N. 1372.

Three arrangements of apparatus for saving drowning persons are shown. They consist of coils or reels of life-lines, with cork buoys at intervals. Capt. Ward's cork belt is part of the equipment, and enables a man to swim out with a life-line. To be ready for use on ice the lines are carried coiled in baskets.

774. Model of life-buoy stowage. (Scale 1 : 6.) Presented by H. S. Harland, Esq., 1874. N. 1371.

This method of carrying buoys was introduced by Mr. Harland in 1868 to avoid the loss of time involved in releasing a buoy that is lashed in position. Circular buoys are placed on the inside of the bulwarks between the stanchions and supported in chocks; they are fastened in front by simple latches.

775. Model of ship's life-boat apparatus. (Scale 1 : 12.) Presented by R. T. Fairbridge, Esq., 1879. N. 1399.

These several appliances were introduced by Mr. Fairbridge in 1872.

The boat-lowering gear consists of a form of trip hook at each end, fitted with lanyards for releasing from amidships.

A combined life-raft and launching slip for boats is shown, also a canvas shoot for conveying women and children into a floating boat.

The boats are shown stowed beneath protective canvas covers.

776. Whole model of combined life-boat and raft. (Scale 1 : 12.) Presented by N. H. J. Smith, Esq., 1863. N. 926.

This arrangement was patented by Mr. G. F. Parratt in 1852–3. The central portion is an ordinary life-boat, but after being lowered a triangular frame of spars is projected from each side; these frames carry netting supported by inflated india-rubber bags, which thus increases the accommodation. Thwarts for the crew are provided on the rafts, rowlocks being fitted on the projecting spars in addition to those on the gunwales.

777. Model of life-net. (Scale 1 : 12.) Presented by the Commissioners of the 1851 Exhibition, 1874. N. 1392.

This arrangement was designed by Lieutenant R. J. Rowe, R.N., about 1874, and has the advantage of being readily improvised from ship's stores. A triangular raft is formed of three spars supported by three barrels; a floor of netting is added.

778. Life-buoy. Presented by Major H. B. Rodway, 1879. N. 1512.

This form was patented by Major Rodway in 1878. It consists of a sealed tin-plate cylinder, 6 in. long by 4·5 in. diam., provided with a strap, which, when adjusted around the neck, will support a person in either a vertical or a horizontal position; the total weight is 1·5 lb.

MARINE ENGINES.

The early methods of obtaining motive power from steam are detailed in the Mechanical Engineering Collection (Catalogue, Part I.). The problem of applying these results to navigation was not solved till the weight of the boiler and engine could be reduced within the limits of displacement of a boat that the engine could propel at a reasonable speed. Thus Denis Papin, in 1707, succeeded in propelling a boat by manual labour applied to cranks, but was unable to adapt a steam engine for the purpose. Jonathan Hulls, in 1736, patented a tugboat accommodating an atmospheric engine with a ratchet-wheel mechanism for obtaining rotative motion (*see* No. 779), but there is no conclusive evidence that it was tried.

Patrick Miller (b. 1731, d. 1815), who was experimenting with double-hulled vessels fitted with paddle-wheels driven by men turning capstans, had his attention drawn to an engine patented in 1787, by William Symington (b. 1763, d. 1831). A trial, in 1788, with this engine (*see* No. 783) fitted to a pleasure boat proved completely successful, as did also another with a larger boat and engine in the following year; Miller tried, without success, to induce Boulton and Watt to join him in this enterprise and also offered his results to the Admiralty.

Great credit is due to John Fitch (b. 1743, d. 1796), of Pennsylvania, who, after five years spent in experimenting with different combinations of engines and propelling apparatus, succeeded, in 1790, with a boat propelled by stern oars in running a service between Philadelphia and Bordentown; it was unsuccessful, however, probably because so little space was available for cargo and passengers.

Symington, in 1801–4, financed by Lord Dundas, produced a thoroughly satisfactory marine engine (*see* No. 784). His boat was tried with success on the Forth and Clyde Canal, but as the proprietors feared damage to the canal banks, the boat was disused and the scheme was not taken up elsewhere. Meanwhile Robert Fulton (b. 1765, d. 1815), who had made successful experiments on the Seine in 1803, ordered from Boulton, Watt & Co. an engine which, in 1807, he fitted into the "Clermont," thus successfully inaugurating steam navigation on a commercial scale in the New World. Development was rapid, and Fulton's unmechanical bell-crank engine was quickly displaced by the "square" or "cross-head" engine of John Stevens, known on this side of the Atlantic as the "steeple" engine and generally credited to David Napier, although, on land and in a slightly different form, it had long before been used by Trevithick.

The first steamboat to run commercially in Europe was Henry Bell's "Comet" of 1812; his engine was of the half beam type (*see* No. 787). The influence of the then standard beam construction is further visible in the marine engine developed by Boulton, Watt & Co. prior to 1820. This was the side-lever engine (*see* No. 794) which remained the standard type till about 1860, having been brought to great perfection by Clyde engineers, and having given rise to minor varieties (*see* Nos. 797–8). This influence also appears in the "walking-beam" engine developed about 1813 for the shallow-draught American river steamers, for which it has not yet been quite displaced; its structural details give a peculiarly striking effect to these enormous steamers (*see* No. 818).

The steeple engine introduced into this country about 1842 by David Napier was an improvement on the side-lever in that it occupied less space and had fewer parts. As the crank-shaft was usually hung just over the cylinder, two or more piston rods were necessary (*see* Nos. 803–4), but other arrangements were also used.

Murdock's oscillating engine of 1785 had been applied to marine work as early as 1822 in the "Aaron Manby," but it was not till 1827, when Joseph Maudslay equipped it with an efficient valve gear (*see* No. 811) that the saving in space due to the absence of connecting rods, was appreciated, and it was only when re-introduced in 1838 by John Penn, of Greenwich, that the type became and has since continued to be such a favourite for paddle steamers.

The practical introduction in 1836 of the screw for propulsion necessitated a higher speed of rotation of the propeller shaft than of the paddle-wheel. At first, this need was met by employing engines of the accepted slow-running type and gearing up to the propeller shaft by ropes, belts, and pitch chains (*see* No. 820). When John Ericsson, who brought out his screw in 1836, employed a direct-acting engine to propel it, its speed was considered unsafe. The introduction of the screw also gave a great impetus to the application of steam to the propulsion of warships and as the machinery was required to be below the water-line, a horizontal type of engine was developed. Ericsson tried one or two remarkable types (*see* No. 835), and finally adopted the return connecting-rod type, which was really only the steeple engine placed horizontally. This was first fitted, by his representative, in the French frigate "Pomone" followed in 1844 by H.M.S. "Amphion"; it remained the standard type of engine in H.M. Navy down to 1876 (*see* No. 849). Another type extensively used for the same purpose during the same period, was Penn's trunk engine; when first introduced for paddle propulsion it found but little favour, but it was revived with success in 1847 for screw propulsion (*see* No. 845). The horizontal direct-acting type was extensively adopted between 1860 and 1885, but was always adversely criticised on account of the shortness of the connecting rods possible in the athwart-ship space available (*see* No. 850).

For the mercantile marine the inverted or steam hammer type has been in favour for screw propulsion since 1860. In the increased space available, consequent on the introduction about 1885 of the protective deck, it became possible to use this type in warships also and it was exclusively so fitted till the introduction of the steam turbine. With it, a number of cylinders can be placed tandem in order to get successive stages of expansion rendering a desired crank arrangement easy (*see* No. 852). Its economy in athwartship space admits, conveniently, of double sets for twin screws. For paddle steamers, now confined to river and estuary services, the oscillating engine, which does not readily lend itself to compounding, has given way to the diagonal direct-acting engine (*see* No. 819) and this type is also displacing the "walking-beam" type in American waters.

The successful introduction into marine practice by Messrs. Randolph, Elder & Co. of compound working in the S.S. "Valparaiso" and "Inca" (1856) was of vital importance in the direction of reducing the consumption of fuel, although as their steam was only at 25 lb. pressure, corresponding to a temperature of 130 deg. C. the full benefit of this advance was not at once apparent. In the S.S. "Thetis" (1853), by Messrs. Rowan and Horton, however, with a steam pressure of 115 lb. (*i.e.*, 175 deg. C.), the coal consumption was only 1·86 lb. per indicated h.p. per hour. Expansion in three successive stages was introduced in 1874 by Messrs. John Elder & Co., in the S.S. "Propontis," and since then, following on the steady increase in pressure and in the number of expansions, the fuel consumption has been steadily diminished till it is now below 1 lb. per indicated h.p. per hour. Surface condensation was a factor which also assisted in this result; it had been tried by Watt and was actually used for marine engines by David Napier in 1820–1, but was not generally introduced till 1833–7 by Samuel Hall and then only slowly displaced the simpler jet arrangement. In recent years high vacuum has assumed great importance and the "augmented condenser" and other apparatus has been adopted to assist the air pump.

The application of the steam turbine to marine propulsion dates from 1894, when an experimental vessel named the "Turbinia" was constructed. As finally fitted the vessel had three turbines, high, intermediate and low pressure, driving three separate shafts each with three propellers, the low pressure and reversing turbines being coupled to the central shaft. This exceptional number of screws was found necessary to distribute the power developed at the high speed of revolution involved, and the remarkable speed of 34·5 knots was attained. This success was followed by the construction of two torpedo boat destroyers, H.M.Ss. "Viper" and "Cobra," fitted with steam turbines. They, however, were lost before lengthy trials had been made. The steam turbine was next applied to fast cross-channel steamers and to Atlantic liners. Comparative trials on H.M.S. "Amethyst," fitted with turbines, and on other vessels of the same class, fitted with reciprocating engines, resulted in the adoption of turbines in H.M. Navy. At present such engines are fitted in practically all new warships and their use is being very greatly extended in the mercantile marine. Their proved advantages over reciprocating engines are: economy of fuel at high speeds, reduction in weight, freedom from vibration, and reliability in service. At cruising speeds the reciprocating engine is more economical, and the experiment has been tried of combining the two systems in the same ship.

The earliest successful application of the internal combustion engine to marine purposes appears to have been made in 1888, when a vessel was fitted with a Priestman oil engine. Steady progress has since been made in this method of propulsion for which its advantages are:—compactness, lightness, and the power being immediately available. A disadvantage is the difficulty of reversing, without having recourse to special mechanism. The fuels at present in use in this connection are:—coal, coke, crude petroleum, paraffin, petrol, and alcohol. Owing to the high cost of petrol, attempts have been made to realise the economy that can be obtained by using producer gas obtained from bituminous coal, and some progress has been made in this direction.

PADDLE ENGINES.

779. Engraving of Hulls's paddle steamer. Received 1870. N. 2172.

In 1736, Jonathan Hulls, of Campden, Gloucestershire, patented an arrangement of steam-propelled vessel to be used as a steam tug, in which a paddle-wheel at the stern was driven by a Newcomen atmospheric steam engine. In the following year he published an illustrated pamphlet upon his invention, a reprint of which is shown. It is stated that Hulls experimentally tried his scheme on the Avon at Evesham in 1737; he appears, however, to have abandoned the subject, as his only subsequent patent, applied for in 1753, describes an arrangement for detecting spurious coins by their specific gravity and an improvement in the logarithmic rule.

The tug represented has a single-acting steam cylinder, 30 in. diam., which in its inward or working stroke lifts a weight equivalent to one-half of its effective pull; by utilising the energy of this weight upon its descent during the return stroke a double-acting engine is obtained, and the reciprocating motion of the piston gives continuous rotation to a paddle-wheel at the stern by a form of frictional ratchet gear. Where the water was sufficiently shallow Hulls proposed to use a pair of connecting rods from cranks on the paddle-wheel shaft, and allow them to rest on the river bottom so as to act as punting poles when the engine was at work.

780. Pen-and-ink sketch of the Marquis de Jouffroy's steamboat. (Scale 1 : 150.) Woodcroft Bequest, 1903. N. 90.

This was copied in 1830 by Mr. R. Prosser from a French print published in 1816 as representing a steamboat constructed by the Marquis de Jouffroy d'Abbans in 1783. The boat is 140 ft. long, 15 ft. beam. and 3·2 ft. draught; it has two paddle-wheels turned by a single horizontal steam cylinder driving through a ratchet mechanism. In Paris is a declaration that on July 15, 1783, the vessel was propelled by steam power for fifteen minutes against the current of the river Saône, but these particulars of the machinery did not appear till thirty-three years later.

781. Engraving of the paddle vessel "Edinburgh." (Scales 1 : 80 and 1 : 24.) Woodcroft Bequest, 1903. N. 91.

The "Edinburgh," designed by Patrick Miller of Dalswinton, an Edinburgh banker, and launched at Leith in October, 1786, was 73·3 ft. in length, and 22·5 ft. in breadth. She consisted of three distinct hulls held together by beams; she had three masts, and each hull had its own rudder, but the three tillers were connected so that all were moved by the central one. She was fitted with two paddle-wheels 6 ft. diam., 4 ft. wide, with eight floats each. One of these wheels was on each side of the central hull, and they were rotated by winch handles driven by manual power; the immersion of the wheels could be varied.

Besides propulsion by paddle-wheels, Miller was at the time also advocating the use of two or three hulls abreast, claiming that they were superior to ordinary ships in the following respects—their small draught of water, great stiffness, small amount of lee way and great buoyancy; moreover they required no ballast.

782. Model of double-hulled paddle ship. (Scale 1 : 48.) Contributed by Miss Miller, 1862. Plate VIII., No. 1. N. 316.

This represents one of the eight or more paddle-driven vessels experimented with by Patrick Miller. It was built at Leith in 1787 by J. Laurie, and probably represents Miller's final design of ship for auxiliary propulsion by muscular power.

The two complete hulls are connected together abreast, but with sufficient space between them for five paddle-wheels 7 ft. diam. placed tandem. Each paddle-wheel can be raised out of the water, when sails alone are used for propulsion, and is driven by a separate capstan on deck worked by manual power. Bevel gear was used. "On the lower part of the capstan was fixed a wheel with teeth pointing upwards to work in a trundle fixed on the axis of the water-wheel." With 30 men at the capstans a speed of 4·3 knots could be maintained. The model has five masts rigged with square and stay sails; each hull has a separate rudder, but the tillers are connected. It is stated that the vessel was presented to the King of Sweden, and that on the voyage to Stockholm it proved easy and weatherly in a gale. The dimensions were:—Displacement, 255 tons; length on deck, 100 ft.; breadth of each hull, 12 ft.; extreme breadth, 31 ft.; depth of hold, 16 ft.; draught, 55 ft.

Another twin vessel built in 1787 had two paddle-wheels worked by cranks instead of capstans; its length was 60 ft., and breadth 14·5 ft.

A lithograph of a vessel of this construction is shown.

783. The original marine steam engine, with drawings. Woodcroft Bequest, 1903. Plate VIII., No. 2. N. 5.

This is the engine made in 1788 for Patrick Miller by William Symington, of Wanlockhead, who in June, 1787, obtained a patent for a "new invented steam engine on principles entirely new." Miller had been making experiments in the propulsion of boats by hand-worked paddle-wheels, and, owing to the severe labour that was found necessary, it was suggested to him by James Taylor, his son's tutor and a personal friend of Symington, that he should employ steam instead of manual power to drive the paddle-wheels. Accordingly Symington was engaged to design an engine, the castings for which, it is recorded, were made in brass by George Watt, of Edinburgh. In October, 1788, the engine was placed on one deck of a double-hulled pleasure boat 25 ft. long by 7 ft. beam, and the boiler on the other deck. The engine was geared up by chains with two paddle-wheels placed one in advance of the other in the space between the two hulls.

It is stated that this machinery propelled the boat on Dalswinton Loch at the rate of 5 miles an hour, but when only a few runs had been made it was removed, and after various vicissitudes was finally dismantled and condemned as scrap in 1853. Mr. Bennet Woodcroft, F.R.S., however, secured the pieces, and Messrs. John Penn and Son re-erected them in 1854, replacing some missing parts, and the engine then ran satisfactorily under steam at their works.

The engine has two vertical open-topped Newcomen cylinders 4 in. diam., by about 18 in. stroke, in each of which works a piston connected by two chains with a drum which turns in opposite directions alternately. Each piston has a rod carried in overhead guides, and the two chains enable power to be exerted in both the up and the down strokes, but it does not appear that the steam used was above the atmospheric pressure, as it could blow out through the condenser. There are two horizontal paddle shafts, on each of which are two loose pulleys with ratchet teeth round their inner flanges, and between each pair of pulleys is a disc keyed to the shaft and carrying two pawls. Chains from the central drum turn these loose pulleys in opposite directions, and the teeth on the ratchet wheels alternately engage with the pawls and so drive their paddle-wheel continuously in one direction.

The lower end of each cylinder is fitted with a second piston used as an air pump, and these air pump pistons are connected by a small oscillating beam arranged beneath the engine tank or bed. Below each cylinder is a jet condenser with three discharge valves and a reverse valve, the details of the arrangement being shown in the adjacent sectional drawings. Each cylinder valve-box contains a steam and an exhaust valve, the space between communicating with the cylinder, and below each exhaust valve is a passage to the condenser controlled by the reverse valve. The valve gear is a tappet arrangement, with a plug-rod worked by a chain from a pulley on the central drum shaft, and having four pins that lift the two steam and the two exhaust valves.

When one of the main pistons reaches the bottom of its stroke, the steam valve is opened, and the steam pressure immediately closes the valve in the air pump piston, and forces the air pump piston downwards until the pressure in this condenser rises to that of the atmosphere. The condenser valves then lift, and the air, steam, and water are discharged into the tank, the reverse valve preventing any passing into the cylinder. The cylinder piston is at the time moving upward, and that in the other cylinder is descending owing to the excess of atmospheric pressure upon it, this doing the useful work.

Symington's engine was really an atmospheric engine with a separate condenser, but it was not considered to be an infringement of Watt's patent. Miller afterwards wrote to Messrs. Boulton and Watt suggesting their co-operation in introducing steam navigation, but they declined.

Three drawings and three lithographs are exhibited adjacently and serve to further elucidate the construction.

784. Model of the stern-wheel steamer "Charlotte Dundas" (working). (Scale about 1 : 24.) Made from particulars supplied by W. H. Rankine, Esq., 1903. Plate VIII., No. 3. N. 2349.

This vessel was built in 1801 by A. Hart at Grangemouth, and engined by William Symington for service on the Forth and Clyde canal. The dimensions of the vessel were:—Length, 56 ft.; beam 18 ft.; and depth 8 ft.

The engine was of 10 nominal h.p., with a single direct-acting cylinder 22 in. diam. and 4 ft. stroke, placed on deck. The piston-rod was guided in slides and the connecting rod acted on an overhanging crank on the paddle-shaft, an arrangement patented by Symington in 1801. The condenser and air-pump were below deck, the pump being worked by a bell-crank from the crosshead. Steam was supplied by an internally-fired boiler that was arranged on the other side of the boat. The engine drove a single paddle-wheel placed at the stern of the vessel in a recess 4 ft. wide and 12 ft. long, the whole being housed in. The double stern carried two rudders, which were controlled by a steering wheel in the fore part of the vessel.

In 1802 two loaded vessels each of 70 tons burden were successfully towed by the "Charlotte Dundas," a distance of 19·5 miles on the canal. The canal owners, however, decided that any benefit which might accrue from the use of steam tugs would not compensate for the injury that would be done to the banks by the wash of the paddles, and therefore rejected the vessel, which then remained for a number of years laid up in a creek of the canal, and in 1861 was finally broken up.

A lithograph and a drawing of the vessel are also shown; the latter shows the engine placed below the deck.

785. Lithograph of P.S. "Clermont." Woodcroft Bequest, 1903. N. 85.

This plate is from Bennet Woodcroft's "Steam Navigation," 1848. The "Clermont" was built in 1807 by Charles Browne of the East River, New York, to the order of Robert Fulton as the outcome of study and practical experiments in navigation by steam carried out by the latter on the Seine at Paris in 1803.

The "Clermont" was wallsided for the greater part of her length with the stem and stern enclosing an angle of 60 deg. The engine was 24 in. diam. by 4 ft. stroke, and was supplied by Messrs. Boulton, Watt & Co. By means of bell-cranks, fly-wheel and spur gearing, designed and executed by Fulton, it worked two side paddle-wheels 15 ft. diam. by 4·1 ft. wide. The boiler was of the externally-fired land type.

The trial trip took place successfully on August 17th, 1807, on the River Hudson between New York and Albany, the speed attained being 4·7 miles per hour. After completing her equipment, she ran as a packet on this route till the end of the season. During the winter of 1807–8, she was rebuilt and refitted and under the name "North River" continued to run on the Hudson for many years.

Original dimensions:—Displacement, 100 tons; length, 150 ft.; breadth, 13 ft.; draught, 2 ft.

786. Rigged model of P.S. "Comet" (working). (Scale 1 : 24.) Presented by the Committee of the McLean Museum, 1900. Plate VIII., No. 4. N. 2255.

This model was made by Mr. T. Rennie, from the original lines of the vessel, which, as well as a model, have been preserved.

The "Comet" was built at Port Glasgow in 1811–2 by Messrs. John Wood & Co. to the instructions of Henry Bell, proprietor of the baths at Helensburgh.

In August 1812 the vessel commenced running on the Clyde between Glasgow and Greenock, as a public conveyance for passengers, at the advertised fares of 4*s.* for the first cabin and 3*s.* for the second. The enterprise was financially unsuccessful, so that in 1813 Bell "made her a jaunting "boat all over the coasts of England, Ireland, and Scotland." The public had, however, found the new mode of travel so convenient that within a year the three paddle steamers "Elizabeth," "Clyde," and "Glasgow" were under construction for the service which the "Comet" had abandoned.

In 1816 the "Comet" was plying on the Firth of Forth, and in 1818 Bell employed her in establishing steam communication between the West Highlands and Glasgow; in 1820, while on a passage from Fort William, she went ashore at Craignish Point and became a total wreck.

The engine (*see* No. 787) was placed on the port side, and the boiler, which was of the land type, was on the starboard. At first there were two sets of radial paddles, on detached arms, on each side, driven by spur gear, but, this arrangement giving trouble, paddle-wheels were afterwards substituted, and the number of wheels was reduced to two; the steaming speed was about 6·7 knots. There was a single funnel, which served also as a mast and carried a yard and square sail as represented in an adjacent drawing which shows the vessel under sail and steam.

The "Comet" was the first vessel moved by steam that carried on a regular service in Europe successfully, and this she did 13 years before the first public steam railway was inaugurated.

Burden, 25 to 30 tons; length on keel, 40·25 ft.; breadth extreme, 11·25 ft.; depth, moulded, 5·6 ft.

787. Engine of Bell's P.S. "Comet." Presented by Messrs. R. Napier and Sons, 1862. Plate VIII., No. 5. N. 904.

This engine, made by Mr. John Robertson, of Glasgow, has a single inverted upright cylinder, 12·5 in. diam. by 16 in. stroke, placed over the crank-shaft and driving, by means of two side-rods, a pair of half side-levers. from which a connecting rod transmits the power to the overhanging crank. The crank-shaft carries a balanced fly-wheel, 6 ft. diam., and a spur pinion; also a single loose eccentric, driven by a pin projecting from the fly-wheel boss and provided with two side holes corresponding with the positions for running ahead and astern. The slide valve is worked from a balanced rocking-shaft, and an extension of the eccentric rod forms the means by which the eccentric is traversed when reversing has to be performed. The condenser is embodied in a single casting, forming the main portion of the engine framing and the water tank, in which the vertical air-pump, driven from the side levers, is accommodated.

Steam was supplied by an externally-fired, low-pressure boiler, made by David Napier, and set in brickwork. When first tried the engine had a smaller cylinder (it was 11·5 in. diam.), but after being used for some months it was replaced by the present one.

788. Oil painting of P.S. "Comet." Presented by Mrs. Campbell Muir, 1903. N. 2344.

This painting, attributed to Alexander Nasmyth, is believed to represent the "Comet" when she was plying on the Firth of Forth (*see* No. 786).

789. Photograph of painting of P.S. "Comet" and "Iona." Lent by John Hamilton, Esq., 1876. N. 1467.

This is taken from a painting by Wm. Clark, of Greenock, in 1874, which illustrates the advance made in marine engineering in half a century. The vessels represented are the "Comet" of 1812 (*see* No. 786), and the "Iona" of 1864—both Clyde passenger steamers.

790. Drawings of early paddle steamers. (Scale 1 : 48.) Lent by George Baird, Esq., 1876. N. 1462.

The first drawing represents the P.S. "Elizabeth," originally a barge, but rebuilt and engined by Charles Baird in 1815 at St. Petersburg for service on the Neva.

The engine was of the side-lever type, with a single cylinder and air pump; the boiler was externally fired and had a brick chimney. The wheel had four floats which were kept vertical by means of bevel gear.

The second drawing shows a steamer built by Mr. Baird in 1817 for carrying passengers between St. Petersburg and Cronstadt. The appended description states that the six-float paddle-wheels were driven at 50 revs. per min. by gearing from a side-lever engine fitted with a fly-wheel; the general arrangement resembles that of the "Comet" (*see* No. 787).

791. Photograph of engraving of P.S. "Prinzessin Charlotte." Lent by G. P. Rubie, Esq., 1876. N. 1452.

This represents ths first steamer built in Prussia. It was a double-hulled vessel constructed in 1816 by John Rubie at Pichelsdorf for the navigation of the Elbe, Havel, and Spree. Between the hulls was a single paddle-wheel driven by an engine of 14 h.p. made by J. B. Humphreys.

B.m., 236 tons; length, 130·4 ft.; breadth, 19·3 ft.

792. Drawings of P.S. "London Engineer." (Scale 1 : 48.) Maudslay Collection, 1900, and "The Engineer," 1897.
N. 2241.

This vessel, which was specially designed and fitted for plying between London and Margate, was built of wood in 1818 by Brent of Rotherhithe, and engined by Messrs. Maudslay, Sons and Field.

The engines were of the bell-crank type, somewhat resembling those of the "Comet" (*see* No. 787), and had two vertical cylinders 36 in. diam. by 30 in. stroke, driving a paddle shaft which had overhung cranks and a pair of paddle-wheels between them. Steam at a pressure of 5 lb. was supplied by three copper boilers, arranged abreast, each with a single furnace.

The paddle-wheels were each 12·5 ft. diam. and 6·5 ft. wide, with eight radial arms carrying floats, and made 28 revs. per min. The two wheels were arranged in a casing built amidship, airtight, but open at the bottom, and the floats projected below the floor level to that of the three keels. As the paddle shaft was only slightly above the water-line, two air compressing pumps were provided, which forced air into the casing and thus lowered the water level therein. It was found, however, that the motion of the paddles rapidly carried away the air, so that the water rose and seriously interfered with the propelling action of the wheels.

B.o.m., 315 tons; length, 120 ft.; breadth, 24 ft.; draught, 5 ft.

793. Photographs of side-lever engine. Received 1900.
N. 2254.

These photographs show the first marine engine constructed by Robert Napier, which is of the type that he subsequently so greatly developed. It was made in 1824 at his works at Camlachie, Glasgow, for the P.S. "Leven"—a river steamer built at Dumbarton (Napier's birthplace), and one of the first to ply between there and Glasgow. In 1877 the relic was presented by his sons, Mr. J. R. and Mr. J. Napier, to the town of Dumbarton, where it is preserved at the pier head. The engine has a single cylinder 31·5 in. diam. by 36 in. stroke; in its details it resembles the larger engine shown in the sectional model No. 797.

794. Model of engines of H.M.S. "Dee." (Scale 1 : 32.) Maudslay Collection, 1900.
N. 2216.

The P.S. "Dee" was a mail packet, built of wood for post office work in 1827 to the designs of Oliver Lang. The first despatch steamer introduced into the Navy was built in 1823, but between 1827–40 nearly 80 steam vessels of this type were constructed.

The model, which is stated to have been the workmanship of Henry Maudslay, represents a pair of side-lever engines as introduced by Boulton, Watt & Co., but with the Gothic framing ascribed to the elder Brunel.

The cylinders were 54 in. diam., by 5 ft. stroke, and were supplied by steam at a pressure of 8 lb. by tubular boilers; the paddle-wheels were 20 ft. diam. and the speed of the "Dee" was 8 knots. The engines closely resemble those built on the Clyde somewhat later and shown in section to a larger scale in No. 797.

795. Model of Galloway's vibrating engine (working). (Scale 1 : 8.) Presented by Messrs. Bullivant & Co., 1902.
N. 1896.

This form of semi-rotary engine for marine propulsion was patented by Elijah Galloway in 1829, and is described in the same specification as his feathering paddle-wheel (*see* No. 951).

The piston is a radial blade secured to a shaft concentric with the cylinder within which it vibrates through an arc of 270 deg. A crank on this shaft has its pin in one end of a slotted link, which is capable of sliding and turning on a block on a fixed pin. A connecting-rod joins the other end of this link to a crank on a fly-wheel shaft, the arrangement of links being such that each double vibration causes one revolution of the fly-wheel. The valve gear is not shown, but was to have been arranged on the top of the cylinder and worked by an eccentric on the main shaft.

796. Model of engines of P.S. "Ruby" (working). (Scale 1 : 16.) Presented by the Institution of Civil Engineers, 1868. Plate VIII., No. 6. N. 1193.

The "Ruby" was built in 1836 by Messrs. Wallis, of Blackwall, for the Diamond Co.'s service between London and Gravesend. Her dimensions were :—Length (b.p.), 155 ft.; breadth, 19 ft.; depth, 10·16 ft,; draught, forward, 4·1 ft.; aft, 4·6 ft.; displacement, 170 tons. Instead of using frames the hull was built of three layers of planking crossing one another and nailed together, but separated by felt; this construction, although strong and durable, was known as "lath and plaster."

The engines were of the regular side-lever type, constructed by Messrs. Seaward & Co., of Poplar; the two cylinders were 40 in. diam. by 3·5 ft. stroke, and were collectively of 100 h.p.; steam at 3·5 lb. pressure was supplied by flue boilers. The paddle-wheels were 17·5 ft. diam. with radial floats 9·16 ft. wide by 1·25 ft. deep; the speed of the "Ruby" was 11·7 knots, which was ·7 knot higher than that of any other Thames steamer of that day.

The arrangement of these engines was the favourite one, not only for river boats, but also for ocean-going steamers, and from its introduction, by the firm of Boulton Watt & Co. prior to 1820, till the general abandonment of paddle steamers for ocean service in 1860–70, nearly all engineers constructed such engines. The design is evidently the result of a re-arrangement of the mill engine to suit a limited height, the beam being placed low down and the connecting-rod working upwards. Such engines worked efficiently and required very little attention or repair, but their weight was excessive and the space occupied was very great; the engines of the "Ruby" required 18 ft. of the vessel's length, and the total length of the space occupied by the machinery and boilers was 42 ft., in a vessel only 155 ft. long.

The engines have two cranks at right angles on the paddle-wheel shaft, each crank being driven by a connecting-rod attached to the end of a pair of beams vibrated by a vertical cylinder arranged between their other ends. The piston-rod crossheads are guided by an interesting modification of Watt's parallel motion.

The air and feed pumps are driven by a crosshead, working in guides and moved by side rods, while the condensers are arranged around the gudgeons or trunnions of the side-levers or beams.

797. Sectional model of side-lever marine engine (working). (Scale 1: 8.) Presented by the Institution of Civil Engineers, 1868. N. 1191.

This shows in detail the arrangement of the type of marine engine which from 1820 to 1860 was most generally and successfully adopted, being fitted to most of the sea-going steamers till paddle-wheels were abandoned for ocean voyages. In the development of this design much was done by Robert Napier on the Clyde, and this model accurately represents his regular practice previous to 1845.

To secure a uniform motion, and for other reasons, it was usual to employ two cylinders driving cranks at right angles; this model only indicates one-half of the actual engine. It is, however, a remarkable property of the arrangement that even with a single cylinder such an engine can be started from its so-called "dead" centre.

The engine represented had two cylinders, 60 in. diam. by 6 ft. stroke, and drove a pair of paddle-wheels 24 ft. diam. at 16 revs. per min. The boiler pressure would be about 15 lb. above atmosphere, and the indicated h.p. about 700. The condensers were of the jet type, and were cleared by vertical single-acting air-pumps. The parallel motion, for guiding the vertically moving rods, is a modification of that of Watt, the "radius-rod" and "back-link" having separate points of attachment.

This model, however, if read to a scale of 1: 9, very closely represents the engines supplied by Robert Napier in 1840 to the four sister ships "Britannia" (*see* No. 183), "Acadia," "Caledonia," and "Columbia," with which the Cunard line was established. They each had a pair of cylinders 72·5 in. diam. by 82 in. stroke, and at 16 revs. per min. indicated 740 h.p.; the speed was 8·25 knots, with a coal consumption of from 31 to 38 tons per twenty-four hours.

The finest engines of this type were probably those of the last paddle-driven Cunarder, the "Scotia," which had two cylinders 100 in. diam. by 12 ft. stroke. The paddle-wheels were 40 ft. diam., and had floats 11·5 ft. by 2 ft. Steam at 20 lb. pressure was supplied by 8 boilers with 40 furnaces, and the speed was 13·5 knots, with a coal consumption of 160 tons per 24 hours.

Note.—The parallel motion levers, the valve gear, and the paddle-wheel of the model were made in the Museum in 1898 from existing records.

798. Model of modified side-lever engine (working). (Scale 1:16.) Presented by the Institution of Civil Engineers, 1868. N. 1192.

The model represents an arrangement by which the space required for the side-lever type of marine engine is reduced. Instead of arranging the pair of cylinders athwartships, they are placed fore-and-aft; one in the usual position driving the crank-shaft by a pair of side-levers, and the other arranged under the crank-shaft, driving directly by side rods. As the crank-pins driven by the two cylinders are at right angles, the engine exerts a fairly uniform turning moment, and will start in any position. The portions of the four-throw crank-shaft are coupled by drag links.

The valves are driven by separate loose eccentrics; no parallel motions are employed, the crossheads being guided by slides secured to the cylinder tops; in most other respects the details resemble those of the common side-lever arrangement.

799. Photograph of tug-boat engines. Lent by Messrs. Westgarth, English & Co., 1887. N. 1719.

This represents the engines of the paddle tug "Pendennis," built in 1885. There is a single cylinder, 25 in. diam. by 42 in. stroke, working the paddle shaft by means of a half-beam.

This modification of the early side-lever engine is generally considered to give the most satisfactory type of engine for such paddle vessels.

800. Model of engines of H.M.S. "Gorgon" (working). (Scale 1: 24.) Presented by Messrs. Bullivant & Co., 1902. N. 1874.

The "Gorgon" was a steam frigate designed by Sir W. Symonds, and launched at Pembroke in 1837. Her dimensions were:—Length, 178 ft.; breadth, 37·5 ft.; depth, 23 ft.; draught of water, 13 ft. forward, 14·5 ft. aft; tonnage, 1,111 tons. She was built throughout of teak, with the exception of the main beams, which were of oak.

The engines, by Messrs. Seaward and Capel, of Limehouse, were the first direct-acting fixed-cylinder marine engines, and owing to the great saving in room and weight that they showed when compared with the then almost universal side-lever engine, they created considerable interest. The substitution of wrought iron columns to carry the upper entablature in place of the usual heavy cast frames was an additional improvement.

The "Gorgon's" engines had cylinders 64 in. diam. by 5·5 ft. stroke, and drove paddle-wheels 27 ft. diam.; the general machinery was 4 ft.

below the water-line. Each cylinder was carried on a foundation plate weighing 10 tons, that contained its condenser and hot-well, while also supporting the air and feed pumps. The piston-rods were guided by a lever parallel motion of peculiar construction, now known as the "Gorgon" type; from a double lever of this motion the pumps were driven. The eight columns supporting the entablature were 7 in. diam. These engines were found to weigh 60 tons less than equivalent side-lever engines, but the chief objection urged against the arrangement was the shortness of the connecting rods.

Steam was supplied by four tubular boilers with twelve grates and two stoke-holds. The coal bunkers were arranged around the engines and boilers, giving a thickness of 8 ft. and a capacity of 400 tons, or 16 days' consumption at a speed of 7·7 knots. On trial the average speed was 9·8 knots and the fuel consumption one ton of Welsh coal per hour.

801. Model of open-topped cylinder paddle engines (working). (Scale 1 : 24.) Presented by Messrs. Bullivant & Co., 1902. N. 1876.

This arrangement of direct-acting marine engine was introduced in 1839 by Messrs. Seaward and Capel, of Limehouse, to avoid the use of the short connecting-rods seen in the earlier "Gorgon" type, which in other respects this strongly resembles. One of the first vessels fitted with these "atmospheric" engines was the P.S. "Sapphire," built of iron in 1842 by Messrs. Ditchburn and Mare. She was 150 ft. long, 19 ft. beam, 4·6 ft. draught, and was fitted with engines having three cylinders 74 in. diam. by 3 ft. stroke, supplied with steam at a pressure of 8 lb. above the atmosphere. These drove paddle-wheels 16 ft. diam. at about 30 revs. per min. The "Alliance" and the "Havre," iron vessels built in 1855–6 for the Channel service, were also fitted with these engines.

The cylinders have no top covers, so that the connecting-rods can be attached close to the pistons, but each piston has a light rod working in a guide which the forked end of the connecting-rod clears. The air and feed pumps are driven by beams rocked by links from the pistons.

The engines in some respects resemble the trunk form subsequently extensively adopted where space was restricted.

802. Model of double piston-rod engine (working). (Scale 1 : 16). Contributed by Messrs. Maudslay, Sons and Field, 1858. N. 120.

The type of vertical engine in which the crank-shaft is placed a short distance above the cylinder and is driven by a return connecting-rod from a crosshead above so as to admit of the use of large cylinders in the limited height available under a paddle shaft appears to have been first introduced in 1837 by Messrs. G. Forrester & Co. of Liverpool, for the P.S. "Rainbow." In this engine the piston rod was extended upward to form a kite-shaped loop within which the crank and connecting-rod could work.

In 1839 Joseph Maudslay and Joshua Field patented the arrangement, shown in the model, in which two piston rods and a return connecting-rod to a crank, which just clears the top of the cylinder, are used. The piston rods are both on the same side of the crank which is consequently off the centre line, thereby increasing the maximum obliquity of the connecting-rod and causing considerable difference in the times of the two strokes. This led to the neglect of the arrangement but not until several engines of 70 h.p. with cylinders 4 ft. diam. by 3 ft. stroke had been built for service on the river Rhône. The air and feed pumps were worked by a sway beam rocked by the crosshead.

The engine is interesting in that it shows the original form of the arrangement, subsequently adopted extensively when placed horizontally, known as the return connecting-rod engine.

803. Model of quadruple piston-rod engine (working). Received 1902. N. 2283.

This shows the improved arrangement of engine (*see* No. 802) patented in 1842 by David Napier of Millwall. He adopted four piston rods which allowed the axes of the cylinder and of the crank shaft to be in one plane, thus giving a symmetrical and satisfactory engine. Napier built many of his four piston-rod engines which became very popular on the Clyde for vessels of shallow draught, owing to their reduced length as compared with those having side levers; on account of the height of their guides above deck, they became generally known as "steeple" engines.

The model, which was in use for driving a small boat, has a pair of cylinders 4·5 in. diam. by 5·3 in. stroke, each with four piston-rods and a return connecting rod, driving cranks at right angles. The valve chests are arranged for long D slide valves, worked by weigh-shafts and gabs from loose eccentrics on the crank-shaft. The condenser is of the jet type, formed in the bed plate, and is cleared by a diagonal air pump 3 in. diam. by 3 in. stroke, worked by an intermediate crank in the shaft, and there is a plunger feed pump, ·6 in. diam, and 1·5 in. stroke driven by an eccentric at one end of the crank-shaft.

804. Model of double piston-rod engine (working). (Scale 1 : 8.) Maudslay Collection, 1900. N. 2220.

The arrangement here shown is an improvement on Napier's steeple engine (*see* No. 803) in that while sharing its symmetrical arrangement, only two piston rods are required.

The cylinder is placed vertically some distance below the crank-shaft, and through its upper cover pass two piston rods, one on either side of the crank-shaft, united above by a crosshead which slides on vertical cylindrical guides. From this crosshead descends the connecting-rod to the crank-shaft while the vertical air, feed and bilge pumps are driven by beams worked by links from the main crosshead. The steam is distributed by a locomotive-type slide valve which is driven by link motion; in this case, however, the link is shifted by a hand wheel and pinion gearing into teeth on the link, the short travel of which would not seriously interfere with the movements of the attendant in reversing or "linking up."

The model represents generally several engines of 30 h.p. with single cylinders 32 in. diam. by 3·5 ft. stroke which were built in 1850 to the order of the Hon. East India Company for shallow-draught river steamers.

805. Model of direct-acting paddle engine (working). (Scale 1 : 16.) Contributed by J. Seaward, Esq., 1860. N. 326.

This is an arrangement of paddle engine in which, by the use of what may be termed "return piston rods," a long connecting-rod is accommodated in a limited height. The cylinder has a single piston rod, terminating in a four-armed crosshead, from which four rods pass downwards to two short cross pieces that are guided by side-levers controlled by a "Gorgon" parallel motion. From these cross pieces a forked connecting-rod extends upward to the crank-shaft above. The air and feed pumps are worked by a crosshead moved by prolongations of the side-levers; the condenser is arranged in the framing and between the cylinder and air pump. The upper entablature is connected with the cylinder by turned columns and inclined stays that give a generally light appearance.

This arrangement of engine, which it is stated was fitted to several tug boats, gives a flexibility in the machine that was of advantage in the early days of marine machinery; but the number of working parts is great, and careless adjustment can cause considerable trouble with so many connecting links.

806. Model of direct-acting paddle engines (working). (Scale 1 : 12.) Contributed by Messrs. Ravenhill, Salkeld & Co., 1859. N. 320.

This arrangement of paddle-wheel engine was patented in 1841 by Mr. Joseph Miller as an improvement on the side-lever type, and was fitted in several vessels. Its merit consisted chiefly in the reduction in the amount of space required, the length being but little more than the diameter of the cylinders, which were arranged vertically under the crank-shaft, with the two air-pumps between them.

The condensers, which surrounded the air-pumps, connected the two cylinders, the whole being bolted together so that no foundation plate was required, the cylinders only being fastened down to the sleepers or keelson of the vessel. The bearings for the crank-shaft were carried in a cast-iron frame supported on wrought-iron columns fixed to the cylinders. The piston rods were guided by vertical slide bars fixed to the cylinder covers, and supported by the framing; the air-pump rods were similarly guided. The slide-valves were of the long D type, and were actuated by eccentrics on the crank-shaft giving motion to rocking-shafts above the valve chests. The feed and bilge pumps were worked by a bell-crank driven from one of the air-pump crank pins.

807. Model of engines of H.M.S. "Retribution" (working). (Scale 1 : 24.) Contributed by Messrs. Maudslay, Sons and Field, 1858. N. 121–2.

The paddle frigate "Retribution" was designed by Sir W. Symonds, and launched at Chatham in 1844. Her dimensions were:—Tonnage, 1,641 tons; length, 220 ft.; breadth, 40·5 ft.; depth, 26·3 ft. She carried 10 guns.

The model represents one of the pair of double-cylinder, or "Siamese" engines, by which the paddle-wheels were driven. The arrangement was patented in 1839 by Messrs. J. Maudslay and J. Field, as a means by which a long cylinder could be fitted in the limited height available in a paddle ship.

Each engine consisted of two vertical cylinders, 72 in. diam., 8 ft. stroke, placed fore-and-aft under the paddle shaft. The two piston rods were attached to a double crosshead of T shape, which worked in guides between the two cylinders, while between them swung the connecting-rod joining the crosshead with the overhead crank; in this way a connecting-rod of ample length was provided for. The air and feed pumps were driven by a pair of levers connected to the main crosshead. Steam was supplied at a pressure of 7 lb. per sq. in., by four flue-boilers, and the engines made 13 revs. per min.

The portion of the paddle-wheel shown has the float cut into three strips, arranged as in the "cycloidal" paddle-wheel (*see* No. 937).

808. Model of engines of H.M.S. "Devastation" (working). (Scale 1 : 16). Maudslay Collection, 1900. Plate VIII., No. 7. N. 2217.

The "Devastation" was a wooden-built paddle frigate, constructed at Chatham during 1840–4 to the following dimensions:—B.o.m., 1,058 tons; length, 220 ft.; breadth, 40 ft.; depth, 26 ft.

The engines were of the twin cylinder or "Siamese" type.

The engines represented had four vertical cylinders each 54 in. diam., by 6 ft. stroke, arranged in pairs and working on two cranks at right angles in the paddle-shaft. The crosshead for each pair returned between the two cylinders and was there controlled by guides, while the connecting-rod extended from this lower end, between the two plates forming the crosshead, to its crank pin. There was a single steam chest and a long piston slide valve for each pair of cylinders; the valves were each actuated through a rocking-shaft by a loose eccentric, while rack-and-pinion gears were added for moving the valves by hand when the gabs were disengaged while reversing. Each pair of cylinders had its own jet condenser, which formed also a base plate, and by means of side levers drove its air and feed pumps which were all arranged vertically. The model shows also the bearers, platforms and columns of the engines, together with the framing of the hull and paddle boxes.

Between 1840–6 nine vessels for H.M. Navy were fitted with these engines, and within 10 years from their introduction 55 sets, representing a total of 48,000 h.p., were supplied for driving paddle-wheels.

809. Model of engines of "Princess Alice" (working). (Scale 1 : 16.) Maudslay Collection, 1900. N. 2218.

The "Princess Alice" was a paddle vessel, built of iron by Messrs. Ditchburn and Mare in 1843 at Blackwall for the Admiralty's channel packet service between Calais and Dover. Her dimensions were:—B.o.m., 270 tons; length, 144 ft.; breadth, 20·1 ft.; depth, 10·9 ft.; mean draught, 6·5 ft.

Her engines were of the annular type, patented by Joseph Maudslay in 1841 and a development of his twin cylinder arrangement; although more compact they were less easily constructed and, therefore, less extensively adopted than those having twin cylinders.

Each of the two cylinders was 43 in. diam. by 3·5 ft. stroke, but through the centre was a hollow column, so that the piston was annular and had two rods. These rods were secured to a double plate crosshead of T shape, the tail of which worked within the central column and at its lower extremity received the small end of the connecting-rod, the big end of which was attached to the crank of the paddle-shaft above. The upper end of the crosshead was also guided, and sufficient clearance was allowed in the central column to permit of the swing of the connecting-rod; the valve gear and the pumps were all arranged as in the twin cylinder engines.

The engines represented were supplied with steam at 16 lb. pressure and drove a pair of feathering paddle-wheels 18 ft. diam., which gave the vessel a speed of 12·5 knots.

810. Models of engines of P.S. "Helen McGregor" (one working). (Scales 1 : 24 and 1 : 12.) Contributed by Messrs. G. Forrester & Co., 1860 and 1869. N. 328 and 1312.

The "Helen McGregor" was built by Mr. John Laird, at Birkenhead, in 1843, for the Hull and Hamburg trade. Her dimensions were:—Length, 180 ft.; breadth, 26 ft.; depth, 15 ft.; register, 573 tons, and she was at the time one of the largest vessels of her class.

The engines, by Messrs. G. Forrester & Co., consisted of two inverted cylinders, 42 in. diam. by 4·5 ft. stroke, carried by four wrought iron columns, which also connected the foundation plate with the entablature and crank-shaft pedestals above. The cylinders were placed athwartship with their stuffing boxes at a sufficient height from the bottom to allow of the crosshead, which connected the two piston-rods, working below them. This crosshead was guided by a lever parallel motion, and from it the power was transmitted to a crank in the paddle-wheel shaft, by a connecting-rod that swung in the space between the two cylinders. The parallel motion contained a strong vibrating frame of cast iron, which prevented cross-winding; the motion served also to work the air-pump as well as the feed, bilge, and brine pumps. To shorten the steam ports, each cylinder had its own slide valve, but these were connected and worked by a single eccentric. The condenser was placed immediately beneath the slide-valve chest, and was connected with the air-pump by a passage in the foundation plate; the capacity of the condenser, including the passage to the air-pump, was 44 cub. ft. The air-pump was 33·5 in. diam. by 2·375 ft. stroke; the hot-well had a capacity of 36 cub. ft., and the waste water from it was discharged by an overflow pipe through the side of the vessel.

Steam was supplied at a pressure of 3·75 lb. by tubular boilers; the paddle-wheels, which were 23·5 ft. diam., made 23·5 revs. per min.

It was estimated that these engines and their boilers saved 25 ft. in length when compared with the space required by the then general side-lever engine and box boiler. The smaller model shows a section of the hull with the engines in position.

811. Maudslay's original oscillating paddle engine. Contributed by Joseph Maudslay, Esq., 1857. N. 112.

This construction of marine engine, patented by Joseph Maudslay in 1827, has been very extensively adopted in paddle ships, although originally the prejudice against it was very strong. The advantages of the plan are, that it is compact and enables large cylinders to be placed in a limited height, while, at the same time, the stresses are taken almost entirely by the engine frame. Oscillating cylinders had been proposed by Murdock as early as 1785 (*see* Catalogue of Mechanical Engineering Collection), and in 1822 Aaron Manby built and fitted an iron ship of the same name, 120 ft. long, 18 ft. beam, and 3·5 ft. draught, with such engines of 80 h.p., by which she steamed in cargo from London to Paris, where she arrived on June 12th, 1822; she was the first iron ship to make a sea voyage, and for several years continued plying between Paris and Havre. Maudslay, however, appears to have independently adopted the arrangement, and to have been the first to provide such engines with an efficient valve gear, and so make them as economical as those with fixed cylinders.

The engine shown has a pair of oscillating cylinders 6·1 in. diam. by 8·5 in. stroke, acting directly on the crank-shaft above; the condenser is arranged between the cylinders, and contains the air-pump, which is driven by an intermediate crank on the shaft. The engine is erected on a cast-iron bed-plate, upon which are A frames that at the top carry the crank-shaft bearings, and lower down the bearings for the cylinder trunnions; the central trunnions communicate directly with the condenser, while the outside ones are connected with the steam-pipe, tightness in both cases being secured by packed glands. The piston rods pass through glands in the top covers, which have long bushes to resist the wear due to the swaying of the cylinders. The valves are of the D type, and are contained in a chest on the exhaust side of each cylinder; the steam is brought to the chest from the other trunnion by a belt round the cylinder. Each valve is driven by a separate eccentric on the crank shaft, and the eccentric rod is provided with a disengaging catch, so that the slide valve can be moved by hand when desired; to reduce the irregularities due to the oscillating motion, the eccentric rod is connected to the valve by a pin that is very near the trunnion.

Engines of this type were fitted by Maudslay to the steamboat "Endeavour," which commenced running between London and Richmond in May, 1829, and remained on the service till September, 1840. They were of 20 h.p., and had cylinders 20 in. diam. by 2 ft. stroke, driving paddle-wheels 10 ft. diam. by 5 ft. wide, at 32 revs. per min.; the boiler pressure was 3·5 lb.

Similar and larger engines were fitted to several other vessels, but the arrangement was at the time so unpopular that it was practically abandoned. In 1838 Mr. John Penn reintroduced it, and considerably improved the form of the valve chest and gear; he then constructed many engines of this type, so that the arrangement is generally known as Penn's oscillating engine.

812. Model of three-cylinder engine. (Scale 1 : 32.) Contributed by John Scott Russell, F.R.S., 1868. N. 1244.

This arrangement of marine engine, patented by Mr. Scott Russell in 1853, is intended to reduce vibration by securing a nearly uniform turning effort throughout a revolution, while at the same time forming a compact engine which could be used for driving either paddle-wheels or a screw.

The feature of the arrangement is the use of three oscillating cylinders, one vertical, and the other two inclined at 60 deg. to it, all acting on a single crank-pin; this is equivalent to three cylinders each at 120 deg., but is much more compact. The vertical cylinder is directly under the shaft, and its piston-rod is connected to the crank-pin by a large end to which the rods of the two other cylinders are pinned, so that all three piston-rods are connected to this crank-pin.

There are two jet-condensers, with two trunk air-pumps inclined together and driven from a single crank on the shaft; this crank partly counter-balances the main crank. The condensers form a single casting, which contains the air-pumps. The steam chests are on the steam trunnion side of each cylinder; a single pair of eccentrics served for the three slide valves, but this gear is not shown in the model.

The Egyptian Government yacht "Cleopatra" (*see* No. 389) was in 1858 fitted with a set of these engines, which had cylinders 40 in. diam. by 4 ft. stroke, and with 25 lb. boiler pressure made 42 revs. per min., and indicated 882 h.p. The paddle-wheels were 16 ft. diam., and had feathering floats; the average speed was 14·7 knots.

813. Drawing of engines and boilers of P.S. "Pacific." (Scale 1 : 24.) Contributed by John Scott Russell, F.R.S., 1868. N. 1241.

The "Pacific," an iron ship of 1,469 tons gross register (*see* No. 201), was built and engined by Messrs. J. S. Russell & Co. in 1853.

The engines consisted of a pair of oscillating cylinders, 74 in. diam. by 7 ft. stroke, which indicated 1,684 h.p., and weighed 240 tons.

Steam, at a pressure of 18 lb., was supplied by four box boilers having in all 1,760 return tubes 6 ft. long by 3 in. diam. Each boiler was 14·8 ft. long, 18 ft. wide, and 12·5 ft. high, and had five furnaces. The total grate area was 420 sq. ft., and the heating surface 9,507 sq. ft. The weight of the four boilers was 91 tons, and they carried 69 tons of water. The boiler room is closed at each end by watertight bulkheads.

The paddle-wheels were 27 ft. diam., and each had 14 feathering floats 10 ft. long by 4 ft. wide. The average speed was 14 knots. She was fitted with two masts, and the area of canvas was 7,947 sq. ft.

814. Model of paddle engines of the "Great Eastern" (working). (Scale 1 : 12.) Contributed by Messrs. John Scott Russell & Co., 1857. Plate IX., No. 1. N. 17.

The steamship "Great Eastern," built at Millwall in 1858, was an iron ship of the following dimensions:—Length, 680 ft.; breadth, 82·5 ft.; depth at side, 58 ft.; displacement, 27,384 tons. The vessel was propelled by paddle-wheels and a screw propeller; this model represents the engines for driving the paddle-wheels.

They were designed and constructed by Messrs. John Scott Russell & Co., and were of the oscillating type, of 1,000 nominal h.p., but indicated 3,411 h.p.; the weight of the engines was 836 tons. The cylinders, four in number, were 74 in. diam. by 14 ft. stroke, and the mean number of revolutions was 10·75. Two of the cylinders drove one crank, and the other two a crank at right angles, on a built-up paddle shaft. There were two air-pumps, driven by a single crank on the intermediate length of the paddle shaft, and there were two independent condensers, reversing gears, &c., so that each paddle-wheel was driven by a complete double cylinder engine that could be run alone if required. The cylinders were inclined at a mean angle of 22·5 deg. from the vertical, and on opposite sides, so that a fairly uniform turning moment was obtained with a single pair. The condensers were of the jet type, arranged under the shaft and between each pair of cylinders. The vacuum maintained was 25·5 in. The slide valves were of the gridiron form, with back relief frames; to reduce the length of the steam passages, the two ends of each cylinder were supplied by separate valves.

Steam at 24 lb. pressure was supplied to the paddle engines by four double-ended tubular boilers of the rectangular or box type, each 17·5 ft. long, 17·75 ft. wide, and 13·75 ft. high, with 40 furnaces and 4,500 sq. ft. of heating surface. Each boiler weighed 50 tons, and carried about 40 tons of water.

The original paddle-wheels were 56 ft. diam., and weighed 90 tons each. The paddle shafts were connected to the engine shaft by powerful friction clutches, so arranged that each could by gearing be released or closed as occasion required; the elaborate power-driven disconnecting gear shown on the model was, however, never actually fitted. These wheels were destroyed during a gale in 1861; the new ones fitted were much stronger, and only 50 ft. diam., while the floats were also narrower; these wheels were on the ship when she was broken up.

The calculated speed of the vessel, with both screw and paddle-wheels working, was 15 knots; a special trial of the ship under paddles alone gave a speed of 7·25 knots.

For a description of the screw engines of this vessel, *see* No. 831, and of the vessel itself, No. 213.

[N.B.—The two balance weights on the model were added in 1895, when it was first shown in motion and did not exist in the actual engines.]

815. Model of engines of P.S. "Mersey" (working). (Scale 1 : 12.) Maudslay Collection, 1900. N. 2226.

The "Mersey" was built of iron in 1859 at Millwall by Messrs. Samuda Bros., for the West Indian Mail service. Her registered dimensions were:—Tonnage, gross 1,001, net 729 tons; length, 260·4 ft.; breadth, 30·2 ft.; depth, 16·2 ft.; mean draught, 18·5 ft.

Her engines were of the oscillating type, patented by Joseph Maudslay in 1827, and had two cylinders 60 in. diam. by 5 ft. stroke. Steam was admitted to the outer trunnion of each, and passed by a belt to the steam chest where it was distributed by two slide valves, the exhaust passing by the inner trunnion into the condenser. The slide valves were worked by rocking levers driven by a sweep which was moved between vertical guides by a loose eccentric reversing gear; the hand movement of the valves when necessary was accomplished by a rack and pinion arrangement. The condenser was between the cylinders, and the two diagonal air-pumps were worked by an intermediate crank in the main shaft; the two feed and bilge pumps on each side of the engine were worked by a single eccentric for each pair, and the driving platform was arranged above one of the air-pumps. The upper framing was tied to the engine bed by eight inclined wrought iron columns.

Steam at 20 lb. pressure was supplied by four tubular boilers, and the coal capacity was sufficient for 12 days' consumption; at 30 revs. per min. of the engine the speed of the vessel was 11·5 knots.

Two arrangements of paddle-wheels are shown in this model, one having fixed and the other feathering floats.

816. Model of engines of P.S. "Leinster" (working). (Scale 1 : 8.) Lent by Messrs. Ravenhill, Hodgson & Co., 1869. N. 1307.

The "Leinster" is one of the four iron vessels that were built in 1860 for the mail service between Holyhead and Kingstown. She is 343 ft. long, 35 ft. beam, 19 ft. deep, and of 1,467 tons gross register, with a draught of 13 ft., and an immersed midship section of 336 sq. ft. (*see* No. 217).

The engines consist of a pair of oscillating cylinders, 98 in. diam. by 78 in. stroke, placed immediately underneath the paddle-shaft. There are two valve-boxes to each cylinder, arranged on opposite sides of the trunnions so that their weights balance each other. Each pair of valves is worked by a single loose eccentric, driving a sliding rod whose lower end is provided with a curved slot in which slide two blocks connected with the valve rods; by this arrangement the motion of the valves is made independent of the oscillation of the cylinders. To reverse the position of the valves, a rack and pinion gear worked by a large hand-wheel is provided, by which, after the valve gear has been released, the valves can be moved so as to reverse the motion, the loose eccentric in the meantime stopping till it is caught by the second driver, which will then continue the motion for reversed running when the gear is again engaged. The condenser is placed between the cylinders, and contains the two air-pumps, which are inclined and worked by an intermediate crank on the paddle-shaft, an arrangement patented in 1841 by Mr. Joseph Miller. The feed and bilge pumps are placed in the corners of the foundation frames, and their plungers are directly moved by brackets attached to the cylinders. Each cylinder weighed when finished upwards of 20 tons, and the condenser 22 tons.

The original boilers supplied steam at 20 lb. pressure; they were multitubular and eight in number, four being placed forward of and four abaft the engines, arranged in pairs with their backs against the sides of the vessel so as to allow the furnaces to be stoked from the middle line. They were 9·25 ft. long by 18 ft. wide, and 12·25 ft. high; the total number of furnaces was 40; there were 4,176 tubes in the boilers, 677 sq. ft. of grate area, and 16,800 sq. ft. of heating surface.

The paddle-wheels are of the usual feathering construction (*see* No. 955), and 32 ft. diam.; each has 14 floats 12 ft. long by 5 ft. wide.

On the trial trips with a boiler pressure of 20 lb. the engines made 25·5 revs. per min. and indicated 4,751 h.p., while the speed of the ship was 17·8 knots. The average speed in all weathers during the first six months of the service was 15·5 knots.

817. Model of high-pressure oscillating engine for paddle launch. (Scale 1 : 8.) Presented by A. T. Horne, Esq., 1894. N. 2037.

This shows a pair of cylinders, 9 in. diam. by 14 in. stroke, working an overhead crank shaft carrying two paddle-wheels 6 ft. diam. The valve motion is of the usual loose eccentric arrangement, fitted with a gab and lever gear for hand working when reversing. In larger engines of this type an air-pump and condenser are arranged between the two cylinders, while in the largest examples rack and pinion gear is added to enable the engineer to move the heavy valves when reversing.

818. Model of beam engine of an American river steamer (working). (Scale 1 : 16.) Made in the Museum, 1906. Plate IX., No. 2. N. 2428.

The type of engine represented was developed and perfected by Robert L. Stevens in the United States about 1822. It has been used chiefly in the Eastern States and especially for the paddle steamers on the Hudson river and on Long Island Sound.

The model shows an engine built in 1884 by the Pusey and Jones Company of Wilmington, U.S.A.; a similar engine was built from the same drawings in 1896, very little change having been made in the design during the interval.

The engine shown has two gallows frames, built up of heavy timbers having cross frames and diagonals, the whole structure being tied and braced by bolts, keys, and timber knees. Two wrought iron box girder keelsons with cast iron crowns support the frames which are secured to them by iron shoes and gusset plates. The cylinder, 3 ft. diam. by 9 ft. stroke, with condenser beneath, is placed between the feet of the forward legs of the gallows frames, webs cast on the cylinder and condenser sides being bolted to the frames. The crank-shaft has outer and inner bearings on each side of the paddle-wheels and bearings near the crank. The paddle-wheel is keyed to the shaft by three sets of keys.

The valve gear for this type of engine is of great interest. It was patented by Mr. Francis B. Stevens in 1841 in the United States, and has been generally adopted there. In front of the cylinder are two vertical cylindrical valve chambers with flaring tops. Box castings connected with the top and bottom of these chambers contain the valve seats for the two upper and the two lower valves. At each end of the cylinder is a steam and exhaust valve; the valve chests are connected by the hollow columns. The left-hand column is the steam chamber, connecting the upper and lower steam valves, and the right is the exhaust, connecting the upper and lower exhaust valves, this latter being connected with the condenser; copper diaphragms at the upper ends of the columns allow for expansion. The valves are of the double beat disc type. There is one eccentric for the steam valves and one for the exhaust valves, the use of two eccentrics being one of the essentials in the Stevens cut-off. The eccentric rods drive two horizontal rocking shafts on which are keyed four curved arms called "wipers." These wipers operate four "toes" on vertical lifter rods connected with the valves. Springs on the lifter rods assist gravity to make the toes follow the movements of the wipers steadily. The wipers for the exhaust valves are only just long enough to give the requisite lead and lift, while they are so arranged on the shaft that as the down stroke of one rod is completed, the up stroke of the other rod is commenced. The admission valves require no lead, and the steam wipers are so arranged that a brief interval elapses between the shutting of one valve and the opening of the opposite one. Below the rocking shafts are placed stops called "gags." The Stevens cut-off is not adjustable, and can only be varied by these gags. When they are in use the steam valve is operated by the exhaust, and steam is used for practically the full stroke. The power is kept up temporarily in this way when encountering heavy ice or in other cases of special necessity. Hand gear is fitted below the gags, consisting of a trip-shaft having toes and wipers similar to the rocking shaft. Stripper rods, worked by a foot lever, throw the eccentric rods out of gear when working by hand. The hand-wheels shown operate the injection valves. Steam for engines of this type was supplied by a single cylindrical return-flue boiler, placed forward of the engine, and tested to a pressure of 65 lb. per sq. in.

The paddle-wheels for this engine are of simple construction. Each wheel is 24·83 ft. diam., and has three sets of radial spokes. Each set of spokes has two concentric rings of iron, and near the centre one of wood. Iron straps with T-ends connect the two iron rings at equal intervals between the spokes. The straps and spokes carry 20 wooden floats, 6·5 ft. long, secured by U-shaped bolts or staples. The six floats nearest the line of dead centres are made narrower than the remainder for greater ease in starting.

The ship structure shows details of a typical boat, of moderate dimensions, as used for cargo and passenger service. Many of these vessels are built entirely of wood, but in the present example the hull is of iron and the remaining upper works of wood; this arrangement provides a structure of increased longitudinal strength and thus dispenses with the huge "hog-frames" or fore-and-aft trusses which are conspicuous features of the wooden-built vessels. Special wooden trusses, however, are used to give local support to the paddle boxes and to the outer shaft bearings on each side; the main truss and "spring beam" are carried upon diagonal struts and plate-brackets attached to the ship's side, and receive supplementary support from diagonal suspension rods attached to upright square masts or king-posts which are in turn tied together in pairs forward of and abaft the paddle-shaft. A central trunk or casing, extending from the main deck to the skylight, encloses the upper parts of the machinery, and the weight of this trunk and adjacent super-structure is distributed by two tiers of pillars placed between the main deck and the side keelsons.

For the general appearance of a completed vessel of this type *see* No. 189.

The principal dimensions of the vessel are:—Length, 160 ft.; depth at side, 8 ft.; draught, 4·5 ft.; breadth of hull, 28 ft.; breadth over guards, 48 ft.

819. Model of engines of P.S. "Princesse Henriette" (working). (Scale 1 : 12.) Constructed by Messrs. Denny & Co. Received 1899. N. 2181.

The "Princesse Henriette" and "Princesse Josephine" are sister ships, built and engined at Dumbarton in 1888, for the Dover and Ostend service of the Belgian Government. They are constructed of steel, and have the following dimensions :—Length, 300 ft.; beam, 38 ft.; depth, 13·5 ft.; gross register, 1,099 tons.

The engines are of the two-stage expansion, surface-condensing type, with the cylinders arranged diagonally, or inclining upwards to the crank-shaft, a construction that is now very generally followed in high speed paddle steamers. The high-pressure cylinder is 59 in. diam., the low-pressure 104 in., and the stroke of each is 6 ft. The high-pressure slide valve is of the piston construction, while that of the low-pressure is a flat double-ported slide; in each case the valve rods extend through the chests both back and front. Each valve is driven by Walschaerts single eccentric gear (*see* No. 854), with the eccentric set at right angles to the crank, the lead, which is constant, being given by a lever connected with the main crosshead; the engine is linked up and reversed by altering the position of the end of the valve rod in a rocking quadrant worked by the eccentric. The valve gears are simultaneously controlled from a shaft that is moved by Brown's steam reversing gear (*see* No. 873). The condenser is cylindrical in form, with the shell made of steel plate; there are two vertical air-pumps, 34 in. diam., by 2 ft. stroke, worked by bell-cranks from the high and low pressure crossheads respectively. The cooling water is circulated by a pair of centrifugal pumps, and the boiler feed is supplied by Weir's automatic pumps, but these independently driven pumps are not shown in the model.

To keep down the weight of the engines, the pistons, entablatures, and ties are made of cast steel, while the air-pumps and the condenser ends are of brass. The framing for the engine-bed and its incorporation with that of the ship are shown in the model, from which it will be seen that four specially deep web frames are provided under the line of the crank-shaft, and that the depth of the longitudinal girders is also increased at this locality.

The paddle-wheels are of the usual feathering type, 24 ft. diam., by 13·5 ft. wide, and have each nine steel floats with concave faces. The star centres of the feathering gear are fixed to the paddle-box beams, but as these beams are not shown on the model, the centres are here supported by brackets.

Steam is supplied by six boilers worked at 120 lb. pressure; on trial the engines indicated 7,000 h.p. at 50 revs. per min., and gave the ship the speed of 21·2 knots.

SCREW ENGINES.

820. Model of engines of S.S. "Great Britain" (working). (Scale 1 : 12.) Presented by Messrs. Gibbs, Bright & Co., 1862. Plate IX., No. 3. N. 330.

The "Great Britain," built at Bristol in 1839–43, was the first large iron ship and the first screw steamer to cross the Atlantic. She was 289 ft. in length, 50·5 ft. beam, 32·5 ft. deep, and on a draught of 18 ft. displaced 3,618 tons (*see* No. 187).

The hull, engines, and boilers, designed by Mr. I. K. Brunel, were at that time considered so large that no contractor could be found willing to undertake their construction, and the Great Western Steamship Co. therefore resolved to undertake the work themselves.

The model shows the original propelling machinery of the ship, which consisted of four direct-acting cylinders, each 88 in. diam. and 72 in. stroke, with their axes inclined 33 deg. to the vertical, each pair working on an overhanging crank-pin.

The cylinders were placed low down in the ship, resting on cast iron base-plates bolted to girders which were riveted to the ship's frames; the crank-shaft was supported in bearings on two massive A-shaped frames, made of hard wood and iron plating, placed athwartship and firmly secured to the beams at each deck level.

In the middle of the crank-shaft was a drum 18·25 ft. diam., and 38 in. wide, connected with a drum directly below it on the propeller shaft, by four sets of flat pitch chains. These chains, of 24 sq. in. section and 7 tons weight, had teeth on their undersides engaging with teak and lignum vitæ blocks on the peripheries of the large and small drums, the propeller shaft making 53 revs. and the crank-shaft 18 revs. per min. respectively. The slide valves were of the piston type, 20 in. diam., each actuated by a single loose eccentric, which by a geared rim could be moved by manual power when disengaged for reversing.

The condensers were of wrought iron, 12 ft. long, 8 ft. wide, and 5 ft. deep, placed amidships between the cylinders; in these were placed the air-pumps, 45·5 in. diam. and 72 in. stroke, worked from the main crank-pins. The feed and bilge pumps were actuated by a lever parallel motion from the crosshead of the air-pump.

The propeller shafting was in three lengths; on the first, 28·25 ft. long and 16 in. diam., was fixed the chain drum, 6 ft. diam.; the second length was 61·66 ft. long and 30 in. diam., built up of two thicknesses of boiler plate riveted together with countersunk rivets; the third length, on which was fixed the propeller, was 25·5 ft. long, and 17 in. diam. at the journals. The thrust bearing was simply a steel plate 2 ft. diam., against which pressed a gun-metal plate of the same diam. fixed to the end of the shaft. A stream of water was found to give sufficient lubrication.

The screw propeller, adopted after numerous experiments, was 15·5 ft. diam. and 25 ft. pitch, with six blades 6 in. thick (not with four blades as shown on the model), the whole being built up and riveted together (*see* No. 986).

Steam was supplied by a double-ended boiler, consisting of a large shell 34 ft. long, 31 ft. wide, and 21·66 ft. high, with rounded top, divided longitudinally into three distinct and independent compartments, each provided with four furnaces at the forward and four at the after end, giving a total of 360 sq. ft. of grate area. The boiler was carried on ten plate-girders, the middle ones 3·25 ft. deep amidships, running the whole length of the ship. The funnel was 8 ft. diam., and round its base was a feed-water heater.

The nominal h.p. was 1,000, but at the normal speed of 18 revs. per min. and a boiler pressure of 5 lb. per sq. in., nearly 2,000 h.p. could be indicated, and a speed of over 12 knots obtained.

821. Model of disc engine (working). Woodcroft Bequest, 1903. N. 56.

This form of steam-engine was patented by Messrs. Taylor and Davies in 1836–8 and has been repeatedly tried since, both on land and at sea.

The chamber which acts as the cylinder is bounded laterally by a zone of a sphere and endwise by a pair of cones, the apices of which coincide with the centre of the sphere. The piston is a ball which forms a joint on which it turns. From the ball, and perpendicular to the disc, projects a rod, the further end of which is socketed in a crank plate attached to the driven shaft. A wedge-shaped partition is fixed across the upper part of the chamber, and a corresponding slot is made in the disc. The partition and the disc divide the chamber into four cells, two of which immediately on one side of the partition are always expanding and the other two contracting as the disc rocks on the conical ends of the chamber. There is a port on each side of the partition, one being for steam and the other for the exhaust.

To obtain better contact between the disc and the conical ends of the chamber, so as to reduce leakages, the cones and the faces of the disc are made with radial teeth gearing into each other.

In 1845 several improvements in this type of engine were patented by Mr. G. D. Bishopp, with whose name it is frequently associated.

822. Model of engines of S.S. "Simla." (Scale 1 : 4.) Lent by G. F. G. Des Vignes, Esq., 1908. N. 2455.

With the practical introduction of screw propulsion for ships in 1836, the established type of slow-running paddle engine with its overhead crank-shaft was adapted to the new conditions, and the necessary speed of the propeller shaft was obtained by the use of multiplying mechanism, such as ropes, belts, pitch chain, or toothed wheels.

The model shows the application of the last of these and is a steeple engine of the type patented by Mr. David Napier in 1842 (*see* also No. 803). It represents the engines of S.S. "Simla," one of the first Peninsular and Oriental boats fitted with a screw propeller. The vessel was built of iron, in 1854, and appears to have been subsequently converted into a sailing vessel. Her dimensions were:—Displacement, about 2,600 tons; length, 330 ft.; breadth, 38 ft.; depth, 27 ft. The vessel, her engines, and the model shown were built by Messrs. Tod and McGregor, Glasgow; the model was exhibited in the Paris Exhibition of 1855.

The engines, which are very compact, consist of two cylinders 90 in. diam. by 78 in. stroke, each with 4 piston rods and a return connecting-rod, driving cranks at right angles. The main slide valves are worked from a weigh-shaft by loose eccentrics on the crank-shaft. Connected with the main eccentric straps are diagonal rods which operate rocker shafts working four gunmetal bilge pumps with clack valves. These pumps are arranged to throw out of gear in pairs, as the upper portions of the diagonal rods are capable of either being locked to, or disengaged from sheaves attached to the lower portions. The expansion valves are driven in a similar manner to the main valves, but they have separate weigh-shafts. Disengaging gear, resembling that on the diagonal rods driving the bilge pumps, allows these expansion valves to be thrown out of action at will. The reversing gear is of the balanced slip sheave kind and reversal is effected for each engine separately by throwing over the loose eccentrics by a hand-wheel and geared quadrant.

The hot-well and jet condenser are formed in the bed plate of the engine, and the latter is cleared by two diagonal air-pumps, one port and one starboard. They are driven from the main crank-shaft by connecting-rods working in trunks. A crosshead attached to the trunk of the starboard air pump drives two plunger feed pumps.

The gearing, in the ratio of 2·75 to 1, is in four steps and consists of a mortise wheel and pinion, the latter, which is a casting, directly driving the propeller. The nominal h.p. was 640, and the boiler pressure 17 lb. per sq. in.

823. Diagram model of four-cylinder condensing engine. (Scale 1 : 8.) Contributed by R. Bodmer, Esq., 1857. N. 57.

This arrangement of balanced engine was patented by Mr. J. G. Bodmer in 1844, and appears to have been intended for driving a screw propeller.

There are two cylinders with trunk pistons, acting downwards upon the crank-shaft at an angle of 35 deg. with the horizontal, and outside each is a larger cylinder with an annular piston of equal area to the inner one; these annular pistons are connected to a crank immediately opposite the crank of the inner cylinder, so that the two sets of pistons move in opposite directions and thus balance their inertia stresses as well as their thrusts on the crank-shaft. The inner pistons were to have elongated trunks, while the annular ones were to be each fitted with two such trunks. The condenser is arranged below and is fitted with two trunk air pumps, driven from the two crank pins; the piston of each pump is without valves, ports in the side of its barrel being periodically covered by the air pump piston, while the water and air which enter the space above the piston are expelled through similar ports at the top, suitably controlled by the cover of the air pump, which has a slight amount of vertical travel.

824. Drawing of Bishopp's disc engine. (Scales 1 : 12 and 1 : 48.) Presented by J. K. Rennie, Esq., 1876. N. 1415.

This arrangement of disc engine has the improvements, patented by Mr. D. G. Bishopp in 1845, on the earlier form patented by Messrs. W. Taylor and H. Davies in 1836.

In this class of engine the steam chamber serving as a cylinder is a portion of a sphere, while the end covers are cones. Inside the chamber is a piston in the form of a circular disc provided with a central boss that fits in spherical seats formed in the covers, while a projecting arm at right angles to the disc engages with a crank-arm on the screw shaft. A fixed radial partition, which intersects the disc, completes the division of the chamber into four cells of varying capacity, and amongst these the steam is suitably distributed by a slide valve.

The disc engine was applied by Messrs. G. and J. Rennie in various mills and factories, and in 1842 was applied to marine propulsion in the "Geyser" pinnace, which at 200 revs. per min. attained a speed of 6 knots. In 1849 a disc engine of 27 in. chamber diam. was so fitted in H.M.S. "Minx" that it could be coupled to the propeller shaft without removing her horizontal high pressure engines; the disc engine gave a speed 11 per cent. higher than that with the ordinary engines.

The larger drawing shows a design, prepared in 1853, for a 60 h.p. condensing engine, while the smaller one shows the proposed application to H.M. wooden sloop "Cruiser"; in the latter case, however, horizontal geared engines were ultimately fitted by Messrs. Rennie.

825. Model of proposed screw engine (working). (Scale 1 : 12.) Maudslay Collection, 1900. N. 2219.

This is a modification of the twin cylinder paddle-wheel engine (*see* Nos. 807 and 808) to suit the requirements of screw propulsion. As the model has only a single crank, however, it probably represents but half of the engine, the great fore-and-aft length of which doubtless led to its abandonment.

There are two vertical cylinders arranged over the crank-shaft with their piston-rods connected by a crosshead, moving in overhead guides, from which a connecting-rod passes downwards between the cylinders to the crank in the screw shaft below. The steam chest is common to the two cylinders and contains a long piston valve driven through a rocking shaft by a single eccentric on the crank-shaft. The jet condenser is arranged in the bedplate, and the air, feed, and bilge pumps are driven from the crosshead by rocking levers.

826. Model of engines of H.M.S. "Ajax" (working). (Scale 1 : 12.) Maudslay Collection, 1900. Plate IX., No. 4. N. 2221.

The "Ajax" was originally a 74-gun line-of-battle sailing ship of the following dimensions:—B.o.m. 1,761 tons; length (b.p.), 176 ft.; breadth, (extreme) 48·54 ft.; draught, forward, 21·5 ft.; aft, 22·9 ft.; in 1848 she was converted into a steam block-ship of 60 guns without being lengthened or seriously altered in dimensions.

Her engines, by Messrs. Maudslay, Sons and Field, were the first horizontal direct-acting screw-engines fitted in the British Navy. They had two horizontal cylinders, 55 in. diam. by 30 in. stroke, on the same side of the crank-shaft which had cranks at right angles; the guides were utilised to tie the cylinders to the crank bearings, and the connecting-rods were four times the crank radius in length. To shorten the steam passages and reduce the size of the slide valves, each cylinder had two valves inclined to each other in a single chest; each pair was driven through a single rocking shaft from link motion reversing gear. The jet condensers (not shown) were in the engine bed, and the two vertical air pumps employed were each driven by a pair of eccentrics on the crank-shaft.

Steam was supplied at a pressure of 6 lb. and the engines made 48 revs. per min., indicated 846 h.p. and drove a screw 16 ft. diam., by 17·9 ft. pitch, and 3·16 ft. long, which gave the vessel a speed of 7·1 knots with a slip of 15·7 per cent. These results were obtained on a draught of 22·54 ft. with an immersed midship section of 807 sq. ft. and a displacement of 3,090 tons.

827. Model of engines of S.S. "Harbinger" (working). (Scale 1 : 12.) Maudslay Collection, 1900. N. 2222.

The "Harbinger" was a screw steamer, built of iron in 1851 by Messrs. C. J. Mare & Co., Blackwall, for the East Indian and Cape mail service. Her dimensions were:—Register, 599 tons, gross, 848 tons; length (b.p.), 186·5 ft.; breadth (extreme), 31 ft.; depth of hold, 19·2 ft.

Her engines, by Messrs. Maudslay, Sons and Field, were of the diagonal direct-acting type and had two cylinders 41·5 in. diam. by 27 in. stroke, acting in an upward direction on a single crank. There were two slide valves for each cylinder, moved by rocking shafts driven by two eccentrics. The condenser was beneath the crank-shaft and formed in the engine framing or bed, while the vertical air-pump was driven by an outside crank, which also drove the feed and bilge pumps, but had a shorter throw than the main crank.

Steam was supplied at a pressure of 15 lb. by tubular boilers, and the engines made 26·5 revs. per min. with a coal consumption of 16 tons in 24 hours; several other vessels were fitted with similar engines between the years 1848–52.

828. Model of engines of H.M.S. "Wanderer" (working). (Scale 1 : 12.) Maudslay Collection, 1900. Plate IX., No. 5. N. 2224.

The "Wanderer" was a gun-vessel designed by the Admiralty and built in 1855 by Messrs. Wigram and Green, in about nine months, during the Crimean War.

Her dimensions were:—Displacement, 745 tons; length, 180 ft.; breadth, 28·3 ft.; mean draught, 10·5 ft.; area of midship section, 231 sq. ft.

Her engines, by Messrs. Maudslay, Sons and Field, were of the return connecting-rod type with two cylinders 45 in. diam. by 24 in. stroke. The condenser was of the jet type and arranged centrally opposite the cylinders; it had two horizontal air-pumps driven by an additional rod from each piston while the other pumps were driven directly from the crosshead; the link motions were counterbalanced and were reversed by rack and pinion.

On trial, with steam at 20 lb. pressure, the engines made 83·25 revs. per min. and indicated 706·8 h.p., which gave the ship a speed of 10·7 knots. The screw was 11 ft. diam., 16 ft. pitch, and 2·5 ft. long, while the slip was 18·3 per cent. Besides the "Wanderer," which was broken up in 1866, 13 other despatch vessels were fitted with this arrangement of screw engine.

829. Drawing of engines of S.S. "Candia." (Scale 1 : 12.) Lent by the Peninsular and Oriental Steam Navigation Co., 1878. N. 1502.

The "Candia" was built of iron at Blackwall in 1854. Her dimensions were:—Displacement, 2,436 tons; length (between perps.), 281 ft.; breadth (moulded), 39 ft.; depth of hold, 26·2 ft.; area of immersed midship section, 527 sq. ft. (*see* No. 203).

The engines, by Messrs. G. Rennie & Co., consisted of vertical trunk cylinders, 71 in. mean diam. and 4 ft. stroke, arranged fore-and-aft. The trunks were on the upper side of the pistons only, but the resulting inequality in piston area was neutralised by the weight of the moving parts, while the trunks greatly reduced the height of the engines.

The condensers were of the jet type, and arranged between the cylinders, with the air-pumps worked from an intermediate crank; the feed and bilge pumps were worked by sway beams from an eccentric.

The crank-shaft was connected to the propeller-shaft by spur gearing, which doubled the speed of the screw, and so avoided running the engines at what, at the time, would have been considered a dangerous speed.

Steam at 22 lb. pressure was supplied by four Lamb and Summers' sheet-flue boilers, with 16 fires, and a total heating surface of 7,905 sq. ft. The engines made 36·5 revs. per min., indicated 1,672 h.p., and drove a two-bladed screw, 15·5 ft. diam., 20 ft. pitch, which gave a speed of 12·6 knots.

830. Diagram model of compound trunk engine (working). (Scale 1 : 12.) Presented by Vaughan Pendred, Esq., 1903. N. 2331.

The construction of a compound, or two-stage expansion engine with a single cylinder, in which by the use of a trunk at one end, the equivalent of two single-acting cylinders of different volumes is obtained, was first carried out in 1830 by Mr. W. Whitham. In such an engine the boiler steam is admitted to the annular or high-pressure cylinder surrounding the trunk and on the return stroke passes to the low-pressure chamber on the other side of the piston, while in the next stroke it is discharged.

The compact modification of this arrangement shown by the model was patented as a marine engine in 1855 by Mr. E. E. Allen. In it there are two cylinders in line, with the crank-shaft between them and the trunks secured together by rods, while from the bottom of one cylinder is a connecting-rod to the crank-pin. The engine-bed forms two jet condensers, which are cleared by inclined trunk air-pumps driven by a single eccentric, and the top of the condensers is used as a hot-well. By the use of opposite cylinders both strokes are maintained of equal power, and to insure uniform turning the crank-shaft has a second crank, at right angles, driven by a similar pair of cylinders.

In 1888, this type of cylinder was tried on a portable compound engine, but the steam consumption was found to be about the same as that with a simple engine; probably because the arrangement, in addition to introducing the cooling action of a trunk, does not limit the cylinder temperature range so well as do separate cylinders.

831. Model of screw engines of the "Great Eastern" (working). (Scale 1 : 12.) Presented by Messrs. James Watt & Co., 1860. Plate IX., No. 6. N. 322.

The steamship "Great Eastern," built at Millwall in 1858, was an iron ship of the following dimensions:—Displacement, 27,384 tons; length. 680 ft.; breadth, 82·5 ft.; depth at side, 58 feet (*see* No. 213). The vessel was propelled by paddle-wheels and a screw propeller; this model represents the engines for driving the screw.

They were designed and constructed by Messrs. James Watt & Co., and were of the horizontal direct-acting type, of 1,600 nominal h.p., but indicated 4,886 h.p.; the weight of the engines was 500 tons. There were four steam cylinders, each 84 in. diam. by 48 in. stroke, driving two cranks at right angles on the shaft, and the mean number of revolutions per min. was 38·8. Each cylinder had two piston rods and a crosshead which moved in guides; from the crosshead of each of the starboard engines proceeded one connecting-rod to a crank-pin, while from the crosshead of each of the port engines two connecting-rods proceeded, so that there were three connecting-rods to each of the cranks. Between the cranks a balance weight in the form of a disc was introduced.

There were four jet condensers arranged between the cylinders, with horizontal air pumps worked from the crossheads. Circular doors were placed on the ends of the condensers opposite to each air pump, through which access to the air pump valves could be obtained or the buckets be withdrawn. The delivery from the air pumps was discharged into the hot-wells and overboard by square pipes that proceeded from the ends of the condensers. The vacuum maintained was 25·5 in.

The slide valves of opposite cylinders were directly connected by a frame, to which motion was imparted by the usual link motion reversing gear. The weight of the link was counterbalanced by a chain, and it could be moved either by a hand-power screw-gear or by a steam reversing gear which had vertical trunk cylinders. The slide valves were of the gridiron type, and on account of their great weight were borne on rollers. The pressure on the valve faces was reduced by a circular relief frame and ring, formed on the back of each valve, and sliding on the inside surface of the steam chest cover.

Steam to these screw engines was supplied at 25 lb. pressure by six double-ended tubular boilers of the rectangular or box type, each 18·5 ft. long, 17·5 ft. wide, and 14 ft. high, giving a total of 72 furnaces and a heating surface of 5,000 sq. ft. Each boiler weighed 55 tons and contained about 45 tons of water.

The propeller was a four-bladed cast iron screw 24 ft. diam., 44 ft. pitch, and weighed 36 tons. The propeller shafting was 150 ft. in length and weighed 60 tons.

In order that the speed of the ship might not be retarded by the screw propeller when under way with paddles alone or paddles and sails, two auxiliary engines of 20 h.p. each were placed abaft the screw engine-room to keep the screw shaft revolving when disconnected from the main engines.

The calculated speed of the vessel with both screw and paddle working was 15 knots; a trial trip of the ship under the screw alone gave a speed of 9 knots. It is now considered that the resistances of both the paddle-wheels and the screw were too great for their respective engines, so that the latter never attained the speeds at which their full powers would have been exerted.

For a description of the paddle engines of this vessel *see* No. 814.

832. Water-colour drawing showing the longitudinal section of the "Great Eastern." (Scale 1 : 96.) Contributed by John Scott Russell, F.R.S., 1868. N. 1262.

This indicates the relative positions of the paddle and screw engines with their boilers; also the general arrangement of the screw shaft and the other machinery. Full particulars of the vessel's hull are given elsewhere (*see* No. 213).

833. Model of engines of S.Yt. "Hebe" (working). Maudslay Collection, 1900. Plate IX., No. 7. N. 2225.

These screw engines were built by Messrs. Maudslay, Sons and Field in 1856, under a patent granted to Joseph Maudslay in that year; the arrangement is, however, an adaptation of the annular engine patented by him in 1841 for driving paddle-wheels (*see* No. 809) to suit the requirements of the screw propeller.

The engine consists of two vertical annular cylinders arranged above the screw shaft, each with its connecting-rod passing from a guided crosshead on the top of the cylinder through the central passage to its crank. The air-pump crossheads, which serve also for the feed and bilge pumps, are worked by levers directly attached to the connecting-rods, and carried on swinging fulcrums; these pumps are all arranged above the jet condensers, which are at the sides.

834. Model of engines of H.M.S. "Marlborough" (working). (Scale 1 : 18.) Maudslay Collection, 1900. N. 2223.

The "Marlborough" was designed a sailing line-of-battle ship of 131 guns and laid down at Portsmouth in 1850, but in 1852 was altered so that when launched in 1855 she was fitted for screw propulsion (*see* No. 82). Her dimensions were:—Displacement, 6,050 tons; length, 245·5 ft.; breadth, 61·2 ft.; depth, 25·8 ft. Her draught on trial was 26·3 ft. with an immersed midship section of 1,190 sq. ft.

The engines, by Messrs. Maudslay, Sons and Field, were of the return connecting-rod type with a pair of cylinders 82 in. diam. by 48 in. stroke; there were two valve chests to each cylinder, and the usual link-motion reversing gear, worked by a screw. The screw propeller was 19 ft. diam., 3·6 ft. long, by about 26 ft. pitch, and the slip was nearly 22 per cent.

Steam was supplied at 20 lb. pressure; the engines made 56 revs. per min. and indicated 3,054 h.p., which gave the vessel a speed of 11·2 knots.

835. Model of engines of U.S. turret ship "Monitor" (working). (Scale 1 : 24.) Presented by J. Ericsson, Esq., 1865. N. 1089.

This construction of screw engine, patented by Mr. Ericsson in 1858, is an improvement on the vibrating piston engine of the U.S. frigate "Princeton," built in 1842. The leading features of these designs is that a single overhanging crank is used, and that two cylinders exert their power upon it in directions at right angles. The arrangement places the machinery below the water line and reduces the length of the space required, but it is probably less efficient than one giving a more direct connection.

The "Monitor" was designed and built of iron by Mr. Ericsson in 1862 for the Federal Government. Her dimensions were:—Tonnage, 614 tons; length on deck, 173 ft.; breadth (extreme), 41·5 ft.; draught, 10 ft. She was protected by iron armour 4·5 in. thick on 21 in. of wood backing. Her principal armament consisted of two heavy guns placed parallel with each other and contained in a revolving turret.

The engines indicated 400 h.p. and had two cylinders of 40 in. diam. by 22 in. stroke, arranged back to back athwartship and separated by a plate which formed a bottom to both. Each piston had a trunk piston-rod, within which swung a connecting-rod that joined the piston to an arm forged on a rocking shaft. From a longer arm on each of these two rocking shafts a connecting-rod proceeded to the crank on the propeller shaft; to reduce frictional losses the throw of this crank was made as long as possible.

The valve chests were placed on the forward side of the cylinders and contained balanced slides with independent cut-off valves: the valves were worked by eccentrics on a small shaft driven by the screw shaft, and the engine was reversed by a hand gear that rotated this small shaft.

There was a single jet condenser and one air pump for both cylinders; this air pump was horizontal and double-acting, and was worked from one of the rocking shafts.

The screw propeller was 9 ft. diam., 16 ft. pitch, and had four blades.

836. Model of engines of H.M.S. "Conqueror" (working). (Scale 1 : 8.) Lent by Messrs. Ravenhill, Hodgson & Co., 1869. N. 1308.

The "Conqueror" was a wooden ship built in 1833, and altered into a screw steamship in 1859. Her first engines were of the horizontal trunk type, but in 1863 these were replaced by the return connecting-rod set represented in the model.

The dimensions of the ship were:—Displacement, 4,300 tons; length (b.p.), 218 ft.; breadth, 55·3 ft.; immersed midship section, 963 sq. ft.; draught, 24 ft. The propeller was 18 ft. diam., 20 ft. pitch, and 3 ft. in length. On the trial runs in 1863 the engines, with 20 lb. boiler pressure, made 61·3 revs. per min., and gave a speed of 9·93 knots.

It is stated that the first engines of the type shown were constructed in 1844 for H.M. frigate "Amphion," with cylinders 48 in. diam. by 48 in. stroke, and that the design was the joint production of Joseph Miller and John Ericsson. Between 1845 and 1863 the makers fitted similar engines to 42 vessels, including H.M.S. "Nelson" and the troopship "Tamar." The horizontal arrangement was adopted, as it placed the machinery below the water-line, and, therefore, out of the reach of shot, while the return connecting-rod permitted the use of a long stroke in ships of only moderate beam.

The engines of the "Conqueror" consist of two horizontal cylinders, 71 in. diam. by 36 in. stroke, each having two piston-rods and a return connecting-rod, driving cranks at right angles on the main shaft. The connecting-rod guides are supported above the bed of the condensers, which are of the jet type, and the air pumps are directly driven from the pistons by rods passing through the glands in the front of the cylinders. The feed and bilge pumps are of the plunger type and are directly driven from the crossheads. The slide valves are moved by the usual reversing link motion controlled from a driving platform above the condensers.

837. Model of horizontal screw engines (working). (Scale 1 : 16.) Contributed by W. Smith, Esq., 1860. N. 325.

This model shows an arrangement of marine engine patented by Mr. J. A. Limbert, R.N., in 1857; the leading features of the design do not, however, differ from those of the return connecting-rod engines then in use, and which are more clearly seen in some of the larger models.

The engine represented was to have two simple cylinders 68 in. diam. by 3·25 ft. stroke, with connecting rods 2·5 times the length of the stroke. The steam chests are arranged above the cylinders, the valves being driven by the usual link motion through rocking shafts. The steam pipes are short, and a single exhaust pipe connects the two cylinders with the condensers. The air pumps are provided with two sets of delivery valves, the upper set delivering air only; modifications were proposed to improve the vacuum obtainable with horizontal and other air pumps.

838. Model of engines of H.M.S. "Valiant" (working). (Scale 1 : 18.) Maudslay Collection, 1900. N. 2229.

The "Valiant" was a wooden-built armour-plated battery ship designed by the Admiralty and built at Millwall in 1861–3. Her dimensions were:—Displacement, 6,364 tons; length (b.p.), 280·2 ft.; breadth (extreme), 56·33 ft.; draught, 24·7 ft.

Her engines, by Messrs. Maudslay, Sons and Field, were of the return connecting-rod type, with a pair of steam-jacketed cylinders 82 in. diam., by 48 in. stroke. There were two double-ported slide valves to each cylinder actuated by the ordinary link motion, but in addition, each cylinder was provided with an expansion gear designed by Mr. J. Field, in which by a revolving valve driven at the same speed as the crank-shaft the supply of steam to the chest could be cut off at any part of the stroke. This gear could be thrown out of use by a sliding wheel, and the angle of advance of the revolving valve was made adjustable by the introduction of a coupling sleeve provided with a helical groove.

There were two jet condensers, arranged opposite the cylinders and each provided with a long-stroke double-acting air-pump; the feed and other pumps were driven by an auxiliary engine.

Steam was supplied by six boilers, three on each side of the vessel with the stokehold amidships.

The screw was of the Maudslay-Griffiths form, 20 ft. diam., with its pitch adjustable from 22·5 ft. to 27·5 ft. The speed realised on trial was 12·6 knots, and the power exerted about 3,350 indicated h.p.

839. Model of engines of H.M.S. "Octavia" (working). (Scale 1 : 16.) Maudslay Collection, 1900. N. 2228.

The "Octavia" was a 51-gun frigate designed by Sir W. Symonds and built at Pembroke in 1846–9; in 1860 she was converted at Portsmouth into a screw frigate of 35 guns. Her dimensions were:—Tonnage, 3,161 tons; length, 252·4 ft.; breadth, 52·8 ft.; draught forward, 20·8 ft.; draught aft, 23·8 ft.

Her engines, by Messrs. Maudslay, Sons and Field, were of the return connecting-rod type with three horizontal cylinders abreast, driving cranks at 120 deg., an arrangement which was claimed to secure a good balance of the moving parts and a nearly uniform turning movement even with a higher grade of expansion than generally used. The cylinders were 66 in. diam. by 42 in. stroke, and were steam jacketed; each had two double-ported slide valves driven by the gear patented by Mr. Charles Sells in 1859. The valves were all worked from a valve shaft which carried a single eccentric for each valve set at a suitable angle of advance for the corresponding crank; this shaft was driven by four spur wheels carried in an adjustable frame, by moving which the valve shaft underwent a relative angular movement which reversed the engine, or would alter the point of cut off from ·25 to ·16 of the stroke.

The two condensers were on the opposite side to the cylinders, and the pumps were driven by two additional rods from each of the two outside cylinders.

Steam at 20 lb. pressure was supplied by tubular boilers and was superheated by passing it through flattened horizontal tubes placed in the uptake. At the trial in 1861, with a displacement of 2,921 tons and immersed midship section of 552 sq. ft., the engine made 69·5 revs. per min., and indicated 2,265 h.p. with a coal consumption of 2·25 lb. per indicated h.p. per hour and gave a speed of 12·25 knots.

840. Model of engines of H.M.S. "Prince Albert" (working). (Scale 1 : 12.) Lent by Messrs. Humphrys and Tennant, 1869. N. 1310.

The "Prince Albert" is a coast defence armour-plated turret ship, designed under the superintendence of Capt. C. P. Coles and built in 1864 at Poplar. She is constructed of iron and has the following dimensions:—Displacement, 3,687 tons; length, 240 ft.; beam, 48 ft.; depth, 25·25 ft.; draught forward, 17·7 ft.; draught aft, 19·8 ft.; area of immersed midship section, 760 sq. ft.

The engines, which were constructed by Messrs. Humphrys and Tennant, are of the horizontal direct-acting type, with two cylinders each 72 in. diam. by 3 ft. stroke, and are remarkable for the shortness of their connecting-rods, which are only 63 ins. long, or 3·5 times the crank radius. The piston rods are exceptionally stiff, and the connecting-rods have forked ends with the pins fast in them. The slide valves are double-ported and cut off at two-thirds of the stroke in full gear; they are worked by the usual shifting link motion direct from the crank-shaft, but the link is of the bar construction, which, although more simple than the usual slotted link, involves the use of a special cylindrical joint to transmit the motion to the valve spindle.

There is a condenser of the jet type, to which the steam from the two cylinders is conveyed by a single central exhaust pipe. The sea water from the wings enters the condenser through a long slotted pipe which breaks up the jets, and the exhaust steam is distributed by a diaphragm plate. There are two double-acting piston air pumps, 22·5 in. diam., within the condenser, and two similar feed or bilge pumps 7·6 in. diam. These pumps are driven by two rods directly from each piston, and so have a uniform stroke of 3 ft.

The central portion of the engine framing is in one piece, and has three vertical hollow box projections forming pedestals for the crank-shaft bearings, while it also carries the slipper guides for the crossheads; the outer bearings for the crank-shaft are stayed to the upper parts of the cylinders by turned wrought-iron struts.

Steam at 24 lb. pressure was supplied by four boilers of the high rectangular multitubular type arranged in one stokehold. The engines indicated 2,128 h.p. at 61 revs. per min., and drove a propeller 17 ft. diam., 21 ft. pitch, and 2·5 ft. long.

841. Model of engines of H.M.S. "Monarch" (working). (Scale 1 : 8.) Lent by Messrs. Humphrys and Tennant, 1869. N. 1309.

H.M.S. "Monarch" was built at Chatham in 1868, and was the first sea-going turret ship. Her dimensions are:—Displacement, 8,000 tons;

length, 330 ft.; beam, 57·5 ft.; depth, 36 ft.; immersed midship section, 1,200 sq. ft.; draught, 24 ft.

The model represents the pair of single horizontal engines, constructed by Messrs. Humphrys and Tennant, with steam-jacketed cylinders 120 in. diam. and 4·5 ft. stroke. Each piston has four piston-rods and drives the crank-shaft by a return connecting-rod from a crosshead that works in guides formed upon the condenser. The valve gear is of the shifting link type, and with the other valves is controlled from a bridge arranged above the crank-shaft. The crank-shaft is 22 in. diam. and the propeller shaft 18 in. diam.

The condensers are of the surface type, with over 17,000 tubes each 6 ft. long, and have a cooling surface of 16,500 sq. ft. To reduce weight the bodies of the condensers are of wrought iron and the tops of cast brass. The air and circulating pumps are driven directly by rods attached to the pistons and passing through glands in the cylinder covers; the feed pump plungers are connected directly to the crossheads. The condenser tubes are of copper, and the circulating water passes outside them, two features that are now seldom seen.

The engines indicated 7,800 h.p., made 64 revs. per min. with a boiler pressure of 31 lb., and drove a two-bladed Griffiths' propeller 23·3 ft. diam. and 26·3 ft. pitch, weighing 22 tons, that gave the vessel a speed of 14·9 knots.

Steam was supplied by boilers possessing 21,000 sq. ft. of heating surface and 770 sq. ft. of grate area.

The "Monarch" was subsequently refitted with modern vertical three-stage expansion engines.

842. Model of single-trunk screw engines (working). (Scale 1 : 12.) Presented by J. K. Rennie, Esq., 1876. N. 1413.

This type of trunk engine was introduced by Messrs. J. and G. Rennie, who fitted them to many vessels both naval and mercantile; the arrangement was found most suitable for powers of from 60 to 400 h.p. The model closely resembles the engines of H.M.S. "Reindeer," a wooden sloop, built in 1860 to the following dimensions:—Displacement, 1,365 tons; length, 185·1 ft.; breadth, 33·2 ft.; mean draught, 14·8 ft.; her speed was 10·6 knots.

The "Reindeer's" engines had cylinders 44·5 in. diam., which, allowing for the trunk, is equivalent to a diameter of 41·5 in.; the stroke was 24 in. The cylinders were placed at opposite corners one on each side of the crank-shaft, with their respective air pumps and condensers beside them; each air pump was driven from the crank pin of the other engine. The cylinders and air pumps had single-ended trunks that admitted the use of connecting rods 2·5 times the length of the stroke. The bearing of the connecting-rod at the bottom of the steam trunks was 6 in. diam., as large as could be got in; it could be tightened whilst in motion by means of a steel bar within the connecting-rod abutting at one end upon the bearing and at the outer end against a cotter set up by a screw. The air pump trunks were single-acting plungers; the feed and bilge pumps were driven by lateral projections from them.

The chief advantages claimed for these engines were: the short and direct connection of the cylinders with their respective condensers, the small space occupied, and the balancing of the parts.

843. Model of engines of S.S. "Carnatic" (working). (Scale 1 : 8.) Lent by the Peninsular and Oriental Steam Navigation Co., 1878. N. 1501.

The "Carnatic" was built by Messrs. Samuda Bros. at Poplar in 1863 for the P. & O. service. She was of 2,800 tons displacement, 285 ft. long (b.p.), 38 ft. in breadth, 28 ft. deep, and had an immersed midship section of 548 sq. ft.

The engines, made by Messrs. Humphrys and Tennant, were of the direct-acting, inverted, two-stage expansion type, with two high-pressure cylinders 43 in. diam., and two low-pressure cylinders 96 in. diam., with a common stroke of 3 ft. The standards contained the surface condensers, and the two low-pressure cylinders bolted together formed a girder connecting them and supporting their high-pressure cylinders, which were arranged tandem-wise above them. The cylinders were steam-jacketed, and each had its own slide valve, but only two sets of link motion were employed. The links were of the bar type, and were reversed by gearing from a central platform; the weight of each pair of valves was counterbalanced by weighted levers.

The air pumps were worked by rods direct from the low-pressure pistons, and it is stated that they served also as feed pumps for the boiler, but the circulation water was forced by a centrifugal pump driven by a separate engine.

Steam at 26 lb. pressure was supplied by boilers of Messrs. Lamb and Summers' sheet flue type, and was somewhat superheated in copper superheaters.

The propeller was a two-bladed screw 16 ft. diam. by 23 ft. pitch; the mean speed on trial was 13·9 knots with 2,442 indicated h.p., and the coal consumption under 2 lb. per indicated h.p. per hour.

844. Model of engines of S.S. "A. Lopez" (working). (Scale 1 : 4.) Made by Messrs. W. Denny and Bros. Received 1871. N. 1195.

This represents the engines of the Cadiz and Havana mail steamer "A. Lopez," built and engined at Dumbarton in 1865. Her dimensions are:—Displacement, 2,665 tons; length, 270 ft.; beam, 38 ft.; depth, 27 ft.; midship section, 492 sq. ft.

The engines are of the inverted vertical type, with two cylinders 66 in. diam. by 3·5 ft. stroke, acting on cranks at right angles. Each piston has two piston-rods connected to a long crosshead working between guides, an arrangement that slightly reduces the total height of the engine. Steam is distributed by slide valves and link motion reversing gear, but on the back of each main slide is a "cut-off" plate driven by a separate eccentric, with a link for varying the travel. By the link motion the periods of exhaust are adjusted, while the "back cut-off" plate gives an independent control of the steam supply so as to permit of any desired degree of expansion. Friction of the main slide is reduced by a relief frame carried in the steam chest cover and making a steamtight joint on the back of the valve, so reducing the unbalanced area; the weight of the valve is counterbalanced by a small piston at the top of the valve rod, working in a cylinder on the steam chest.

The condenser is of the surface type, with horizontal tubes giving a cooling surface of 3,488 sq. ft., and is arranged between the two engines. The air, circulating, feed, and bilge pumps are driven directly from the crossheads; to balance the loads each is in duplicate, and both engines are complete and independent. The pumps are vertical and have solid pistons, the portions above the pistons acting as air pumps and those below as circulating pumps, but the feed and bilge pumps have simple plungers. The valve boxes are arranged in the condensers with external doors, and have removable grids provided with rubber disc valves. Circulating water enters the pumps through two pipes at the engine base, and after passing through the tubes of the condenser is delivered overboard by a large pipe at the back of the engines. The exhaust steam passes through pockets round the cylinders into the top of the condensers, and the feed pumps draw from a hot-well in the bottom of the condenser. Provision is made however, for working it as a jet condenser should the surface condensing arrangements break down.

On trial the engines indicated 1,427 h.p. at 45·5 revs. per min., with a boiler pressure of 18 lb. and a vacuum of 24 in. The speed was 13·3 knots, with a mean draught of 17 ft.

[N.B.—The model would exert about 15 h.p., but is now running light under low pressure air with one cylinder only, and drives the other marine models in the gallery by a shaft beneath the floor. A fly-wheel has been added to give the momentum that the screw propeller provides in the actual engines.]

845. Model of engines of H.M.S. "Northumberland" (working). (Scale 1 : 12.) Received 1903. Plate IX., No. 8. N. 2325.

H.M.S. "Northumberland" (*see* No. 96) is an iron-built sea-going armourclad of 26 guns, designed by the Admiralty and completed in 1865–8 at the Millwall Ironworks. Her dimensions are:—Displacement, 10,780 tons; length (b.p.), 400·2 ft.; extreme breadth, 59·3 ft.; mean draught, 27·2 ft.

She and one sister ship, H.M.S. "Minotaur," were fitted by Messrs. John Penn and Sons with horizontal trunk engines, as represented in this model, while the other sister ship, H.M.S. "Agincourt," was fitted by Messrs. Maudslay, Sons and Field with the horizontal return connecting-rod engines represented, to the same scale, in the adjacent model No. 846. Both constructions enabled the engines to be placed completely below the water-line, and therefore out of the reach of shot, the more modern arrangement with vertical cylinders only becoming possible in warships after the protective power of inclined armour had been demonstrated.

The single-trunk engine had been patented in 1784 by Watt, and also subsequently by others, but the double-trunk construction, by which equality of piston area was attained and the engine adapted for horizontal working, was first patented in 1845 by John Penn, who successfully introduced and extensively fitted it for driving screw propellers. The arrangement gave a light and compact engine, without piston rod or guides, and the thrust of the connecting-rod, when steaming ahead, materially reduced the downward pressure due to the weight of the piston. On the other hand, the cooling losses due to the surfaces of the trunks were serious and inconvenient, the gland friction was excessive, and the bearing at the small end of the connecting-rod was almost inaccessible.

The engines represented have two simple cylinders, 112 in. diam. by 52 in. stroke, but from the front and back of the pistons extend trunks 41 in. diam. which reduce the areas to those of cylinders of 104 in. diam. The gudgeons to which the small ends of the connecting-rods are attached are on the pistons, and the large ends of the connecting-rods act on balanced cranks set at right angles, the internal diameter of the trunks being such as just to permit of the full swing of the connecting-rods. The two condensers are of the jet type, and are arranged close together on the opposite side to the steam cylinders; the horizontal double-acting air-pumps for clearing them are directly driven by a rod from each piston, passing through a gland in the cylinder cover. Another rod from each piston similarly drives the feed and bilge pumps, which are arranged with the condensers.

Steam is distributed to each cylinder by a large double-ported slide valve, fitted with a circular relief-frame and worked by the usual shifting-link motion. An early steam cut-off is provided for by a large gridiron expansion valve, arranged above the steam chest and actuated by a separate eccentric through a link by which the point of cut-off can be varied; this arrangement includes the steam chest in the clearance space until the link-motion gives a second cut-off, the diagram obtained consequently being what is known as "broken-backed."

The propeller was a 4-bladed Mangin screw, 24 ft. diam., whose pitch could be varied from 22·5 ft. to 28·5 ft., but was set at 25·5 ft.

Steam at 25 lb. pressure was supplied by 10 tubular boilers, each having four furnaces; the total heating surface was 23,040 sq. ft., and the grate area 956 sq. ft. At the sea trials the engines made 58·4 revs. per min., and indicated 6,545 h.p., which gave the vessel a speed of 14·1 knots. With half boiler power the revs. were 47·6, the indicated h.p. 3,213, and the speed 11·7 knots.

The base of this model shows the general arrangement of engine seatings and adjacent ship-structure. The former consists of three large transverse box-girders combined with three smaller fore-and-aft girders, the whole being well secured to the ship's main frames. These latter illustrate details of the single-plate frames with joggled and stapled angle-bars used in early iron-built warships. A complete inner skin was fitted in the way of engine and boiler rooms. Additional structural features of this class of vessel are shown (*see* No. 658).

846. Model of engines of H.M.S. "Agincourt" (working). (Scale 1 : 12.) Maudslay Collection, 1900. N. 2230.

The "Agincourt" is an armour-plated cruiser designed by the Admiralty and built of iron in 1868 by Messrs. Laird Bros. at Birkenhead. She is a sister ship to the "Northumberland" (*see* No. 96), and her dimensions are:—Displacement, 10,600 tons; length (b.p.), 400 ft.; breadth (extreme), 59·4 ft.; draught, 27·75 ft.

The engines, by Messrs. Maudslay, Sons and Field, are of the horizontal return-connecting-rod type and have a pair of cylinders 91 in. diam., by 54 in. stroke, fitted with steam jackets. To reduce the friction of the several glands, the nuts of each are connected by worm-gearing so as to ensure alignment while tightening up.

The slide valves are actuated by the ordinary reversing link motion controlled by screw gearing from the platform, but the weight of the links is supported by counterbalancing levers. Each cylinder has an expansion valve, of the revolving cylindrical type introduced by Mr. J. Field, fitted where the steam pipe enters its steam chest. By this the supply of steam is cut off independently of the link motion, but the steam chest for the time becomes part of the cylinder clearance space. These rotary expansion valves are driven by spur gearing from the crank-shaft and at the same speed, but in each connection there is introduced a sliding sleeve with a helical groove by which the point of cut-off can be altered; there is also a disengaging clutch. (Another arrangement of this expansion gear is seen in the engines of H.M.S. "Valiant," *see* No. 838).

Opposite to the cylinders are the two condensers which are of the jet type. The two air pumps are horizontal, double acting, and driven directly by a separate rod from each piston; between them are the crosshead guides and above is the driving platform.

On trial, in 1865, the engines exerted 6,667 indicated h.p. at full boiler power, which gave the vessel a speed of 15·48 knots.

The engine bearers and local ship-structure are represented by the base of the model. A combination of three transverse box-girders with five longitudinal girders is used for the former while the latter consists of the heavy plate-framing which was generally adopted before the introduction of bracket-framing and watertight double-bottoms. The inner skin-plating extends only to the first longitudinal on each side of the middle line. Additional structural features of this class of vessel are shown (*see* No. 658).

847. Drawing of engines of S.S. "Edinburgh Castle." (Scale 1 : 12.) Presented by Messrs. R. Napier and Sons, 1874. N. 1376.

This vessel was built and engined by Messrs. Napier and Sons in 1872 for the Cape Mail Service. She is an iron vessel of the following dimensions:—Gross register, 2,624 tons; length, 335·3 ft.; beam, 37·7 ft.; depth, 28·2 ft.

The engines represented are of the inverted two-stage expansion type, with cylinders 44 in. and 72 in. diam., by 42 in. stroke, and were supplied with steam at 63 lb. pressure. The high-pressure cylinder has its steam jacket formed by the insertion of a liner, but the low-pressure cylinder has its jacket cast with it. The piston of the latter has a separate rod by which steam is admitted to the piston jacket. The high-pressure valve has a back cut-off expansion valve, worked by a separate eccentric, and has the pressure on the back reduced by Dawe's relief arrangement (*see* Mechanical Engineering Collection). The low-pressure valve has a back cut-off plate, which is stationary but can be adjusted in position.

848. Model of engines of S.S. "Britannic" (working). (Scale 1 : 12.) Maudslay Collection, 1900. Plate X., Nos. 1 & 2. N. 2231.

The "Britannic" is a four-masted barque, built of iron at Belfast in 1874, by Messrs. Harland and Wolff, for the White Star Line. Her registered dimensions are:—Tonnage, 3,152 tons net, 5,004 tons gross; length, 455 ft.; breadth, 45·2 ft.; depth to main deck, 33·7 ft.

The engines, by Messrs. Maudslay, Sons and Field, are of the inverted two-stage expansion type, with two high-pressure cylinders 48 in. diam., and two low-pressure cylinders 83 in. diam., arranged in tandem pairs with the high-pressure cylinders at the top; the common stroke is 60 in. Between the tandem cylinders is an open distance piece by which access is obtained to the intermediate glands. The main slide valves of each set are moved by a single valve rod worked by the usual link-motion, but on the back of each high-pressure slide valve is an expansion valve worked by a separate eccentric and provided with an arrangement by which the cut-off of each can be simultaneously adjusted. The link-motion is fitted with a screw reversing gear assisted by a steam cylinder. Both engines exhaust into a single surface condenser, which is cylindrical in form and is arranged behind them. There are two vertical air pumps and duplicate feed pumps driven by levers from the crossheads, but the circulation is performed by a centrifugal pump independently driven by a pair of vertical steam cylinders. The details of the pumps and their valve boxes are clearly shown in the model. The various steam and exhaust pipes are of copper and are provided with a form of bellows expansion joint to give some flexibility under the stresses due to unequal temperatures.

Steam at 70 lb. pressure was supplied by eight oval boilers, fired at each end and possessing a total heating surface of 19,500 sq. ft, while they contained 2,423 tubes. The engines indicated 4,971 h.p. and drove a screw 23·5 ft. diam., with a pitch increasing from 28 ft. to 31·5 ft. The first voyage from Queenstown to Sandy Hook took 7 days 20 hrs., with an average speed of 13 knots.

The after part of the screw shaft was originally fitted with a universal joint so that it could be lowered till the boss was level with the keel—an arrangement introduced by Sir E. J. Harland in 1871 as a means of securing greater immersion and so preventing racing.

The engine bearers and a portion of the hull of the vessel are shown in section, but not in detail; an adjacent drawing, however, shows, to a scale of 1 : 96, the complete general arrangement of the similar though smaller machinery fitted in vessels of the fleet of the Compagnie Générale Transatlantique.

849. Model of engines of H.M.Ss. "Boadicea" and "Bacchante" (working). (Scale 1 : 12.) Presented by J. K. Rennie, Esq., 1876. N. 1414.

These unarmoured corvettes were built at Portsmouth in 1875–6 to the following dimensions:—Displacement, 4,130 tons; Length, 280 ft.; beam, 45 ft.; draught, 23·25 ft.

The engines are of the horizontal, three-cylinder, two-stage expansion, return-connecting-rod type, with a high-pressure cylinder 73 in. diam. and two low-pressure cylinders 92 in. diam.; the stroke of each piston is 4 ft. The cylinders are steam-jacketed over both barrel and ends, and the cylinder castings are fitted with liners. Each piston has attached to it a plunger, the bottom of which slides on a suitable adjustable bearing block, so as to carry the weight of the piston; the back cover of each cylinder is provided with a projecting bonnet that clears its plunger. On the front side of each piston are two piston-rods which extend past the crank-shaft and are attached to a crosshead working on a bar guide on the port side. The high-pressure cylinder is fitted with J. E. Outridge's patent (1868) equilibrium slide valves and a separate gridiron cut-off valve on the side of the main valve chest. The main slides of the high-pressure cylinder are driven by the ordinary link motion through a rocking shaft, and the cut-off valve by a separate eccentric through levers that give a variable travel. In order to get the necessary port area within the restricted space, the equilibrium valves were made double. The low-pressure cylinders were fitted with ordinary double-ported slide valves, and these valve chests were made large so as to serve as intermediate receivers. The engines were fitted with both steam and hand reversing gear. The three cranks were not arranged equally, the low-pressure cranks being opposite each other while the high-pressure crank was at right angles to them.

There are two surface condensers containing collectively 10,214 tubes ·75 in. diam. and 4·75 ft. long, giving a total condensing surface of 9,545 sq. ft.; these tubes are arranged vertically and the steam passes through them. The two air pumps are double-acting, with pistons 20 in. diam., each driven by a rod from the low-pressure pistons. The condensing water is circulated by two centrifugal pumps with fans 30 in. diam. fixed on the backs of the condensers. Each pump is driven by a diagonal engine with a single cylinder 12 in. diam. by 8 in. stroke; they force the water through the condensers and are arranged to draw either from the bilge or direct from the sea. The bilge and feed pumps are worked directly from the low-pressure crossheads.

Steam at 70 lb. pressure is supplied by ten single-ended boilers 12 ft. diam. by 9·8 ft. long, each with three furnaces, giving a total heating surface of 14,170 sq. ft. and 625 sq. ft. of grate area.

The engines drive a two-bladed lifting Griffiths' screw 20·5 ft. diam. by 23 ft. pitch, and on trial the "Boadicea" indicated 5,300 h.p. with 74·5 revs. per min., and had a speed of 14·8 knots.

850. Drawing of engines of H.M.Ss. "Iris" and "Mercury." (Scale 1 : 48.) Maudslay Collection, 1900. N. 2252.

The "Iris" and "Mercury" are twin-screw sister vessels, designed by the Admiralty for despatch service and constructed of mild steel at Pembroke Dockyard in 1876–8. Their dimensions are:—Displacement, 3,750 tons; length (b.p.), 300 ft., (o.a.), 333 ft.; breadth (extreme), 46·1 ft.; draught (mean), 19·7 ft.; midship section, 777 sq. ft.; coal capacity, 780 tons.

The engines are of the horizontal direct-acting two-stage expansion type, in two sets, the port engine being placed aft of the starboard one. In each set there are two high-pressure cylinders 41 in. diam. and two low-pressure 75 in. diam., by 36 in. stroke, arranged as tandem compounds working on cranks at right angles. The two surface condensers are entirely of brass, and together contain 74,000 ft. of tube ·625 in. internal diam. The air and feed pumps are arranged vertically and driven by bell-cranks worked from the low-pressure pistons; the two circulating pumps are of the centrifugal type and driven by independent steam engines.

Steam is supplied by twelve Scotch boilers having a total grate area of 700 sq. ft. and 18,700 sq. ft. of heating surface. With a boiler pressure of 62 lb. the engines made 97 revs. per min. and developed 7,735 h.p., which gave a record speed of 18·57 knots with four-bladed propellers 16·25 ft. diam. by 20 ft. pitch. Earlier trials with the larger and finer pitched propellers shown in the drawing gave a speed of 16 knots.

851. Model of engines of S.S. "Orient" (working). (Scale about 1 : 10); and photographs. Presented by J. G. S. Anderson, Esq., 1895. N. 2060.

The "Orient," the pioneer vessel of the Orient Line, was built and engined by Messrs. John Elder & Co. at Glasgow in 1879. She has a displacement of 9,500 tons at load draught, and a gross tonnage of 5,386, is 445 ft. long, 46·25 ft. broad, and 36·8 ft. deep.

The model shows the general arrangement of the engines; the details, however, have not been reproduced to scale, being modified to render the model a workable engine suitable for driving a small launch; the adjacent photographs, however, represent the actual engines.

The engines are of the vertical, inverted, two-stage, surface-condensing type, with one high-pressure cylinder 60 in. diam., and two low-pressure cylinders of 85 in. diam., working on separate cranks arranged at 120 deg., with a common stroke of 5 ft. The valves are of the piston type arranged in a chest at the back of each cylinder and driven by link-motion reversing gears from the crank-shaft. A rocking lever for each valve transmits the motions from the link block to the valve rod, but the three gears are simultaneously reversed by a single reversing shaft, which in the actual engines is moved by a steam reversing gear.

The air, circulating, and feed pumps are fixed at the back of the engines and driven from the two low-pressure crossheads by levers; the condenser is formed in the lower portion of the back standards. The engines are supplied with steam at 75 lb. pressure, and indicate 5,400 h.p.

852. Model of engines of S.S. "Flamboro" (working). (Scale 1 : 4.) Made by Palmers Shipbuilding and Iron Co. Received, 1895. Plate X., No. 3. N. 1727.

This represents the engines and propeller of the S.S. "Flamboro," built and engined at Jarrow in 1885. The dimensions of the vessel are:—Displacement, 4,400 tons; length, 265 ft.; beam, 39·6 ft.; depth, 23·5 ft.; and midship section, 730 sq. ft.

The engines are of the three-stage expansion, surface-condensing, inverted direct-acting type, with three cylinders of the following diameters:—High pressure, 22 in.; intermediate, 35 in.; and low pressure, 58 in.; all having a stroke of 42 in., and each cylinder acting upon a separate crank, the cranks making with each other an angle of 120 deg. The distribution of the steam is controlled by a piston valve in the high-pressure, and flat slide valves for the intermediate and low-pressure cylinders, driven by the ordinary link-motion reversing gear. The high-pressure and intermediate steam chests are directly above the crank-shaft, but the steam chest of the low-pressure cylinder is placed at the front or starting platform side of the cylinder, the valve being driven by a rocking lever pivoted on the after column. The engines are reversed by means of a single-cylinder steam reversing engine of the "all-round" type, combined with which is a hand-wheel gear.

The air and circulating pumps are contained in one cast iron case, fixed on the back of the condenser and driven from the low-pressure crosshead by means of levers and links. The circulating pump is 12 in. diam. and double-acting, while the air pump is 18 in. diam. and single-acting; both have a stroke of 18 in. The circulating pump forces the water twice through the condenser, first through the lower half and back again through the upper half, the water being inside the tubes. The feed pumps are placed at the forward end of the air and circulating pumps side by side, and the bilge pumps at the after end of the pump case; all of the pumps are driven from one crosshead connected to the levers and links before mentioned.

The propeller is a four-bladed screw 15·3 ft. diam., 17 ft. pitch, and 64·8 sq. ft. in area. The thrust of the propeller is taken by a thrust bearing with six collars on the shaft. The ends of the bearings are complete, but between them are five horse-shoe plates that fit between the shaft collars, thus leaving the lower portion of the shaft open to the oil chamber below. The horse-shoes are supported upon side screws, along which each can be independently adjusted so as to distribute the thrust equally between all of the collars.

On trial the indicated h.p. of the engines was 1,125, the revs. 67 per min., and the speed of the vessel fully laden 10·5 knots. The working steam pressure of the boilers is 150 lb. per sq. in.

853. Motion diagram of engines of S.S. "Orinoco." (Scale 1 : 12.) Lent by the Royal Mail Steam Packet Co., 1891. N. 1868.

The "Orinoco" is a steel-built vessel, constructed and engined by Messrs. Caird & Co. at Greenock in 1886 (*see* No. 284). Her leading dimensions are:—Gross register, 4,478 tons; length, 409·7 ft.; beam, 45 ft.; depth, 25·4 ft.

The diagram shows both the longitudinal and transverse sections of the main engines, which are supplied with steam at 150 lb. pressure and indicate 5,863 h.p. The engines are of the three-stage expansion type, the steam working successively in cylinders 42 in., 62 in., and 96 in. diam. respectively, by 66 in. stroke. The valve motion is of the ordinary shifting link type, but the valves of the three cylinders differ; that of the high-pressure cylinder is of the Trick form and has a back relief frame; the two others are of the gridiron construction and have vertical balance cylinders.

854. Drawings of engines of S.Yt. "Gladiator." (Scale 1 : 8.) Lent by Messrs. Ramage and Ferguson, 1887. N. 1708.

The "Gladiator" is an iron-built steam yacht, constructed and engined by Messrs. Ramage and Ferguson in 1886 to the following dimensions:—Register, 111·7 tons; length, 119·6 ft.; beam, 20·1 ft.; depth, 11·7 ft. She is schooner-rigged, but has an auxiliary screw which is fitted with the "Bevis" feathering arrangement, so that when not in use its resistance can be minimised.

The engines consist of a three-stage expansion set with cylinders 9·25 in., 15 in., and 24·5 in. diam., by 18 in. stroke, indicating 162 h.p. at 145 revs. per min. Steam at 150 lb. pressure is supplied by a cylindrical boiler, described in No. 900.

These engines were the first three-stage expansion set fitted with Walschaerts valve gear (*see* Mechanical Engineering Collection). Each cylinder has a single eccentric which gives the 90 deg. of angular advance required in a valve motion, while the further advance necessitated by the lap and lead of the valve are obtained from a lever rocked by the piston-rod crosshead. Linking-up and reversal are done on a link that is rocked by the single eccentric; the gear gives a practically constant lead at all grades. The indicator diagrams obtained are shown combined on the drawing.

855. Drawing of engines of S.S. "Prometheus." (Scale 1 : 24.) Lent by Messrs. Robert Stephenson & Co., 1886. N. 1698.

The "Prometheus" is an iron-built vessel, constructed by Messrs. A. Leslie & Co. at Newcastle in 1886, and engined by Messrs. Stephenson & Co. Her dimensions are:—Length, 321 ft.; beam, 36·5 ft.; depth, 26 ft.; with a carrying capacity of 3,000 tons on a mean draught of 23 ft.

Her engines are on the tandem two-stage expansion system, and have a single overhanging crank and a fly-wheel on the shaft, an arrangement introduced by Mr. A. Holt. The cylinders are 27 in. and 58 in. diam., by 5 ft. stroke; the high-pressure cylinder is uppermost and has its piston rod attached to a crosshead above, from which two rods, passing through stuffing boxes in the low-pressure cylinder cover, extend to the low-pressure piston; in this way the use of an inaccessible gland between the two cylinders is avoided. The high-pressure slide valve is of the piston type and is fitted with Buckley's rings, while the low-pressure valve is of the ordinary flat form; both valves are worked by the same pair of eccentric rods and the usual Stephenson's link motion. The crank-shaft is of steel 14 in. diam., and has the two eccentrics forged with it immediately behind the thrust collar. The crank cheek is of wrought iron shrunk on and keyed; the fly-wheel weighs 5 tons, and is used as the wheel of the turning gear, which with a single crank engine is of special importance. It consists of a steam cylinder and oil cataract attached to the bulkhead just over the fly-wheel; the piston rod of this "heaving-round" cylinder is square in section and is fitted with strong steel pawls, which engage with teeth on the rim of the fly-wheel for forward or backward motion as required. The condenser is of the usual form and has 1,925 sq. ft. of surface, given by tubes 1 in. outside diam. The air pump is 18 in. diam. by 22·5 in. stroke, and is single-acting, while the circulating pump is 13·5 in. diam. by 22·5 in. stroke, and is double-acting. These and the other pumps are worked by the usual lever arrangement, but there is an independently driven 6 in. centrifugal pump for emergencies.

Steam at 80 lb. pressure is supplied from a double-ended boiler, having 5,015 sq. ft. of heating surface and 153 sq. ft. of grate area (*see* No. 898). The propeller has four blades and is 15·75 ft. diam. by 20·5 ft. pitch. The ordinary indicated h.p. is 1,350 and the speed 12 knots.

Engines of this type are very lofty, but on the other hand they require less space than a double crank engine, leaving room for from 200 to 300 tons of additional cargo.

856. Drawings of engines of S.S. "Majestic." (Scale 1 : 16.) Presented by W. S. Clayton Greene, Esq., 1910. N. 2540.

The "Majestic," together with her sister ship "Teutonic," was built and engined by Messrs. Harland and Wolff in 1889 for the White Star line. As the first vessels for this Company's service in which sail-power was finally abandoned, they mark a stage in the development of this fleet. The dimensions of the "Majestic" are:—Displacement, loaded, 17,800 tons; length (o.a.), 582 ft.; breadth, extreme, 57·8 ft.; depth, moulded, 42·2 ft.

The drawings represent one of a pair of three-stage expansion engines fitted on this vessel. From left to right on the wall the views shown are:—(1) A rear elevation, showing the condenser, 20 ft. in length; (2) an end elevation, from the high-pressure end; (3) a front elevation. The engines are of the direct-acting, inverted type; the cylinders, which are not steam jacketed, being of 43 in., 68 in., and 110 in. diam. respectively, by 60 in. stroke. All the cylinders have piston valves, the intermediate and low-pressure cylinders having two each. Tail rods are provided for the pistons of these two cylinders. The framing is of cast steel, and each cylinder is supported on two frames, an A frame at the front, and a single frame at the back. This method gives three points of support, and ensures stability. The crank-shaft is of Whitworth steel with crank pins 22 in. by 22 in. Valve gear of the Stephenson type is employed. Each set of engines has two air pumps worked by levers from the high and low-pressure cross-heads; these levers also drive the bilge pumps.

The screw shafts are placed so close together that the screws, which are 19·5 ft. diam. by 29·5 ft. pitch, overlap to the extent of 5·5 ft. To allow for this the starboard propeller is astern of the other by 6 ft., an opening being made in the deadwood to allow for this arrangement.

Steam is supplied by 12 double-ended and 4 single-ended boilers at 180 lb. pressure, and Howden's system of assisted draught is employed. The total heating surface is 40,968 sq. ft.; grate area, 1,160 sq. ft.; indicated h.p., 17,000; speed, 19·5 knots.

857. Prints of engines of S.S. "Aska." (Scales 1 : 8 and 1 : 24.) Lent by the Ailsa Shipbuilding Co., 1890. N. 1846.

This steamer was built of steel in 1889 by the Ailsa Company for the Indian coasting trade. Her dimensions are:—Gross register, 527 tons; length, 190 ft.; breadth, 29 ft.; depth, moulded to main deck, 12·25 ft. (*see* No. 294).

The engines are of the three-stage expansion type, with cylinders 16 in., 26 in., and 42 in. diam., by 30 in. stroke. Steam at a pressure of 160 lb. is supplied by a double-ended boiler 12 ft. diam. by 16 ft. long, having four furnaces with Farnley flues of 39 in. diam. The heating surface is 2,305 sq. ft. and the grate area 78 sq. ft., while the surface condenser exposes an area of 923 sq. ft. The screw propeller is 9 ft. diam., 13·5 ft. pitch, and has an area of 34 sq. ft. On trial the speed was 12·9 knots, with the engines making 120 revs. per min., and indicating 892 h.p.

858. Drawings of engines and boilers of S.S. "City of Dundee." (Scale 1 : 16.) Lent by Messrs. J. Howden & Co., 1893. N. 2011.

The S.S. "City of Dundee" was built of steel at Glasgow in 1890 to the following dimensions:—Tonnage, 3,427 tons gross; length, 361·7 ft.; beam, 42·7 ft.; and depth, 26·4 ft.

The four drawings give the following views of the machinery:—Longitudinal section of the steamer, showing the engines and boilers; cross section of the ship, giving front view of the boilers; cross section showing end view of the engines; and a horizontal section showing the engines and boilers in plan.

The engines, by Messrs. Howden & Co., are a three-stage expansion set, with cylinders 25 in., 42 in., and 68·5 in. diam., by 4 ft. stroke. The crank-shaft is in two duplicate end throws joined by couplings bolted to the webs of the intermediate crank. The crank-shaft is carried in four bearings, of which the central pair are larger than the end ones so as to insure uniform wear. The valves are all on the sides of the cylinders and are worked from the connecting and piston-rods by Morton's gear (*see* Mechanical Engineering Collection).

Steam at 160 lb. pressure is supplied by two single-ended cylindrical boilers 14·25 ft. diam. by 11·5 ft. long, each with three furnaces 42 in. diam. Forced draught on Howden's system (*see* No. 913) is fitted to these boilers, which have produced steam equivalent to 25 indicated h.p. per sq. ft. of grate area.

859. Diagrams illustrating the arrangement of machinery in H.M. warships. Presented by the Institution of Civil Engineers, 1894. N. 2040.

These were prepared to illustrate a paper by Sir A. J. Durston, K.C.B., in 1894, and represent typical vessels built under the Naval Defence Act of 1889.

Three views show the machinery of H.M.S. "Ramillies," a first-class, steel-built, armoured battleship constructed at Glasgow in 1892. It is contained in six watertight compartments, the engines being two independent sets separated by a central compartment extending past the boilers and used as a magazine, while the boilers are in two sets of four each, fired athwartships. Protection is afforded by a protective deck over the engines and boilers, also by side armour and side coal bunkers below deck.

The three views of H.M.S. "Royal Arthur," first-class, deck-protected, wood-sheathed cruiser, built at Portsmouth in 1891, show engines arranged as before; but the single-ended return tube Scotch boilers are in sets of four each, in two compartments and fired in a fore-and-aft direction; there is no central magazine. Protection is afforded longitudinally and transversely by coal bunkers, by a protective deck, and by an armour coaming round the engines. The engine platform is built up above the cellular bottom on plate frames.

Three similar views of H.M.S. "Forte," second-class, deck-protected, wood-sheathed cruiser, built at Chatham in 1893, shows her to be similar to the last, the coal protection at the boilers being, however, varied slightly.

In the three views of H.M.Ss. "Onyx" and "Renard," torpedo gunboats built at Birkenhead in 1893, the engines are shown arranged abreast in two sets as above. The stokehold compartments are fitted forward of the engines, and there are four locomotive wet-bottom boilers, with furnaces divided by water spaces.

860. Diagrams showing framing of engines for warships. Presented by the Institution of Civil Engineers, 1894.
N. 2040.

These were prepared in 1894 to illustrate a paper by Sir A. J. Durston, K.C.B. Each frame is for a cylinder of the same size, and the weight of the corresponding bed-plate, standards, and guides is given.

In H.M.S. "Royal Arthur" all four standards are of cast steel, bracketed I-section, with the guides bolted to both the back and front. Weight, 47·77 tons.

In H.M.S. "Ramillies" the back standard is of cast steel box section, forming the condenser, the guides being on the face. The front standards are forged steel pillars. Weight, 78·08 tons.

H.M.S. "Crescent" is very similar, but has the back standard of cast iron. Weight, 82·08 tons.

H.M.S. "Gibraltar" has all the standards of forged steel, with bracing in two directions. Weight, 67·2 tons.

H.M.S. "Royal Oak" has forged steel back and front pillars, diagonally braced in two directions. Weight, 69·77 tons.

861. Diagrams of engines and boilers of H.M.S. "Daring." (Scale 1 : 2.) Contributed by Messrs. John I. Thornycroft & Co., 1895.
N. 2059.

These show one of the two sets of three-stage expansion engines fitted to this twin-screw torpedo boat destroyer.

There are four cylinders in each set arranged in pairs, the high pressure 19 in. diam. and intermediate pressure 27 in. diam. forming one pair, and the two low-pressure cylinders (each 27 in. diam.), the other. The cylinders of each pair are inclined from the vertical alternately to the right and to the left, thus enabling their axes to be brought close enough together in a fore-and-aft direction to introduce a three-webbed crank, the central web being common to the two cranks. The cylinders are not jacketed; piston valves are used on the high pressure, and flat valves on the other three cylinders. The reciprocating parts in most cases balance one another, small counterweights only being necessary, and but little vibration is felt. The framing is of the light and open character common to torpedo boat engines; each steel column, which is a prolongation of the main bearing bolts, is stiffened by diagonal stays secured to a continuous bed-plate, which is attached to the main bearings. There are two air-pumps, worked by side-levers, to each set of engines, all other pumps being independent.

Steam is supplied by three boilers of the Thornycroft water-tube type, similar to those fitted to H.M.S. "Speedy" (*see* No. 902), but modified so as to use two furnaces in each, and thus obtain a greater area of fire-grate in the available space. Each boiler has 63 sq. ft. of grate area, and 2,630 sq. ft. of heating surface; the total power indicated is 4,400 h.p., representing 23·3 h.p. per sq. ft. of grate.

The guaranteed speed of the "Daring" was 27 knots, but during a series of trials in June 1894, she realised at her designed displacement an average speed of 29·2 knots; owing to a deeper immersion necessitated by Admiralty requirements, her official trials resulted in 27·7 knots.

862. Two-stage expansion launch engine. Made by Messrs. W. Sissons & Co., Ltd. Received 1908. Plate X., No. 4.
N. 2464.

This shows the propelling engine of a launch or cutter, in which, as is now almost invariably arranged, the cylinders are above the crank-shaft. The set is of non-condensing, two-stage expansion type, with cylinders 5·5 in. and 8 in. diam. respectively, by 5·5 in. stroke, acting on separate cranks formed at right angles in a steel crank-shaft, the whole of which, including the balance weights, is in one piece. The three main bearings are carried in a cast-iron bed-plate, from which the cylinders are supported by three vertical steel columns at the back and two raking ones at the front. The rear columns are braced together and carry the guides, which are formed of single rectangular bars, each being enclosed by its crosshead which is forged solid with the piston-rod. The guide bars are independently adjustable to insure accurate alignment, and the crosshead surfaces are also adjustable for wear.

The steam is distributed through both the high and low pressure cylinders by a development of the radial valve gear introduced by Hackworth, in which a single eccentric for each cylinder is employed and the reversing and linking-up are performed by altering the position of the centre of a suspended lever; both gears are simultaneously altered by a shaft at the back of the engine controlled by a simple reversing lever. The adoption of this valve gear is facilitated by inclining the direction of the valve rods so that they are not parallel with the piston-rod.

Lubricant is distributed from a large oil vessel at the back of the cylinder by copper pipes leading to the various bearing surfaces, but in some positions independent lubricators are provided.

This set of engines is designed for working with a boiler pressure of 150 lb. per sq. in. and to run at 480 revs. per min., when it is capable of developing about 30 h.p.

863. Launch engine (working). Presented by M. E. Rowe, Esq., 1910. N. 2556.

This engine is of the four-stage expansion condensing type, with the cylinders arranged in tandem pairs, the high pressure and the first intermediate over the forward crank, and the second intermediate and low-pressure over the after one. The cylinders are 3 in., 4 in., 5·25 in., and 7 in. diam. respectively, by 4 in. stroke. The crank-shaft, with its balance weights, is of Siemens mild steel in one piece. As is usual in quick-running engines of this type the framing is of a light and open character, and consists of steel columns in the front and a cast-iron frame at the back, bolted to a cast-iron bed plate; the guides are formed in the back standard. The slide valves are placed outside the cylinders in order to be easily accessible. Reversing is effected by link motion of the Stephenson type. Steam is distributed to the high-pressure and first intermediate cylinders by a single slide valve having a large port at the upper end of sufficient width to serve for both ports of the high-pressure cylinder, so that the steam exhausting from the high-pressure cylinder at the termination of each stroke of the pistons, passes through this port to the first intermediate cylinder. Steam exhausting from this cylinder passes through the pipe at the back of the cylinders to the valve-chest of the second intermediate cylinder. A valve of similar construction serves for the second intermediate and low-pressure cylinders, and is shown separated from the engine. This type of valve was patented by Mr. G. Kingdon and Messrs. Simpson, Strickland & Co. in 1897, together with a method of dispensing with a stuffing-box in the partition plate between each pair of cylinders. The rods of the two upper pistons have annular grooves cut in them, leaving a number of collars on the rods, which fit the hole in the partition plate and form a steamtight joint without the aid of a stuffing-box. Both the feed and air pump are driven direct from the engine crossheads and have metal valves.

In conjunction with the water-tube boiler using liquid fuel (*see* No. 909), this type of engine has been very successful. It occupies little fore-and-aft space, but, on account of the imperfect nature of the balancing possible with a two-crank engine, it is not so well adapted to high-speed running as a three-stage expansion engine.

The engine shown is designed for working with a boiler pressure of 175 lb. per sq. in., and is capable of developing 14 indicated h.p.

864. Petrol launch engine with reversing gear. Lent by the Wolseley Tool and Motor Car Co., Ltd., and Messrs. Hesse and Savory, Ltd., 1911. N. 2594.

The engine shown is a high-speed petrol motor working on the Otto cycle; it has mechanically operated valves and electric ignition. The four cylinders with their jackets, and the top part of the crank case, including the combustion chamber heads, are cast *en bloc*. The lower part of the crank case, which is of aluminium, contains the crank-shaft bearings, and has four arms for bolting the whole to the engine bearers. The water circulation is effected by a pump driven by enclosed gear off the crank-shaft. The exhaust pipe, which is connected with a silencer (not shown), is cast on the cylinders; this pipe, together with all passages and cylinder walls in contact with the hot gases, is water cooled.

Lubrication is carried out by means of a rotary pump driven off the cam-shaft. The oil is delivered to narrow troughs under each connecting rod and the big ends are fitted with scoops which dip into the troughs at every revolution, keeping up a continuous splash on the gudgeon-pins and pistons. The level of the oil in the troughs is kept constant by means of the pump, the pressure of oil in the system being registered by a gauge. All oil is filtered before being distributed.

A cam-shaft, driven from the crank-shaft by enclosed gearing at half its speed, operates the inlet and exhaust valves by means of rockers formed solid with the shaft; the valves are returned by springs. Access to any valve is readily obtained by removing its cap.

The carburetter, where the explosive mixture is prepared, is of the float-feed spray type. A cylindrical chamber in which petrol, fed by gravitation or a feed pump, is maintained at a constant height by a needle valve actuated by a float, is connected with the mixing vessel. In order that the richness of the mixture of petrol and air can be regulated, a flat valve controlled by a spring governs the admission of air. When running at high speeds more air is admitted owing to the increased air-suction causing a greater depression and consequent opening of the valve. A throttle valve, controlled by hand, regulates the supply of the explosive mixture. In addition to the main jet, a small supplementary jet is provided to facilitate starting. This jet communicates with a small-bore suction pipe which passes direct to the main induction pipe, and is unaffected by the position of the throttle. The mixing chamber is heated by being jacketed with the exhaust gases, a small pipe being led from the main exhaust for this purpose.

High tension ignition on the Bosch system is employed, and the time of ignition can be varied. Starting is effected by means of a handle and completely enclosed chain, fitted at the forward end of the motor; the chain can be tightened without removing the cover.

The combined clutch and reversing gear is of the type patented in 1905–8 by Mr. G. Savory. It is compactly enclosed in a light welded sheet steel case, the clutches and bevel gear running in an oil bath. Upon the end of the crank-shaft is a keyed cone clutch—the motor clutch. For ahead driving, this clutch engages with an inner clutch keyed to the propeller shaft. This drive is direct, and the reversing bevel gear is idle. Embracing the motor clutch is a third or astern clutch, which is fixed to one member of the reversing mechanism. The latter reverses the bevel wheel driving the dog clutch on the propeller shaft. The total travel of the propeller shaft and propeller for engaging ahead or astern respectively is only 1·375 in. An important feature of the design in this gear is that the propeller thrust tends to keep the ahead clutch in engagement with the motor clutch when running ahead, and the propeller pull acts similarly on the astern clutch when running astern. A hand-operated lever gives ahead, astern, or neutral positions in the 12 h.p. example shown; in large sizes of the gear a wheel is substituted for the lever. At the motor or forward end of the gear is fitted a thrust block, the lubrication of which is ensured by needle oil-ways between the collars and the oil receptacles into which the thrust collars dip.

The four cylinders are each of 3·125 in. diam. by 4·5 in., stroke developing 13 brake h.p. when running at 1,000 revs. per min. The total weight of the engine without the fly-wheel is approximately 300 lb.

865. Model of torpedo boat engine. (Scale about 1 : 24.) Lent by R. L. Robinson, Esq., 1908. N. 2485.

The model shows the usual arrangement of a set of three-stage expansion engines as fitted to small fast vessels such as torpedo boats and large yachts. The introduction of wrought iron or steel pillars and diagonal bracing by Sir J. I. Thornycroft in the engine framing of a river yacht has since found universal application in small high-speed vessels. This light and open framing is shown on the model.

Large bearing surfaces are usually provided in this type of engine in order that it may be run at high speeds without excessive heating and wear. The reversing gear which is controlled from the starting platform by a large hand-wheel is of the usual shifting-link type. The air-pump is driven from the low-pressure crosshead by rocking levers.

A single four-bladed propeller and the thrust block are shown.

866. Model of Parsons marine steam turbine. (Scale 1 : 24.) Lent by the Parsons Marine Steam Turbine Co., Ltd., 1908. Plate X., No. 5. N. 2487.

The model shows a typical three-shaft arrangement of marine steam turbine as usually fitted to mercantile vessels and yachts. The arrangement consists of one high-pressure turbine driving the centre shaft, and two low-pressure turbines, working in parallel, driving the wing shafts; in the exhaust casing of each of the low-pressure turbines is placed a reversing turbine. When going ahead, steam from the boilers is admitted through the main regulating valve to the high-pressure turbine by the two steam pipes shown, and after expansion it passes to each of the low-pressure turbines, and from them to the condensers in the wings of the ship. When manœuvring, the wing shafts only are used, steam being admitted by the smaller valves shown on the bulkhead, directly into the low-pressure turbines or into the reversing turbine as required. By this means the port or starboard engine can be worked ahead or astern independently of each other and of the high-pressure turbine, which rotates idly in a vacuum whilst the vessel is manœuvring.

In recent practice the rotor wheels are of cast steel, the spindles of forged steel, the casings or outer cylinders of cast iron, and the blades of hard drawn brass.

Thrust blocks are fitted at the forward ends of each of the spindles. These are necessary because the steam thrust aft does not always balance the propeller thrust forward. The former is usually in excess at full power, and the latter at low power. The difference between these two thrusts is transmitted by collars turned on the end of each rotor spindle. These act on the top half of the thrust block when the steam thrust is in excess, and on the bottom half when the propeller thrust is in excess. Independent gear is provided for the top and bottom halves of the thrust block in order to move the rotor for the adjustment of clearances.

Where the rotor spindles pass through the ends of the drums, glands specially designed by Mr. Parsons are fitted. For the greater part of the length of the gland radial fins extend alternately from the spindle and from the casing into the annular space between. The action of these fins is alternately to wire-draw and to expand the steam, thus reducing the steam pressure as it travels outward. At the outer end are fitted four Ramsbottom rings, and the small amount of steam which is allowed to leak past them for lubrication is conveyed by means of a pocket to the auxiliary condenser or exhaust tank. In the event of the fins not sufficiently reducing the pressure of the escaping steam, this pocket, in the high-pressure turbine, can be connected with the low-pressure turbine at a point where the pressure is just below the atmosphere. In the case of the low-pressure glands, air can be prevented from leaking in by maintaining a pressure of from 2 to 3 lb. per sq. in. in the pocket by means of a small steam pipe.

Provision is made for neutralising the steam pressure on the end of the rotor wheels by balancing it against a similar pressure on a balance piston or dummy which is fitted at the forward end of each turbine inside the casing, a similar astern dummy being fitted at the after end of the reversing turbine. This balance piston has a steam-packed gland between it and the turbine casing.

As the efficiency of a steam turbine depends largely on keeping the leakage of steam at a minimum, great attention is paid to maintaining very small clearances. Over the tips of the blades, this is effected by milling them to a thin edge, so that if they accidentally touch the drum they will grind clear. The ahead and astern dummies and the gland fins are tapered away for a similar reason. The clearances can be measured directly by a micrometer gauge fitted for the purpose.

Governor gear, operated by a worm on the rotor shaft, is fitted to each of the turbines, and shuts off the supply of steam should the revolutions of the turbines increase much above the normal speed. Special attention has been paid to the lubrication of the main bearings and adjusting blocks in this type of engine. Oil under pressure is delivered by steam pumps to the bearings, after which it flows to a cooling tank fitted with copper coils through which the water is circulated. After passing through oil filters it is then re-delivered to the bearings. A complete water circulation is also maintained through the bearings, which are made hollow for this purpose.

Lifting gear consisting of screws and worm gear driven by electric motors is provided in the engine-room in order to facilitate the removal of the upper halves of the turbine casings for inspection or repair.

Owing to the importance of a high vacuum, a special fitting called a "vacuum augmenter" or "augmented condenser" has been introduced; it consists of a steam jet placed in a contracted pipe between the condenser and the air pump. The jet draws the air and vapour from the condenser and, in the contracted pipe, the mixture is compressed to about one-half of its bulk. It is then delivered to the air pump through a small auxiliary condenser, the condensed water gravitating directly from the condenser to the air pump.

In the S.S. "Manxman" with this fitting, the vacuum, at low power reached 29 in. with the barometer at 30·2 in., the rise due to the augmenter varying from 1·25 in. to 1·5 in., representing an additional economy of 7 to 8 per cent. Greater power is provided for by fitting a by-pass in the high-pressure turbine which will admit steam directly to a lower set of blades.

A sectional model of a portion of a Parsons steam turbine showing the construction of the blading is exhibited in the Mechanical Engineering Collection.

MARINE ENGINE DETAILS.

867. Photographs of engines of S.Yt. "Sareea," fitted with Bremme's valve gear. Presented by Messrs. Ross and Duncan, 1887. N. 1705.

The vessel is an Egyptian coastguard yacht, and is fitted with a two-stage expansion surface condensing engine, having cylinders 10 in. and 20 in. diam. by 14 in. stroke. With a boiler pressure of 100 lb., 120 h.p. was indicated at 200 revs. per min., and the speed attained was 9·55 knots.

The valve gear used is that patented in 1879 by Mr. G. A. C. Bremme, of Liverpool, in which only a single eccentric is used, both linking up and reversing being performed by moving the centre of a swinging lever that controls the motion of the eccentric rod. Another photograph shows a small three-stage expansion engine made for the Japanese Naval College at Etajima, in which this valve gear is also employed.

The Bremme valve gear is identical in action with that invented and introduced by Mr. J. W. Hackworth in 1859, which is described and shown in motion in the Mechanical Engineering Collection.

868. Drawing of Stévart's valve gear. (Scale 1 : 10.) Prepared from information contributed by Druitt Halpin, Esq., 1903. N. 2326.

This modification of Walschaerts valve gear was introduced by Prof. A. Stévart in 1868, and the drawing shows it as applied to some steamers plying on the river Meuse. The arrangement is only applicable to engines having two cylinders set at right angles and driving one crank-pin, or else two cylinders in the same plane driving cranks at right angles.

The oscillation of the link of the usual Walschaerts gear, giving motion to the valve equivalent to that from an eccentric with 90 deg. advance, is here obtained, for one engine, from the crosshead of the other, while the lead for each is derived in the usual manner from its own crosshead; the result is that the motions for both valves are obtained without the use of eccentrics or return cranks.

869. Photographs of marine engines fitted with Marshall's valve-gear. Presented by F. C. Marshall, Esq., 1881. N. 1550.

These show a pair of two-stage expansion horizontal engines for driving twin screws. They were built by Messrs. R. and W. Hawthorn, of Newcastle, with cylinders 30 in. and 60 in. diam., by 36 in. stroke; with steam at 90 lb. pressure they made 55 revs. per min., and indicated 2,700 h.p.

The valve gear employed is that invented and introduced by Mr. Marshall in 1879–80; it is similar to that of Mr. J. W. Hackworth, which is shown in motion in the Mechanical Engineering Collection. The adjacent indicator diagrams were obtained by Mr. Marshall in 1880 from the engines of S.S. "Lord Jeffrey," which indicated 927 h.p.

870. Motion diagram of Joy's radial valve gear. Presented by David Joy, Esq., 1900. N. 2087.

This reversing and variable expansion gear, introduced by Mr. Joy in 1880, has been very extensively adopted in both land and marine engines. It dispenses with eccentrics, the motion for the valves being derived entirely from the travel and swing of the engine connecting-rod.

The valve rod is connected to the short end of a long lever, the other end of which is indirectly coupled to the engine connecting-rod. The fulcrum of this lever is fitted with a block sliding in a curved guide, and the engine is reversed or "linked up" by altering the angle that this guide makes with the valve rod. The guide is shaped to a circular arc of a radius equal to the length of the valve rod, and the block, when the engine is running, works equally on both sides of the centre of this guide. The sliding motion of the lever in the curved guide gives the equivalent to 90 deg. of angular advance in an ordinary eccentric gear, while the rocking motion of this lever gives the lead. As the crank-shaft rotates, any point on the connecting-rod has a nearly elliptical path, which would give an unequal distribution of the steam at the two ends of the cylinder if the long lever were directly attached to the connecting-rod. To avoid this objection the motion is obtained from a link, one end of which is attached to the connecting-rod and the other to a radius rod. A point in this link describes an oval path, giving a symmetrical motion to the slide valve.

It is stated that, in mid-gear, steam is admitted into the cylinder to the extent of the lead at each end, and that the lead is constant for all positions, although unequal lead can be arranged for if preferred.

For the sliding block and a curved guide a swinging lever is sometimes substituted, the inclination of the curved path so obtained being altered by changing the position of the stationary end of the lever. An adjacent photograph, of the engines of the Italian ironclads "Re Umberto" and "Sicilia," shows this arrangement.

In this diagram a simplification, by Mr. Joy, of the valve arrangements for a three-cylinder marine engine is also represented. With each cylinder acting on separate cranks set at 120 deg., cylinders Nos. 1 and 3 each has a complete gear, while the valve of No. 2 receives a corresponding motion from the centre of a lever connecting the valve rods of Nos. 1 and 3, without further mechanism. To facilitate the examination of this point, the three cylinders in this motion diagram are shown displaced from their true positions.

871. Drawings of Laing's valve gear. (Scale 1 : 16.) Presented by Andrew Laing, Esq., 1887. N. 1706.

The engines represented are a two-stage expansion set, with oscillating cylinders 60 in. and 104 in. diam. by 7 ft. stroke, supplied with steam at 80 lb. pressure, and indicating 4,000 h.p. Seven sets of these engines were fitted to the paddle steamers of the Queenboro' and Flushing service.

The valves are worked by Laing's single eccentric gear. This is a radial valve motion, in which the swinging of the cylinder gives the movement equivalent to the 90 deg. advance of a simple eccentric; the lead is given by a single fixed eccentric arranged in a line with the crank. Reversal is performed by altering the position of the fulcrum of the lever by which these combined motions are transmitted to the valve. In Walschaerts reversing gear (*see* No. 854), which also has only one eccentric, the two duties are distributed in the opposite manner.

872. Motion diagrams of Joy's fluid pressure valve gear. (Scale 1 : 6.) Presented by David Joy, Esq., 1900. N. 2085–6.

This arrangement for altering the grade of expansion of an engine, or for reversing it, was patented by Mr. Joy in 1892. The feature of the gear consists in the use of a single eccentric which can be readily moved in a straight path from the position for forward gear to that for backward. It is shown fitted to a marine engine of 9,000 indicated h.p., with cylinders 33·5 in., 49 in., and 74 in. diam. by 39 in. stroke.

The eccentric is forced over by means of fluid pressure, acting upon rams formed on the crank-shaft and working in cylinders fixed within the eccentric sheave. The fluid is introduced to these cylinders through central holes drilled along the crank-shaft, and by pipes connected with the fluid distributing arrangement. This consists of two vertical cylinders with a common piston rod, the upper cylinder being for steam, and the lower for oil or other fluid supplying the pressure. Steam is admitted to either end of the upper cylinder through a small slide valve worked by the hand lever, and there is also a slide valve in the oil cylinder. The steam admitted into the upper cylinder moves the piston in the oil cylinder, and so, by the fluid connection, moves the eccentric over to a corresponding extent.

If the oil leaks or an eccentric ram leather gives way, the eccentric goes to full gear, forward or backward, according to the way that the engine is running, and remains there.

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873. Model of steam starting engine (working). (Scale 1 : 4.) Made by Messrs. Brown Brothers & Co. Received 1903. Plate XI., No. 1. N. 2335.

The original form of this arrangement for applying steam power to move the reversing gear of a large steam engine was patented by Mr. A. B. Brown in 1867. It differs from the "all-round" reversing gears in that the steam pressure acts directly upon a piston connected with the reversing shaft, instead of through a small rotative steam engine and worm gearing.

The appliance, which is usually attached to one of the standards of the main engine as shown in the model, consists of a lower steam, or motive, cylinder and an upper hydraulic, or control, cylinder; their two pistons are connected by a common piston-rod from which the power is transmitted to the weigh, or reversing, shaft of the main engine by side links. The valve of the steam cylinder and a by-pass valve of the hydraulic cylinder are connected by a common valve rod, so that when the steam valve is moved from its mid position the by-pass is opened and allows the piston to move; when in the mid position, however, the pistons are held stationary owing to the hydraulic by-pass being closed.

Reversal by this apparatus is effected by a small hand lever connected to an intermediate point in a nearly horizontal floating lever, one end of which is connected to the arm of the weigh-shaft and the other end to the valve-rod. When the hand-lever is moved it moves the valves and thereby causes a corresponding but greater movement to be made under steam pressure by the weigh-shaft, till the resulting motion, through the floating lever, again closes the valves so that the mechanism stops and is retained in the new position.

An air vessel is connected with the hydraulic control valve, to take up surplus water resulting from the piston-rod being single-ended; there is also a small hand pump for forcing water directly into the hydraulic cylinder and so reversing the main engine when steam is not available.

In the model of the engines of the P.S. "Princesse Henriette" (*see* No. 819) is represented a later arrangement of this starting engine, patented in 1882, in which the reduced motion for the valve is obtained by the use of a quick-pitched screw and a slower one in place of a lever; both forms are, however, still made.

874. Model of marine engine governor. (Scale 1 : 8.) Presented by T. Silver, Esq., 1869. N. 1318.

This governor, patented by Mr. Silver in 1857, for controlling the throttle-valve of a marine engine, depends for its operation upon the resistance offered by the air to the rotation of a fan. When the pinion-shaft (which is independent of the fan-shaft) rotates at a sufficient speed, the toothed segments carried by the fan-shaft are turned through a few degrees by the pinion engaging with them, compressing to a small extent the helical spring, and driving the fan. When the speed of driving is increased, the balance is disturbed; the resistance of the air retarding the fan and its shaft, the segments are turned through larger arcs, compressing the spring to a further extent (*i.e.*, till it again balances the resistance), and partially closing the throttle-valve.

875. Marine engine governor. Lent by Aspinall's Patent Governor Co., 1902. N. 2295.

This governor, patented in 1893 by Mr. H. Aspinall, belongs to that class in which the change in the momentum, or inertia, of a reciprocating mass, controls the regulation.

It consists of a frame bolted to any reciprocating part of an engine, usually the air-pump lever, and carrying a swinging weight and two pawls so connected together that when one pawl is projecting the other lies back. The swinging weight is, by an adjustable spring, retained in its position against the normal momentum effort at the reversals of its motion, but an increase of about five per cent. above the intended speed of the engine causes this effort to overcome the spring, so that the weight swings and protrudes the other pawl.

To the engine framing is secured a bracket, carrying a lever connected with the throttle-valve rod and so arranged that when the lower, or excess-speed pawl is projecting it comes in contact with this lever and lifts it throughout the whole upward travel, thus closing the throttle-valve in this stroke. A detent, that has retained the swinging weight, is now released by the throttle handle, so that, if the racing has stopped, the weight moves the pawls into the original position and the upward pawl re-opens the throttle-valve. An emergency gear is also provided, which comes into operation in the case of excessive racing, such as would result from losing a propeller; this acts by a small additional swinging weight which, under exceptionally rapid reversal, locks the main weight in the shut-off position, so as to prevent the throttle-valve from re-opening automatically.

A diagrammatic working model of the governor to a scale of 1 : 8, which was made in the Museum, is shown in its position on the engine.

876. Cylinder drain and relief valve. Lent by H. P. Holt, Esq., 1879. N. 2518.

This arrangement of valve, patented by Mr. Holt in 1878, combines in one fitting the drainage and relief safety valves for both ends of an engine cylinder. Pipes from the two ends enter the casing shown, and the discharged water from the cylinder is carried off by a central pipe. In the casing is a valve for each end of the cylinder, and each of these valves consists of a central disc or relief valve, and also of a double-seated annular valve outside, which is the drain valve; these annular valves are kept on their seats by springs. The action is such that, when steam is on one side of the cylinder, its pressure opens the drain valve of the other end or exhaust side, while, at any time, the central or relief portion of the valve will open should the pressure, through priming, exceed the limit determined by the springs.

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877. Model of rope-driving arrangements for screw shafts (working). (Scale 1 : 16.) Contributed by Messrs. Maudslay, Sons and Field, 1862. N. 440.

At the time that the screw propeller was introduced, marine engineers had developed an arrangement of engine that was most suitable for driving paddle-wheels. Its features were: a slow running crank-shaft high above the keel, with large cylinders placed low down in the hull. The early screw ships were accordingly fitted with similar engines; the connection between the crank-shaft and the propeller shaft being made by mechanism, which usually increased the speed of the screw. Spur gearing was frequently used; but, in addition to being noisy, it was found very liable to strip. Leather belting on smooth pulleys slipped seriously, and was unsuited to such short centres, while pitch chain possessed similar defects to those of spur gearing.

The arrangement shown was patented by Joseph Maudslay in 1843, and is an early example of rope driving. It consists of a frame supporting an extension of the engine shaft, on which is secured a six-grooved rope pulley; the lower part of this frame supports a similarly grooved pulley of one-fourth of this diameter keyed to the propeller shaft. The pulleys are connected by six independent endless ropes, which are simultaneously tightened by a pulley carried in a swinging frame, adjustable by means of a screw.

878. Model of link-driving arrangements for screw shafts (working). (Scale 1 : 8.) Received 1862. N. 439.

The model shows one of the methods proposed for connecting the early paddle-wheel type of marine engine with a screw-propeller shaft. It is a parallel crank chain, and was probably derived from the coupling-rods of a locomotive.

The engine would have two cylinders and overhead crank-shafts. These shafts are connected, by overhanging cranks and a triangular connecting-rod, to an overhanging crank on the screw shaft. There is no dead point in the transmission, and this chain has been proposed for electric locomotives as a means of raising the motors above the road dust and mud.

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879. Model of Turton's crank-shaft. (Scale 1 : 12.) Made in the Museum, 1903. N. 2302.

Owing to the difficulty of constructing large cranks from a single forging, and the liability of such large masses of metal to contain defective portions, many forms of crank-shaft built up from several pieces have been adopted. The early engines usually had cast-iron shafts and crank-arms, staked together, and a wrought-iron crank-pin cottered in, but in recent years forged steel is the material generally used throughout for such parts.

In the construction patented by Mr. T. Turton in 1880, the crank-pin has one half of the web at each end forged with it, while the other halves of the webs form solid ends to the two portions of the crank-shaft. The two halves of each web are connected by a keyed dovetail joint and two large through bolts.

The model represents a crank-shaft made in 1881 for the S.S. "Virginian," which had a pair of tandem compound engines of 5 ft. stroke, indicating 3,000 h.p. The shaft was 16·5 in. diam., and there were two cranks, at right angles, each similar to that shown.

880. Model of built-up crank-shaft. (Scale 1 : 12.) Made in the Museum, 1903. N. 2304.

This represents one throw of the crank-shaft constructed in 1881 by Sir J. Whitworth & Co., for the S.S. "City of Rome." The shafts, webs, and pin were made separately of Whitworth fluid-compressed steel, and the cylindrical portions were forged from hollow ingots; the webs were secured to the shafts by shrinking and keying, but the pin was retained in the webs by shrinkage alone.

The engines for which this crank was built were of the three crank tandem two-stage type, with a stroke of 6 ft., and indicated 10,000 h.p.; the crank-shaft consisted of three portions, each similar to that shown, which were connected by flange couplings, and weighed altogether 66 tons. Since its construction, crank-shafts of this type have been very generally employed for large engines in the mercantile marine.

The first process in building up these crank-shafts is to shrink a web on to each piece of the shaft, and then further secure them by pins or keys driven into holes half in the web and half in the shaft, to nearly the full depth of the web. The two pieces of shaft are then bolted to a vertical plate and retained in their correct relative positions by distance pieces, so that the crank pin can be immediately lowered into its place after the holes in the web have been sufficiently heated, usually by internal gas jets.

When the crank-shaft for the "City of Rome" was being built numerous experiments were carried out to determine the amount of shrinkage to be allowed, and from these it was decided to leave the shaft and pin one-thousandth larger in diameter than the corresponding holes in the web when cold.

881. Model of Dickinson's crank-shaft. (Scale 1 : 12.) Made in the Museum, 1903. N. 2303.

In this construction of built-up crank-shaft, patented in 1881 by Mr. J. Dickinson, the crank-pin and webs are formed in one piece, of such dimensions that flanges on the body of the shaft can fit into recesses bored in the webs; the parts are then held together by bolts, the nuts of which are secured by locking plates.

A crank-shaft of this form was the first in which a crank-pin and its webs were made of cast steel; when submitted to the Board of Trade, in 1882, it was subjected to a series of tests which showed the material to be suitable for the stresses experienced.

882. Model of Foster's crank-shaft, (Scale 1 : 12.) Made in the Museum, 1903. N. 2305.

In this method of building up a crank-shaft, patented in 1884 by Mr. H. F. Foster, the crank-pin and the webs are forged or cast in one piece, which is then secured to the shaft by shrinking and keying the webs on to the adjacent ends. These ends are made somewhat larger than the journals so that the keys can be driven in from outside the webs. This plan can also be used for repairing a broken crank-shaft which has been made in one piece, since by cutting away the webs and the pin, the shaft ends can be turned down to receive a new throw complete.

883. Models of disconnecting cranks. Contributed by Messrs. Jackson and Watkins, 1861. N. 412 and 415.

With ocean-going paddle-steamers it was very advantageous to be able to disconnect their paddle-wheels, as, should one wheel be seriously damaged, the other wheel and the full engine power could be used to complete the voyage. To readily effect this change, some form of disconnecting crank was most generally introduced, whereby the crank-pin could be left free of the crank web nearest the damaged wheel. These three wooden models show some of the devices, patented by Samuel Seaward in 1840, as a means for thus releasing the outer length of the paddle-shaft.

(*a*) In this crank the crank-pin is secured to the nearer web, while the outer web has a block sliding on it worked by a radial screw; when the block is forced outwards a jaw on it secures the squared end of the crank-pin, and so completes the connection in a way that can be readily released.

(*b*) This arrangement resembles the above, but has the sliding jaw working in guides arranged within the outer web.

(*c*) Here the outer web terminates in an eye that carries a thick sleeve, across which is a slot through which the outer end of the crank-pin can freely pass. This sleeve can, however, be turned through 90 deg. so as to place the slot in a position that secures the outer end of the pin, and so completes the connection.

884. Models of disconnecting cranks. Presented by Messrs. Bullivant & Co., 1902. N. 1890.

These three brass models show modifications of the connecting arrangements patented by Samuel Seaward in 1840.

(*a*) In this construction the crank-pin, which is fixed to the inner web of the crank, is hollow and has within it a pin which, by a central screw, can be forced into the eye in the outer web.

(*b*) This plan closely resembles (*a*), but the closing pin is screwed into the crank-pin from the outer web, and is fitted with a special locking device, to prevent the screw from working back.

(*c*) The outer crank web has in its face a deep slot through which the crank-pin can sweep; contained within the web are two square bolts, which, by means of screws, can be forced across the slot, so as to secure the squared projecting end of the crank-pin.

885. Model of disconnecting crank. Contributed by Messrs. Maudslay, Sons and Field, 1861. N. 441.

The outer web of the crank terminates in a heavy sleeve, in the face of which is a slot through which the crank-pin can sweep. This sleeve can, however, be turned in its eye through 90 deg., and be thus caused to retain the free end of the crank-pin. The device is almost identical with (*c*) in No. 883.

Note.—A very large example of disconnecting cranks is represented in the model of the "Great Eastern" paddle engines (*see* No. 814).

886. Clutch for propeller shaft. Lent by Henry Emanuel, Esq., 1885. N. 1695.

This is a claw clutch intended for use in disconnecting the propellers of launches, etc.

The clutch is loose on a sleeve keyed to the tail shaft, and when in gear the claws engage in recesses on a flange on the engine shaft, and are maintained in gear by a helical spring. When disconnected, the claws are prevented from entering the jaws by an intervening masking flange, which, when connection is to be made, can be turned into a position in which the claws can pass through it.

887. Model of clutch for propeller shaft. (Scale 1 : 12.) Contributed by Messrs. Benjamin Hick and Sons, 1859. N. 327.

This is a friction clutch, arranged within a large drum secured to the tail shaft. On the engine shaft is a boss with a flange supported by four ribs which serve as guides for four sector-pieces arranged inside the drum; these are forced apart by right and left-handed screws in pairs, turned by levers attached by links to a sliding sleeve, which is forced home by a screw independently supported.

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888. Stern bush of S.S. "Royal Charter." Presented by Messrs. Gibbs, Bright & Co., 1861. N. 465.

This bearing for the shaft of a screw propeller was made in accordance with John Penn's patent of 1854. It consists of a gunmetal bush somewhat larger than the shaft journal; the interior of the bush is provided with dovetail grooves into which are inserted lignum vitæ blocks so shaped as to project above the metal. The wooden ridges are then bored to the diameter of the journal, and form the bearing surfaces, while the intervening spaces allow free passage for the water, which is an excellent lubricant for metal sliding on lignum vitæ. The screw shaft bearing had previously given great trouble, but Penn's invention, which is now universally adopted, has proved a perfect solution of the difficulty except where sandy water prevails.

The bush shown was used over a distance of nearly 200,000 miles, without suffering any material wear. It was recovered, after nearly two years' submersion, from the S.S. "Royal Charter," an iron-built vessel of 2,719 tons and 200 nominal h.p., which was wrecked in Moelfra Bay, Anglesea, in 1859, during a memorable gale.

MARINE STEAM BOILERS.

The earliest boilers had only to sustain the stresses due to the weight of the water within them, the steam being at atmospheric pressure, so that they were simply water tanks with external grates and flues; thus the boiler of the "Clermont," 1807, was a tank set in brickwork and externally fired.

Watt's wrought iron "wagon" boiler was for many years almost the only type of steam generator used on land, and after it had been improved by the introduction of an internal furnace flue, it developed into the marine "box" boiler, with internal flat-sided flues and furnaces, which remained in almost universal use till 1845. These boilers, even when well stayed, were not suitable for pressures exceeding 35 lb., but in other respects they were satisfactory; they could be made to fit the available space in the ship, had considerable heating surface, and gave evaporative results that would even now be considered satisfactory.

The vertical or modified "haystack" boiler was employed in steamships by David Napier in 1842; with numerous modifications and improvements it remains a popular and compact form for the smaller types of steamboats.

The substitution of tubes for the flat flues in box boilers was advocated by the 10th Earl of Dundonald about 1850, the tubes to be about twice the diameter of those that had then been common in locomotive practice since 1829. Small cylindrical multitubular boilers working at 90 lb. pressure were in use in 1854, but there was a strong prejudice against such pressures being used at sea, and the advance was not at the time followed up.

The reduction in fuel consumption resulting from the use of higher pressures, particularly after two-stage expansion engines were adopted, caused a general increase in pressure to about 60 lb.; this necessitated the use of the cylindrical shell and flues, and so led to the construction that is frequently described as the "Scotch" boiler. This type of steam generator has been that chiefly favoured in marine work from 1870 till the successful introduction of the water-tube boiler, although with the general use of three-stage expansion engines the working pressure gradually increased to 155 lb.

Where lightness and large steaming capacity were desired, as in torpedo craft, the locomotive type of boiler was at first adopted, with pressures of from 120 to 180 lb., the exhaust steam creating the draught. The introduction of surface-condensing engines into such boats deprived them of their blast, but this loss was more than counterbalanced by the introduction of fan draught.

The use of still higher pressures led to the introduction of the water-tube boiler composed entirely of tubes filled with water and steam. Such boilers were fitted in the mercantile marine on the Clyde about 1857, but owing to rapid corrosion of the tubes they were not successful. Rowan fitted them in the S.S. "Propontis" in 1874, and in 1878, Loftus Perkins provided the S.Yt. "Anthracite" with a "pipe" boiler working at 500 lb. pressure consisting wholly of layers of horizontal tubes enclosed in a lined sheet-iron case externally resembling a square vertical boiler. In 1879, a type of water-tube boiler, the "Belleville" (*see* No. 903), having tubes of large diam. placed at a slight inclination and very closely stacked in separate elements, was successfully used on a despatch vessel in France, where its application was after some years extended to larger war-vessels. This type of boiler was also adopted for the passenger steamers of the Messageries Maritimes.

The different types of water-tube boiler at present in use have been classified into groups depending on the amount and freedom of the circulation of water, but the most general division is into two groups respectively known as "large" tube and "small" tube boilers. The former are suitable for large ships, while the latter are suitable for small ships and short runs at high speed. These have also been called "express" boilers.

The "Thornycroft" boiler (*see* Nos. 902 and 908) was patented in 1885, and first fitted on H.M. torpedo-boat "Speedy." It was followed by the "Yarrow" boiler in 1889, the "Reed" boiler (*see* No. 906) in 1893, and many others of the small-tube express type. The "Belleville" boiler was used in H.M. Navy in 1893 on H.M.S. "Sharpshooter" and subsequently the large cruisers, H.M.Ss. "Powerful" and "Terrible," each of 25,000 indicated h.p., were supplied with them. Since then many large British warships have been fitted with these boilers, but they are not used in the British mercantile marine. A type of large-tube boiler which has been very successful in recent years is the Babcock and Wilcox (*see* No. 905), which was fitted on the S.S. "Tasso" in 1893. Many vessels of the mercantile marine and of the British and the United States Navies have been supplied with this type of boiler. A boiler of the large-tube type which differs somewhat from any of the preceding is the "Niclausse" (*see* No. 907), which has double tubes, acting similarly to Field tubes. Great difficulties were met with when the Belleville boiler was introduced into H.M. Navy, in part owing to the highly skilled attention which such boilers continually required. On the advice of an expert committee their use was not further extended. The present practice is to fit either the Babcock and Wilcox, the Yarrow large-tube (*see* No. 904), the Niclausse, or the Dürr type to large vessels, either as a complete installation, or in combination with a number of Scotch boilers. For small vessels, *e.g.*, torpedo-boat destroyers, one of the many approved types of express boiler is used.

Of the many advantages for marine work which the water-tube or tubulous boiler possesses over the Scotch or tubular type, comparative immunity from accidents, ability to stand high pressures, lightness, and rapidity in raising steam are those which are most important.

A method of increasing the steaming powers of boilers, and therefore of reducing their relative dead-weight, is by burning more fuel per square foot of grate area. This is done either by forced, or by induced draught. In the first case the stokehold or else the ash-pit is air-tight and has air forced into it by a centrifugal fan, while in the second, the waste gases are pumped from the smoke box by a similar fan and forced up the funnel. Both arrangements permit the use of an inferior class of fuel and also render the stokehold cooler. Although at first only fitted in torpedo vessels, forced-draught arrangements are now always provided in the ships of H.M. Navy, and to a lesser extent in those of the mercantile marine.

889. Model of marine boiler and funnel. (Scale 1 : 12.)
Presented by the Earl of Dundonald, 1861. N. 537.

Thomas Cochrane, 10th Earl of Dundonald (1775–1860), in his remarkable career, did much to hasten the introduction into the Royal Navy of propulsion by steam power, and designed a war-vessel, H.M.S. "Janus," which he fitted with four boilers, resembling this model, each with three furnaces; he also made experiments in the introduction of hot air into the combustion chamber, and a plate on the model states that it represents a boiler "which evaporated 785 cub. ft. of water per hour by his system of economical firing."

The boiler is of the rectangular type, with numerous flat-stayed surfaces and three flat-sided furnace flues; the opposite flat surfaces were tied together by internal stays, which, however, are not represented in the model. The three furnaces open into a common combustion chamber, from which the gases pass to the front through horizontal return tubes that deliver them into the smoke-box under the uptake, just as in the modern "Scotch" boiler. Passing the uptake through the steam space, as here shown, has now been generally discontinued, owing to the rapid deterioration that these plates suffered. The funnel is fitted with an air jacket, and contains a swinging damper.

The water level is automatically maintained by a float-controlled valve; the safety valves have dead weights hanging within the boiler but fitted with easing gear that can be worked from outside. The waste steam pipe has a drain for collecting condensed water, so that it shall be returned to the hot-well. On the front is an internally opening unloaded valve, by which air would enter if the steam pressure was lowered, thus preventing the boiler from collapsing under atmospheric pressure, a risk that was greater than its bursting under its steam pressure.

890. Model and drawing of Hawthorn's boiler. (Scale 1 : 12.)
Lent by Messrs. R. and W. Hawthorn, 1869. N. 1316.

This construction, patented by Mr. W. Hawthorn in 1868, combines several features of the earlier flue boilers with others of the usual marine "Scotch" type. In 1869 a pair of these boilers, illustrated, were fitted n the S.S. "Mercury," a vessel 235 ft. long, 28 ft. broad, and 18·2 ft. deep. Her engines were two-stage expansion, and indicated 434 h.p.

The shells of the boilers were semi-cylindrical with flat sides, and were 11 ft. long by 9 ft. wide, by 11·25 ft. high. Each boiler had two furnace flues and a central flue, all oval, but with the flat sides mutually staying each other; these flues were 2·5 ft. wide by 3·5 ft. high, and the grates were 5 ft. long. Below these flues were three cylindrical flues, the middle one 2·5 ft. diam. and the outer ones 1·9 ft. diam.; at the front was a dry uptake from the two outer of these lower flues. The flues and chambers were strengthened by water-tubes 8 in. diam.; these also increased the heating surface and promoted circulation. The flames and gases from the furnaces passed to a combustion chamber at the back and returned through the central flue to the front, then downwards into the central circular flue, and so to the back, finally reaching the uptake by the two other circular flues.

The combined heating surface of the two boilers was 1,320 sq. ft., and the grate area 42·2 sq. ft. The evaporation per lb. of coal was 9·124 lb. of water from 50 deg. F., and the total evaporation per hour was 10,000 lb.; the steam pressure was 45 lb. per sq. in. The weight of the two boilers was 25·5 tons, and they carried 17·75 tons of water when steaming.

891. Model and drawing of marine boiler. (Scale 1 : 24.)
Lent by William Gray, Esq., 1874. N. 1380.

This design was patented by Mr. Gray in 1872; its chief features are the means provided for superheating the steam and for heating the feed-water.

A pair of these boilers are shown in their setting. Each boiler consists of a main shell 20 ft. long by 8·5 ft. diam., provided with a large number of horizontal tubes which open into a combustion chamber situated in the middle of the length of the shell. There is a grate under each end of the shell, and the gases from them, after passing externally beneath the boiler, enter the combustion chamber and return to the two ends through the tubes; from these they are delivered into a smoke box at either end.

Above the shell is a long steam drum connected to it by numerous vertical pipes and covered by a saddle water tank that rests on the shell, but leaves a flue between. The funnel rises from a passage in the middle of this tank; the gases from the smoke boxes, in their passage to the funnel, superheat the steam and also give off some of their heat to the feed-water in the saddle tank.

Each furnace has a grate area of 25 sq. ft., while owing to the boiler being externally fired each shell accommodates 239 tubes 8 ft. long by 3 in. diam., ranged at 4·5 in. centres. The combustion chamber has 120 sq. ft. of heating surface; the pair of boilers represented has a total grate area of 200 sq. ft., and 7,116 sq. ft. of heating surface distributed as follows:—Over fires, 200 sq. ft.; combustion chambers, 240 sq. ft.; tubes, 5,736 sq. ft.; superheater, 520 sq. ft.; and feed-water heater, 420 sq. ft.; the working pressure is 100 lb.

Provision is made for introducing heated air beyond the bridges by passages at the side of the grate.

892. Drawing of "Howard" marine boiler. (Scale 1 : 16.) Lent by Messrs. J. and F. Howard, 1874. N. 1379.

This construction of boiler was introduced by Messrs. Howard and Bousefield in 1869–74, and was fitted to the S.Yt. "Red Rose," a vessel of 380 tons, in which the then exceptional steam pressure of 87 lb. was used. The leading idea in this arrangement is to avoid the stresses in large shells by using a number of smaller ones about 42 in. diam. In the drawing there are three bottom shells, each containing a single furnace flue; above these are three shells containing return tubes, and these support three top shells which act as water and steam drums. The combustion chamber is water-jacketed by flat surfaces supported by screwed stays, while the other sections of the boiler are placed in connection by large flanged necks. The three upper shells are joined by a transverse drum above them, which acts as a steam collector.

893. Drawing of marine boiler. (Scale 1 : 16.) Lent by J. Dickinson, Esq., 1876. N. 1459.

This form of steam generator was patented in 1875 by Messrs. Dickinson and Mace. It is an externally-fired boiler in a casing lined with fire-brick. There are two horizontal cylindrical shells traversed by a large number of ordinary boiler tubes; these shells are arranged one above the other and connected together by a waist, while the upper one is surmounted by a steam drum. The lower shell is directly heated by the fire, and both elements are heated by the gases traversing their tubes as well as by the gases in the casing.

894. Print of boilers of P.S. "Galatea." (Scale 1 : 12.) Lent by W. Willis, Esq., 1876. N. 1460.

The "Galatea" was built and engined by Messrs. Caird & Co. at Greenock in 1868 for the Corporation of the Trinity House. The hull was constructed of iron, 219·5 ft. long, 26·2 ft. beam, 13·8 ft. deep, and of 507 tons register. The engines consisted of a pair of oscillating cylinders 52 in. diam. by 66 in. stroke.

In 1876 two new boilers as represented were fitted, which indicate a transition stage between the old rectangular form and the internally fired cylindrical construction; the crown is cylindrical, the sides and ends are flat, while the four furnaces have cylindrical crowns but dry bottoms, the sides of the furnaces extending downwards as water legs merely. Each boiler is 9·25 ft. long, 16·25 ft. wide, 12·3 ft. high, has four furnaces 3·5 ft. wide, and 200 return tubes 3 in. diam.; it is surmounted by a vertical steam chest 4·5 ft. diam. by 4·75 ft. high. Their combined grate area is 186 sq. ft.; heating surface, 5,308 sq. ft.; water space, 1,392 cub. ft.; and steam space, 732 cub. ft. With these boilers the vessel attained a speed of 14·5 knots.

895. Model of marine boiler. (Scale 1 : 8.) Lent by Captain G. J. Scott, 1883. N. 1587.

This arrangement was patented by Mr. Scott in 1876, and was fitted in several vessels of the India General Steam Navigation Company; the main object of the construction was to avoid the injury commonly resulting from the deposit of sediment, on the heating surfaces, from muddy river water.

The boiler represented consists of two cylindrical shells placed side by side and each fitted with a large number of ordinary boiler tubes. At the bottom of each shell, and in communication with it, is a deep water pocket to which the feed water is supplied and from which the solids deposited can be blown off. The grate is arranged between the two pockets, which thus form the sides of the fire-box, while beyond the furnace bridge is a brick-lined combustion chamber by which the gases are directed upwards through the boiler tubes; after passing through these to the front of the boiler they enter the smoke-box and escape into the funnel. Above the two shells is fitted a steam drum, the drainage from which is led back into the feed depositing pockets.

The model represents a boiler fitted to a steam launch, and worked at 100 lb. pressure; in some larger vessels groups of three or four shells were similarly fitted and worked at a pressure of 125 lb.

896. Model of vertical marine boiler. (Scale 1 : 12.) Lent by Messrs. Cochran & Co., 1896. N. 2083.

This is a modification of the Cochran boiler (*see* Mechanical Engineering Collection) so as to adapt it better for use as a steam generator on board ship. The vertical shell and the short horizontal return tubes are retained, but the grates are in two short cylindrical furnace flues opening into a water-enclosed combustion chamber as in the usual marine tubular boiler. The top of the boiler is domed so as to avoid stays and similarly with the bottom; a flat front is used so as to accommodate the furnaces, but these act as stays. The hemispherical top serves as a steam drum, while it is claimed that the floor space required by the boiler is comparatively small. The furnace tubes are flanged to take the tube plate behind and stay it. The back of the combustion chamber is formed within the shell so as to leave a water space, and is supported by screwed stays.

These boilers are made in sizes up to about 2,000 sq. ft. of heating surface, and for a working pressure of 75 lb. per sq. in. The one represented has 800 sq. ft. of heating surface, and would evaporate in ordinary work about 4,700 lb. of water per hour, which, with a two-stage expansion condensing engine, would give about 200 indicated h.p.

897. Model of marine boiler with corrugated flues and expansion ring. (Scale 1 : 12.) Lent by Samson Fox, Esq., 1879. N. 1525.

This model shows the application of the corrugated furnace flue invented by Mr. Fox in 1877, and of the shell expansion ring patented by Mr. G. Hepburn in the same year.

In internally fired boilers the furnace flues, so long as they remain cylindrical, offer great resistance to a collapsing pressure, and only fail ultimately by a local flattening, which, however, rapidly extends. Many means have been adopted to strengthen such flues against collapse by assisting them in retaining a circular section, but for marine purposes the corrugated flue has been the construction most extensively applied.

Upon the introduction of this flue, experiments were made to test the relative strengths of a corrugated and a plain furnace tube. They were of similar general dimensions and were tested by hydraulic pressure from without; it was then found that while the corrugated flue sustained a pressure of 1,020 lb. per sq. in., the plain unstiffened flue failed at 225 lb. In addition to the greater strength obtained, the corrugations increase the heating surface and also permit longitudinal expansion.

The shell expansion ring shown in the model is an application to the shell of a boiler of the furnace ring known as the "Bowling hoop." This hoop possesses a certain amount of elasticity and is introduced into the boiler shell as a means of diminishing the stresses due to the unequal expansion and contraction of the top and bottom portions.

898. Drawing of marine boiler. (Scale 1 : 16.) Lent by Messrs. Robert Stephenson & Co., 1886. N. 1698.

This represents the boiler of the S.S. "Prometheus," built in 1886 (*see* No. 855.

It is a double-ended steel boiler 16 ft. diam. by 24 ft. long, with six Fox's furnaces 4·25 ft. diam., and 213 return tubes 4 in. outside diam. by 9 ft. long. The tube surface is 4,015 sq. ft., and the total heating surface 5,015 sq. ft.; the grate area is 153 sq. ft. The total weight of the boiler, including water and fittings complete, is 159 tons. The working pressure is 80 lb.

899. Drawing of Kemp's boiler. (Scale 1 : 16.) Lent by Messrs. Alex. Stephen and Sons, 1887. N. 1709.

The left-hand side shows one of the boilers of the S.S. "Bleville," a ship of 3,800 tons carrying capacity, built in 1886. This construction of boiler was patented by Mr. E. Kemp in 1885 as a combination of high and low temperature boilers, but the arrangements are similar in principle to those of a factory boiler when fitted with the form of feed-water heater known as an "economiser."

The high temperature boiler is an ordinary cylindrical boiler 10·6 ft. diam. by 10 ft. long, with two corrugated furnaces 3·5 ft. diam. and 108 return tubes 3·5 in. diam. by 7 ft. long; its grate area is 36 sq. ft. and the heating surface 884 sq. ft.

The low temperature boiler consists of four stacks, each containing 90 tubes 2 in. diam. by 9 ft. long, arranged in the smoke-box and uptake of the true boiler. The total surface of these secondary boilers is 1,696 sq. ft., and through these tubes the feed water is forced in the opposite direction to that in which the external gases flow, so that the coldest gases are heating the coldest water.

For increasing the draught when required, a fan 6 ft. diam., and driven by an external engine is fitted in the uptake, above the low temperature tubes. The boilers worked at 160 lb. pressure, and on trial it was found that the feed-water at 120 deg. F. was heated to 300 deg. F. before entering the true boiler, while the gases, leaving the true boiler at 640 deg. F., had a temperature of only 300 deg. F. when leaving the system.

The right-hand side shows a modification patented by Mr. Kemp in 1886. In it the gases pass through the tubes of the secondary boiler, which take the form of four multitubular cylinders; above these is a nest of tubes through which the air for the furnaces is forced, before it is led down to a closed ash-pit.

900. Drawing of small marine boiler. (Scale 1 : 8.) Lent by Messrs. Ramage and Ferguson, 1887. N. 1708.

This represents the boiler of the S.Yt. "Gladiator," built in 1886, full particulars of which are given in No. 854.

The boiler is of steel, 8·5 ft. diam. by 7·75 ft. long; it has a single Fox's furnace, and 98 return tubes 3 in. diam. The tube surface is 410 sq. ft., and the total heating surface 500 sq. ft.; the grate area is 15 sq. ft.

The drawing also gives particulars of the joints and other details in the construction of the boiler, which is designed for a working pressure of 150 lb. per sq. in.

901. Sectional model of "Scotch" marine boiler. (Scale 1 : 12.) Made by the Admiralty, 1889. Setting added in the Museum, 1902. Plate XI., No. 2. N. 1831.

The early marine boilers were of rectangular form, with slight modifications to make them more completely fit into the vessel; the difficulty in obtaining sufficient strength with such shapes was not serious with the low pressures employed. On the substitution of surface for jet condensers, however, the steam pressure used, which had been 20 lb. above atmospheric, was increased to 35 lb., and this alteration soon showed the unsuitability of the large flat surfaces of the box boiler. Small cylindrical marine boilers working at 90 lb. pressure had been employed on gun-boats as early as 1854, but it was not till about 1870 that the cylindrical form of boiler was generally adopted, and the steam pressure raised to 60 lb. From that time there was a steady advance to the pressure of 135 lb., which was that used in the Royal Navy at the date when this model was made. Since then the cylindrical boiler has been almost completely superseded by the water-tube boiler, but in the mercantile marine the cylindrical type is still generally used. The boiler is shown with the interior portion removed to render the details visible, the two portions being placed in the setting for two separate boilers—this latter portion together with the section of the vessel's bottom were made in the Museum in 1902.

The boiler represented is one of a set of six single-ended high or return tube "Scotch" boilers fitted in H.M.S. "Trafalgar," built at Portsmouth in 1887. The shell is formed of two rings of plate 1·156 in. thick, united longitudinally by internal and external cover straps, treble-riveted, with rivets 1·125 in. diam. The end plates are in three pieces, flanged to take the furnace flues and to join the shell, and are stayed above the tubes and combustion chamber, and below the furnaces, by long bar stays passing through the plates, with nuts inside and nuts and washers (not shown) outside, the washers being riveted to the plates.

The four furnace tubes are of Fox's corrugated construction, ·47 in. thick, 3·6 ft. diam. by 7·3 ft. long; they are riveted to the front end plate, and to the bottom and tube plates of the combustion chambers. In the model, however, one has been replaced by a plain tube, made in short lengths, and strengthened by Adamson's flanged seam; and another by a "Farnley" flue, in which helical corrugations are utilised to give the necessary resistance against collapse. The fire grates are 7 ft. long, and have cast-iron fire bars 1 in. wide, with ·5 in. air spaces.

There are two combustion chambers, one to each pair of furnaces, constructed of plates ·5 in. thick, and separated by a water space 5 in. wide. The flat sides of the combustion chambers are stayed with screwed stays 1·25 in. diam., 7 in. pitch, with nuts at each end; the roofs are each stayed with ten girder or "dog" stays, carrying bolts 1·25 in. diam. screwed through the combustion chamber plate from below. There are 245 return tubes for each combustion chamber, 2·5 in. external diam., 6·6 ft. long, pitched 3·5 in. apart, and one-fourth of the number are stay tubes fastening the front tube plate to the front of the boiler. At the fire-box end of each tube is fitted a cap ferrule which is only in contact with the tube at some distance from the plate, the cap thus protecting the tube-end from the hot gases, and thereby saving much trouble from leaky tube-ends.

The smoke-box and uptake form an entirely external fitting, instead of being partly built in the boiler as in the earlier low-pressure types, and there are six manholes in the front plate above the furnace tubes as well as one into the steam space. In the model the usual boiler mountings and their internal connections are represented, including the surface blow-off and bottom blow-out valves, the main feed and the auxiliary feed valves; the deflecting arches and separating walls of fire-brick built in the combustion chamber are also shown.

By reference to the separate model of the forced-draught arrangements for this ship (No. 916), it will be seen that a set of three boilers is placed in each stokehold on opposite sides of the vessel. Each of these sets is supported upon two continuous longitudinal plate-girders or bearers, riveted to the inner-bottom plating of the ship and connected together by cross-bearers placed directly under each boiler, the whole being carried upon the usual cellular framing of the ship-structure below, of which the principal details are here shown.

Above the longitudinal bearers are strong crutch-frames or rolling-chocks fitted closely to the lower part of the boiler shell and forming a complete cradle or setting for each boiler. To prevent the boilers from shifting under the heavy rolling or pitching motions of the ship, plate straps connect the boilers together, and angle-iron straps or lugs connect each boiler to the fore-and-aft bulkhead at the rear. The severe stresses which would arise from ramming or a collision are further provided for by diagonal frames or "ramming-chocks" fitted between the end boilers in each set and the adjacent transverse bulkheads of the ship. Portions of the main bulkheads to the boiler-room are shown, and also of the shovelling flat which extends from the front of the boiler furnaces to the wing coal bunkers. The "air-lock" is shown complete, together with parts of the screen plates fitted between and at the sides of the boilers to reduce the stokehold temperature.

The boiler represented is 16·1 ft. diam. by 10·25 ft. long, and weighs with its water, fittings, and proportion of uptake, and funnel, 84 tons. It has 3,050 sq. ft. of heating surface, and 110 sq. ft. of grate area: the working pressure is 135 lb. per sq. in.; and the steam it supplies is equivalent to 1,400 indicated h.p. under natural draught, or 2,100 indicated h.p. with forced draught, when used in three-stage expansion engines.

902. Diagram and photographs of Thornycroft boiler. (Scale 7 : 16.) Lent by Messrs. John I. Thornycroft & Co., 1889. N. 1834.

These show a boiler of H.M.S. "Speedy" (*see* No. 130), a torpedo gun-boat built and engined at Chiswick in 1893, which was the first vessel in the BritishNavy, with the exception of torpedo boats, to have boilers of this type. The dimensions of the "Speedy" are:—Length, 230 ft.; beam, 27 ft.; displacement, 810 tons.

The arrangement of the boiler illustrated is very similar to No. 908, a model of a modern type of this boiler, with the exception that the early form had only two lower water barrels instead of the three shown in the later form. The generating tubes are of 1·25 in. external diam., and are secured at each end to the drums by the use of a roller expander.

The "Speedy" was fitted with eight boilers of this kind, having a total heating surface of 14,720 sq. ft., and a total grate area of 204 sq. ft. They supply steam, at 200 lb. pressure, to three-stage expansion engines, which develop 4,500 indicated h.p. under forced draught, and 2,500 indicated h.p. under natural draught, giving a maximum speed of 29·2 knots.

903. Sectional model of Belleville boiler. (Scale 1 : 5.) Made by Messrs. T. and C. J. Coates, from particulars supplied by Messrs. Maudslay, Sons and Field, 1897. Plate XI., No. 3. N. 2124.

This form of boiler was developed and introduced by Messrs. Delaunay, Belleville & Co., of St. Denis, France, but is now constructed in this country, and has been fitted to some of the largest ships in the Royal Navy. In common with all water-tube boilers, its construction permits of the use of very high pressures, and gives great steaming capacity in proportion to the space occupied. The model shows a complete boiler; but as four boilers are usually built together, it only represents a fourth of the usual unit for marine work.

Each boiler consists of a set of "elements," or continuous tubes, running to and fro ten times over the fire, always inclining upwards, and finally opening into the "steam collector" which is common to the set; a "feed collector" connects the lower ends of the elements. The boiler represented has eight elements, but one of these is withdrawn so that its construction and attachments are visible. The straight tubes are of mild steel, 4·5 in. external diam. by 7 ft. long, and are screwed into malleable cast-iron bends or "junction boxes," of which those at the front have hand-hole doors. The junction boxes stand one on another, and the lowest row at the back rests on a roller, so as to permit free expansion.

The feed collector is a square cast-steel pipe, into which the lower end of each element is secured; at each end of it is a mud-drum, with a salinometer and a blow-out cock to give a continuous discharge. Each mud-drum is connected to the steam collector by a vertical pipe, through which the water carried over with the steam returns; the steam generated in each pipe circuit passes upward into the collector, carrying much water with it, but the latter is separated by a complete system of baffle plates. Lime water is introduced into the mud-drums with the feed water, in order to precipitate the solid impurities that would otherwise be deposited in the tubes. Above the left-hand mud-drum is the automatic feed-regulator, controlled by a vertical cylindrical float within a vessel connected by copper pipes with the steam and water spaces of the boiler; to the front of this vessel the water and pressure gauges are fitted.

Above the fire doors runs a square tube or "gas-mixer," supplied with air under pressure which is discharged through a number of nozzles into the furnace to complete the combustion of the gases. Deflecting plates are placed above the tubes to promote circulation of the hot gases, and small deflectors are also fixed to the casing. The grate bars slope considerably, and the furnace is protected round the sides by a firebrick lining.

The doors and the whole of the external casing of the boiler are formed of flanged plates, so arranged as to give stiffness without preventing free expansion. The uptake is similarly constructed, its weight being carried by lattice girders which rest on four corner columns that constitute the vertical framing of the structure.

The boiler, as constructed in the model, was fitted on H.M.Ss. "Powerful" and "Terrible," but on later ships a smaller set of elements was placed above the main set or generator, and was called the economiser. This upper set acted as a feed-water heater, the water passing through the small tubes before entering the lower tubes of the generator. Between the two sets of tubes a large space was allowed, into which air was admitted from nozzles, the space forming an efficient combustion chamber. H.M.S. "Diadem" (*see* No. 134) was the first British ship fitted with this improved boiler.

The boiler represented has a grate area of 48 sq. ft. and 1,500 sq. ft. of heating surface; it would supply about 10,000 lb. of steam per hour at a pressure of 250 lb. per square inch, or sufficient for over 500 indicated h.p.

904. Sectional model of Yarrow boiler. (Scale 1 : 10.) Made in the Museum from drawings supplied by Messrs. Yarrow & Co., 1903. Plate XI., No. 4. N. 2348.

This water-tube boiler is a development of the type of "small-tube" or "express" boiler patented by Mr. A. F. Yarrow in 1889 and which he so extensively employed in torpedo boats. As the advantages of the water-tube system of construction became more generally realised, the advisability of using in cruisers and battleships similar boilers, but adapted for continuous steaming, led to the introduction of the "large-tube" modification shown by the model. The boiler represented is one of 24 fitted in 1903 on two Chilian battleships, now H.M. ships "Swiftsure" and "Triumph," there being 12 boilers in each vessel, arranged in four groups of three; the model shows the centre one of a group together with a portion of its uptake.

The boiler itself consists of an upper horizontal cylindrical vessel, or steam drum, and two lower ones, or water barrels, connected by inclined straight tubes expanded at their ends into holes in the shells which are thickened where serving as tube plates. The water barrels are of flattened section, owing to their tube plate portions being made of the same curvature as the steam drum, while their diameter is less. Each of these cylindrical vessels has a manhole at the front end, and the upper vessel is provided with the usual mountings and valves, including an internal steam collecting pipe. There are 1,008 tubes 1·75 in. external diameter to each boiler, all delivering into the steam drum below the water level, and those in the rows nearest the fire are of extra thickness; the tubes as well as the shells are of steel, the use of brass tubes having been discontinued by Mr. Yarrow since 1894. To accurately maintain the spacing and to give rigidity to the mass of tubes, strips of plate provided with semicircular notches and known as "dodge grips" are inserted diagonally between the rows of tubes at the middle of their length. There are no external downcomers or water return tubes provided in this boiler, these having been dispensed with after trials on a torpedo boat had shown that the outer rows of tubes adequately served this purpose, while acting also as heating surface.

The whole area between the two water barrels is occupied by the grate, the sides of which are formed of firebrick supported by ribbed cast-iron backing; the ends of the furnace are also of firebrick, which is, however, supported by a double casing of sheet steel packed with asbestos to reduce the radiation losses. The flame and gases from the furnace, after passing between the tubes and thereby giving up most of their heat, enter the outer casing, by which they are led to the uptake and funnel; this casing fits over the steam drum and has its outer surfaces built of three thicknesses of sheet steel, the space between the two inner ones forming an air jacket while the outer space is packed with asbestos. Suitable doors are provided in the front and side of the casing to give access to the interior and to the tubes for inspection or repairs. Uniform distribution of the gases around the tubes is facilitated by two horizontal baffle plates which contract the central portion of the opening into the uptake; there are also two baffles restricting the flow of gases at the upper ends of the outer tubes.

The boiler is carried upon feet which are secured to bearers constructed as web frames and attached to the inner skin of the ship. The ashpans and grate are supported by three main girders, carried by plate frames arranged beneath the front and back of the boiler and extending upwards from the inner skin; these girders are further supported by three intermediate **A** frames. The firebar bearers directly rest upon cast steel girders supported by short columns from the main girders beneath them.

The boiler represented has 3,127 sq. ft. of heating surface, and 55·3 sq. ft. of grate area; the working pressure is 280 lb. per sq. in., and the steam it supplies is equivalent to 1,000 indicated h.p.

905. Drawings of Babcock and Wilcox water-tube boiler. (Scales 1 : 8 and 1 : 12.) Presented by Messrs. Babcock and Wilcox, Ltd., 1904. N. 2359.

These drawings represent the marine type of Babcock and Wilcox boiler which, in essential features, differs very slightly from the land boiler (*see* Mechanical Engineering Collection).

The original form of this boiler was introduced into the American Navy in 1889, and in 1893 was fitted in the S.S. "Tasso" by Messrs. T. Wilson, Sons & Co., of Hull. Extensive trials made with in 1897–98 in H.M.S. "Sheldrake" proved so satisfactory, that it is now one of the few standard types of water-tube boiler used in H.M. ships. The pressure parts of the boiler are constructed wholly of wrought steel, and consist of an arrangement of inclined tubes forming the heating surface attached to vertical sinuous boxes or headers. Connected with the upper ends of the front headers by short tubes is the steam drum, whilst horizontal tubes connect the drum with the rear headers. The bottoms of the front headers are connected by nipples with a square forged steel sediment box, through which the boiler can be completely drained. The furnace extends to nearly the full width of the boiler, and is built of ordinary firebrick or of light fire tiles bolted to the side plates.

The inclined tubes are divided into vertical sections placed at 15 deg. to the horizontal. These tubes are of seamless steel; opposite each of them in the header is a handhole for cleaning purposes.

There is a continuous circulation in this boiler, cold water coming down the front headers from the bottom of the steam and water drum, whilst steam and hot water flow up the tubes and rear headers and to the steam drum by means of the horizontal return tubes at the top. Baffle plates are placed in the steam drum, against which the steam and water are directed, thus causing the water to be thrown down whilst the steam passes round the ends of the baffles to the perforated pipe connected with the stop valve. Wash plates are fitted within the steam drum to prevent undue movement of the water when the ship is rolling.

The whole of the pressure parts are encased in a double sheet steel casing with asbestos between; an outer corrugated plate provides an air screen. Removable doors are constructed in both side and end casings to give access to the tubes.

The chief difference between this boiler and the land type is the position of the steam drum, which is, in this case, in front of the boiler and across the tubes, instead of running from front to back as in the land type. The tubes must, therefore, be inclined downward from back to front, in order that the valves and fittings on the steam drum may be at the stoking end of the platform.

The left-hand drawing represents a boiler suitable for battleships, with tubes 3·25 in. diam., whilst the other drawing shows a boiler, designed for either battleships or cruisers, which has two rows of tubes 4 in. diam. at the bottom, the remainder being 1·37 in. diam.

Some data concerning the boilers appear on the drawings.

906. Sectional model of Reed boiler. (Scale 1 : 10.) Made in the Museum from drawings supplied by Palmers Shipbuilding and Iron Co., Ltd., 1905. N. 2387.

The water-tube boiler represented is of the small-tube "express" type, and was patented in 1893 by Mr. J. W. Reed. It has been largely used in the British Navy for torpedo boats and destroyers.

There are three horizontal vessels; the upper cylindrical one is the steam drum and the two lower ones of flattened section are the water barrels. Provision for the return of water from the steam drum to the water barrels is made by four downcomers. The water barrels are connected with the steam drum by 1,774 generating tubes, 1·0625 in. diam., except the two rows on each side nearest the fire which are 1·3125 in. diam. There are no water-walls.

The special feature of this boiler is the tube joint. On each end of the tube, a hemispherical washer or nut is fastened which fits into a corresponding recess in the tube plate. When the nuts on the tube on the inner side of the tube plate are screwed up, the spherical surfaces fit closely, the joint thus accommodating itself to any slight deviation of the tube from the correct line. An accompanying sketch shows the joint on a larger scale.

A manhole door for access to the steam drum is provided at the front end, whilst the water barrels have a number of handhole doors along their flattened sides. There are the usual mountings on the steam drum; an internal steam collecting pipe is dispensed with, however, by taking the steam from a steam dome. The grate comprises the whole area between the two water barrels, its sides, front and back being formed of fire-brick.

To guard against radiation losses the casing enclosing the boiler is made of two sheets of steel with a 2 in. air space between, the whole being made rigid by channel bars, perforated by 1 in. holes to provide for a continuous circulation of air, between the casings. A lining of ·5 in. asbestos covers the inner casing. To ensure the gases traversing the whole of the tubes before escaping to the uptake, asbestos baffles are provided, resting on the backs of the outer tubes. Doors are provided in the front casing to give access to the tubes for cleaning purposes and for repairs, whilst the side casing consists of large portable doors, by means of which repairs are easily executed. The boiler is shown with a portion of the uptake, the latter being of the same construction as the boiler casing. Baffles, consisting of three sheets of steel forming a hollow triangular prism, are placed in the uptake to direct the flow of the gases. The boiler is carried on two cradles placed under the water barrels, each consisting of a plate girder (forming also the furnace side) with gusset plates at either end. The weight is thence transmitted to the floor plates and outer skin of the ship by means of deep longitudinal frames. The grate is supported independently by bearers on vertical columns attached to the centre and side keelsons of the vessel. The boiler represented has 79·75 square ft. of grate area, and 3,878·5 sq. ft. of heating surface; the working pressure is 250 lb. per sq. in.

907. Sectional model of Niclausse boiler. (Scale 1 : 10.) Made in the Museum from drawings supplied by Messrs. Humphrys, Tennant & Co., 1904. Plate XI., No. 5. N. 2362.

This is a form of water-tube boiler in which slightly inclined tubes closed at one end have within them circulating tubes opening into separate portions of vertical water chambers or headers; each double tube acting similarly to the well-known Field tubes. This arrangement was patented in 1878 by M. Collet, but its practical success is due to the work of M. M. Niclausse, who patented, between 1891 and 1900, an improved form of tube joint for this purpose.

The model represents one of 18 boilers fitted in 1904 on H.M.S. "New Zealand," being four-fifths of the total boiler power. It shows, partly in section, one of a group of six boilers, together with part of the uptake.

The boiler contains 16 elements, each consisting of a malleable cast-iron header with 20 steel tubes inclined at 6 deg. to the horizontal, arranged zig-zag in two vertical rows. The headers are each divided by an internal partition into two chambers, one behind the other, and they are all connected at the top, by means of bolts and double-coned nipples, to a collecting drum.

The outer tubes communicate with the back chambers of the headers, while the inner tubes open into the front chambers, so that the water from the drum may pass down the headers and through the inner tubes to the end of the larger ones, and then, together with the steam generated, return through the space between the two tubes and up the headers again into the drum, without the two streams mixing or interfering. The water level is 3·5 in. below the centre of the drum, and over each header is fitted a cap which separates the hotter from the cooler water.

The headers are connected at the bottom with blowing-out pipes, but this form of boiler cannot be completely emptied without removing the tubes. The outer tubes pass through the headers and are fitted with cone joints at the front and back intersections; the tubes themselves are enlarged to form the rear cones and to fill the orifices in the partitions, while steel collars screwed on the ends provide the front cones. Portions of the tubes are cut away on both sides of the partition to form passages for the water. Each inner tube is riveted to a skeleton extension piece screwed to a cap, which is itself screwed into the outer cone ring, while passage of the water from the front chamber to the outer tube is prevented by a surrounding ring; the back end of the tube is supported by a winged collar. Dogs outside the headers keep the conical surfaces in contact, little retaining pressure, however, being required owing to the areas being nearly equal; an adjacent drawing shows this joint in detail. The outer tubes are 3·3 in. external diam. and 7·36 ft. long, the four lower rows being ·236 in. thick, and the remainder ·16 in. thick; the inner tubes are 1·56 in. diam. and ·036 in. thick. The back ends of the tubes are closed by screwed caps, and are supported in holes in cast-iron plates; small spaces are left between the headers to allow the tubes to be cleaned outside by a steam jet.

The headers and tubes are supported on shelves at front and back, and are surrounded by a casing built of flanged steel plates. The side walls above the furnace are of two plates, with non-conducting material between, and on the outside walls a third sheet forms an air casing. The uptake rises behind the drum, and is built up of three sheets stayed together and stiffened by angles; the inner space forms an air casing, and the outer is packed with lagging material. There are three furnace doors; the whole area below the tubes is occupied by the grate, which slopes at the same angle, and is carried by transverse bearers supported on the walls; the sides of the furnace are formed of firebrick. The flame and hot gases from the furnace, after passing between the tubes, enter directly into the uptake and chimney; their passage is retarded by baffles formed of pipes resting on the tubes. The front of the boiler above the furnace is closed by shutters secured by **H**-bars and cotters. Air for combustion is supplied through the ash-pan doors, some of it passing through the grate, and some entering above it through passages in the back brickwork; air jets also enter from a pipe above the fire doors. The boiler is carried on plate girder bearers attached to the inner skin of the ship, and the ash-pans rest on these.

The boiler has 1,992 sq. ft. of heating surface and a grate area of 63·5 sq. ft.; the working pressure is 220 lb. per sq. in.; it supplies about 15,000 lb. of steam per hour, equivalent to about 850 h.p.

908. Sectional model of Thornycroft-Schulz boiler. (Scale 1 : 10.) Made in the Museum from drawings lent by Messrs. John I. Thornycroft & Co., 1904. Plate XI., No. 6. N. 2352.

The original form of this water-tube boiler was patented by Sir John I. Thornycroft in 1885, and first fitted on H.M. torpedo boat "Speedy" (*see* No. 902). It was subsequently extensively used in other vessels of the class, but when, in 1890, the larger vessels known as torpedo-boat destroyers were being introduced, a type of "express" boiler was required with increased heating and grate surface; this more powerful development was first adopted on H.M. destroyer "Daring," and afterwards on many other destroyers. The boiler represented in the model is, however, a modification of the "Daring" type in that, by an arrangement of tubes patented in 1894 by Herr R. Schulz, a somewhat different course is given to the gases; it is, therefore, known as a Thornycroft-Schulz boiler.

The boiler has four horizontal cylindrical vessels, the three lower ones being water barrels, while the upper and larger one is a steam drum. The steam drum is connected to the central water barrel by eight curved downcomers, while one large external tube forms the downcomer by which the water passes from the steam drum to each of the other barrels. Manhole doors are provided at each end of the barrels and at the front end of the drum, and the latter carries the usual mountings and an internal collecting pipe; there is also within it an automatic feed-water regulator, controlled by a long cylindrical float, and having an external adjustment by which the water level can be varied.

The generating tubes connecting the water barrels to the steam drum are 1,764 in number and mostly 1·125 in. diam., those exposed to the furnaces being, however, 1·375 in. diam. The tubes form the sides and crowns of the two furnaces, and, to prescribe a definite path for the flame and gases around them, the rows adjacent to the furnaces, as well as the external rows, are formed into "water walls" by the tubes in two rows being brought together so as to form a complete wall, except at the ends, where they are necessarily splayed to enter the tube plates. In this way the gases are caused to travel along nearly the whole length of the tubes before escaping to the uptake, while owing to the shape of the tubes the steam drum is protected from the direct action of the flames.

The boiler is completely enclosed in a casing made of a sheet of steel, with an asbestos lining fitting closely on to the outer water walls; in the region above the furnaces an air casing is provided. The furnaces are lined with fire-brick, and the water barrels are protected from the direct action of the fuel by the same material.

In the earlier forms of this boiler, the tubes were "undrowned," *i.e.*, they all opened into the steam drum above the level of the water in it; in some of the later examples, however, a considerable proportion of the tubes enter the steam drum below the water level, or are "drowned." The boiler is shown with a portion of its uptake, the latter being constructed of thin sheet steel with sheet asbestos on the outside, and secured by 2-in. strips of steel placed over the joints.

The boiler represented has 4,040 sq. ft. of heating surface, 67 sq. ft. of grate area, with a working pressure of 220 lb. per sq. in.

909. Water-tube boiler with paraffin burner. Lent by the Lune Valley Engineering Co., 1909. N. 2503.

This is a sectional example of a water-tube boiler in which a large heating surface relative to the space occupied is obtained. It is designed to burn vapourised oil, and, in combination with a light high-speed steam engine, forms an alternative method of propulsion to the petrol motor, both for cars and launches.

The boiler is of the type patented by Messrs. J. G. A. Kitchen and L. P. Perkins in 1902. It consists of a vertical central drum or steam chamber, surrounded by coils of tubes of mild steel. Each coil contains three turns, and has both ends in communication with the central drum, into which the ends are expanded. This flexible arrangement of the tubes provides for free expansion and contraction, and minimises the possibility of leakage; also cleaning or replacement of a coil can easily be effected. The steam chamber is either supported from the top by ribs extending to the outer casing, as in the example shown, or prolonged at the bottom, the lower end forming a mud drum. An outer casing, consisting of sheet steel, lined with non-conducting fire-proof material, surrounds the tubes.

The burner is of the type patented by Mr. Kitchen in 1900. The oil, which is common paraffin, enters at the top of the burner by the vertical pipe on the right, and thence passes through the coil and another vertical pipe to the nozzle below. During its passage through the coil it becomes vapourised and is lighted at the nozzle. The jet then impinges on the dome-shaped deflector, over which it spreads in a thin film, and mixes with the air necessary for combustion. Regulation of the size of the flame is provided for by a needle, which projects through the nozzle, and is operated by the hand lever shown. Movement of the needle also tends to clear the nozzle of carbon. This is important, because the deposition of carbon from petroleum vapour would choke the burner, and this would be a serious objection to this method of steam generation for continuous use. To start the burner, a little methylated spirit is lighted in the asbestos-lined tray under the nozzle. This sufficiently warms the coil to allow of the oil feed being slightly opened. It is stated that with this boiler and burner an evaporation of 15 lb. of water per lb. of oil from and at 100 deg. C. can be obtained.

MARINE BOILER ACCESSORIES AND FITTINGS.

910. Model of the natural draught arrangements of H.M.S. "Inflexible." (Scale 1 : 24.) Made by the Admiralty, 1889. N. 1826.

The "Inflexible" was a sea-going turret ship, built at Portsmouth in 1881. Her dimensions were :—Displacement, 11,880 tons; length, 320 ft.; beam, 75 ft.; draught, 25·3 ft. She was propelled by twin screws, driven by two-stage expansion engines, indicating 8,000 h.p., and giving a speed of 13·8 knots. Steam, at 60 lb. pressure was supplied by 12 oval boilers, giving a total of 36 furnaces, 829 sq. ft. of grate area, 22,288 sq. ft, of heating surface, and weighing with water, uptakes, funnel, &c., 756 tons.

The model illustrates the method of supplying air to the boiler-rooms, which have no forced draught arrangements. A complete stokehold is shown and a portion of another, together with the middle-line bulkhead between them. The complete stokehold contains two single-ended boilers, which are placed with their backs against the wing passages, and one double-ended boiler, which is placed parallel with and near to the middle-line bulkhead.

The fresh air is collected above the upper deck by cowl pipes, and then led by air trunks to various parts of the stokehold. The cowl pipe A has a lead terminating in front of one of the single-ended boilers, and another terminating in front of one end of the double-ended boiler. The cowl pipe B has a lead terminating at one end of the double-ended boiler, and the other terminating in the next stokehold. The ash hoists also serve as ventilators.

In consequence of the difficulty of arranging suitable cowl openings in the upper deck, and in carrying air trunks from thence to the stokeholds, it has always been requisite in large warships to fit fans to blow air into the stokeholds. The system of closing in the stokeholds, since adopted, is an expansion of this plan, but it permits a larger supply of air and also insures that all air blown into the stokeholds shall pass through the furnaces.

911. Sectional model of forced draught arrangements in Thornycroft torpedo boats. (Scale 1 : 12.) Made by the Admiralty, 1889. N. 1829.

In a boiler of this kind there is a broad rectangular fire-box with considerable height above the fire to allow for complete combustion. Below the fire-bars is simply an ash-pit, so that the furnace is open or "dry bottomed." The tubes are closely spaced, so that the water space of the boiler is small, and the weight of the boiler in comparison to its heating surface is minimised. As all parts except the barrel have to be closely stayed, the interior of the boiler is not accessible for cleaning, so that the use of sea-water is impossible. The coal consumption per sq. ft. of fire-grate varies from 80 to 100 lb. per hour, when supplied with forced draught at a pressure of sometimes as much as 5 in. of water.

The boiler represented is isolated by means of bulkheads, and in addition there are, worked across the boiler room, two more bulkheads of light air-tight screens through which the ends of the boiler project about 18 in., thus leaving but a small space in front of the boiler under air pressure.

The air is forced into the stokehold by fans, and enters the furnace through the doors in the "protection box" in front of the ash-pit. These doors are light and are hinged at the top to open inwards only; the pressure in the stokehold keeps them open, but in case of any steam escaping into the furnace the doors act as flap valves, and confine it and any flame to the ash-pit, whence they escape to the funnel.

912. Sectional model of forced draught arrangements in Yarrow torpedo boats. (Scale 1 : 12.) Made by the Admiralty, 1889. N. 1830.

In this arrangement an air-tight flat is worked along each side of the boiler at its central line, leaving the underneath part of the boiler clear throughout its entire length. From this flat there are worked over the top of the boiler two screens fitted with non-return air-flaps which open outwards from the stokehold.

When under way the ash-pit doors, which are used only for the removal of ashes, are bolted up, and the air, forced into the stokehold by blowing fans, passes along through the air passages and non-return flaps to the forward end of the boiler, and thence returns underneath to the furnace. Should any accident occur to the boiler, the flaps close, and prevent steam or flame from entering the stokehold.

913. Sectional model of Howden's arrangements for forced draught. (Scale 1 : 24.) Made by the Admiralty, 1889. N. 1828.

This arrangement, patented by Mr. J. Howden in 1883, belongs to the "closed ash-pit" type; the chief feature of the system is, however, the provision made for warming the air before it is admitted to the furnaces.

To the front of the boiler an air-tight jacket is secured, into which the air from the fans is delivered. This jacket is made of light iron plate, and it extends over the front from some distance above the upper row of tubes downwards, so as to enclose the furnaces and ash-pits. Immediately above the smoke boxes are tubes through which the gases pass on their way to the funnel; while the hot gases pass through the inside of these tubes, the air from the fan sweeps round amongst them, and so recovers a considerable portion of the heat that would otherwise be lost.

The smoke-box of each stack of tubes is completely separated from the air chamber by casings, as are the furnaces and ash-pits, so that no air can enter the ash-pits and furnaces except through the passages regulated from the outside by valves. On the front of the casings referred to the outer furnace doors and the ash-pit doors are hinged, while attached to the outer furnace doors are the inner and true doors of the furnaces, which shut on the front plate in the usual manner.

A dead plate, between the outer and inner front plates, separates the ash-pits from the furnaces above the fire-bars, and into the space between the dead plate and the inner and outer furnace doors, air is admitted in the desired quantity through simple plate valves. After passing through the perforations in the doors, at the sides and above the doors, the air is received into cast-iron boxes, which serve the double purpose of protecting the front plate and furnace doors, and distributing the air. When a furnace or ash-pit door is opened for stoking purposes, the air valves for that furnace close.

One of the early tests of this system was made in 1884, with the S.S. "New York City," an iron cargo steamer of 3,700 tons displacement. The engines were two-stage expansion, with cylinders 33 in. and 61 in. diam. by 33 in. stroke. The original natural draught boiler had 2,173 sq. ft. of heating surface and 75 sq. ft. of grate area. This was replaced by a boiler with 1,310 sq. ft. of heating surface and 36 sq. ft. of grate area, fitted with this system of forced draught. It was found that, while the earlier boiler consumed 13·5 tons of fuel in 24 hours when indicating 564 h.p., the new boiler consumed 9·5 tons for 623 h.p.

Drawings of the boilers of S.S. "City of Dundee," fitted with this system of forced draught, are shown in No. 858.

914. Drawing of Ferrando's arrangements for forced draught. (Scale 1 : 8.) Lent by Messrs. Scott Bros., 1886. N. 1669.

This arrangement was patented in 1884 by Mr. J. Ferrando, and has been somewhat extensively adopted in cargo steamers on account of its permitting the use of the cheap, small coal known as "duff."

In attempting to burn coal dust in an ordinary furnace, it was found that the fire-bars had to be so very close together that the slag soon choked the air passages, while if forced draught was resorted to, it carried off unconsumed up the chimney a considerable portion of the fuel. The slag difficulty was reduced by the use of grate bars of considerable depth, lying close together and dipping partly in water, whereby the temperature was kept sufficiently low to prevent the slag from adhering.

Mr. Ferrando's furnace was introduced to avoid the loss through the dust being blown away unconsumed; for this purpose he arranged his fire-bars, which were ·19 in. apart, transversely to the furnace, whereby the coal particles blown up remained longer over the glowing fuel, and so might get consumed. The air is supplied by a blower, and is delivered into the closed ash-pit, from whence it passes in a somewhat heated condition to the grate, upon which even the poorest fuel has been successfully burnt.

On the S.S. "Calanas," a vessel of 1,586 tons register, fitted with two-stage expansion engines, supplied with steam at 80 lb. pressure, it was considered that 337 tons of "duff" costing 51*l.*, with this arrangement did the same voyage as 400 tons of coal costing 140*l.*, when burnt in open furnaces.

915. Sectional model of the forced draught arrangements of H.M.S. "Mersey." (Scale 1 : 24.) Made by the Admiralty, 1889. N. 1824.

The "Mersey" is a second-class cruiser, built at Chatham in 1885. Her dimensions are:—Displacement, 4,050 tons; length, 300 ft.; beam, 46 ft; draught, 18 ft. She is propelled by twin screws, driven by horizontal two-stage expansion engines, indicating 6,000 h.p., and giving a speed of 18 knots. Steam at 110 lb. pressure is supplied by six cylindrical boilers, arranged in two stokeholds. The six boilers give a total of 18 furnaces, 399 sq. ft. of grate area, 11,700 sq. ft. of heating surface, and weigh with water, uptakes, funnel, &c., 306 tons.

In the closed stokehold system all openings into the stokehold are closed by air-tight doors, except the inlets from the fans and the outlets through the fires to the funnel. Communication between the boiler rooms and the engine room on the deck is obtained by means of a passage at one side, in which are air-locks, or pairs of air-tight doors, only one of which is opened at a time. By their aid the pressure in the stokehold can be maintained, in the same way as the gates of a canal lock retain the upper water.

The model shows the boiler fronts projecting through a vertical air-tight screen, worked from the bearers up to the ceiling, and dividing the boiler-room, so that only a comparatively small space in front of the boilers is under pressure.

The supply of air is collected above the deck, by means of cowl pipes which terminate at the ceiling of the stokehold. There are two cowl pipes to each stokehold, and at the foot of each pipe is a 5-ft. fan for forcing the air into the stokehold. As the air supply for both natural ventilation and forced draught is brought through the same cowl pipes, provision is made by means of doors for feeding the fans when in use, and stopping the natural air supply. When the boilers are under forced draught the doors A and B are open and C is closed; when under natural ventilation the doors A and B are closed and C is open. When under natural draught, the doors in the passage and air casings are also opened.

The average indicated h.p. developed during the trial was 6,628, with an air pressure in the stokeholds equal to 2 in. of water. This represents 16·61 indicated h.p. per sq. ft. of fire grate, and 21·7 indicated h.p. per ton of boiler; the coal used per indicated h.p. was 2·48 lb. In ships of the time, with natural draught, about 10·5 indicated h.p. was developed per sq. ft. of fire grate, but with moderately forced draught between 16 and 17 indicated h.p. were obtained. Taking the weight of the boilers as a basis, the effect of the application of forced draught was to increase the power obtained from a given weight in the proportion of 3 : 5 under similar conditions.

916. Sectional model of the forced draught arrangements of H.M.S. "Trafalgar." (Scale 1 : 24.) Made by the Admiralty, 1889. N. 1827.

The "Trafalgar" is a sea-going turret ship, built at Portsmouth in 1887. Her dimensions are:—Displacement, 11,940 tons; length, 345 ft.; beam, 73 ft.; draught, 27·5 ft. She is propelled by twin screws, driven by three-stage expansion engines indicating 12,000 h.p., and giving a speed of 16·5 knots. Steam at 135 lb. pressure is supplied by six cylindrical boilers arranged in two stokeholds. There are 24 furnaces, and the total grate area is 659 sq. ft., the heating surface 18,300 sq. ft., while the total weight of the boilers, &c., is 501 tons.

The engine and boiler rooms are divided at the middle line of the ship by a watertight passage, 10·5 ft. wide, the upper part of which affords communication between the ends of the ship, and is used for the transfer of ammunition.

The model shows one stokehold of the "Trafalgar," with its three single-ended boilers placed with their backs to the central tunnel. As in the "Mersey" (*see* No. 915), the forced draught is supplied from a closed stokehold system, but since the "Trafalgar's" boilers have return flues, a somewhat different arrangement is adopted. In addition to the vertical screen, an air-tight casing is constructed in front of the smoke-boxes, and along the ceiling and bulkheads hinged doors are fitted which can be closed when working under air pressure. Communication with the stokehold is made through air-locks. The air is forced into each stokehold by three fans.

In the model, one boiler has the casing and smoke-box removed to show the boiler front; another has part of the forced draught casing removed to show the ordinary air-casing within; the third shows the air-tight casing for the forced draught, complete, with the exception of the doors, which have been omitted to show the smoke-box.

During the trial the indicated h.p. developed under natural draught was 8,520, with an air-pressure of 0·5 in.; under forced draught 12,822 indicated h.p. was developed, with an air-pressure of 2·1 in. This represents 19·4 indicated h.p. per sq. ft. of fire-grate, and 25·5 indicated h.p. per ton of boiler, under forced draught; against 12·9 indicated h.p. per sq. ft. of fire grate, and 17 indicated h.p. per ton of boiler, under natural draught.

917. Sectional model of Martin's arrangements for assisted draught. (Scale 1 : 24.) Made by the Admiralty, 1889. N. 1825.

To avoid the inconvenience resulting from the use of a closed ash-pit or stokehold, while retaining the increased rate of combustion due to mechanically assisted draught, Mr. W. A. Martin in 1885 introduced his induced draught system. In his arrangement the fans, instead of blowing into the furnaces, are employed in withdrawing the gases from the smoke-boxes or uptake, and then delivering them into the funnel.

The model shows, in section, a vessel with a three-furnace boiler, placed fore-and-aft and flanked by coal bunkers. At the base of the funnel two fans are placed, one on each side of the uptake, and mounted on a shaft carried through the uptake. A damper is fitted by which the passage of the products of combustion may be regulated, or the course altered to that for natural draught. As the fans have to work upon gases at a high temperature, their shafts are fitted with hollow couplings, by which the transfer of heat along the shaft is so checked that the temperature at the journals is kept within safe limits.

In 1890 a series of experiments upon Mr. Martin's system of artificial draught was carried out at Portsmouth Dockyard. The boiler so fitted was of the locomotive type, and originally belonged to H.M.S. "Polyphemus" (1881). It had two furnaces, divided by a water partition; the total grate area was 20·7 sq. ft., and the total effective heating surface 758 sq. ft. In the final test, which lasted for 96 hours, with intervals for cleaning fires, steam was maintained at a pressure of 75 lb.; the coal consumed was 39·87 lb., and the water evaporated 389·6 lb. per sq. ft. of grate per hour.

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918. Model of the "Farnley" corrugated flue. (Scale 1 : 16.) Lent by the Farnley Iron Co., 1887. N. 1713.

This illustrates the furnace flue patented by Mr. H. P. Fenby in 1885, and brought out by the Farnley Co. The resistance to an external collapsing pressure is obtained by corrugations, which, however, run round the flue at an angle of about 45 deg., forming helical grooves.

It is claimed for this form of corrugation that it not only stiffens the tube, but also renders it a valuable stay for the ends of the boiler, since when under pressure it tends to shorten; in one case, under a pressure of 200 lb. per sq. in., some flues 42 in. diam. by 7·25 ft. long, shortened ·031 in., and returned to their original length on the pressure being relieved.

919. Model and drawing of the "Purves" ribbed flue. (Scale 1 : 24.) Presented by Messrs. John Brown & Co., 1889. N. 1833.

This construction of stiffened furnace flue was patented by Mr. D. Purves in 1885. By special machinery the tube is rolled with projecting rings at a pitch of 9 in., the intermediate portions of the tube being left cylindrical and thinner than the metal in the ribs.

The adjacent drawing, together with a section cut from an actual tube, give some further information not obtainable from the model. Like the Fox and Farnley corrugated tubes, the Purves construction is designed to strengthen cylindrical flues without introducing riveted joints.

920. "Serve" boiler tubes. Presented by Messrs. John Brown & Co., Ltd., 1904. N. 2353.

These boiler tubes, patented in 1885 by Mons. J. P. Serve, are provided with internal longitudinal ribs or fins which increase the surface for the absorption of heat from the furnace gases into the surrounding water; some experiments with ribbed and plain tubes of the same diam. and length showed that the ribbed tubes increased the amount of water evaporated per lb. of coal by about 15 per cent. It is also claimed that a boiler of given power fitted with "Serve" tubes is lighter than a similar boiler with plain tubes, a smaller number of the ribbed tubes of larger diam. providing the requisite heating surface and flue area. The ribs are cut away for some inches at each end of the tubes, to allow of their being expanded into the tube plates.

The specimens show different stages in the process of manufacture, which consists in preparing, by rolling, a plate of the required width and thickness having the necessary ribs projecting from its surface; this plate is then bent to cylindrical shape and a lap-welded joint formed, either by passing the tube between welding rolls or under a powerful hammer, while a suitably shaped mandrel is within it.

The tubes are made of mild steel, and for marine boilers, in which they are largely used, the sizes range from 3·25 in. to 4·5 in. in external diam.; the specimens shown are 3·25 in. diam., ·125 in. thick, and have eight ribs projecting ·625 in.

921. Model of smoke-box door. (Scale 1 : 4.) Lent by the Airtight Smoke Box Door Syndicate, Ltd., 1905. N. 2388.

This door was patented by Mr. J. H. Silley in 1903, and was designed to provide means of quickly opening and closing smoke-box or furnace doors whilst preserving an air-tight joint when shut.

Along each side of the door to be fastened is a stiff angle iron turning in brackets on the door and capable of sliding in the direction of its axis. Mounted on this angle iron is a series of wedge fasteners with inclined faces to engage in a corresponding number of hooks or catches on the casing. When the door is fastened and is to be opened, the angle is slid up in its bearings in an axial direction until it disengages the inclined faces of the wedges from the hooks on the casing; it is then turned about on its axis so as to clear the catches and allow the door to open. By carrying the angle the whole length of the door an intimate contact between the door and the casing is obtained in the closed position, an air-tight joint thus being secured.

It is stated that this form of door prevents buckling when subjected to high temperature and air pressure, and thus keeps the door in working condition.

922. Model of boltless furnace front. (Scale about 1 : 4.) Presented by T. Downie, Esq., 1910. N. 2558.

This construction of furnace front was patented by Messrs. T. Downie and D. Brown in 1906. It is designed to enable any of the removable parts of the flame plate, or the door frame to be replaced quickly and simply without the use of tools, as no bolts are employed.

The flame plate is in three parts, the upper piece having a projecting lug or cotter cast on it. The lug passes through the furnace front and is engaged and held in position by the upper part of the door frame. The two lower side portions of the flame plate are held in position by the upper portion, whose inner edges hold them in position. Each side portion is also held at its lower edge by a lug on the dead-plate. The door frame slides vertically into position and is held by four lugs, two at each side.

In the example shown the furnace front itself is in halves; this construction is for fronts of steel plate, and is intended to obviate failure due to unequal expansion and contraction.

Furnace fronts of this construction are being fitted to the White Star liners "Olympic" and "Titanic."

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923. Model of telescopic funnel. (Scale 1:12.) Contributed by Messrs. Jackson and Watkins, 1861. N. 542.

When vessels used their steam machinery chiefly as an auxiliary power for employment only in exceptional cases, it was customary to provide means by which the funnel could be stowed away so as to reduce the air resistance. Small funnels were sometimes arranged to turn back, as on our river steamboats that pass under bridges, but for larger examples some form of telescopic funnel was generally adopted.

The arrangement shown has only two telescopic lengths. The elevating is done by two winches driven simultaneously by powerful worm gearing. It resembles to some extent a device fitted by Messrs. Seaward and Capel to H.M.S. "Sidon" in 1846, which appears to have somewhat anticipated Taplin's design, subsequently so extensively adopted.

924. Model of telescopic funnel. (Scale 1 : 12.) Lent by R. Taplin, Esq., 1857. N. 40.

The model shows an arrangement, designed by Mr. Taplin, of Woolwich Dockyard, in 1848, which was awarded a medal at the 1851 Exhibition. It was tried on H.M.S. "Hydra," and was subsequently adopted on nearly all vessels in the Royal Navy, and to some extent in the mercantile marine.

The funnel is made in four lengths, the bottom one being fixed below the deck level, and the other three telescoping within it; each length is lifted simultaneously by chains passing over pulleys on the top of the length below. The chains of the lowest length are led to winch barrels, rotated by hand-worked worm gear in the ratio of 1 : 36. The waste steam pipe has also a telescopic length sliding in a simple stuffing-box, and is drawn up by the second length of the funnel.

925. Model of telescopic funnel. (Scale 1 : 12.) Presented by H.M. Commissioners of Patents, 1859. N. 543.

In this arrangement there is only one telescopic length, raised by blocks and wire rope tackle, from a stout wire rope stretched from the crosstrees of the adjacent masts. The hoisting winches are fixed to the masts, and have a ratchet and pawl to prevent running back; when the sliding length is up it is further secured by four hinges and pins.

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926. Salinometer. Contributed by W. Smith, Esq., 1866.
N. 1091.

Where boilers are fed with sea-water, it becomes a matter of great importance to ascertain the degree of saltness of the water, since after this has reached a certain density, the salts become precipitated as an incrustation on the sides and tubes of the boiler.

The instrument shown was patented by Mr. A. P. How in 1849, and measures the amount of salt present by indicating simultaneously the specific gravity and the temperature of the solution.

The apparatus is combined with the water-gauge fittings of a boiler, and consists of a gun-metal vessel which, by suitable cocks, can be filled from the boiler and emptied as required. The top of the chamber is provided with two openings, one for holding a thermometer, the other being fitted with a perforated lining for holding a float by which the specific gravity of the water is noted while at the same time the thermometer records the temperature. On the front of the vessel is a short table of temperatures and densities.

927. Salinometer. Lent by T. O. Buss, Esq., 1874. N. 1374.

This is a form of hydrometer of variable immersion, specially constructed and graduated for determining the density of water drawn from a steam boiler. It is made in German silver in the form of two cones with bases together, and a vertical stem which is graduated downwards in steps. It floats at zero in distilled water or at $\frac{1}{32}$ in sea water; $\frac{3}{32}$ is the maximum reading that the water in a marine boiler is allowed to attain. A quantity of water is drawn off in a suitable can for each test, and when it has cooled to 200 deg. F. (93·3 deg. C.) the reading is taken.

928. Salinometer. Contributed by George Nasmyth, Esq., 1858. N. 216.

This instrument, which was patented by Messrs. F. G. Spray and G. Nevett in 1849, registers the amount of salt present in the water within a boiler by indicating the temperature at which the solution boils under atmospheric pressure.

The apparatus consists of a gun-metal globe connected to the boiler front by a cock and having an outlet below, while projecting above the globe is the stem of a thermometer. By opening the connection with the boiler the water to be tested flows through the gun-metal casing until a steady temperature is obtained which is that of the solution at atmospheric pressure and the thermometer is graduated to read off the amount of salt in the solution. Normal sea water containing about one part in thirty-two boils at 213·2 deg. F.

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929. Water circulator. Lent by Messrs. G. and J. Weir, 1890.
N. 1835.

This apparatus, called a "hydrokineter," is for promoting circulation in boilers while steam is being raised. It consists of a series of nozzles placed in line as in an injector. Steam from an auxiliary boiler is passed as a jet through the central nozzle, drawing in and heating some of the surrounding water, which it delivers at a high velocity in the direction in which the circulation is defective. By this means the temperature of the water in the boiler is equalised, and so steam can be rapidly raised without causing any severe strains through unequal expansion of the various portions of the boiler.

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930. Asbestos-packed cocks for boiler fittings. Lent by Messrs. J. Dewrance & Co., 1880. N. 2507.

Three forms are shown, but the special feature is the same in each, and consists in the introduction of fibrous asbestos packing to secure tightness. The plug is of the usual construction, but has comparatively little taper, and the key is fitted to the smaller end. The body of the valve is formed with four longitudinal recesses and a circular recess at each end, all to be packed with asbestos. Above and below the plug are screwed covers, which act as glands for tightening up the asbestos packing as required. It is stated that such fittings permanently retain their tightness, and are less liable to set fast than those of the simple metal on metal construction.

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931. Model of feed water regulator. (Scale 1 : 2.) Made by Messrs. Henry Watson and Sons, 1899. N. 2205.

This apparatus was introduced to automatically control the feed water in water-tube boilers, in which, owing to the small water capacity and great rate of evaporation, the water level is subject to excessive fluctuations. It was patented in 1895 by Mr. Alfred Blechynden and was first fitted in the Royal Navy on the "Blechynden" boilers of H.M.S. "Pactolus."

The complete apparatus is placed in the separating drum at the top of the boiler, and is controlled by a float enclosed in a perforated screen which damps out temporary changes of level due to commotion in the surrounding water; the lever of this float is connected by a short arm to the regulator shown, by which the feed water is admitted.

The float lever actuates a partially balanced double-beat valve, the seatings for which are formed in a sleeve, adjustable longitudinally by an external hand-wheel; the position of this sleeve determines the level at which the water will be maintained; the sleeve can moreover be so far withdrawn if required, as to leave a free passage for the feed water.

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932. Drawing of Kirk's evaporator. (Scales 1 : 24 and 1 : 8.) Presented by Messrs. R. Napier and Sons, 1891. N. 1859.

This is an arrangement introduced by Dr. A. C. Kirk for distilling sea water and so obtaining sufficient pure water for making up the boiler feed, etc., without using additional fuel.

The evaporator is simply a cylindrical drum or low-pressure boiler placed in the uptake of the main boilers of the ship. This drum has a few necessary fittings and is fed with sea water, from which it generates steam at a low pressure but in sufficient quantity to make up for the losses of fresh water from the working of the engines, etc. The steam generated is taken either into the receiver of the main engines to help in propulsion or direct to the condenser; the salt accumulating in the evaporator is removed by systematic blowing out, as usual in marine boilers working with sea water.

The drawing shows the evaporator fitted in the S.S. "Damascus," a vessel of 3,700 tons register, built and engined in 1887 by Messrs. Napier. The evaporator is 4 ft. diam. by 26·5 ft. long, weighs 3·5 tons, and contains 4·5 tons of water. In practice it was found that when the main engines were developing 2,000 h.p. the pressure in the evaporator was from 13·5 to 14 lb., and the production 3 tons of fresh water per 24 hours. After 40 days' work a scale ·125 in. thick was formed, but it was easily removable.

933. Automatic evaporator. Lent by Messrs. Caird and Rayner, 1902. N. 2296.

This apparatus, which is used in conjunction with a special condenser, prepares drinkable fresh water from sea water by distillation, and also provides suitable water for making up the loss in boiler water resulting from the various small leakages existing in engines, boilers, and condensers. As originally practised, boiler steam was directly cooled in a special condenser, but owing to the grease and other impurities carried over with the priming water in this steam, the distilled water obtained was most unsatisfactory, while the whole of the impurities removed from it were deposited as scale in the main boiler. To overcome these defects the steam or vapour for the special condenser is now usually generated by evaporating sea water in a vessel heated by a coil of pipes supplied with steam from the main boiler, the vapour thus obtained for condensation being practically pure, while the deposited solids remain in an apparatus from which they can be easily removed. The primary steam from the main boiler by its condensation in the coils of the evaporator generates secondary steam, which when condensed gives practically pure distilled water, a plant acting in this way being accordingly known as a "double distiller."

The evaporator shown was patented by Mr. T. J. Rayner in 1888, and it also embodies several later improvements introduced by Mr. E. B. Caird. It consists of a vertical cylindrical vessel in the lower part of which is fitted a series of spiral coils of solid drawn copper pipe, the two ends of which are rigidly fixed to the door in such a way that they can expand and contract with the variations of the temperature and pressure to which they are subjected. Sea water is admitted and maintained at a constant level within the vessel by an automatic valve, while boiler steam is admitted within the pipes so that it transmits much of its latent and sensible heat to the sea water, thus boiling it off while the water from the boiler steam is again returned to the boiler. The solids from the sea water deposit chiefly on the heating pipes, from which, however, they are continually flaking off owing to the slight movement that takes place in the coils, so that the deposit can be removed by washing out and occasional scraping. The secondary steam or vapour from the evaporator passes off from the top of the vessel, where is fitted a series of baffle plates for the purpose of preventing water being carried over.

In the example shown the surface of the heating coils is 10 sq. ft., and their evaporating capacity 300 lb. of pure water per hour. The steam from the evaporator is conveyed to a condenser (not shown), which is of vertical tubular construction and has vapour inside the tubes and sea water outside them; with the object of reducing the amount of heat carried away by the process, the cooling water from the hottest portion of the condenser is used for feeding the evaporator. The distilled water drained from this condenser is sprayed into fresh air to aerate it somewhat, and then passed through the test tank into the storage tanks of the ship.

PROPELLERS.

PADDLE-WHEELS.

The radial float paddle-wheel, suggested possibly by the water-wheel, is recorded to have been tried spasmodically as a ship propeller, rotated of course by muscular power, from the 15th century onwards, but it never seems to have threatened seriously the simpler reciprocating oar. With the application of the steam engine to marine propulsion the paddle-wheel, along with many other apparatus (*see* p. 341), was tried, but the former, connoting as it does a rotative movement, proved most convenient, so that it alone survived. It was independently decided upon by the pioneers in steam navigation: Symington for the "Charlotte Dundas," 1801; Fulton for the "Clermont," 1807; and Bell for the "Comet," 1812.

The paddle-wheel has been placed in many positions; in the "Comet," two wheels, one abaft the other on each side, were used, but this quickly gave way to the modern single wheel. It has also been placed in a casing amidships or in the space between twin hulls; as recently as 1877 the P.S. "Calais Douvres," a vessel of the latter type, was so fitted. The stern wheel was used in the "Charlotte Dundas," and at the present day it is preferred for exceptionally shallow draught as it is less influenced by rolling, besides occupying less width than side wheels.

The modifications of the wheel that have been tried are very numerous. When used as an auxiliary power or with the varying draught incident to an ocean voyage, it was proposed to raise the wheel bodily, but the usual plan was to reef the floats by moving them radially along the arms. To reduce splashing, floats have been given a sinuous form with right and left hand inclination on opposite sides. They have also been divided into separate slats or provided with holes and valves to let out entangled air. Galloway in 1835 introduced the "cycloidal" wheel in which a float is made up of horizontal slats arranged on a cycloidal curve and several such wheels were successfully used.

As speeds increased, the defects of the radial float became more apparent and attempts have been made, in two directions, to reduce loss of power by "feathering." In one, the resistance of the air to the float when out of the water has been reduced just as is done by a rower feathering his oar, by arranging the float to turn on a radial axis; numerous paddle-wheels were invented with this object in view, but the practice has not survived. In another direction the loss of power arising from the oblique blow with which a radial float strikes the water and the splashing it occasions when leaving have been minimised by turning the float on an axis parallel to that of the shaft. Robertson Buchanan in 1813 patented a wheel in which the floats always remained vertical (*see* No. 944), but this solution, although frequently repatented, is only correct at the moment the vessel starts; when under weigh it may be as imperfect, although in the opposite direction, as the radial float. John Oldham's wheel of 1827 (*see* No. 948) gave a true action but involved the use of spur gearing. Elijah Galloway in 1829 patented what was subsequently known as Morgan's wheel; in this there is, within the wheel, a fixed eccentric pin to which the floats are connected by rods and brackets. By varying the eccentricity of the pin any inclination, for a predetermined slip ratio, can be given to the floats. With the exception that the fixed pin is outside the wheel—an improvement introduced by John Seaward—Morgan's wheel still represents the latest practice (*see* No. 955). The floats now used in conjunction with this feathering mechanism are curved and present a concave face to the water; they were brought out in 1877 by A. C. Kirk and fitted to boats on Continental and other routes.

Paddle-wheels have, for many reasons, long been displaced, for ocean steamers, by the screw propeller; the "Scotia" of 1861 was the last Cunarder so fitted. They are, however, still retained for river traffic where the available draught is limited.

934. Paddle-wheel with radial floats. (Diam. 10 in.) Contributed by William Morgan, Esq., 1860. N. 410.

This is a wheel with a single ring, the floats being supported by back struts; the ring is feather-edged.

The usual construction of the common radial float paddle-wheel is shown in the side-lever engine model No. 797, while the largest examples ever built are represented in the model of the engines of the "Great Eastern," No. 814.

935. Rennie's paddle-wheels. (Diam. 9·5 in. and 12 in.) Presented by George Rennie, Esq., 1857. N. 144–5.

These four models represent various forms of fixed-float paddle-wheel patented by Mr. Rennie in 1839, and practically applied at the time with some success. The floats are trapezoidal in form, generally with the diagonals in the ratio of 2 : 3 and with the longer one radial, while the surfaces were to be plain, convex, or concave. The shape of the float reduced the suddenness of the shock on entering and leaving the water, and was considered to give increased thrust with a diminished water-lifting action.

Two of the models have rhomboidal floats, and in one wheel the shorter diagonals are radial; the third model has trapezoidal floats. In the fourth model the floats are triangular in shape, and this wheel was known as the "duck-foot" propeller from its resemblance to the webbed foot of a bird; a small model of a steamer fitted with this form of paddle-wheel is also shown.

In 1840 the trapezium form of paddle-wheel float, when tried on a Thames steamboat, gave an increase of 14 per cent. in speed over that with ordinary floats; Mr. Rennie considered that his construction halved the weight and width of the paddle-wheels required for attaining similar speeds under like conditions, when compared with those with rectangular floats.

936. Paddle-wheel with radial floats. (Diam. 8·7 in.) Contributed by W. H. Muntz, Esq., 1862. N. 786.

This fixed-float paddle-wheel was patented by Mr. Muntz in 1862.

The floats in outline resemble a canoe paddle and are arranged three in a row, on three rings. They were intended to dip deeper than common floats and to cause less shock on entering.

937. Model of "cycloidal" paddle-wheel. (Scale 1 : 32.) Made in the Museum, 1898. N. 2170.

This form of fixed float wheel was introduced in 1833 by Joshua Field, F.R.S. In 1835 Elijah Galloway re-invented the arrangement, and it is from his patent specification that this model has been made.

Each float, instead of being in a single piece, is divided into several narrow widths set stepwise in advance of one another, as the circumference is approached, approximately along a cycloidal curve. In this way the shock on entering was reduced and distributed, while the discharge of water and air from the floats was facilitated.

Galloway's wheels were first tried on the City of Dublin steam packets, and they were in considerable use by about 1845 (*see* Nos. 182 and 807); many modern steamers have each float in two pieces arranged in this manner.

938. Model of "cycloidal" paddle-wheel. (Scale 1 : 20.) Maudslay Collection, 1900. N. 2233.

This represents Field's construction of the cycloidal paddle-wheel (*see* No. 937), as fitted in 1838 to the "Great Western," a vessel 1,320 tons register, 236 ft. long, 35·3 ft. broad, and 23·25 ft. deep, which was one of the pioneer steamships crossing the Atlantic (*see* No. 182).

Each float is in four separate parts stepped one behind the other from the circumference towards the centre, approximately on cycloidal curves; the parts of the float nearest the centre are wider than those further away. The arms of the wheel are not quite radial, being tangential to a circle somewhat larger than the boss; in this way the faces of the float, being parallel with the arms, are more favourably placed for quietly entering the water. Each float is of wrought iron, and is secured to the stepped framing at each end by hooked bolts.

By thus dividing the area of the float into horizontal sections the escape of air is facilitated, while by the arrangement of the sections, an action on entering is secured that somewhat resembles feathering.

939. Model of wooden paddle-wheel (1843). (Scale 1 : 24.) Presented by D. Lapraike, Esq., 1868. N. 1201.

This represents one of the paddle-wheels of the American river steamer "Empire" (*see* No. 189). At that period wood was the material almost exclusively used in the construction of American vessels and their paddle-wheels, as it compared favourably with iron in being both light and cheap, while the frequent repairs, necessited by the presence of floating ice and timber, were easily made locally.

In the wheel represented there were four sets of arms, and the arms of each set were bolted alternately into recesses in each side of a cast-iron boss or "centre" keyed to the wrought-iron paddle shaft. Each set of arms was consolidated by a concentric ring, and the sets were tied together at the circumference by the floats without any cross bracing. Divided floats were adopted (*see* No. 938), which diminished the loss arising from there being no feathering motion. The wheel was 32·5 ft. diam., and had 26 floats, 12·5 ft. wide by 2 ft. deep (in two parts).

940. Paddle-wheel with oblique floats. (Diam. 12 in.) Contributed by Messrs. Jackson and Watkins, 1860. N. 413.

This is a wooden model of a paddle-wheel with radial floats fixed obliquely, and probably represents the wheel patented in 1829 by Archibald Robertson; the construction was patented subsequently by many others.

Each float is a portion of a left-handed helix with an angle of about 45 deg.; to neutralise the side thrust the other paddle-wheel was to have its floats oppositely inclined. This oblique setting was probably introduced to reduce the blow given by a common float on entering the water.

941. Paddle - wheel with oblique floats. (Diam. 7 in.) Woodcroft Bequest, 1903. N. 1338.

This wheel was designed by Mr. Bennet Woodcroft in 1850, and is a modification of No. 940. Each float is V-shaped, being formed by the meeting of a right-handed and a left-handed helical surface, so that side thrust is avoided while gradual immersion is secured.

942. Paddle-wheel with sinuous floats. (Diam. 8 in.) Lent by Messrs. McClennan and Owen, 1883. N. 1599.

This paddle-wheel was patented by Messrs. J. McClennan and R. Owen in 1880. It is intended to diminish the noise and swell usually created by paddle-wheels.

Instead of float boards, a continuous sinuous blade is employed which acts like a series of oblique floats; enclosing side discs are added to prevent lateral escape of the water.

943. Paddle-wheel with reefing floats. (Diam. 18·7 in.) Contributed by J. J. Brunet, Esq., 1860. N. 406–7.

When paddle steamers were used for ocean voyages considerable loss of efficiency was experienced owing to the change in the immersion of the floats that resulted from the consumption of the coal on board.

The wheel shown was patented in 1843 by Mr. Brunet as a means for correcting this. It has arrangements by which the floats can be quickly and simultaneously moved further from the centre as the vessel becomes lighter. On the paddle-shaft is a wheel connected by a separate rod to each float in such a way that a partial rotation of the wheel relatively to the shaft slides the floats along the radial arms of the paddle-wheel. This relative motion is given by a train of gearing worked by a winch handle. The floats are in two parts, one being in front and the other behind the wheel arm; they are united by brackets which clamp them to the arms when canted by a second set of rods and a wheel worked similarly to the first.

A second model shows a simplified form of the arrangement in which gearing is omitted, the float arms being secured by lashing.

944. Buchanan's feathering paddle-wheels (working). (Diam. 12·5 in. and 7·5 in.) Presented by Messrs. Bullivant & Co., 1902. N. 1887–8.

Very soon after the practical introduction of marine propulsion by paddle-wheels the loss of power resulting from the oblique action of the entering and leaving floats of a radial wheel was realised, with the result that many modifications were proposed. The model represents the wheel patented by Robertson Buchanan, of Glasgow, in 1813, which, although a failure, introduced the four-bar mechanism that subsequently led to the now universal construction known as Morgan's wheel.

In the Buchanan wheel each float has through its centre a horizontal spindle, which keeps the side rings together and also carries a crank-arm which is attached to a ring that turns freely on a sheave fixed to the ship, but not concentric with the paddle-wheel. The eccentricity of the sheave is equal to the radius of the cranks, and as the wheel revolves the floats remain vertical, thus entering and leaving the water edgeways, provided the ship is not moving. When the ship is in motion, however, its velocity so alters the conditions that this constantly vertical position of the floats is as unsatisfactory as the radial position in the simple wheel.

In the later model of Buchanan's wheel shown, the floats are smaller but more numerous; they have cranks at both sides controlled by rings revolving on eccentrics.

945. Model of Napier's feathering paddle-wheel (working). (Scale 1 : 24.) Made in the Museum, 1898. N. 2171.

This feathering arrangement, patented in 1841 by David Napier, of Millwall, resembles Buchanan's wheel in principle, but instead of the ring which moves the crank-arms being controlled by an internal eccentric, it is made massive, so that gravity supplies the restraining force without other assistance.

Wheels of this construction were successfully fitted in 1842 to the celebrated London and Margate iron-built passenger steamers "Eclipse" and "Isle of Thanet," driven by Napier's steeple engines and haystack boilers. The "Eclipse" was of 278 tons b.m., 156 ft. long, 19 ft. beam, and 9·5 ft. deep. Her paddle-wheels were 16·5 ft. diam., and her load draught 5 ft.

946. Feathering paddle-wheel (working). (Diam. 21 in.) Contributed by Richard Sheward, Esq., 1866. N. 1090.

This modification of Buchanan's wheel (*see* No. 944) was proposed in 1865. The guiding ring is fitted with rollers to reduce the friction between it and the fixed sheave.

947. Feathering paddle-wheel (working). (Diam. 11 in.) Presented by Messrs. Bullivant & Co., 1902. N. 1885.

This represents the automatic feathering arrangement patented by W. H. Hill in 1825.

Each of the four floats is free to move on its horizontal axis; but to its back is fixed a rod connected by links to the float behind and to that in front, the intention being that the resistance of the water should secure the feathering action. By lashing the floats to the arms it could be converted into a fixed float wheel.

948. Oldham's feathering paddle-wheel (working). (Diam. 13 in.) Presented by Messrs. Bullivant & Co., 1902. N. 1886.

This arrangement, patented by John Oldham in 1820–7, is an interesting expansion of the linkage introduced by Buchanan for the same purpose.

The floats turn on horizontal axes, and are connected by short outside cranks to the feathering rods, which are the arms of a frame embracing an eccentric attached to a loose sleeve on the main shaft. This sleeve is so geared to the shaft that the eccentric makes one revolution for every two revolutions of the paddle-shaft, the result being, that instead of the floats remaining constantly vertical, as in Buchanan's wheel, they revolve at half the speed of the wheel, so that, while vertical at the bottom of their path, they become horizontal at the top, and vertical when again at the bottom; but they are then presenting the other face to the water. The gearing and the reversal of the floats are objectionable features, but the feathering action appears to be perfect.

Oldham's paddle-wheels were, in 1822, fitted to the "Aaron Manby," an iron boat, constructed at Horseley, near Birmingham (*see* No. 811).

949. Poole's feathering paddle-wheels (working). (Diam. 9 in.) Presented by Messrs. Bullivant & Co., 1902. N. 1883–4.

This feathering arrangement, patented in 1829 by William Poole, of Lincoln, was fitted to numerous paddle-steamers by Messrs. Seaward and Capel.

The floats are secured to horizontal shafts, each of which terminates in an arm carrying a friction roller that travels in a groove, formed in a circular ring, secured to the vessel, but not concentric with the paddle-wheel.

Such wheels, fitted to several river packets plying between Lincoln and Boston, showed an increase of 20·7 per cent. in speed and a decrease of 19 per cent. in fuel consumption, when compared with the plain wheels that they replaced. To obviate the noise made by the friction rollers, they were subsequently made of sole leather.

A modification of Poole's wheel, introduced by Messrs. Seaward, is shown; the race for the rollers, instead of being circular, has two semi-circular ends joined by straight portions.

950. Model of feathering paddle-wheel (working). (Diam. 10·7 in.) Maudslay Collection, 1900. N. 2234.

This is a greatly improved form of Poole's wheel (No. 949) and is probably of much later date, the paddles resembling those of the early Galloway wheel (No. 951), to which its action is equivalent. Each float has a shaft carried between the two main rings of the wheel and provided with an external crank-arm, the pin of which is controlled by a circular groove in a large ring, free to turn on a pin secured to the outer sponson beam. Through the rotation of the ring, the wear and resistance of the circular race are almost entirely eliminated.

951. Galloway's feathering paddle-wheel (working). (Diam. 17 in.) Contributed by J. J. Brunet, Esq., 1860. N. 408.

This model represents the original form of the wheel patented by Elijah Galloway in 1829.

Each float turns on an axis along one edge, and has a short arm projecting from its centre connected by a long rod to a ring which turns on a crank-pin held stationary within the wheel near the centre. The mechanism gives a practically perfect feathering action, but the construction is unsatisfactory on account of the severe stress on the feathering rods; also because the wheel is only driven at one side, as provision had to be made for supporting the internal crank-pin.

The patent was purchased by William Morgan, of New Cross, who brought the invention to a practical success, and in 1838 patented improvements in the wheel, so that it is generally known as Morgan's. (*See* No. 953.)

952. Galloway's feathering paddle-wheel (working). (Diam. 14 in.) Presented by Messrs. Bullivant & Co., 1902. N. 1882.

This model of Galloway's wheel closely resembles the adjoining example, but renders the construction more clearly visible, since the crank-pin which moves the feathering rods has no bearing in the end of the paddle-shaft The rods are strengthened by struts.

953. Model of Morgan's feathering paddle-wheel (working). (Scale 1 : 24.) Contributed by William Morgan, Esq., 1861. N. 409.

Morgan's improvements upon the Galloway wheel consisted chiefly in increasing the number of floats; turning them on central spindles; altering the arms connecting the feathering rods with the floats, and strengthening the wheel by cross-bracing—a matter of great importance, owing to one side only being directly driven.

This improved construction was fitted in 1830 to H.M. gun-brig "Confiance." When tried against her sister ship, the "Echo," which had simple radial floats, the Morgan wheel showed an increase in speed of from 28 to 55 per cent., according to the state of the sea. In consequence of these results such wheels were fitted to many vessels, including H.M.S. "Medea," which was the largest war steamer then under construction: she was launched in 1833. The "Medea" was 179·4 ft. long, 42 ft. broad over sponsons, and 835 tons burden; her wheels were 24·5 ft. diam., with floats 5·625 ft. long by 4·5 ft. broad, and are probably represented by this model.

954. Feathering paddle-wheels (working). (Diam. 17 in. and 11 in.) Presented by Messrs. Bullivant & Co., 1902. N. 1880–1.

This wheel was adopted by John Seaward after he had seen a similar arrangement in use on a French steamer in 1833, and which he was informed was the invention of François Cavé of Paris. The owners of the patent rights in the Galloway or Morgan wheel instituted an action, but it was decided that Seaward's construction was not an infringement of Galloway's patent.

The floats are carried by shafts turning in the rings of the wheel, and are feathered by rods that connect a bracket on the back of each float to a strap on a fixed eccentric sheave secured to the vessel's side. In one model the strap is driven round by a strengthened feathering rod that acts as a lever; in the other, all of the rods are strengthened so as to assist in this work. In Cavé's original wheel, a drag-link attached to an arm on the strap did this driving.

955. Feathering paddle-wheel (working). (Diam. 17 in.)
Presented by Messrs. Bullivant & Co., 1902. N. 1889.

This wheel was brought out by John Seaward in 1835, and closely resembles No. 954, but has a crank-pin adjustable by a screw, instead of an eccentric sheave, for feathering the floats. In this form it only differs from Morgan's in having the crank-pin outside instead of inside the wheel. This difference, however, greatly improved the construction, and all modern feathering wheels are so fitted (*see* Nos. 816 and 819).

956. Feathering paddle-wheel (working). (Diam. 18 in.)
Presented by Messrs. Bullivant & Co., 1902. N. 1879.

This construction of wheel was adopted by Messrs. Seaward and Capel in 1850.

Instead of a crank-arm on the end of each float shaft Mr. Seaward in 1835 substituted a bracket bolted on to the float. The feathering rods are moved by a ring on a disc, the eccentricity of which is adjustable by a screw.

957. Feathering paddle-wheel (working). (Diam. 11·5 in.)
Presented by the Commissioners of Patents, 1859. N. 141.

This modification of Morgan's wheel was patented by Mr. J. P. Holebrook in 1838, and was an attempt to simplify and strengthen the construction.

The internal crank-pin is brought to one side of the wheel, although still within it; the long feathering rods are replaced by a large rigid frame, which is connected to toggle links that connect adjacent floats, and thus feather them in pairs. The wheel combines the large feathering ring of Buchanan with the unequal eccentricity and consequent feathering action of Galloway.

The latest construction of the feathering paddle-wheel is seen in the model of the engines of the "Princesse Henriette" (*see* No. 819).

958. Feathering paddle-wheel (working). (Diam. 18 in.)
Received 1861. N. 416.

This wheel was patented by William Tipple in 1861; it is one of the numerous proposals made for securing a feathering motion of the floats by weighting their lower edges.

The rings of the wheel are connected by horizontal axes on which the floats can turn; the axes are on the centre of each float, but balance weights are added to maintain the floats in a nearly vertical position.

959. Feathering paddle-wheel (working). (Diam. 11·5 in.)
Contributed by Messrs. Jackson and Watkins, 1860.
N. 414.

This construction closely represents that patented by Mr. H. C. Daubeny in 1840 and subsequently by many others.

The floats are sector-shaped and are held between an external rim and the centre of the wheel on radial spokes. The inner end of each float is fitted with two sets of lugs, which act as teeth in turning the floats through 90 deg. twice in a revolution, as the lugs come into contact with projections on a cam surface attached to the vessel.

960. Feathering paddle-wheel (working). (Diam. 14 in.)
Contributed by Richard Vines, Esq., 1861. N. 760.

This arrangement was patented by Mr. Vines in 1860 as a means by which the floats should be so turned as to pass edgeways through the air, but present their full faces while immersed. The floats turn on radial spokes, but not round a central line, and are so weighted that on leaving the water they swing round and turn into the plane of the wheel. This weighting causes them to turn again when entering, and the position of the axis, together with a stop, ensures that the floats remain full-face while acting on the water.

961. Paddle-wheel with revolving floats (working). (Diam. 11·5 in.) Contributed by William Smith, Esq., 1870.
N. 1321.

This feathering arrangement, patented by Mr. John Dean in 1861, has been described as a compound paddle-wheel. A similar idea had been patented in 1827 by Mr. Paul Steenstrup.

On the circumference of the wheel are six cylindrical frames that are practically small radial-float paddle-wheels. On the axis of each small wheel is a pinion of 15 teeth gearing into a spur ring of 120 teeth fixed to the vessel's side, so that each frame makes seven revolutions for every one of the wheel, and its floats describe trochoidal loops. The small wheels were to dip into the water up to one-third of their diameter.

SCREW PROPELLERS.

Although the Archimedean screw is at least 2,000 years old, its application to navigation is a comparatively recent invention. In 1752 Daniel Bernouilli described a plan for a boat propelled by wheels with vanes inclined at an angle of 60 deg.; these wheels were, however, to be placed at the sides, bow, and stern, and to be driven by bevel and spur gear. Bramah, in his patent of 1785, proposes a similar wheel, and as both windmills and smoke-jacks were then quite common, it is not surprising that many others saw the possibility of such an arrangement being converted into a propeller. The blades of these early proposals were not true helices, however; but when the correct principle was recognised, screws of at least two complete turns were thought necessary, and in this form they were at first generally constructed. As regards the position for the screw, there is scarcely any place round the vessel that has not been proposed, but Lyttleton, in 1794, placed it in an opening in the deadwood aft, where it has since been most generally accommodated.

The first experimental screw steamer appears to have been a launch tried on the river Hudson in 1804 by Col. J. C. Stevens, of Hoboken, N.J. It had a cylinder 4·5 in. diam. by 9 in. stroke, and a boiler of 1 in. diam. copper tubes. There were two propellers driven by gearing from the engine, and the speed attained was 3·5 knots.

To Sir F. P. Smith as patentee, Henry Wimshurst as shipbuilder, and the Ship Propeller Co. as financiers, must be given the credit of bringing the screw into practical use when in 1838 they built and exhibited all round the coast of Great Britain the S.S. "Archimedes." Smith's original screw had one complete turn of a single thread, but it was quickly, though accidentally, found that less would do and that a quarter of a turn with two or three threads was all that was necessary with a properly designed afterbody. To the general neglect of the influence of the afterbody must be attributed the great amount of "slip" and the conflicting results obtained from the different early screws subsequently introduced.

When the screw was established the number of the propellers proposed was enormous, even birds and beasts being drawn upon to serve as models; but the only early modification which achieved general success was that of Robert Griffiths, which is still extensively adopted for all services.

As the application of the screw propeller extended, a serious practical difficulty arose in large vessels through the rapid wearing of the outer bearing of the shaft. Numerous special alloys were tried, but with little success, and it is stated that in the "Malacca," a ship of 1,700 tons, this bearing wore away at the rate of 5·2 lb. per day. In 1854, however, John Penn invented the lignum vitæ bearing which has since been universally adopted; it was first tried on the "Malacca" with the result that after she had steamed 15,000 miles the wear was only ·03 in. In addition to the slight friction and wear of this arrangement, it has the merit of requiring no lubrication beyond that given by the surrounding sea-water.

As engine power was at first generally auxiliary, some means of obviating the resistance of the screw when under sail alone was generally required. The two methods were, by raising the screw above the water-level, or by turning its blades till they offered their least resistance. In both methods the two-bladed screw was usually employed; in the former it was lifted from its normal position up into a well reaching to the deck, while in the latter it was turned vertically and then had its blades set till they were nearly flush with the deadwood. Lifting the screw is now almost abandoned, but arrangements for readily altering the pitch or inclination of the blades are frequently fitted on steam yachts in which the best total result can only be obtained with a pitch that is suited to the sailing power of the wind.

The first twin screws driven by separate engines were fitted in 1840 by Capt. E. J. Carpenter, R.N., but the arrangement did not come into extensive use till the increased power of marine engines rendered subdivision more desirable. In 1866 they were first adopted in the Royal Navy, being tried in some of the smaller vessels, and after 10 years' experience were generally fitted in all classes of warships; their use in the mercantile marine dates from about 1881, when the first twin-screw liner crossed the Atlantic.

With the introduction of the steam turbine into vessels, and the higher power developed in modern ships, a further subdivision of power has become necessary. The Hon. C. A. Parsons, on the "Turbinia" in 1894, employed nine screws on three shafts, but tandem screws have since been abandoned for turbine-driven vessels, as the turbine is now designed to move sufficiently slowly for the power to be transmitted by a single screw on each shaft.

The phenomenon known as cavitation, first investigated by Mr. S. Barnaby, *i.e.*, the formation of air spaces in the water being acted upon by the screw, generally produced by high speed, or too small blade surface for the power transmitted, assumed great importance when the steam turbine appeared, and it became necessary to construct propellers of comparatively small diameter and blades of increased width. At the present time the practice on turbine vessels is to subdivide the power amongst three or four screws on separate shafts.

The modern screw usually has three or four blades, shaped after the Griffiths pattern, the blades being usually cast with a flange by which they are bolted to the hollow boss secured on the propeller shaft. The materials used have comprised wrought iron, cast iron, cast steel, and various bronzes, the last being now most generally employed.

EARLY SCREW PROPELLERS.

962. Models showing the forms of screw propeller surfaces. Woodcroft Bequest, 1903. N. 32–3.

A is a plain disc. If a section of this (as shown by the white paper) be taken and placed at an angle to the axis the ineffective inclined plane propeller is obtained (*see* No. 1000).

B is a screw of uniform and large pitch. A portion cut from this (as shown by the white paper) gives the ordinary type of screw propeller.

C is a screw of increasing pitch, *i.e.*, the angle of inclination of the thread to the axis continually decreases. A portion cut off as before gives the type patented by Mr. Bennet Woodcroft in 1832. The second model shows this still more clearly.

The advantage of increasing pitch is that the greater pitch of the after part of the helix compensates for the backward motion given to the water already acted on by the fore part. Had a complete turn of the thread been necessary, this would undoubtedly have been of importance, but with the short length now found to be more suitable it is a refinement of little value. Experiments were made in 1841 in the "Archimedes" with this increasing pitch, when it was found that the same speed was obtained as with a uniform pitch with 5·5 per cent. less engine power; in 1844 a similar test by the Admiralty showed a saving in power of 6·5 per cent., but these screws were much longer than those now used.

963. Single and double helices. Contributed by Messrs. Jackson and Watkins, 1861. N. 422.

These models have thin-bladed brass screws working in a sectional metal nut of considerable length. One screw is single of two turns 3 in. pitch; the other screw is double of four turns 1·5 in. pitch. Short sections of these threads would represent forms of propellers that have been used.

964. Stern model with Bramah's propeller. Contributed by Messrs. Jackson and Watkins, 1861. N. 425.

This was made from the description contained in a patent taken out by Joseph Bramah in 1785. A paddle vessel with a stern wheel of 16 floats is there illustrated; but instead of this "may be introduced a wheel with "inclined fans or wings similar to the fly of a smoke-jack or the vertical "sails of a windmill," this may be fixed in or beyond the stern and "may be wholly under water."

965. Stern model with Lyttleton's propeller. (Scale 1 : 24.) Contributed by Messrs. Jackson and Watkins, 1861. N. 426.

This was made from the patent drawings deposited in 1794 by Mr. William Lyttleton, a merchant of London.

The screw is triple-threaded and of a length equal to one complete turn; 35 deg. is the angle recommended for the thread, and the number of threads or "sweeps" is to be in proportion to the diameter. The screw is supported in a frame hung either beneath the stern outside the rudder, at the bow, or at the sides. It is turned by men working at a winch connected by ropes and pulleys to the screw shaft; but "it may be done far more effectually by "means of a small steam engine."

966. Stern model with Shorter's propeller. (Scale 1 : 16.) Contributed by Messrs. Jackson and Watkins, 1861. N. 427.

This shows the "perpetual sculling machine" included among other propelling devices in the 1800 patent of Edward Shorter, a mechanic of Newington, Surrey. It was made from his patent drawings which show a screw of "two blades or more, similar to the sails of a windmill and set in the same angular direction." The screw is entirely submerged in the vessel's wake, but supported by a buoy to prevent it sinking too deeply. The screw is driven by shafting and universal joints from a capstan, but "a steam or vapour engine may be substituted." Two "guye ropes" from the shaft to each side of the stern "have the effect of a rudder."

The arrangement was successfully employed in 1802 to propel H.M. transport vessel "Doncaster" in Gibraltar Bay and again in Malta Harbour; the speed attained was 1·5 miles per hour with eight men at the capstan (*see* attached facsimile of certificate).

967. Pencil sketch of proposed propellers. Woodcroft Bequest, 1903. N. 92.

This sketch was made by Alexander Nasymth in 1819 to explain his proposed "method of propelling vessels on water by steam power or otherwise."

A screw of five turns is arranged in the deadwood aft, as shown in Lyttleton's patent of 1794 (*see* No. 965). Another propeller is shown, in which a number of inclined blades are secured to the shaft and to an enclosing drum, after the manner of a smoke-jack.

968. Whole model of the "Sarah" of Lewes. (Probable scale 1 : 16.) Lent by Arthur Godlee, Esq., 1872. N. 1334.

This represents a double-hulled boat or raft, fitted with a screw, which is placed in the midwater forward and driven, through a universal joint and a long shaft, by manual power on deck. The screw is double-threaded, with about three-quarters of a turn of each thread; the central portion is open.

The actual boat is said to have been tried on the Sussex Ouse in 1823, but to have been decidedly slow.

969. Stern model with screw propeller. (Scale 1 : 32.) Woodcroft Bequest, 1903. N. 42.

This framed model was made to the drawings deposited in 1828 by Mr. C. Cummerow, with his application for a patent for a communicated invention.

There is some evidence that the inventor was Jacob Ressel, of Bohemia, who in 1827 is reported to have constructed at Trieste a screw-propelled boat, 62·2 ft. long, 11·4 ft. beam, and 6·2 ft. draught giving about 80 tons displacement. The screw was 5·2 ft. diam. and 5·2 ft. pitch, the engine of 6 h.p., and the speed from 3 to 6 knots. In his French patent he says that for an 80-ton boat the screw should be 6 ft. diam., 9 ft. long, and be driven by an engine of 10 h.p.; this he estimated to give a speed of 16·5 knots at 180 revs. per min. In a boat of 200 tons the h.p. was to be 30.

From Cummerow's vague specification it appears that the screw was to have a single whole turn, and that it might be arranged in the deadwood aft, or at the bow, or in the middle space of a double-hulled boat; the steam engine was to drive the "spiral" at 150 revs. per min. by means of gearing.

An adjacent block model (scale 1 : 24), contributed by Messrs. Jackson and Watkins, gives another representation of this scheme (N. 428).

970. Whole block model of S.S. "Francis Smith." (Scale 1 : 12.) Woodcroft Bequest, 1903. N. 43–44.

This represents a launch built in 1836 at Wapping, in accordance with the patent of Sir F. P. Smith, and successfully tried on the Paddington Canal in the following year. At the time the patent was granted Mr. Smith was a farmer at Hendon, in Middlesex, and had constructed a clockwork-driven model of a screw ship which propelled itself successfully on a pond at the farm. This was followed by the boat represented, which was the first practical experiment; the boat was of 6 tons burden, and was driven by a steam engine with a cylinder 6 in. diam. by 15 in. stroke. The propeller was of wood, and in one of the trips about one half of it was broken off; it was then noticed with much surprise that the accident had materially increased the speed of the boat.

The screw was as described in the patent, and had two complete turns, as seen in the model. It was located aft, but some distance in front of the stern post, and was driven by bevel gearing through a vertical shaft that by other bevel wheels was connected with the engine. From the information derived from this boat, Mr. Smith amended his specification, and described his screw as one having a single turn only, or two half-turns. The boat was subsequently fitted with a metal screw of the improved form, and then made some short trips, as from London to Folkestone, at a speed of about 5·5 knots.

From the model, the boat appears to have had a clean run aft, and to have been of the following dimensions:—Length (b.p.), 29 ft.; breadth, 5·75 ft.; draught, 4 ft.; screw, 2 ft. diam.

971. Models of the stern framing of S.S. "Archimedes." (Scales 1 : 24 and 1 : 32.) Lent by Henry Wimshurst, Esq., 1873. N. 1342-4.

From the successful results obtained with the "Francis Smith" (*see* No. 970), it was decided by several gentlemen to commercially test the system of screw propulsion by forming a syndicate, which became the "Ship Propeller Co.," and purchased Sir F. P. Smith's patents. Mr. Wimshurst, who was one of the members, was instructed to build the "Archimedes"; she was launched in November, 1838, and was of the following dimensions: burden, 240 tons; length (o.a.), 125 ft.; length (b.p.), 106·7 ft.; breadth (extreme), 22·5 ft.; depth of hold, 13 ft.; draught forward, 9 ft.; draught aft, 10 ft.; immersed midship section, 140 sq. ft.

The engines, constructed by Messrs. J. and G. Rennie, had two cylinders, 37 in. diam. by 36 in. stroke, made 26 revs. per min., and were supplied with steam at a pressure of 6 lb. per sq. in. They drove the propeller shaft through gearing in the ratio of 3 : 16, so that the screw made 140 revs. per min.

The propeller shown was that first tried, and was 7 ft. diam., 8 ft. pitch, and 8 ft. long, the helix making one complete turn. The two detached models show modifications subsequently tried, in which double-threaded screws are employed and the length reduced; the propeller finally adopted was 5·75 ft. diam., 10 ft. pitch, and two-bladed, as described in Smith's amended patent.

On the wall are two aquatints, representing the "Archimedes." (*See* No. 972.)

972. Aquatints of S.S "Archimedes." Presented by Vice-Adm. E. P. Halsted, R.N., 1866. N. 1296.

These represent this pioneer screw vessel on her voyage from London to Portsmouth in 1839, which she accomplished at a speed of 8 knots against wind and tide.

She afterwards went round the British Isles, and did some over-sea voyages. (*See* No. 971.)

973. Testimonial plate. Bequeathed by Sir Francis Pettit Smith, 1871. N. 1332.

This silver jug and silver vase were presented to Sir F. P. Smith in 1858, as a recognition of his labours in introducing screw propulsion. Upon them is engraved a view of the S.S. "Archimedes." The accompanying address gives the names of the screw ships in the Royal Navy in 1858, together with other particulars, and also contains some interesting signatures.

974. Whole block model of S.S. "Novelty." (Scale 1 : 24.) Lent by Henry Wimshurst, Esq., 1878. N. 1504.

This represents a screw steamer built at Blackwall in 1839 by Mr. Wimshurst, to further test the merits of screw propulsion. It was a considerably larger steamer than the "Archimedes" (*see* No. 971), and was a great improvement on the earlier vessel in having the propeller as close to the stern post as possible, and in the form of the propeller, which had only two blades, each making a quarter of a turn. The "Novelty" was the first screw cargo steamer; her first commercial voyage was from Liverpool to Constantinople, when she took 420 tons of cargo, besides coal, and returned to London with a cargo of fruit, without any trouble occurring.

The engines had two cylinders 14·5 in. diam., that drove the propeller shaft directly; they were supplied with steam at 60 lb. pressure, but owing to the objections raised, new engines working at a pressure of 15 lb. only were subsequently substituted. The ship was barque-rigged, but the mizen-mast was built of iron, 58 ft. long by 15·5 in. diam., and was utilised as a funnel. It was the first iron mast ever used.

Length, 117 ft.; breadth, 24·5 ft.; depth, 14·5 ft.

975. Built model of stern of S.S. "Novelty." (Scale 1 : 24.) Lent by Henry Wimshurst, Esq., 1878. N. 1343.

This shows in detail the construction of the afterbody and the position of the screw; in the whole model of the "Novelty" (*see* No. 974) the proportions of the screw differ considerably from those here indicated. The vessel was provided with two wells and an arrangement of davits, by which, after the propeller had been slightly raised it could be lifted on deck, over the ship's side, so as to avoid its resistance when under sail only.

976. Stern model with Ericsson's propeller. (Scale 1 : 24.) Contributed by Messrs. Jackson and Watkins, 1861. N. 429.

This propeller was patented in 1836 by John Ericsson, the celebrated Swedish engineer. It consists of two drums, from the exteriors of which project seven helical blades strengthed by an external hoop; the interior of each drum contains the boss and three blades which act also as arms. The drums are arranged behind the rudder on a common axis; the forward drum is secured to a tubular shaft through which passes the shaft of the after drum. The blades of the two drums are of opposite inclination, and the drums revolve in opposite directions; the forward drum rotates at 1·2 times the speed of the other. The object of this duplex arrangement is to avoid loss due to the rotary motion left in the water discharged from a single screw; later experience has shown that the energy so lost is unimportant and not worth the extra complications that its recovery necessitates; the fact that tandem screws are used in the Whitehead torpedo is due to the amount of ballast that would otherwise be necessary to prevent the torpedo itself rotating.

The first experiment made with Ericsson's propeller was conducted in 1837, when the "Francis B. Ogden" was built and fitted. She was 45 ft.

long, 8 ft. beam, 2·25 ft. deep, and had a high pressure engine with two cylinders 12 in. diam. by 14 in. stroke, making 30 revs. per min. with a boiler pressure of 50 lb. She towed a ship of 630 tons burden at a speed of 4·5 knots, against the tide.

The second experiment was the "Robert F. Stockton," built by Messrs. Laird Bros. in 1838. She was 63·4 ft. long, 10 ft. beam, 7 ft. deep, 33 tons register, and 30 h.p.; she attained a speed of 13 knots on the Thames with the tide. She afterwards crossed the Atlantic under canvas, and worked for many years as a New York tug, under the name of the "New Jersey." A lithograph of this vessel is shown adjacent.

By the end of 1842, thirteen river steamers with Ericsson's propeller were in use in America, and in 1844 H.M.S. "Amphion" was fitted with this means of propulsion.

977. Model of propeller. (Scale 1 : 12.) Presented by Messrs. Bullivant & Co., 1902. N. 1894.

This appears to represent the central blades of one of Ericsson's duplex propellers of 1836 (*see* No. 976). The piece is therefore much more like a modern propeller than was the complete arrangement.

978. Experimental whole model of a screw ship. Presented by Mrs. H. Vansittart, 1874. N. 1365.

This was constructed by James Lowe between 1834 and 1838, the date of his patent, to test the merits of his screw propeller. It is fitted with a spring-driven clock-train that works a four-bladed propeller, about one-eighth of a turn in length.

Lowe had been apprenticed to, and was subsequently in partnership with, Edward Shorter (*see* No. 966), and so had his attention turned to screw propulsion. He was assisted financially by several gentlemen, who, in 1837, purchased the barge "Wizard," afterwards named the "Cycloid," a vessel of 25 tons burden, 50 ft. long, and 8 ft. beam. She was fitted with 12 h.p. engines, and experiments were tried with one, two, three, and four blades, set at angles varying from 22 to 42 deg. The boiler was only of 7·5 h.p., but a speed of 6 knots was attained.

In 1843 an action was commenced with the object of invalidating the several patents relating to screw propulsion then in force; after seven years' litigation it ended in each side paying its own costs. The following patents were assailed—B. Woodcroft (1832), F. P. Smith (1836), J. Ericsson (1836), J. Lowe (1838), and G. Blaxland (1840); the owners combined to defend. In the first three cases extensions of six, five, and five years respectively were ultimately granted; the others were not extended.

979. Stern model with Lowe's propeller. (Scale 1 : 24.) Contributed by Messrs. Jackson and Watkins, 1861. N. 430.

This propeller, patented by James Lowe in 1838, is equivalent to a pair of two-bladed screws superposed on a single shaft; the blades are shaped like pruning knives and are riveted to the boss.

980. Drawings of Lowe's propellers. Presented by Mrs. H. Vansittart, 1874. N. 1370.

(*a*) The first engraving shows the various forms patented by James Lowe in 1838 (*see* also No. 978).

(*b*) This is a specification drawing from Lowe and Wyche's patent of 1852. It shows two- and four-bladed screws on an oval boss and cast solid therewith. (A model of this is also shown, N. 1367.)

(*c*) This is from Lowe's patent of 1855; the blades are divided into two or more parts and placed in sets in a line inclined to the axis of the boss at 30 deg. The object of the arrangement was to avoid the total loss of a blade should any solid obstruction be encountered. The screw was first tried in 1857 on H.M.S. "Bullfinch."

(*d*) This is Lowe and Harris's patent of 1862. In this screw any circular section of a blade is a sinuous curve, and the surface is one of varying pitch (*see* also No. 1001).

981. Model of "conoidal" propeller. (Scale 1 : 8.) Presented by George Rennie, Esq., 1857. N. 143.

This propeller was patented by Mr. Rennie in 1839. It is three-bladed, and the surface of the blades is "obtained by the descent of a tracer down the surface of a cone or conoid"; the blade so constructed has increasing pitch, and is shown tapering in width from the centre to the tips.

982. Model and drawing of "conoidal" propeller. (Scales 1 : 8 and 1 : 16.) Presented by J. K. Rennie, Esq., 1876. N. 1416–7.

The model shows an improved form of No. 981, obtained by cutting away the inefficient portion of the blade near the centre. It was in this form, as seen by the drawing, that the screw was fitted in 1842 to the "Mermaid," afterwards H.M.S. "Dwarf." The engine had two vertical cylinders, 40 in. diam. by 32 in. stroke, and made 36 revs. per min.; it drove the propeller shaft through two sets of multiplying spur gear. In March, 1843, the "Mermaid" attained the then exceptional speed of upwards of 11 knots.

The drawing shows also the outer bearing for the screw-shaft and a claw coupling for disconnecting.

983. Propeller of H.M.S. "Rattler." Contributed by the Admiralty, 1858. N. 283.

The "Rattler," a sloop-of-war built at Sheerness Dockyard in 1843, was the first screw vessel constructed by the Admiralty. Her dimensions were:—Displacement, 1,078 tons; Length (b.p.)., 176·5 ft.; beam, 32·7 ft.; mean draught, 13·5 ft.; immersed midship section, 330 sq. ft.

The engines, of 437 indicated h.p., were of Maudslay's "Siamese" type (*see* No. 807), and were adapted to driving a screw shaft by the use of spur gearing, which increased the revolutions of the screw to four times those of the crank.

The screw is a gunmetal casting weighing 1·325 tons, is 10 ft. diam., 11 ft. pitch, 1·56 ft. long, and has two blades. It was secured to the shaft by a through cotter. The tips of the blades have been strengthened by patches riveted on.

984. Aquatint representing a trial of paddle *v.* screw (1845). Woodcroft Bequest, 1903. N. 89.

This represents H.M. screw sloop "Rattler" fastened stern by stern to H.M. paddle sloop "Alecto," and both steaming full speed ahead so as to test the relative powers of the two methods of propulsion. The trial took place in a calm on April 3rd, 1845, in the North Sea; the "Rattler" towed the "Alecto" stern foremost at a speed of 2·43 knots.

The "Rattler's" engines had four steam cylinders 40·125 in. diam. by 4 ft. stroke, and made 25·76 revs. per min., which drove the screw (No. 983) at 113 revs. per min. Her boiler pressure was 10 lb.

The "Alecto" had direct-acting paddle engines, with two cylinders 53·125 in. diam. by 4·5 ft. stroke, and drove paddle-wheels 23 ft. diam., with radial floats. Her boiler pressure was 5 lb. Although the two vessels were very similar in size and nominal h.p., the contest was in other respects inconclusive.

985. Lithograph representing a trial of paddle *v.* screw (1849). Received 1860. N. 708.

This represents H.M. screw corvette "Niger" and H.M. paddle sloop "Basilisk" engaged in a "tug-of-war."

The trial took place in the English Channel on June 20th, 1849, and lasted for one hour, during which time the "Niger" towed the "Basilisk," stern foremost, 1·46 knots. The following particulars give some further information:—

	"Niger."	"Basilisk."
Length - - -	194·33 ft.	190 ft.
Breadth - - -	34·66 ft.	34·42 ft.
Engines - - -	Maudslay twin.	Miller oscillating.
Indicated h.p. - -	919	—
Cylinders - - -	Four 47·625 in. diam.	Two 74-in. diam.
Stroke - - -	22 in.	72 in.
Propeller - - -	Screw 12·5 ft. diam., 17 ft. pitch, 2·8 ft. long.	Radial paddle-wheel 24 ft. diam.
Speed in knots - -	10·43	9·75
Boiler pressure - -	8 lb.	10 lb.

986. Model of the propeller of S.S. "Great Britain." (Scale 1 : 60.) Woodcroft Bequest, 1903. N. 1340.

This represents a propeller tried on the early screw ship "Great Britain," built at Bristol in 1843. It shows a six-bladed fan made in a single casting; but in the working model of the engines the screw represented has four blades.

The propeller finally adopted was a built-up wrought-iron fan, of six blades; it was 15·5 ft. diam., and 25 ft. pitch, corresponding to an angle of 28 deg. Each blade had an area of 56·25 sq. ft., or a projected area of 47·4 sq. ft. The outer edges of the blades were finished in a lathe; while the faces were rubbed smooth and varnished. Further particulars of the ship and engines are given in Nos. 187 and 820.

987. Drawing of screw propellers proposed before 1850. Presented by Sir F. P. Smith, 1857. N. 709.

This drawing, compiled by Mr. E. J. Powell, indicates the distinctive features of 28 of the most important screws patented in Great Britain; it was shown at the 1851 Exhibition. Many of the types are represented by models in the collection.

SIMPLE SCREW PROPELLERS.

988. Stern model with propeller. (Scale 1 : 12.) Presented 1860. N. 151.

This model shows an arrangement that has been proposed by many for increasing the efficiency of a propeller. The screw is placed on the stern post and the rudder still further aft.

989. Model of propeller. (Scale 1 : 8.) Contributed by F. H. Hodd, Esq., 1880. N. 1539.

This is a two-bladed screw with perforated blades, patented by John Fisher in 1853. The perforations are slots parallel to the shaft and are intended to discharge any cushioning air that may be on the blade face.

990. Model of two-bladed propeller. (Scale 1 : 12.) Contributed by the Society of Arts, 1861. N. 437.

This screw is a modification of one patented by Mr. A. Mitchell, of Belfast, in 1854. It is called the elliptical propeller, because the surface of the blade along a radial line is curved with increasing curvature from the axis to the circumference and is part of an ellipse.

The screw is intended to be auxiliary, and the most successful case of its application was to the S.S. "Malvina," where it replaced a straight-armed one. An increase of speed of 1·5 knots with lessened vibration, and a decreased coal consumption of 25 per cent. is stated to have resulted.

991. Screw propeller. Presented by Henry Walduck, Esq., 1857. N. 114.

This construction was patented by Mr. Walduck in 1854, to obviate slip from centrifugal motion of the water. The surface of the blades is formed in a series of terraces, concentric with the shaft but each of greater pitch than its inner neighbour. The example is two-bladed and is 13·5 in. diam.

992. Model of propeller. (Scale 1 : 12.) Presented by Messrs. Bullivant & Co., 1902. N. 1893.

This is a screw with four somewhat tapering blades, which are curved forward although remaining in the same plane. The sickle-like form so obtained has been extensively adopted, with the intention of preventing centrifugal motion of the water.

993. Model of two-bladed propeller. (Scale 1 : 12.) Presented by J. B. Oubridge, Esq., 1858. N. 149.

This represents the two-bladed screw propeller of H.M.S. "Thunderbolt," one of three floating batteries built of iron by Messrs. Napier of Glasgow during the Crimean war. They were of the following dimensions :—Tonnage, 1,973 tons; length, 186·7 ft.; breadth, 48·5 ft.; depth, 15·54 ft.; h.p., 200; armament, sixteen 68-pr. guns.

The screw has very wide blades and a fine pitch.

994. Model of two-bladed propeller. (Scale 1 : 8.) Contributed by Capt. G. Peacock, R.N., 1862. N. 845.

This construction of screw was patented by Capt. Peacock in 1855, and is intended to form a light propeller suitable for temporary use as an auxiliary screw.

Each blade is built of iron plate strengthened with angle bars and supported by a stay rod to the boss. The front face of the blade is dished, and the greatest width is at one-third of the diameter. The whole of the propeller was to be galvanised.

995. Whole model of vessel with twin screws. (Scale about 1 : 48.) Contributed by Capt. A. M. Skinner, R.N., 1861. N. 421.

This shows the arrangement of twin screws patented by Capt. Skinner in 1859. The screws are placed "very much before the stern post and well under the quarters of the ship"; two two-bladed screws are placed on each shaft. The arrangement shown protects the propellers but interferes with the lines of the vessel and with the flow of water to the screws.

The first twin screw vessel on the Transatlantic service was the S.S. "Notting Hill," built at Glasgow in 1883 (420·3 ft. long, 45 ft. broad, 26·5 ft. deep, and 3,902 tons). Such screws had, however, been long in use in the British Navy, and in 1840 Capt. E. J. Carpenter, R.N., patented the use of a screw on each quarter, an arrangement that he applied to the "Geyser" pinnace.

996. Model of Hirsch's propeller. (Scale 1 : 12.) Maudslay Collection, 1900. N. 2240.

This construction of screw was patented by Mr. Hermann Hirsch in 1860–66 and somewhat extensively adopted. The chief feature of the blade is, that its section, by a plane perpendicular to the screw-shaft, is a spiral with the leading edge concave, the intention being to prevent centrifugal movement of the water. The blade has increasing pitch and tapers considerably from the centre towards the tips.

The propeller represented has four separate blades, fixed by flanges and screws to the boss; it is 24 ft. diam. and is intended for utilising 7,000 indicated h.p.

997. Model of Hirsch's propeller. (Scale 1 : 20.) Presented by Walter Child, Esq., 1908. N. 2501.

This model represents the four-bladed screw-propeller of the S.S. "Périere," a vessel built in 1865–6 by Messrs. R. Napier and Sons for the Compagnie Générale Transatlantique. The "Périere" was originally fitted with a four-bladed Griffiths screw, 19 ft. diam. and 29·5 ft. pitch, so that the propeller represented must have replaced it subsequently.

It differs slightly from No. 996, which has blades bolted to the boss.

Particulars of the vessel are :—Displacement, 5,100 tons; length, 339 ft.; breadth, 43·5 ft.; depth, 29 ft.; load draught, 22 ft. The average h.p. exerted at sea was 2,500, giving a speed of 13·5 knots, with a steam pressure of 25 lb. per sq. in. On the measured mile at Cherbourg breakwater in 1866 a mean speed of 15·3 knots was obtained.

998. Experimental ship-model with Rigg's guide-blade propellers. Received 1909. N. 2523.

This is the original model used by Mr. Arthur Rigg, jun., in 1863–64, at Chester, for testing the efficiency of various forms of re-action or guide-blade propellers. The essential idea of using fixed vanes or reverse blades at the rear of the ordinary screw propeller (or paddle-wheel) is to utilise any available momentum in the water leaving the revolving blade in order to increase the total propulsive effect.

On the model are shown, in their relative position, two 12-bladed screws, each 3 in. diam.; the foremost, or revolving screw, is attached to a shaft driven by internal spring mechanism, while the rearmost or fixed screw, with reversed deflecting blades, is separately attached to a hanging bracket or stern-frame. This latter frame is removable and provided for the interchange of differing forms of both revolving and fixed blades. Enclosing both screws was a cylindrical casing arranged concentric with the axes; this casing or tunnel limited the volume of water affected by the propellers, and was specified in Mr. Rigg's original patent of 1864; it has also formed an integral part of the arrangements adopted by later investigators.

In addition to experiments with the model propellers here shown, and many others similar in size but varying in pitch, curvature and number of blades, Mr. Rigg's plans were tried on a small boat fitted with a 3-ft. propeller, and also on the S.S. "Corcyra," with a 12-ft. propeller. The guide-blade principle was tested by the Admiralty on H.M.S. "Bruizer" in 1875, and also by Sir J. I. Thornycroft, on H.M.S. "Lightning" in 1877–83 (*see* No. 116). Although on some of these trials an increase of speed and reduction of vibration were recorded, they were not uniformly satisfactory.

In 1866 Messrs. Rigg and Griffiths patented an arrangement of guide-blade propeller in which adjustable blades were proposed in place of rigidly fixed ones.

999. Model of propeller of H.M.S. "Lord Warden." (Scale 1 : 16.) Maudslay Collection, 1900. N. 2239.

The "Lord Warden" was an armoured wooden vessel of 7,675 tons displacement, launched in 1865; her engines were similar to those of the

"Octavia" (*see* No. 839) and indicated 6,705 h.p., which gave a speed of 13·5 knots.

The four-bladed propeller represented was 22·8 ft. diam., 21·37 ft. pitch and 11·7 ft. long. The blades were fixed to the boss by flanges, with slotted holes for the studs so as to allow of the pitch being altered. A two-bladed screw was also tried on this vessel, but was found less efficient, although more convenient as an auxiliary propeller.

1000. Stern model with screw propeller. (Scale 1 : 24.) Contributed by W. H. Crispin, Esq., 1861. N. 433.

This propeller was patented by Mr. Crispin in 1860. It resembles a two-bladed screw, but the blades are flat discs set at an angle; two modifications are shown.

1001. Model of screw propeller. (Scale 1 : 4.) Presented by Mrs. H. Vansittart, 1874. N. 1369–70.

This two-bladed screw was patented in 1868 by Mrs. Vansittart, daughter of James Lowe, and named the "Lowe-Vansittart" propeller.

Each blade has a surface of varying pitch, and is rectangular in outline with rounded corners. The root of each blade is flanged out, and fixed to the boss by studs.

This screw was fitted by the Admiralty in 1869 to several warships, and in 1873 the Allan Liner "Scandinavian" had its propeller, which was 18 ft. diam. by 25 ft. pitch, replaced by a Lowe-Vansittart screw with very favourable results.

1002. Model of De Bay's propeller. (Scale 1 : 8.) Lent by C. W. Crossley, Esq., 1910. N. 2554.

This represents the propeller of the steam yacht "Iolair," a schooner-rigged vessel, 81·5 ft. long, 12 ft. beam, and 8·17 ft. deep, with a gross tonnage of 40·37. The type of propeller shown was patented in 1876 by Mr. C. S. De Bay. It consists of two screws of equal and opposite pitch, mounted on the same shaft and revolving in opposite directions. The diameters of the screws differ slightly, the larger having three blades and the smaller four blades. Portions of the blades of each propeller are cut out and the remaining portions of the blades of each screw revolve in the spaces left in the blades of the other screw.

This construction is an attempt to prevent the loss of energy caused both by centrifugal motion of the water acted upon, and by all other motions of the water except that in an astern direction parallel to the keel of the vessel. It was held that wasteful motions of the water caused by one propeller would be neutralised by similar motions in an opposite direction caused by the other propeller, and the final effect would be for the pair of propellers to drive the water in a true astern direction.

The mechanism employed in order to obtain the reverse motions of the screws consists of a tubular shaft attached to the four-bladed screw through which runs the shaft carrying the other screw. The inner shaft is driven direct from the engine, and the tubular shaft, which runs loose on it, is driven in the opposite direction by a pair of spur wheels, the motion being transmitted to the spur wheels by cranks and connecting rods from the inner shaft. The spur wheels have stepped teeth so that the wheels can be moved circumferentially for taking up wear.

The special form of the framing shown was designed to enable the gear to be put as far aft in the vessel as possible.

Comparative trials of a propeller of this construction and a four-bladed Griffiths screw similar to that of H.M.S. "Lord Warden" (*see* No. 999) were made with specially designed apparatus in 1879, and are stated to have indicated an increased efficiency of at least 40 per cent. in favour of the De Bay propeller.

On trial, the "Iolair," with a four-bladed Griffiths propeller of 6·17 ft. diam. and 6·34 ft. pitch, is stated to have obtained a speed of 7·4 knots at 124 revs. per min. When fitted with the propeller shown in the model, of 4·67 ft. diam. and 7·5 ft. pitch, the vessel is stated to have obtained a speed of 8·3 knots at 128 revs. per min., representing a gain of nearly 1 knot on the speed of the vessel.

1003. Model of screw propeller. (Scale 1 : 24.) Presented by R. Griffiths, Esq., 1881. N. 1542.

This is a form of four-bladed screw, patented in 1880 by Mr. W. J. Griffiths. The leading edges of the blades are convex for the whole length, while the after edges are convex near the root and concave near the point, the point of inflection being half-way. The blade surface from about two-thirds of the radius to the point is curved or bent forward. These features were introduced to reduce vibration.

1004. Model of torpedo-boat propeller. (Scale 1 : 4.) Presented by J. K. Rennie, Esq., 1879. N. 1514.

This screw was designed for shallow draught vessels, in which the diameter is very restricted; the area obtainable is increased by bending the blades aft; this also prevents centrifugal motion of the water.

The blades are wedged into the boss from the end, and held in place by a conoidal cap. The propeller represented was 5·4 ft. diam., and 6 ft. pitch.

1005. Model of stern framing with Duncan's propeller. (Scale 1 : 12.) Presented by Messrs. Ross and Duncan, 1887. N. 1705.

This represents the stern of the Egyptian Government yacht "Sareea," built in 1886, and fitted with Duncan's screw propeller. The dimensions of the vessel are :—Length (o.a.), 68 ft.; length (b.p.), 63·4 ft.; beam, 12 ft.; depth, 6·1 ft.; depth (moulded), 7 ft.

The extremities of the blades are curved aft and are somewhat dished, the object being to prevent centrifugal motion of the water.

The engines are of the two-stage expansion, inverted cylinder, surface condensing type, with cylinders 10 in. and 20 in. diam., by 14 in. stroke, supplied with steam at 100 lb. pressure by a double furnace multitubular steel boiler. On the trial trip the mean speed was 9·5 knots, the engines indicating 120 h.p. at 200 revs. per min.

1006. Motor-boat propeller. Presented by Messrs. D. Ramsay Smith & Co., 1909. N. 2510.

This represents a typical form of propeller used in high-speed motor boats of fine lines and small displacement. It has three right-handed blades of oval form, with an increasing pitch both towards the tips and from the leading to the following edges of each blade. The blades are dipped aft in order to concentrate the column of water acted upon and to avoid centrifugal action of the water. The design of this propeller is stated to be such as to reduce cavitation to a minimum. The material employed is bronze, toughened to withstand shock.

SCREW PROPELLERS WITH ADJUSTABLE BLADES.

1007. Models of adjustable pitch propellers. (Scale 1 : 8.) Woodcroft Bequest, 1903. N. 34–5 and 37.

These show modifications of the adjustable pitch screw patented by Mr. Bennet Woodcroft in 1844; the blades have the increasing pitch patented by him in 1832.

The object of altering the pitch or angle of inclination of the screw is to find experimentally the most efficient angle, and also to enable the engines to give out their full power under varying states of wind, load, etc., as these seriously affect a vessel in which the screw is auxiliary.

(*a*) Shows a two-bladed screw with an arm fitted to the stem of each blade; a block on the end of the arm slides in an inclined groove in a collar, which slides on a feather and is moved by a lever on deck.

(*b*) Resembles (*a*), but has a four-bladed screw, and the sliding collar is moved by bell-crank levers from a spindle worked by a hand-wheel on deck. An indicator shows the angle of the blades.

(*c*) Another modification of (*a*); instead of grooves on the collar, there are short links from it to the arms of the blade stems. For fixing the blades in any position a similar collar is provided aft, with two wedge-shaped arms which act on small sliding pieces that lock the stems.

1008. Woodcroft's adjustable pitch propeller. Contributed by the Lords of the Admiralty, 1857. N. 36.

This is the first propeller constructed in which the pitch of the screw could be varied. It was made by Messrs. J. Whitworth & Co. in 1845, to the order of the Admiralty, after they had seen the Woodcroft model, No. 1007 (*a*), for trial on H.M.S. "Dwarf" (*see* No. 982), but was never fitted.

The propeller is 5·75 ft. diam., has two blades 2·5 ft. wide, and a pitch that can be adjusted from 4·75 ft. to 10·75 ft.

1009. Drawing of H.M.S. "Dwarf." (Scales 1 : 12 and 1 : 48.) Woodcroft Bequest, 1903. N. 88.

This shows the vessel with the Woodcroft adjustable screw in place; it was, however, never so fitted, although some trials with it on H.M.S. "Minx" gave very satisfactory results.

1010. Woodcroft's adjustable pitch propeller. Woodcroft Bequest, 1903. N. 150.

This is a small example of a propeller similar to those in the models (*a*) and (*c*), No. 1007, and as patented by Mr. Bennet Woodcroft in 1832–44. The blades are forged from boiler plate.

1011. Model of Maudslay's self-adjusting screw. (Scale 1 : 16.) Maudslay Collection, 1900. N. 2237.

By this arrangement, patented by Mr. Joseph Maudslay in 1848, the blades of the screw, when the engines are not working, turn into the plane of the shaft and thus reduce the sailing resistance.

There are two propeller blades, each having a shank passing completely through the boss and capable of turning in the same. One blade is further aft than the other, and the two shanks are formed with teeth by which they gear together; at the termination of the teeth are stout lugs or stops, by which the swing of the blades is limited between the fore-and-aft position and the working pitch. The centre of area of each blade is considerably behind the axis of the shank, so that the action of the water causes the desired turning; a locking clutch, moved by a lever from the deck, secures the blades in either position and permits of the engines being reversed.

1012. Stern model with adjustable pitch propeller. (Scale 1 : 16.) Contributed by Messrs. Maudslay, Sons and Field, 1858. N. 113.

In this are embodied the improvements patented by Joseph Maudslay, in 1853 on a screw propeller patented by him in 1848.

On the stem of each blade and within the boss of the propeller, is fixed a short arm connected by links to a lug cast on a collar sliding on a prolongation of the propeller shaft. The collar is moved endwise by bell-crank levers worked by a screw from the deck; this causes the blades to turn on their axes till the most efficient angle for a particular speed is found, or till in line with the stern post when the vessel is under sail alone. The whole apparatus is mounted in a frame whereby it can be raised to the level of the vessel's deck.

1013. Model of adjustable pitch Griffiths propeller. (Scale 1 : 8.) Contributed by Robert Griffiths, Esq., 1860.
N. 438.

This represents the general proportions of blade and boss patented by Mr. Griffiths in 1849, and subsequently so largely adopted.

The leading features of the Griffiths' screw are that the central portion is filled up by a spherical or ellipsoidal boss about one-third the diameter of the screw, while the blades have their greatest width at their mid-length, and taper to the point more on the leading than the trailing side. Mr. Griffiths first tried his screw on a steamer at Bristol about 1850; it was afterwards applied to the S.S. "Lariston" by one of the Clyde builders, and then the Admiralty allowed it to be tested on H.M.S. "Fairy," when such results were obtained that its use rapidly extended. The screw showed an increase of speed over older forms, but its popularity is chiefly due to its other advantages, such as increased strength of boss, separable blades, reduced vibration, and less resistance when used as an auxiliary. The large boss was introduced to reduce the centrifugal motion of the water, and to dispense with that part of the screw where the whirling action is greatest.

Both blades of the model are adjustable in pitch, from 18 to 24 ft. In the first arrangement, patented in 1853, the cylindrical stem of a blade has snugs on it which fit into a corresponding hole in the boss; when inserted it is rotated through a right angle and retained in the desired position by cotters and packing pieces. In the second arrangement, patented in 1858, a cotter through the stem of a blade rests in a sector-shaped slot in the boss, and adjustment is made by varying the packing pieces on its sides; both ends of the boss are smoothly finished off by caps that enclose the cotters, etc.

1014. Adjustable pitch propeller. Presented by W. Hewitt, Esq., 1863.
N. 852.

This construction of screw was patented by Mr. Hewitt in 1855. On the axis of each of the four blades, which are circular discs, is a toothed sector, gearing with a bevel wheel fixed to a sleeve on the propeller shaft. This sleeve can be rotated by worm-gearing, and thus the pitch of the blades can be simultaneously adjusted; when this is accomplished the sleeve can be locked to the shaft by a sliding collar which acts as a clutch. The worm is then put out of gear by lowering its bearings.

1015. Models of auxiliary propellers. (Scale 1 : 8.) Lent by the Rev. P. A. Fothergill, B.A., F.R.S., late R.N., 1871.
N. 1325.

Two models are shown in which by an invention made by the lender in 1865, the propeller blades are so arranged as to automatically set into the position of least resistance when not being used, while they return to the correct pitch when the engine power is exerted. The blades have each a cylindrical stem, fitting into the boss and provided with a stop by which the pitch angle is prevented from being reduced below the working value. The reefing is performed by the resistance of the water, but it is not clear by what means the arrangement is modified so as to permit of driving astern.

1016. Model of stern frame with adjustable pitch propeller. (Scale 1 : 8.) Lent by W. J. Griffiths, Esq., 1873.
N. 1363.

This is an adjustable screw patented by Mr. R. Griffiths in 1868. The screw is intended as an auxiliary, and can be adjusted from within the ship.

Inside the boss the shank of each blade is provided with an arm, which is connected by a link to a collar, secured on a sleeve that is loose on the propeller shaft. The after end of the sleeve has turned in it a groove, in which fits a brake which can be tightened on the collar by a screwed tube from a hand-wheel on deck. While this is being done the engines are made to rotate the shaft slowly, thus screwing the collar along and feathering the blades. In the tube to the brake is a rod resting on an eccentric groove cut in the collar; the rise and fall of this rod indicates the amount of adjusting that is being performed.

1017. Models of adjustable pitch screw propellers. (Scale 1 : 8.) Lent by W. Andrews, Esq., 1899. N. 2180.

These show two modifications of a method of altering the pitch of screw propeller blades, patented by Mr. H. B. Young in 1866–70. The shanks of the two blades are inserted in a hollow boss, and extend nearly through it, but are retained in position by arms projecting from them. These arms are controlled by a nut on a screwed rod which extends through the main boss, and can be turned by a suitable key. This key is manipulated entirely from within the vessel, after the propeller has been placed in the vertical position. In one of the models there is an additional key, which actuates a wedge for locking the blades after they have been set.

1018. Reversible propeller (working). Lent by the Gaines Reversible Propeller Co., Ltd., 1910. N. 2587.

With the application of internal combustion engines to marine propulsion, some independent reversing arrangement became necessary. The difficulty of obtaining motion in the reverse direction can be obviated simply by changing the pitch of the propeller blades: the arrangement shown, patented in 1904 by Mr. G. Spicer, is of this kind.

The blades turn on cylindrical shanks with spherical bearings within the boss, the after half of which is removable. The propeller shaft is hollow to accommodate the rod for moving the blades; this ends inside the boss in a piece of triangular section, in each face of which is a pin fixed eccentrically. The pins engage in slots in the enlarged ends of the blades, and form virtual cranks about which the blades can rotate when the rod is moved axially. To effect this there is a lever working in a fixed quadrant, which operates by means of pins projecting from it, a collar sliding on the propeller shaft. This collar is pinned to the rod inside, a slot in the propeller shaft allowing of axial movement. The collar, rod, and shaft rotate as one.

In some forms of this gear a hand-wheel and screw mechanism is used to operate the lever. By this means very slight changes in the pitch of the blades can be made to suit any conditions of running. The lubricant used inside the boss is thick grease. The stern bush and thrust block are shown.

LIFTING AND SIMILAR SCREW PROPELLERS.

1019. Stern models with lifting screws. (Scale 1 : 36.) Contributed by J. Seaward, Esq. N. 423–4.

These show methods proposed in 1846–9 by Messrs. Seaward and Capel for applying an auxiliary screw to a 90-gun ship, at the time when it was decided to fit a large number of wooden sailing ships with steam power.

(*a*) In this arrangement the propeller is abaft the rudder, and is carried in a frame which can be raised by a screw in a nut secured to it. The shaft terminates in a flat-sided crosshead which fits into a notch cut in the face of the propeller boss. The rudder is expanded so that, although penetrated by the propeller boss, it is not cut in two nor is its motion interfered with.

(*b*) This plan resembles the above, but to avoid the alterations to the rudder the propeller is placed on one side of the stern post, the rudder being simply notched to give the necessary clearance.

1020. Stern model with lifting screw. (Scale 1 : 24.) Contributed by Messrs. Maudslay, Sons and Field, 1861.
N. 420.

This is fitted with an arrangement for lifting an auxiliary screw, introduced by Joseph Maudslay in 1846.

The screw is two-bladed, and is carried in a frame formed of two links and a cross-head which slides in guides, and can be lifted by rope tackle to the deck level; the connection to the shaft is made by a slot and feather in the face coupling.

1021. Model of stern with screw propeller. (Scale 1 : 96.) Maudslay Collection, 1900. N. 2235–6.

This arrangement was proposed about 1850 for fitting existing line-of-battle ships with auxiliary screws without extensive structural alteration. The propeller is placed abaft the stern post and a rudder post is added outside it, the head being accommodated by a rounded projection at the stern. The screw is connected to the shaft by a slotted face-coupling, and is arranged for lifting in the way patented by Mr. Joseph Maudslay in 1846. (*See* No. 1020.)

In another model relating to the arrangement, to a scale of 1 : 64, the lifting propeller is disengaged by moving the tail shaft forward until its squared end is clear of the boss.

1022. Model of stern frame with lifting screw. (Scale 1 : 12.) Presented by Messrs. Bullivant & Co., 1902. N. 1895.

This represents the two-bladed screw propeller and lifting arrangements of H.M.S. "Blenheim," a wooden 72-gun ship fitted with an auxiliary screw in 1847 by Messrs. Seaward and Capel.

The end of the screw-shaft was flanged out and a slot cut partially across it to receive the end of the screw, which was supported in bearings formed in a frame which could be lifted in its guides by rope tackle from a winch. The propeller was 16 ft. diam., 20 ft. pitch, and 3·3 ft. long; on trial in 1849 it drove the vessel at 5·8 knots with 938 indicated h.p.

1023. Model of stern frame with lifting screw. (Scale 1 : 12.) Presented by Messrs. Bullivant & Co., 1902. N. 1891.

This shows the hydraulic arrangement of John Seaward for lifting a screw when not steaming, fitted in 1848 to H.M.S. "La Hogue," an existing line-of-battle ship, which thereby became one of the first screw-propelled men-of war.

The screw is hung in a frame which slides in guides and is raised by telescopic hydraulic rams arranged in the guides. The end of the propeller shaft is flanged out and slotted to receive a corresponding projection on the tail shaft.

1024. Stern model with auxiliary propeller. (Scale 1 : 36.) Contributed by Messrs. Jackson and Watkins, 1861.
N. 431.

This shows a vessel's stern fitted with a screw shaft placed on one side of the rudder. The propeller is two-bladed, and each blade is cottered through its stem into a central casting that serves as a boss.

1025. Stern model with Seaward's folding propeller. (Scale 1 : 16.) Presented by Messrs. Bullivant & Co., 1902.
N. 1892.

This arrangement for reducing the resistance of an auxiliary propeller when the engines are not being used was designed by Mr. Seaward in 1848. The propeller is two-bladed, but is cut into short lengths which can be turned so as to cover one another, in a similar way to that in which a lady's fan closes; in this way the width can be so reduced that but little projects beyond the deadwood. The foremost section is fixed to an outer annular shaft, and the hindmost section to the internal or main shaft; the intermediate sections have pins and notches so that by rotating the hollow shaft upon the main one, by means of worm gear, the fan can be opened or closed.

1026. Stern model with unshipping propeller. (Scale 1 : 24.) Contributed by W. H. Crispin, Esq., 1861. N. 434.

This is fitted with a screw carried in a narrow frame, which is removable sideways by means of ropes from two deck winches.

1027. Lifting propeller (working). Presented by the Rev. J. M. Kilner, 1878. N. 1505.

This arrangement, patented by Mr. Kilner in 1870, has been tried in a boat and on a ship of 1,274 tons. When propelled by one man the boat attained a speed of 3·47 knots, but the mechanism is also adapted for being driven by steam power.

The propeller is a two-bladed screw, carried in a frame which is lowered through a well at the stern so that the screw is below the keel level when in use. The propeller is rotated by bevel gear from a vertical shaft driven by a modified double-ended winch handle; but a long horizontal connecting-rod has been used in a similar arrangement when employing several men.

1028. Model of stern with auxiliary screw propeller. (Scale 1 : 48.) Lent by J. Wimshurst, Esq., F.R.S., 1902. N. 2298.

The arrangements here represented, for reducing the resistance created by the propeller when a vessel is proceeding under sail, were patented by Mr. H. Wimshurst in 1840–59.

The propeller is four-bladed, but is formed of two two-bladed screws provided with clutch faces where their bosses are in contact, and only one screw is secured to the shaft, the other being free to move backwards through 90 deg. When the propeller is in use the resistance of the water keeps the blades apart, while at other times the loose portion can be so turned that its blades are in contact with the fixed ones, and thus leave but very little projecting beyond the deadwood.

To further reduce the resistance occasioned by the propeller when not in use, two shutters are provided, hinged to the rudder and capable of being swung back so as to enclose the folded propeller and cover the hole in the deadwood; two narrow flaps hinged to the stern post are added to retain the shutters in position. When the propeller is in use the shutters are swung round to the sides of the rudder, and there secured by a hinged strap. The propeller is, moreover, so mounted that it can be unshipped sideways, and then be brought upon deck in the manner shown in the model of the S.S. "Novelty" (*see* No. 975).

1029. Stern model with auxiliary propeller. (Scale 1 : 36.) Presented by the Institution of Civil Engineers, 1868. N. 1194.

The invention consists in an arrangement of shutters by which the resistance of a screw that is not being driven is reduced. The screw is two-bladed, and when in the vertical position it can be closed in by two vertical shutters sliding in grooves. These shutters close in the projections and secure regular stream lines when the ship is under sail.

Such an arrangement was patented by Mr. J. M. Hyde in 1857, and by many others subsequently.

1030. Whole model of vessel with protected screws. (Scale 1 : 24.) Lent by W. J. Griffiths, Esq., 1874. N. 1362.

In 1873 Mr. R. Griffiths experimented with a clockwork driven model arranged very much as in this example. The result obtained he considered most promising, but soon afterwards he neglected the scheme in favour of others of a less revolutionary character.

The model represents an armoured frigate, built with a circular tunnel at each end sloping downwards in an easy curve to the bottom, and in each tunnel is fitted a screw propeller with wide tipped blades. The screws were in this way protected, while possibly a better supply of water was obtained than when arranged in the ordinary manner.

Mr. Griffiths considered that by dividing the power between these two screws an increase of 30 per cent. in the speed resulted over that obtained with all of the power applied to a single screw at the stern; a gain of 50 per cent. in speed over the stern screw when an engine of equal power was applied at the bow; and that these tunnel screws gave 12·8 per cent. more speed than ordinary twin screws with the same power and revolutions. He found his best result when the water supplied was 60 per cent. greater than the estimated requirement of the screw.

1031. Stern models with special arrangements of Griffiths propellers. (Scale 1 : 24.) Lent by W. J. Griffiths, Esq., 1882. N. 1571.

This group contains two half and three whole models of sterns, showing certain arrangements of propeller introduced by Messrs. R. and W. J. Griffiths.

(*a*) and (*e*) Represent twin and single screws respectively, arranged under protecting concentric hoods fixed to the stern; these are considered to have increased the vessel's speed by 7 per cent.

(*b*) Illustrates a protector for screws, described in Mr. R. Griffiths' last patent (1877). It is formed of two fixed cylinders concentric with the screw, the inner one just clearing it and the outer one 1·125 times its diam. The arrangement has been fitted to several trawlers, and is stated not to have reduced the speed.

(*c*) Shows a screw arranged ·66 of its diam. further aft than the end of the vessel's run, as patented by Mr. W. J. Griffiths in 1878. In this position the screw is clear of the dead water, and it is claimed that it gives an increase of 12 per cent. in speed over that obtained when further forward.

(*d*) Shows an arrangement patented by Mr. R. Griffiths in 1853, in which the propeller is placed abaft the stern post, the requisite space being obtained by cutting away the rudder where necessary.

1032. Stern model with Mallory's propeller. (Scale 1 : 4.) Lent by the Mallory Propeller Co., 1879. N. 1519.

This combined propelling and steering screw was introduced in 1878 by Col. W. H. Mallory, of the United States.

The propeller is carried by a frame resembling a rudder, and is rotated by bevel gearing from an engine on deck. As the screw is adjustable in direction it will turn the vessel even when she has no way on. A modification of the arrangement has been introduced in which the screw is directly driven by an enclosed electric motor receiving its current through a flexible cable; all such propellers are, however, limited to small powers.

MARINE PROPULSION OTHER THAN BY PADDLES OR SCREW.

The earliest known method of propelling a raft or boat through the water is by means of muscular effort applied to paddles or oars, the former being the more primitive apparatus; nor does it appear that any means more effective than the long oar to enable a man to employ his own effort has been discovered down to the present day.

The adjustable sail acted on by the force of the wind, an invention later than the oar since it requires some steering power before it can be successfully employed, had been brought to considerable perfection in prehistoric times as evidenced by the earliest Egyptian monuments. The sail still remains the only important appliance for utilising the energy of the wind, although windmills driving propellers and kites for hauling canal boats have been repeatedly tried, without any considerable success.

Hydraulic propulsion, *i.e.*, by admitting water near the bow through a trunk and forcing it out near the stern, requiring as it does simple power arrangements, has received much attention. Between 1784 and 1793 James Rumsey in the United States and later in England demonstrated by experiment the feasibility of the method. John and Morris W. Ruthven between 1839 and 1866, employing a centrifugal pump, persisted in this direction till, at the latter date, H.M.S. "Waterwitch" was built to make comparative tests; she attained a speed of 9·25 knots, but the power developed would have given a higher speed if exerted on a suitable screw propeller. The method, however, has received a limited application in situations where the propelling mechanism must be protected (*see* No. 504).

When the rotative steam engine had been sufficiently developed to permit of attempts being made to apply it to marine propulsion, almost every conceivable propeller was tried. John Fitch in 1786–92 experimented with a series of connected paddles, either at the sides or the stern, and actually ran a boat so fitted for a short time in 1790. The idea has been repeatedly revived since, and as late as 1845 on the Thames a boat named the "Propeller" was driven by two reciprocating dashboards. The action of a man sculling at the stern with a single oar has also been imitated mechanically. Earl Stanhope adopted Genevois's idea, *i.e.*, a collapsible propeller resembling the foot of an aquatic bird; this he actuated through a trunk by an engine on the centre line of a boat, but the speed attained on actual trial in 1790–3 was disappointing; the idea was revived as late as 1882. Another method experimented with was a chain of float boards passing over two sprocket wheels at each side; this was employed by Desblanc in 1802 (*see* No. 1033).

The numerous methods of propelling canal boats by poles, wheels or screws working against the bottom, have shown no important advantages. A chain or rope resting on the bed of the river, &c., and picked up by a power-driven wheel on the boat, which thus hauls itself along, has had a wide application for ferries, and to a limited extent on canals, where the power has been supplied through an overhead conductor to an electric motor on board. The latter system has been applied to drive a screw propeller, but a more promising method is traction by electric motors with overhead rails.

1033. Model of paddle-chain (working). (Scale 1 : 8.) Contributed by the Commissioners of the 1851 Exhibition, 1857. N. 31.

This apparatus was patented by Mr. John Spurgin in 1837, as a means for providing a shallow vessel with the equivalent of a paddle-wheel of large diameter. A similar arrangement had been patented in France in 1802, by Desblanc.

On each side of the hull is an endless pitch chain running round a return pulley fore and aft, and over a large sprocket wheel between them, fixed on the crank-shaft. To the chains are secured floats, which thus describe a catenary curve of a dip that is adjustable by means of the sliding bearings in which the return pulleys are carried.

Mr. Spurgin also patented this mechanism as a continuous elevator (*see* Mechanical Engineering Collection).

1034. Model of reciprocating propeller (working). (Scale 1 : 48.) Maudslay Collection, 1900. N. 2232.

This arrangement of mechanically moved paddle has been frequently proposed, probably on account of its being more compact than any form of paddle-wheel. In the scheme represented there is a single steam cylinder driving a crank-shaft on which are two flywheels, from each of which extends a connecting-rod giving a horizontal reciprocating motion to a concave board or float. A vertical movement is also introduced, by links from the crosshead, and the compound motion thus given to the floats causes them to describe oval curves, so that they are above the water during the return stroke. The floats extend through a hole in the deadwood, and overlap, but, owing to their alternate action, clear one another.

1035. Half-block model of H.M.S. "Waterwitch." (Scale 1 : 48.) Received 1869. N. 1317.

This was an armour-plated gunboat designed by the Admiralty, and launched at Millwall in 1866.

She was propelled by a hydraulic reaction arrangement, introduced by Mr. J. Ruthven. The engines were of 150 nominal h.p. and drove a centrifugal pump, that had a horizontal fan 14·3 ft. diam., by which water entering through orifices in the bottom of the hull was forced out with considerable velocity, through pipes laid fore-and-aft along the ship's sides below the water-line. The motion was reversed by valves that controlled the delivery, not by reversing the engines (*see* also No. 504).

The armament was two 6·5-ton M.L.R. guns, and the ship's complement 80 men.

Displacement, 1,190 tons; length, 162 ft.; breadth, 32 ft.; depth, 11·3 ft.; immersed midship section, 344 sq. ft.

STEERING ARRANGEMENTS.

Ancient vessels were steered by large oars or paddles, passing through loops on either stern quarter and held vertically. This inconvenient arrangement was in general use till late in the 15th century and is still employed in a few countries.

The right-hand quarter, looking forward, being the more convenient, was that usually chosen by the helmsman and to this is due the name "starboard" still applied to that side of a vessel.

The rudder appears to have been introduced during the 13th century, probably from China, where it still remains in a form that closely resembles a steering paddle lashed to the stern. It soon after reached its present form, however, for in a seal of 1338, a rudder is represented hinged, by its forward edge, to the stern post, as is now usual.

The lever or "tiller" fixed to the head of the rudder was for centuries moved by hand, but as ships increased in dimensions a compound lever was adopted, a vertical lever pivoted on the upper deck beams being added to give more power over the tiller; this arrangement was generally employed till the end of the 17th century. The application of a block and tackle to the tiller, whence ropes or chains were led to a winch barrel turned by a spoked wheel known as the steering wheel, dates from the beginning of the 18th century; it, however, remains the most popular arrangement, and even where steam power is applied the wheel is retained in its original form.

Numerous trains of gearing have been introduced to assist manual power in steering, but they all reduce the speed with which the rudder is set over, although at the same time they prevent the rudder from overpowering the steersman. An arrangement that has been frequently used was first patented by John Rapson in 1834, in which the shaft of the steering wheel is cut with right and left-handed threads into which engage two corresponding nuts attached by links to a yoke on the rudder head. Rapson also in 1839 brought out his "slide," in which the tiller is embraced by a loose block which slides in an athwartship guide, thus preventing the slackness of the tiller ropes that otherwise arises from their varying inclinations. Charles, 3rd Earl Stanhope, in 1790 patented an "equipollent" or balanced rudder in which the axis was in the centre of the width; such a rudder would not balance, however, but by placing the axis further forward a great reduction in the turning effort required is now frequently effected.

The great increase in the size of ships that took place in the last century soon led to an excessive number of seamen being required at the helm. The desirability of utilising steam power for this work was recognised by many, but it was not till 1867 that Mr. Macfarlane Gray introduced the first successful steam steering gear. This was fitted to the S.S. "Great Eastern," and it had the "differential" valve motion by which, as in all subsequent gears, any movement of the steering wheel admitted steam to an engine that correspondingly drove the tiller winch, while this engine by its motion stopped itself when the equivalent movement of the rudder had been completed (*see* No. 1065).

In ships which are full at the stern, one of the most satisfactory forms of steam steering gear in present use is Rapson's slide (*see* No. 1063), but, as it occupies a considerable amount of thwartship space, its use is confined principally to battleships.

Mr. W. H. Harfield in 1889 patented a compensating steering gear for use with steam or manual power, which is now largely adopted. This gear is suitable for vessels with narrow sterns (*see* No. 1064). The steering gear, patented by Mr. A. B. Brown in 1888, and fitted chiefly in the Mercantile Marine, has the engine placed on the tiller, the latter engaging with a fixed quadrant by means of a worm wheel held between jaws at its after end. In conjunction with this gear is fitted a device called a "telemotor," by means of which the motion of the steering wheel is transmitted to the engine by hydraulic pressure instead of by shafting or bevel wheels, the fluid employed being usually a solution of glycerine which will not readily freeze.

The application of hydraulic power to steering ships offers many advantages over steam power, among which may be mentioned its certainty of action, safety and simplicity. One example of this type of gear is shown in No. 1055.

Steam steering engines are now commonly fitted in H.M. ships in duplicate on specially stiffened vertical bulkheads in the main engine-room in order to economise space (*see* No. 1065).

The action of a rudder being due to the new direction it gives to the stream lines passing the stern, the lines of the afterbody have an important influence on the steering properties of a ship; in all ordinary vessels it is found that the quickest turning is performed with the rudder at about 35 deg. from its mid position.

1036. Model of rudder. (Scale 1 : 24.) Presented by the Rev. J. Hardie, 1866. N. 1139.

In this design by Mr. Blake the timbers are scarfed together and fastened with gun-metal pins. The disposition of the braces and gudgeons is indicated.

1037. Boat stern-post and rudder. Lent by H. Emanuel, Esq., 1885. N. 1692.

This rudder, for attaching to row boats, was proposed by Mr. Emanuel in 1884.

The pintle is one continuous bar and slides in a slotted gudgeon above, which guides it on to the ordinary gudgeon below, so reducing the difficulty usually experienced in shipping the rudder.

1038. Stern model with jury rudder. (Scale 1 : 24.) Presented by the Rev. J. Hardie, 1866. N. 1114.

This was designed by Mr. R. F. S. Blake, master shipwright in H.M. dockyards, 1806–55, to illustrate how a vessel might be fitted with a jury rudder in case of accident.

The rudder is made up of spars, held together by battens nailed across, and weighted with ballast lashed to it. It is supported by a temporary iron gudgeon held to the rudder post by ropes at the quarters.

1039. Models of jury rudders. (Scale 1 : 12.) Presented by Lady Commerell, 1903. N. 2329.

As the loss of the rudder is such a serious accident to any large vessel unless she be provided with twin screws, efforts are generally made in such circumstances to improvise a temporary or "jury" rudder from the spare planks, plates, cordage and other materials in the ship's store, no spare gear for the purpose being usually carried. The models A and B, however, show the special form of jury rudder patented in 1874–82 by Admiral Sir J. E. Commerell, G.C.B., V.C., and fitted on H.M.Ss. "Fawn" in 1876, "Cormorant" and "Wolverine" in 1881, and subsequently on some other vessels. They were carried as part of the ship's spare equipment and could, in case of emergency, be fitted while at sea.

In both arrangements a temporary rudder-post or spindle of metal is substituted outside the gudgeons or braces of the original rudder-post, by stepping its lower end into the ordinary shoe-casting, or into a special bracket bearing attached to the lower gudgeon. The rudder-blade is then built up by lowering, singly, a number of interlocking plates, each of which is free to slide down a deep undercut groove or key-way in the spindle; to minimise the openings required in the decks for the passage of these plates, they are lowered vertically until clear of the ship, when they turn into the horizontal position and interlock; they are then simultaneously fixed by the stuffing-box in the rudder aperture. The earlier model (A) shows the blades of wood sheathed with metal, and each having a hinge-pin sliding in the slot of the post; in the later model (B) the blades are entirely of metal, and are hinged to sliding sleeves, while a roller bearing is provided under the rudder-head to reduce the resistance to turning.

Frequently, the most difficult work in connection with the fitting of a jury rudder is the removal of the damaged original rudder, which is usually held in position by a fixed plate or wooden chock bolted or riveted to the rudder-post at or near the water-line. Model (C), however, shows the frame of a rudder in which the locking plates slide on the spindle and are actuated from within the ship. Each locking-plate forms part of a collar sliding upon the spindle, which is hollow, and these collars are moved by an internal shaft having right and left-handed threads so that the collars move oppositely and therefore lock both ways. A relatively small movement of the locking-plates permits of the rudder being lifted out of the lower socket and completely removed.

1040. Model of expansible rudder. (Scale 1 : 4.) Presented by the Rev. J. Hardie, 1866. N. 1099.

This illustrates Mr. Blake's plan for increasing the steering power of gunboats and other shallow vessels. The bottom lower corner of an ordinary rudder is fitted with a piece which embraces it, and which can by a hauling rope be so turned round a pin as to increase the area of the rudder.

1041. Model and woodcut of telescopic rudder. (Scale 1 : 2.) Presented by Chas. Stewart, M.A., 1880. N. 1537.

This represents a proposal by Mr. Stewart for a rudder of variable area. The rudder is in two thicknesses, and between them is a plate that can be protruded by a chain when extra steering power is required.

1042. Model of steering arrangements for a light draught steamer. (Scale 1 : 24.) Lent by Alex. Chaplin, Esq., 1862. N. 890.

The features in this arrangement, patented in 1856 by Mr. Chaplin, are that there is no keel, stem or stern post, and that steering is accomplished by two blades placed obliquely to the centre line at both bow and stern in narrow vertical trunks. One of these rudders is raised while the other is lowered, by bell-crank levers worked from the usual steering wheel.

Many of these vessels were supplied to the Indian Government for the navigation of shallow rivers.

1043. Stern model with "angulating" rudder. (Scale 1 : 48.) Lent by Henry Lumley, Esq., 1865. N. 1043.

This shows three arrangements of the double rudders patented by Mr. Lumley in 1862–3.

The idea is to divide the rudder into two parts, a "body" and a "tail," the latter being hung from the body in a similar way to that in which the body is hung from the stern post. By a simple arrangement of links the tail is given a greater motion than the body, so that the acting face of the rudder becomes concave when set over, and thus more efficiently deflects the passing water. The tail may, however, be locked to the body, thereby converting the rudder into the ordinary form.

With this rudder the tiller at 10 deg. nearly equals the ordinary at 20 deg., while the circles described by vessels are as much as 50 per cent. less in diameter than with the ordinary rudder.

The "Lumley" rudder was fitted to H.M. gunboat "Bullfinch" in 1862, and subsequently to several other war-vessels as well as to ships in the mercantile marine.

1044. Stern model with duplex rudder. (Scale 1 : 24.) Lent by Capt. the Hon. J. T. Fitzmaurice, R.N., 1865. N. 1088.

This rudder was introduced in 1864 by Capt. Fitzmaurice, when commander of H.M. training brig "Sealark."

It consists of two triangular plates, connected along one edge and stayed apart at an angle of 33 deg. This wedge gives greater effect than a flat rudder for a moderate movement of the tiller, but at the cost of additional resistance when not steering.

1045. Stern model with twin rudders. (Scale 1 : 16.) Lent by Capt. T. B. Heathorn, R.A., 1879. N. 1523.

This illustrates Capt. Heathorn's double-rudder and speed-checking device, patented in 1879.

The vessel is provided with two stern posts and rudders, leaving space for the screw to work between. The tillers consist of bell-crank levers, the outer arms of which are connected by the usual ropes to a steering wheel, while the two inner arms are slotted and have a pin travelling in them, by which means they are so connected as to secure their acting in unison.

There is, however, a second wheel further aft, which when operated moves the travelling pin, by screw gear, and causes the two rudders to turn outwards through about 45 deg., in which position they act as brakes in arresting the motion of the vessel without exerting any turning action.

1046. Stern models with balanced rudders. (Scales 1 : 24 and 1 : 48.) Presented by J. Scott Tucker, Esq., 1865. N. 1059–60.

These show the rudder proposed by Mr. Tucker in 1864. The gudgeons project considerably from the stern post and support the rudder nearer its centre, so that the resistance of the water has no turning action on the rudder. Slots in the rudder, underneath the gudgeons, permit it to be lifted and unshipped.

1047. Stern model with twin screws and balanced rudder. (Scale 1 : 48.) Lent by Prof. C. W. Merrifield, F.R.S., 1869. N. 1297.

This shows an arrangement of twin screws proposed by Prof. Merrifield; two Griffiths' screws are employed, but the stern does not extend between them, as now usual. The rudder is of the balanced type and is arranged in the centre line of the ship; it depends for support entirely upon its head, which is accordingly of unusual strength; the weight is carried by friction rollers.

H.M.S. "Penelope" (1868) had an arrangement of stern somewhat similar to this.

1048. Model of Lawson's bracket rudder. (Scale 1 : 4.) Lent by Messrs. Bates, Austin & Co., 1905. N. 2377.

This arrangement for facilitating the repair or renewal of bushes and bearings to ships' rudders was patented by Mr. W. R. Lawson, in 1895, and has been adopted by many important shipping companies.

It consists essentially in carrying the weight of the ordinary rudder upon one or more special "bearing brackets" placed between the usual gudgeons and braces; the latter take no vertical bearing whatever, but are fitted with pintles for steadying only; the pintles and bushes are rendered capable of easy inspection or removal. The bearing brackets are forged or otherwise attached to the stern post and rudder, preferably at positions above the light load line of the vessel, and their working faces are slightly recessed for hardened steel bearing plates or friction discs 1·25 in. thick; by slightly lifting the rudder these may be readily taken out and renewed when necessary. The pintles, instead of being fitted as usual on the rudder braces with their points downwards, are here inverted and seated in the gudgeons on the stern post and lignum-vitæ bushes are fitted to the rudder braces. These bushes, formed of eight separate staves, are put in place from above, and a tapered metal key driven in to complete the circle; the whole is then finally held in place by a metal collar which is tap-bolted to the upper part of the brace. To rebush the pintles no unshipping or lifting of the rudder is necessary; by removing the collar and then withdrawing the key by means of a stud-bolt, as shown, the whole of the staves may be taken out and replaced.

Full size models of a bearing plate and of the bushing arrangements are shown, and also a scale drawing with sectional details of the same.

1049. Telescopic tiller. Lent by Henry Emanuel, Esq., 1885. N. 1694.

This is a tiller for small sailing or row boats; it can be lengthened at will by drawing out the metal tubes of which it is composed.

1050. Model of steering gear. (Scale 1 : 12.) Presented by the Admiralty, 1864. N. 1003.

This modification of the tiller gear was proposed in 1861. The tiller rope is led through double blocks as usual, but on the tiller is an adjustable double block, for which possibly a position may be determined that reduces the slight alterations ordinarily found in the length of the tiller rope.

1051. Model of hand-steering gear. (Scale 1 : 3.) Received 1903. N. 2320.

The use, as a tiller, of a geared quadrant driven by spur gearing from either a vertical or a horizontal steering wheel was patented in England as far back as 1779. Since then various forms of such mechanism have been invented and largely used in both hand and steam gears for the steering of ships; the modification shown, however, is that patented in 1862 by Mr. D. L. Allen.

A quadrant-shaped toothed segment attached to the rudder-head is the tiller, to which the movements to port or starboard are transmitted by a pinion gearing into the toothed rim of the quadrant and driven by a vertical shaft connected by bevel wheels to the horizontal shaft of the usual steering wheel. Extra depth is given to the face of the pinion to allow of the rise and fall of the rudder-head in a seaway.

1052. Stern model with steering gear. (Scale 1 : 12.) Presented by the Admiralty, 1864. N. 1002.

This illustrates Admiral Martin's steering arrangements for a vessel with a well for raising the screw, as fitted in several of H.M. ships about 1858.

The tiller, which is worked by a wheel in the usual manner, is fixed to a false rudder-post on the starboard side of the trunk, and the true rudder-post is connected to it by double arms on each post and side rods.

1053. Model of steering wheel. (Scale 1 : 8.) Lent by Andrew Murray, Esq., C.B., 1867. N. 1166.

This is known as the "Niagara" wheel, from its having been fitted in 1857 to the U.S. corvette "Niagara." It was designed by Mr. Murray when chief engineer at Portsmouth Dockyard.

The wheel is placed directly over the axis of the rudder, whose weight is taken by a collar resting on six friction rollers. The top of the rudder post is hooped by a ring, with two lugs on it, each embracing a pin attached to a separate half-nut sliding between guides on a square double-threaded screw, cut both right and left-handed, so that only diamond-shaped pieces are left as threads. One nut is right-handed and the other left, so that when the wheel is moved the nuts travel in opposite directions and turn the rudder by a couple of nearly balanced forces.

1054. Stern model with screw steering gear. (Scale 1 : 4.) Presented by Messrs. R. Napier and Sons, 1867. N. 1169.

This represents the steering arrangement fitted by the donors to the mail S.S. "Ville de Paris," "Périere," (*see* Nos. 236), and many other ocean steamers.

The foremost steering wheel has an ordinary chain pulley, loose on its shaft, but which can be secured to it by a clutch; from this pulley a chain leads to a double block and tackle at the tiller in the usual way.

In rough weather this arrangement is discarded, and both wheels are used to work the more complex and powerful gear. This consists of a steering shaft, screwed with a single right-handed square thread screw for half its length, while the other half is left-handed. On each of these threads is a long nut sliding on parallel guide-rods and connected by links to a double-armed lever on the head of the rudder-post. Both screws tend to turn the rudder in the same direction by balanced forces, as in Murray's arrangement (*see* No. 1053).

1055. Model of hydraulic steering gear. (Scale about 1 : 24.) Received 1907. N. 2449.

The apparatus shown was patented in 1877 by Messrs. A. Lafargue and C. Martin and was adopted on the Thames, repeated failures of steam steering gears about this time having brought the subject into notice.

On the deck of the vessel is fixed a cylinder, to the piston of which is attached a trunk or hollow piston rod and to the rod a crosshead working in fixed guides. Securely fastened to the rudder-head is a helically grooved collar, in the grooves of which work friction rollers attached to the crosshead so that the elevation or depression of the crosshead and trunk produces a circular motion in the rudder. Rotation of the piston and crosshead is prevented by the guides. The under side of the piston is always open to an accumulator, the water in which is at constant pressure, whilst the upper side can be put into communication with the pressure or exhaust by means of a slide valve controlled by the steering wheel. As the area of the upper side of the piston is considerably greater than that of the under side, the admission of water under pressure to the former causes a downward movement of the piston. When the upper side is in connection with the exhaust there is an upward movement and a contrary motion on the rudder. To indicate the angle of the rudder at the steering platform, a chain passes in opposite directions round a quadrant fixed to the rudder-head, and thence round a quadrant on a hollow vertical rod, which has a lever at its lower end and communicates with the indicator at its upper end. The lever is connected with a crank on the valve spindle and this arrangement acts as an automatic cut-off to the slide valve. The gear is controlled by means of a second crank attached to the valve spindle, operated by the steering wheel through an inner vertical rod.

In case the rudder should be struck by a heavy sea, a cylinder relief valve is provided which opens inward and allows the water to flow back into the accumulator. The hand pump shown is for raising pressure in the accumulator. It is stated that the amount of water required is so small that about 5 gal. will suffice to work a vessel of from 1,000 to 5,000 tons.

1056. Archer's steering gear. Lent by the Dunstan Engine Works Co., 1883. N. 1591.

This is a neat and compact application of epicyclic gearing, patented by Mr. Thomas Archer in 1882 by which the motion from the hand-wheel to the sprocket-wheel of the tiller-chains is so reduced as to give sufficient power, while at the same time the gear is self-holding.

To the shaft of the steering-wheel is secured an eccentric, on which runs loosely a spur-wheel of 27 teeth; this wheel has an arm extending from it which passes down the supporting column and is steadied by a fixed pin at the lower end. The chain wheel runs loose on the shaft, but on its side has an internally geared spur-ring, containing 30 teeth, which is driven by the teeth of the wheel on the eccentric shaft, the result being that 10 turns of the hand-wheel are made to one turn of the tiller-chain wheel.

1057. Model of hydrostatic steering gear. (Scale 1 : 16.) Lent by Admiral E. A. Inglefield, R.N., C.B., F.R.S., 1871. N. 1331.

This apparatus was fitted in 1869 to H.M.S. "Achilles," a battleship of 6,121 tons displacement launched in 1863. At that period sails were much used by warships, so that although steam had been successfully applied to steering, it was considered that such power would not be at all times available; to overcome this difficulty Admiral Inglefield invented the gear shown, in which water entering the ship supplies the motive power, and the floating vessel becomes a form of hydraulic accumulator.

The pressure due to the difference in level of the water in the bilge and that outside (about 8 lb. per sq. in.) moves a large piston, the rod of which extends in both directions so as to form rams that give a hydraulic pressure of 600 lb. per sq. in. This pressure-water is conveyed to two hydraulic cylinders connected to a Rapson's slide actuating the tiller. The used water, that is necessarily discharged into the bilge, is removed at intervals by the ordinary pumping arrangements of the vessel.

1058. Steering gear. Lent by D. S. Porteous, Esq., 1890. N. 1839.

This alternatively hand or steam gear was patented by Mr. D. W. Porteous in 1886, and embodies a winch mechanism patented by him in 1884–5.

When used as a manual gear, the effort exerted on the steering wheel is transmitted by spur gearing to a lower shaft on which is an eccentric. Running loose on this eccentric is a double spur ring, which gears into an internally toothed ring secured to one of the standards of the machine, and also with an internally toothed ring formed in the boss of the sprocket wheel that controls the tiller chain; the gearing and this epicyclic train causes the tiller chain drum to revolve at one-tenth of the speed of the steering wheel.

When used as a steam gear, the change-over is effected by a sliding clutch, worked by a small horizontal hand-wheel at the top of the casing. The power is given by a pair of diagonal cylinders 4 in. diam. by 5 in. stroke, at the forward end of the machine; to secure compactness the piston-rods terminate in kite-shaped loops in which swing the return connecting-rods, and these act on a crank fixed on the shaft of the epicyclic gearing previously described. The steam cylinders have simple slide valves worked by a single eccentric, but this eccentric is carried on a block and is capable of being moved across the shaft between the positions for forward and backward gear. This motion is given by a radial screw, driven by bevel gear from a loose sleeve that is rotated indirectly by the steering wheel; when the steering wheel is moved in one direction, a corresponding movement takes place in the position of the eccentric, and the steam gear starts; but, as the engines revolve they carry round the eccentric sheave and so cause a relative motion, that, if the steering wheel remain stationary, will screw the eccentric into the mid-gear position again and so stop the motion.

In additional to this differential arrangement there is an extension from it, which automatically cuts off steam from the engines except when they are called upon to do steering work.

The steering wheel shaft is fitted with stops and a sliding nut, to prevent damage by over-running the limits; there is also a small indicating finger which constantly shows the position of the rudder.

1059. Sectional model of steam steering gear. (Scale 1 : 2.) Made by the Harrison Patent Steering Engine Co., 1894.
N. 2038.

In this small steam "quartermaster" the chains from the tiller are led to a helically-grooved barrel, to the shaft of which a worm wheel is secured. Above the wheel is a worm, formed on the crank-shaft of a double cylinder horizontal engine with cranks at right angles. Each cylinder has a piston valve, driven by an eccentric without lead, and the engine is reversed by interchanging the steam and exhaust passages.

The steering wheel is carried on a small box above the steam chest, and by worm gear rotates a circular slide valve. This slide valve rests on a circular disc or valve, provided with ports that correspond with ports on the steam chest face, and this disc is secured to a vertical spindle below, which through bevel gear is rotated by the chain barrel. When standing, the upper valve closes the ports in the lower one; any rotation of the upper valve lets steam through, and past the lower one into the valve chests and cylinders, so causing the engine to run. In so running, however, the lower valve is slowly carried round by the engine until its motion has closed the opening that resulted from the movement of the upper valve and the engine stops. Rotating the upper valve to the right lets the live steam into the ends of the piston valves, and places their centres in communication with the exhaust; movement in the opposite direction places the ends to exhaust and the centres under steam, so causing a reversal of the engine.

1060. Diagrams showing steering arrangements of warships. (Scales 1 : 12 and 1 : 24.) Made by the Admiralty, 1887.
N. 1800.

The two upper diagrams show the steering arrangements on vessels of the "Inflexible" type.

The gear is alternatively hand or steam, the latter being wholly below the protective deck for use in action, while the hand gear is in a poop house. The steam gear can also be used as a hand gear.

The tiller is held by a socket, through which it slides as it is put hard over. The tiller chains, which are attached by right and left-hand adjustable screws, are led by pulleys along the starboard side; there is a locking plate to the rudder head.

The two lower diagrams show in elevation and plan the arrangement on vessels of the "Admiral" class. Steering is performed by a form of Rapson's slide moved by either steam or hand power from the lower deck forward or aft, or by steam alone from either of the conning towers.

The rudder is double with the two posts connected by links, and there is a locking plate. The tiller is embraced by a socket, as above, while the chain lies in a slide and is continuous, passing over sprocket wheels arranged at the quarters and driven from below by the steering engine on the after lower deck. Connections from this engine are made by bevel gearing and shafting, led under the deck beams to clear the funnel hatches. The whole of the gearing in this design is protected.

1061. Diagrams of the steering arrangements of H.M.S. "Daring." (Scale 1 : 6.) Contributed by Messrs. John I. Thornycroft & Co., 1895. N. 2059.

This torpedo-boat destroyer is fitted with twin rudders of the balanced type, placed outside and abreast of the twin screw propellers; the outer edges of the screws revolve within 3 in. of the faces of the rudders, which are curved to correspond. These rudders are turned simultaneously, by means of worm quadrants driven by a worm-shaft connected with a steam steering engine. By arranging the quadrants on alternate sides of the worm shaft the end thrusts neutralise.

The extreme helm angle is 35 deg. and a complete circle is performed in 1 min. 27 secs. with a diam. of about 3·5 times the vessel's length.

Owing to the great pressure upon the rudders at full speed, the rudder-heads are of solid steel 7 in. diam. It has been found that twin rudders offer their least resistance to progress when inclined at 7 deg. to each other, the after edges being the nearer.

1062. Buffer for tiller chain. Lent by Messrs. Loveridge, Ltd., 1902. N. 2290.

Buffers of coiled steel spring have for a considerable time been inserted in the chain, between the tiller and the steering engine, with the object of minimising the stresses resulting from the rudder being struck by a heavy sea.

The small example shown, which is for insertion in ·75-in. diam. chain, embodies improvements patented by Mr. T. Loveridge in 1899, by which the spring is protected from entanglement and from corrosion by being enclosed in a cylinder of oil. One end of the buffer spring beds upon one cover of an oil cylinder while the other end of the spring abuts upon a slack piston, the rod of which passes within the spring and through a stuffing-box in the cylinder cover. The chain is connected to the rod and to one end of the cylinder in such a way that any excessive stress, due to shock in the chain, compresses the spring, but the ordinary travel of the chain in steering is not interfered with, as the cylinder is free to travel on rollers on its bed. An accompanying drawing shows this buffer in longitudinal section.

1063. Model of Rapson's slide steam steering gear (working). (Scale 1 : 12.) Made in the Museum from information supplied by the Admiralty, 1908. Plate XII., No. 1. N. 2453.

This gear was patented by Mr. J. Rapson in 1839, as a hand gear, to remedy the trouble caused by the slackness of tiller ropes due to the fact that whereas the end of the tiller moves in an arc, the ropes work in a straight line. It has the advantage of being compensating, although in its earliest form it was designed to provide uniform turning moment. The model illustrates the gear and adjacent ship structure of one of the "Formidable" class of battleships.

A long and heavy tiller is attached by parallel rods to a cross-head on the rudder spindle. The forward end of the tiller is of parallel section and passes through a saddle which is free to swivel inside a block which can only move transversely. To the ends of the block is attached a sprocket chain of heavy design, which passes over guide pulleys at the ship's sides and under a sprocket wheel at the centre line of the vessel. The sprocket wheel can be actuated either by steam or by manual power, the general arrangement of both these methods being very similar to that shown in No. 1064. Provision is made for tightening the chain by inclined bottle-screws and guide pulleys, the latter being attached to the casting carrying the sprocket wheel. Side thrust is provided for by grooved gun-metal guides carried by a special frame. The maximum angle of inclination of the rudder is 35 deg. on either side of the mid-position. In common with other well-known gears, however, this one is reversible, a disadvantage which is provided for, as far as possible, by fitting a friction brake to hold the rudder in case the sprocket chain or wheel should break. This brake is also required to hold the rudder when the gear has to be changed from hand to steam or *vice versâ*. It consists of three fixed horizontal plates fastened to the ship's sides, and embraced by four small sliding plates hanging from a bracket which is attached to the under side of the saddle plate. This bracket and its connections slide with the tiller. The plates are gripped together by two lugs, whose upper ends are forked and contain nuts on a screwed shaft in the bracket. One half of the shaft has a right-handed thread and the other half a left-handed one, hence when this shaft is rotated through the medium of bevel wheels, the lugs, whose fulcra are at their centres, close on the friction plates or *vice versâ*. A hand-wheel applies the brake, but its actual position on the ship is on a longitudinal bulkhead considerably further forward.

This model also shows constructional details of the vessel, which has an arched or overhanging stern. A steel casting forms the rudder-post and heel; this is connected with the hull by the ordinary shell-plating and also by a special horizontal steel plate, 2 in. thick, which rigidly joins the two lower arms of the casting and extends sufficiently forward to make a good connection with the vertical keel. It likewise forms a suitable palm-plate for the lower scarf of the propeller brackets. Strong, closely-spaced plate-frames, fitted vertically below this plate, give further stiffness to the overhanging heel; the cellular spaces beween the frames are usually filled with a mixture of cement and coke.

For a separate model of the stern casting, *see* No. 706.

The steering flat itself is about 13 ft. below the normal water-line of the ship and about 9 ft. below a curved protective deck, 2·5 in. thick; a portion of this deck is represented at the extreme after end of the model.

The gearing, through which the hand-wheels or either of the two steam steering engines actuate the main driving shaft, is not shown, but would be placed in the rectangular recess, or well, partially indicated at the forward end of the steering flat.

1064. Model of Harfield's steam steering gear (working). (Scale 1 : 8.) Made in the Museum from drawings supplied by Messrs. Harfield & Co., 1901, Plate XII., No. 2. N. 2262.

The model represents, in detail, the modification of this type of gear adopted in a cruiser with double rudders, but if the lower links are disconnected, it shows the simple arrangement used for a single rudder.

The rudders shown are of the balanced type, and the weight of each is carried by a casting attached to the rudder-head and capable of turning on a circular channelled slide secured to a horizontal table forming part of the main stern casting. The heads of the main and auxiliary rudders are connected by parallel links to a supplementary head to which is keyed a quadrant taking the place of a tiller. This quadrant is formed as a toothed rack engaging with a driving pinion keyed eccentrically on a vertical shaft from which the steering effort is received; this mechanism constitutes the compensating gear, since when the rudders are amidships the longest radius of the pinion is acting on the rack, while when the resistance of the rudders increases, through their being set over, the acting radius of the pinion is in the meantime diminished, so that approximately the same steering effort is required throughout. The shaft of the eccentric pinion is driven by a horizontal bevel wheel, secured to it and engaging with the driving shaft which is common to both the hand and the steam operated gears.

The hand gear is separated from the steering mechanism by a watertight bulkhead, through which the driving shaft passes by a stuffing-box; three hand-wheels are provided and their shaft is connected to the driving shaft by spur gearing having a ratio of 1 to 4 and so arranged as to increase the turning effort exerted. To the hand shaft is also fitted a friction clutch controlling gear, patented in 1894 by Mr. W. H. Harfield, which automatically checks any tendency of the rudders to take charge should they be struck by a heavy sea. It consists of a friction disc and two loose pawl wheels placed between two fixed collars on the shaft; the pawls are arranged as nipping levers acting in opposite directions, and the friction disc is, by an internal screw which carries the driving pinion, forced against one or other of the discs, so securing it to the shaft; the one thus secured acts as a ratchet wheel in preventing the reverse motion until it is automatically released by any movement of the hand-wheel. Eight complete turns of the hand-wheel suffice to move the rudder from the central position to the maximum angle of 35 deg. on either side, and there is an index finger near the hand-wheel which shows the position of the rudder; there is also a travelling nut on the hand-shaft which engages with safety stops when the maximum angle is attained, and there are also projecting stops on each side of the main rudder frame.

For locking the rudder head in any desired position two arrangements are provided. The first is a hydraulic brake patented by Mr. W. H. Harfield, in 1895, which consists of an oscillating cylinder containing fluid and provided with a bye-pass controlled by a valve, while the piston-rod is connected to the head; the other arrangement consists in the provision of suitable holes through which locking pins can be passed so as to connect the heads with the deck plates.

The whole steering mechanism is carried upon a combination of deep transverse girders and crown plates, extending the full breadth of the vessel and riveted both to the side and the deck plating. A number of the plate frames supporting the steering flat are shown, and these indicate the general character of the ship's framing in this locality; the model also shows the usual method of connecting the cast steel stern post with the flat keel plates, the vertical keel, and the transverse framing of the ship. To protect the steering arrangements from gun fire they are arranged below the water-line and completely covered by a 2-in. protective deck made in two thicknesses.

1065. Model of steam steering engine (working). (Scale 1 : 4.) Made in the Museum from drawings supplied by Messrs. Bow, M'Lachlan & Co., 1903, Plate XII., No. 3.
N. 2327.

This represents the steam steering engine fitted to H.M.S. "Gladiator," built in 1896; similar engines are now generally employed in all large vessels to supply the power necessary for rapidly moving the rudder, while being capable of control from a steering wheel on the bridge and also from below the water level. For many years steering engines for warships were arranged horizontally and in a separate compartment, but space is now saved by fixing the engine in the main engine-room on a vertical bulkhead, as shown, specially stiffened to prevent vibration.

The essentials for such an engine are, that it should continually follow the movement of the steering wheel, both in amount and direction, so that by its aid the rudder can be placed and retained in any position by the slight effort necessary to move the small wheel controlling the steam supply. There are many arrangements for obtaining this result, but the principle in all is the same, namely:—that the engine as it revolves always tends to undo the change made by the movement of the steering wheel.

The steering engine represented has two simple cylinders 8 in. diam. by 9 in. stroke, each provided with a piston slide valve and a single eccentric set without lead. Control and reversal are effected by a third piston valve known as the "differential" valve, which is arranged between the two cylinders; it is without lap, and its function is to interchange the steam and exhaust connections of the ports to the valves of the cylinders. When the steering wheel is turned, it screws the differential valve from its middle position, thus allowing steam to pass to the cylinder valves and causing the engine to rotate. This motion of the engine, however, commences to again close this central valve, owing to a worm on the crank-shaft being in gear with a worm-wheel which acts as a nut for the screwed end of the valve spindle, so that the nut being fixed laterally, the valve is screwed back to the mid or closed position. The engine is connected with the mechanism working the rudder by the large shaft, shown broken off, on which is a heavy worm-wheel gearing with a worm on the engine crank-shaft.

An indicator shows the number of turns of the steering wheel that the rudder is from its mid position, eight being sufficient to place the rudder from hard over to hard over; safety stops are provided which, at the limits, prevent further motion of the steering wheel. As the engine has to work with steam from the main boilers, it has to be capable of standing high pressure, the present example using boiler steam of 300 lb. reduced by throttling to 200 lb. A sectional elevation through the valves is shown on an accompanying drawing.

Another working model shows to a smaller scale the steering gear and rudders which this engine is employed to drive, and also the hand gear that is provided for use should manual power have to be resorted to (*see* No. 1064).

CAPSTANS, WINCHES, ETC.

The capstan, with its vertical drum and numerous long radial arms, is the most elementary device for using the advantage of a lever for the exertion of great hauling power. The arms are about 10 feet long and of considerable number, while on ship-board there may be arms at two or more decks, so that it is possible to employ the effort of as many as 100 men in this way for special purposes. Backward motion is prevented by pawls dropping into teeth fixed to the deck, but the arrangement possesses a serious element of danger owing to the consequences that follow the breaking of the hauling rope or its blocks. Some efforts have been made to construct geared capstans, but the introduction of steam power has generally resulted in the abandonment of an arrangement that occupies such a serious amount of deck room as does any form of hand capstan.

The windlass, or horizontal arrangement of the capstan with loose bars, is much more compact than the vertical form, but cannot employ many men; it, however, readily admits of the introduction of gearing and so becomes the winch, in which the convenient short handle is used to obtain a powerful, though slow, haul. The general application of steam power to winches and capstans is at the present time being superseded by electrical power on board ship, and electric motors are taking the place of steam engines for modern capstans.

For lifting cargo some form of jib or derrick to support the overhead pulley is necessary, but a form of automatic derrick, known as the Temperley transporter, is now successfully used. By its aid the load is lifted, then moved horizontally any required distance, and finally lowered, all by the motion given to the lifting rope of a single winch or jigger cylinder.

The modern steam capstan or windlass for anchor cables (*see* No. 1069), in addition to its hauling capabilities, also controls the cable while being run out and holds it where required, but to give further security when anchored the cable is usually given one or two turns round a massive post, called a "riding-bitt," which is fixed to the anchor deck.

1066. Model of geared capstan. (Scale 1 : 8.) Presented by Messrs. Bullivant & Co., 1902. N. 2284.

The capstan type of lifting or hauling appliance, now so generally adopted on ships, is believed to have been introduced into this country from Portugal in the 16th century. It then consisted merely of a vertical post turned by bars fixed through the head, but from it the later shape represented in the model has been developed.

The winding drum, or barrel, has its diameter increased by the addition of a number of renewable ridges or "whelps" tapering upwards, which, in addition to increasing the grip of the rope, facilitate its surging upwards while being wound on. The drum head is provided with sockets into which removable capstan bars are fitted, so that the space occupied when not in use can be greatly diminished; at the lower end of the drum is a series of reversible pawls of different lengths engaging with a fixed spur ring secured to the deck, so that accidental backward motion is promptly prevented and the drum can be retained in any position.

The example shows, moreover, the addition of gearing to further increase the mechanical advantage derived from the use of levers, an extension which, with the application of an epicyclic train, was patented in 1819–27 by Captain C. Phillips, R.N. In the model ordinary gearing is employed and the head, which, by lifting a pin, can be unlocked from the barrel and the gearing thrown into action, can revolve at three times the rate of the barrel; in Phillips's capstan the gearing increased the advantage in the same ratio.

1067. Model of elastic windlass for ships. (Scale 1 : 8.) Contributed by W. H. Muntz, Esq., 1862. N. 785.

This was introduced in 1860 by Mr. Muntz as a means of reducing the shocks experienced by a cable when holding a vessel at anchor.

The windlass is mounted on horizontal rods, which are bolted to the riding bitts secured to the deck. On the rods are buffer springs of steel or rubber which take up the strain on the windlass.

1068. Model and drawing of Baxter's cable windlass. (Scale 1 : 12.) Lent by H. C. Baxter, Esq., 1898. N. 2161.

This form of vertical windlass for working anchor cables, introduced by Mr. S. Baxter, was first adopted in the British Navy on the "Admiral" class of battleships. Power is supplied by a double cylinder engine driving, through bevel gear, a horizontal shaft that, by a single worm, rotates two chain drums; a bevel pinion on this shaft drives also a capstan for general purposes, in which rope is used and less power required. Reversal of the motion is accomplished by a claw clutch on the crank-shaft, by which either of the two bevel pinions can be made the driver. In an adjacent drawing a reversing engine is shown, which is arranged below the deck.

To prevent excessive stresses on the cable, through shock, the sprocket drum of each windlass is connected to its gear-driven vertical shaft by friction discs, forming a "Weston's" friction clutch. The closing pressure is applied by a cap screwed on this shaft and rotated by a suitable lever.

The cable from the locker passes through a hole in the casting, then round the windlass, and along to a stopper fixed on deck close to the hawse pipe. This stopper forms an inclined guide for the cable, but has a portion fitted with a lowering lever, which when depressed allows the link on it to drop into a recess resembling the space on a sprocket wheel; by this means the cable may be temporarily held while making fresh connections.

The rope capstan is fitted on the top with two plugs which act as drivers; by removing these the capstan can be worked independently with handspikes.

1069. Model of "overlead" cable windlass (working). (Scale 1 : 8.) Made in the Museum from information supplied by Messrs. Harfield & Co., 1909. Plate XII., No. 4. N. 2513.

With the application of the stockless anchor to vessels of the mercantile marine, it was found desirable to modify the existing type of "underlead" windlass, in order that a direct pull might be obtained on the anchor when stowed in the hawse pipe, The present type of steam windlass was introduced by Mr. W. H. Harfield for this purpose. In the model shown, the cables from the hawse pipes pass over the tops of the cable-holders, and thence through chain pipes formed in the bed-plate into chain lockers directly underneath. In the "underlead" type of windlass the direction of the out-going cable as it leaves the cable-holder is horizontal. This arrangement allows a much larger portion of the circumference of the cable-holder to grip the cable than in the type illustrated, but this advantage has been sacrificed in order to obtain the inclined direction of the out-going cable.

The main bearings and standards form part of the bed-plate and the standards also contain bearings for the intermediate shaft. The engines are of the vertical type with a cylindrical reversing valve (on the model the chest of this valve is shown in section). Reversal is effected by interchanging the steam and exhaust ports of the cylinder valves. This is accomplished by altering the position of the reversing valve by means of a screw and hand-wheel.

On the crank-shaft is a steel pinion gearing into a shrouded spur wheel on an intermediate shaft. This shaft also carries two steel pinions gearing into large purchase wheels with shrouded teeth, keyed to the main windlass shaft. A very large mechanical advantage is thereby obtained. To prevent the windlass taking charge, *i.e.*, being pulled round by the strain on the cables, each of the purchase wheels is fitted with a monkey pawl consisting of two wrought-iron side plates with flanges projecting inwards to overlap the flanges of the purchase wheel. Two small bolts hold the plates loosely together, whilst a large bolt forms the axis of the pawl lever. The pawl allows the purchase wheel to revolve in one direction only; when it is required to reverse the windlass, the pawls are tripped, *i.e.*, lifted out of action by means of cams placed underneath them, which are worked by a lever at the side of the windlass.

The cable-holders on the main shaft are fitted with frictional disc connectors (one of which is shown in section on the model), patented by Mr. T. A. Weston in 1863, and modified by Mr. Harfield in order to adapt them to windlasses. Each connector consists of 16 discs alternately connected to the cable-holder and to the boss of the purchase wheel by feathers. Tightening is effected by a hand-wheel, which, with a square-threaded brass sleeve loose on the shaft, forms a screw fixed in position. The nut consists of a circular plate connected with another plate at the end of the frictional discs, these two plates enclosing and gripping the discs, when the hand-wheel is rotated. By this means, each of the two cables can be worked independently; also, the cable-holders rotate idly on the shaft when the frictional connectors are free. Strap brakes are fitted to the cable-holders to enable the cables to be checked when veering. Barrels are fitted to the intermediate, or counter shaft for quick warping.

This type of windlass is made in sizes suitable for cables of from ·75 in. to 3·125 in. diam., corresponding to pulls of from 3 to 60 tons. The model represents a windlass giving a pull of 30 tons at a speed of 30 ft. per min., and using a cable of 2·625 in. diam., as fitted to the R.M.S. "Amazon."

1070. Model of picking-up gear for cable ship. (Scale 1 : 12.) Received 1909. N. 2531.

In this gear, for hauling inboard a faulty submarine cable, a winding drum receives motion, by means of toothed gearing, from a steam engine with two inclined cylinders. On the engine shaft there are two wheels of different diameters cast together, which can be moved along a feather by means of a hand lever, and either wheel thrown into gear with its corresponding wheel on a second shaft, on one end of which is a pinion gearing with an annular wheel on the drum. This arrangement allows alternative speed reductions of 12 to 1 or 20 to 1 to be employed according to the nature of work to be executed. The drum is fitted with a powerful band brake which is controlled by a hand wheel.

The cable comes inboard over the bow sheave and, after passing over a guide sheave and under a sheave on a dynamometer which indicates the tension, makes three or four turns round the drum, whence it proceeds over a hauling-off sheave to the cable tank. The last sheave is so connected with the drum by gearing that its circumferential speed slightly exceeds that of the drum, while fitting into a groove on the sheave is a jockey wheel mounted on a lever carrying a weight. A pulling action is thus exerted on the cable which ensures that it is kept taut. To prevent the cable winding itself across the drum a fleeting knife—not shown in the model—is provided. This has a curved face and is placed near the drum on the side to which the cable is fed and continually moves the coils sideways across the drum.

On repair ships this gear is also employed for paying-out cable from the bows. For this purpose the engine is disconnected from the drum, and as the hauling-off sheave must now hold back the cable to keep it taut, the circumferential speed must be less than that of the drum. It is consequently thrown out of gear with the latter and controlled independently by a small brake.

ANCHORS, CABLES, ETC.

Anchors.—The earliest form of anchor was a stone or other weight to which a rope was secured, so that when resting on the bottom it was capable of offering sufficient frictional resistance to prevent a vessel from drifting. By enclosing the stone in a wooden frame provided with projecting teeth, as shown in some of the Chinese models, an additional ploughing action was secured which greatly increased the holding power; in all modern anchors the design is such as to insure this action under all circumstances.

The principal parts of an anchor are: the vertical stem or "shank," the "arms" with their terminal blades or "flukes," and the cross-bar or "stock" which prevents the anchor from being dragged flat-ways along the bottom.

An anchor of about B.C. 50 was constructed of lead, but was of the ordinary shape except that the ends of the arms were not widened out into flukes; after the general introduction of iron for anchors but little further change took place till the present century, when the introduction of the steam hammer and the employment of ingots of mild steel facilitated the construction of larger types.

In addition to the common form of anchor, however, many descriptions of "patent" anchor have been introduced, some of which are now very extensively adopted. One of the most common of these has the two arms as a separate forging pinned to the shank so that it can swing to some extent; in this way a good bite is obtained, while the upper fluke is occupying a position in which the chance of its being fouled by the cable is greatly reduced. This arrangement was first patented in 1838 by W. H. Porter, and was subsequently improved by J. Trotman and others.

Another class of "patent" anchor is the "self-canting," and therefore usually "stockless," variety in which the arms are so swung that they can both bite into the ground together. The first anchor of this type was patented in 1821 by R. F. Hawkins, but it was many years later before such an arrangement was successfully introduced. An incidental advantage of these anchors is their great compactness and the consequent ease with which they can be stowed.

For mooring purposes, the wedge clump anchor (*see* No. 1093) has been found satisfactory. This type of anchor gives good holding power in soft muddy bottoms.

The size of anchors has steadily increased; the bower anchors of the "Great Eastern" each weighed 5·4 tons, while the centre bower anchor of the "Olympic" weighs 15·5 tons, and the two side anchors 8 tons each; the sheet and spare anchors in H.M. Navy usually weigh 5 tons each.

Anchors only possess considerable holding power if the pull of the cable is nearly horizontal, so by hauling in the cable until the pull becomes more nearly vertical an anchor breaks from its ground and can be lifted.

Cables.—The earliest cables appear to have been of hide or animal membranes, then of flax or hemp, and possibly some were of bronze chain; in modern times cotton, hemp and jute have been used, but iron chain is the material now generally adopted. Such iron cable was tried and advocated by Commander Sir S. Brown, R.N., about 1810, but it met with great opposition largely due to its uncertain quality; he, however, in 1812, constructed a machine for testing the links, and generally developed the manufacture of chain into a successful industry.

The cable in general use is of either the short link or the stud link variety; in the former the links are so short that there is only sufficient room in them for the loops of the adjacent links, while in the stud link the length is increased by the diameter of a transverse stud which, in addition to keeping the links in their correct positions, also struts the longer link thus permissible. The stud chain is considered to be 10 per cent. lighter than the close chain of equivalent strength.

1071. Models of Belcher's anchors. (Scale 1 : 12.) Contributed by Admiral Sir E. Belcher, K.C.B., 1876. N. 1455–6.

This anchor was designed in 1815 by Sir E. Belcher, then a midshipman. The two arms are forged together, and turn in a fork formed in the shank, as in the Porter anchor introduced in 1838; but the form of the arms does not reduce the risk of fouling, as does that of Mr. Porter. Another model shows a temporary anchor, prepared from one of these pairs of arms, three kentledge blocks, and a shackle.

1072. Model of Hawkins's anchor. (Scale 1 : 12.) Presented by the Commissioners of Patents, 1863. N. 886.

This anchor, patented by Mr. R. F. Hawkins in 1821, introduces the leading features of most of the modern stockless anchors. The shank terminates in a large eye, through which the forging forming the two arms is passed; the flukes are then inserted in the ends of the arms and secured. A separate pair of arms keeps the main arms in position, and also forms a pair of toggles which causes the flukes to dig into the bottom; the toggles also acted as stops to limit the cant of the arms. Hawkins pointed out that by the arrangement both flukes were utilised, the anchor required no stock, and that the risk of fouling was obviated. The anchor was not appreciated at the time, although its features are now found in several leading forms.

1073. Model of Admiralty pattern anchor. (Scale 1 : 12.) Presented by the Lords of the Admiralty, 1864. N. 1004.

This is generally known as Sir W. Parker's anchor, and was introduced into the Royal Navy about 1840, replacing the old long-shanked anchor, upon which it was a slight improvement. The arms are curved and the length of the shank is three times the length of each arm. The stock is formed of two beams of oak, hooped together; the spare stocks, which were always carried, were frequently used for "fishing" masts and similar repairs. The largest of these anchors weighed five tons.

1074. Model of Rodger's hollow-shanked anchor. (Scale 1 : 4.) Presented by Lieut. Wm. Rodger, R.N., 1857. N. 81.

This modification of the Admiralty old pattern anchor was patented by Lieut. Rodger in 1828. Instead of a solid shank, it has a shank formed in two bars, the space between them being filled with a piece of oak; the compound member is then clamped together by wrought-iron hoops. A 25 cwt. anchor of this style was constructed, but the arrangement was not generally adopted.

1075. Models of Rodger's anchors. (Scale 1 : 4.) Presented by Lieut. Wm. Rodger, R.N., 1857. N. 82–4.

These four models illustrate modifications in the Admiralty anchors, patented by Lieut. Rodger between 1833 and 1846. At the earlier date he proposed using very small spade-shaped palms, and one model shows for comparison an Admiralty anchor in which one of the palms has been reduced as proposed. The other models show modified palms in which the size is increased; they are similar to the then Admiralty pattern, but the flat face of the flukes is outside. A metal stock of triangular section is used, in which one flat face is uppermost; the stock is also forged with an eye through which the shank is passed aud then secured with a cotter.

1076. Model of protected anchor. (Scale 1 : 12.) Presented by the Commissioners of the 1851 Exhibition. N. 446.

This anchor, patented in 1836, is of the usual pattern, but has two iron rods running from the corners of the palms parallel with the arms, so as to reduce the probability of the cable fouling the upper fluke. A similar anchor was introduced by Mr. Isaacs, and tested in the official experiments of 1852.

1077. Models of Aylen's anchor. (Scale 1 : 6.) Presented by Capt. J. Aylen, R.N., 1862. N. 814–5.

These two modifications of the Admiralty pattern anchor were tried in some official experiments in 1852; the results were considered to be somewhat better than those obtained with the standard form, from which, however, the designs but very slightly differ.

1078. Model of Trotman's anchor. (Scale 1 : 8.) Presented by J. Trotman, Esq., 1862. N. 817.

This very successful anchor was patented by Mr. Trotman in 1852, as an improvement on the anchor patented by Mr. W. H. Porter in 1838, which patent was subsequently extended for six years. The arms are forged in one piece, which is carried on a pin that secures it in a fork formed in the lower extremity of the shank; this arrangement allows the lower fluke to dig deep into the ground, while the upper one closes down on to the shank, and so reduces the chances of fouling and other risks. The improvement introduced by Mr. Trotman consisted in forming the palms with large external projections, which insured that the arm canted in the way necessary for holding.

The model represents a bower anchor of H.M. yacht "Victoria and Albert," but to a scale of 1 : 12 it would represent one of the bower anchors of the "Great Eastern," weighing 5·4 tons.

1079. Model of Roberts's anchor. (Scale 1 : 12.) Contributed by Richard Roberts, Esq., 1858. N. 175.

This construction of anchor was patented by Mr. Roberts in 1852. The leading feature of the arrangement is that, instead of making the anchor of solid forgings, it is built up of thick plates, riveted together but separated by distance pieces. The arms are formed of two plates, and the palms by two other plates riveted to them; the shank is of two plates, connected by distance pieces, and at the upper end twisted in such a way that the stock, which works between them, shall, when lowered, be in the same plane as the arms, so as to reduce the space occupied. The arms are of the oscillating type introduced by Mr. Porter.

1080. Martin's anchor. Contributed by E. Rettig, Esq., 1860. N. 444.

This is a small example of the early form of anchor patented by Mr. F. Martin in 1859. The shank is forged with a fork at the lower end, in which are large eyes through which the arms can be passed. In the jaws of the fluke is placed a "throat piece," into which a projection of the arm engages, so that this piece forms a stop for the arms. The arm forging is prevented from moving sideways by two side plates, while projections on the throat piece secure the canting of the flukes. At the upper end of the shank is a small curved stock, cottered in. The anchor weighs 140 lb.

1081. Model and photograph of Peacock's anchor. (Scale 1 : 4.) Contributed by Capt. G. Peacock, R.N., 1861. N. 435.

This is a single fluke anchor, patented by Captain Peacock in 1861. The shank is formed of two plates, between which swings a single palm provided with toggles to insure the correct canting. At the side of the shank are two loops which act as a stock, although arranged at the lower end. A photograph of an actual anchor of this construction is also shown.

1082. Model of Hunter's anchor. (Scale 1 : 4.) Presented by Samuel Hunter, Esq., 1862. N. 825.

This early form of self-canting anchor was patented by Mr. Hunter in 1862. The shank is forged with a large loop, in which can swing a bar that connects the two arms, close to the flukes. The central portions of the arms are halved together and secured by cotters, and in this way are got into position within an eye formed in the lower end of the shank. The connecting bar has its motion limited by two stops on the shank. and it transmits the stress from the flukes. A metal stock is fitted, which is of exceptional length.

1083. Coryton's anchor. Lent by J. Coryton, Esq., 1874. N. 1357.

This is a small anchor introduced by Mr. Coryton in 1869. The example, which is for use on a small boat, is constructed of cast iron, and is also exceptional in that the arms curve in the reverse direction to that usually adopted. The shank is in halves which, when bolted together, grip the shackle pin and also tbe journal of the double arm casting. Projections on the arms engage with lugs on the shackle, and thus limit the canting of the arms to 30 deg. on either side. It is claimed for the arrangement that it is less liable to fouling than the ordinary construction.

1084. Model of drogue or sea anchor. (Scale 1 : 12.) Made in the Museum from the designs of Prof. C. W. Merrifield, F.R.S., 1869. N. 1298.

The object of a drogue is to prevent a boat or vessel from drifting when in deep water, or to keep it head to windward. Many forms have been constructed, frequently during an emergency, but that represented consists of an equal armed cross, made with two spars, which extends a sail 10 ft. square. Ropes from the four ends of the spars are connected to a hawser about 100 ft. long. The whole is supported by a buoy which maintains it at a depth of about 30 ft., so as to be below the moving surface water. For a boat the anchor would be 2 ft. square.

1085. Models of Swinburne's anchors. (Scale 1 : 12.) Lent by Capt. T. A. Swinburne, R.N., 1877. N. 1471.

These two models represent anchors patented by Captain Swinburne in 1876. The shank is a square bar upon which the arms, which are in one forging, are slipped and secured by a through pin; the mooring strain is, however, taken by the solid end of the shank. The stock is a duplicate of the arms, and can be readily removed for storage; when turned it can be slipped down the shank so as to stow against the ordinary arms. In the second model the shank is twisted, so that in lowering the stock it automatically turns into the plane of the arms.

1086. Models of Wasteneys Smith's anchor. (Scale 1 : 8.) Lent by W. Wasteneys Smith, Esq., 1876. N. 1403.

This form of stockless anchor was patented by Mr. Wasteneys Smith in 1871, and he subsequently introduced several modifications. The shank has a cross arm fitted to it, bearing on a solid end, and secured by a cotter. The ends of the cross arm form journals that receive the two flukes, which are prevented from coming off again by cotters. These flukes have two projecting toggles, which secure their canting; being separate the flukes are able to cant independently. The degree of canting is limited to about 42 deg. each way by stops on the flukes, which engage with the sides of the cross arm. At the lower end of the shank is a fishing shackle, round which the anchor will balance.

1087. Models of Martin's anchor. (Scale 1 : 10.) Lent by C. Martin, Esq., 1874. N. 1387.

This improved form of the self-canting anchor shown in No. 840 was patented by Messrs. C. and H. Martin in 1872. Several methods of construction are described in the specification, but the model, which shows a 2-ton anchor, represents that generally adopted. The shank is formed with a large end, which is bored out, and on one side is further recessed so as to form two stops for a projecting lug on one side of the pair of arms. The arm forging is in one piece, and it is threaded through the hole into position, and there secured by a pin which drops into a recess in the bearing, and is fixed by the pin of the fishing shackle; the arrangement allows the plane of the arms to swing through an angle of 42 deg. on each side. At the upper end of the shank is secured a wide concave metal stock, which considerably increases the holding power. A second model shows the pieces separated.

1088. Model of Baxter's anchor. (Scale 1 : 8.) Lent by H. C. Baxter, Esq., 1898. N. 2160.

This represents a 2·5-ton trunnion anchor of the pattern introduced by Mr. Samuel Baxter in 1882. It has no stock, and is designed for being hauled directly from the bottom into its seating, formed as an enlarged hawse pipe in the bow of the ship, thus avoiding the labour of the usual operations of "catting" and "fishing." When so carried, the anchor is also ready for letting go at any moment.

The anchor consists of two steel castings, which form the flukes, and when bolted together enclose the trunnions that project from the forged steel shank. The flukes can swing through an angle of 45 deg. on each side, and are provided with projections that cause the anchor to bite when pulled horizontally, or will assist in breaking the ground when being lifted.

An adjacent photograph shows the bow of the Brazilian ironclad "Riachuelo," of 5,700 tons displacement, the first warship fitted with these anchors, which in this case weighed 3·3 tons each.

1089. Model of "Lenox" Royal Navy anchor. (Scale 1 : 24.) Presented by Messrs. Brown, Lenox & Co., 1908. N. 2466.

This represents a modern form of self-canting stock anchor used by the Admiralty, and contains improvements patented by Messrs. G. C. L. Lenox and D. Morris in 1886 and 1891. The crown and flukes, together with the two concave canting toggles are in one piece and form the arm casting, which is secured to the shank by a single pin. The stock has four arms, a modification patented in 1891. An additional grip is obtained by this means, as the small arms or projections of the stock take the unbroken ground between the flukes.

The model represents a 40-cwt. anchor.

1090. "Simplex" anchor. Lent by the Liquid Fuel Engineering Co., 1899. N. 2184.

The example shown is the smallest size self-canting or stockless anchor, constructed under the patent granted to Messrs. H. A. House and R. R. Symon in 1893. Such anchors are made in steel or bronze, and in sizes weighing from 4·5 to 224 lb.

The arms and flukes, together with the canting toggles, are first cast or forged in one piece. This is afterwards coated with fireclay and plumbago, and placed in a prepared mould into which the metal for the shank is subsequently poured, so that the shank-eye is cast round the middle of the arm. The whole anchor is afterwards annealed, to remove any cooling stresses, and is usually finished by galvanising.

1091. Model of Byers's anchor. (Scale 1 : 12.) Presented by Messrs. W. L. Byers & Co., 1904. N. 2357.

This anchor, patented by Mr. W. L. Byers in 1887 and improved in 1900–3, is of the self-canting stockless class. The crown and flukes, together with four canting toggles or tripping pieces, are in one casting which is secured to the shank by a single shrough pin. The trips are each made with a flat face which, when resting on the sea bed, support the crown, giving at the same time a downward direction to and pressure on the flukes so as to ensure their digging into the ground when the cable tightens. The anchor represented weighs 45 cwt.

1092. Models of Mitchell's mooring screws. (Scale 1 : 4.) Received 1899. N. 2201.

This modification of the screw pile, patented by Alexander Mitchell in 1833, consists of a single turn of a cast-iron screw of large diam. and small pitch, provided on its lower surface with a gimlet-point. In one example, the screw is fitted with a shank by which it may be rotated and thus force its way into the ground; the top of this shank is provided with a shackle and swivel for receiving the mooring chain. In the other example the screw has a short stem over which fits the socket used in sinking it, but which is afterwards removed, the mooring chain and buoy being then attached to the short chain secured to the screw. The serrated edge shown on these screws is a later improvement which was found to facilitate rotation and entrance in stony ground. One of these mooring screws, 4 ft. diam., weighs 11·5 cwt. and is used with a 1·25 in. diam. cable.

1093. Model of wedge-clump mooring anchor. (Scale 1 : 24.) Presented by Messrs. Brown, Lenox & Co., 1908. N. 2465.

The anchor represented was patented in 1901 by Mr. G. C. L. Lenox and is a development of the earlier mooring clump previously adopted by the

Admiralty. It was first used in the river Orwell at Ipswich on hard smooth ground and gave very good results even on such unfavourable anchorage.

The example shown is wedge-shaped, wider and deeper at the back than at the front, and has a shank hinged to the inside of the clump and working through a slot in the front of the anchor, which allows the shank to rise and fall through a limited angle. This construction prevents the anchor from turning over on its back, as sometimes happened in former mooring anchors, any such tendency being arrested by the upper part of the slot coming in contact with the shank. The liability to skid is similarly prevented by the lower part of the slot. In very rugged ground, a stock is sometimes added to a prolonged shank, as in such ground a tendency to turn over sideways has been observed.

It is stated that the holding power of these mooring anchors has been found to be at least three times that of some other forms. They are made in various sizes, weighing from 1 to 12 tons.

1094. Model of anchor and cat-head. (Scale 1 : 12.) Presented by the Rev. J. Hardie, 1866. N. 1106.

This shows the arrangement introduced by Mr. R. F. S. Blake for so carrying an anchor that it can be readily released; it very closely resembles the arrangement still generally used. The shackle end of the anchor is supported by a rope that passes over horns on the sides of a projecting beam known as the "cat-head," while the arms of the anchor rest on a sloping shelf, known as the "bill-board," on which they are retained by another rope. The ends of these ropes are secured by two levers, which are retained in position by two hand-levers, so that when the two hand-levers are pulled both ropes are released, and the anchor descends without any constraint in running out beyond that offered by the mooring cable.

1095. Model of anchor and cat-head. (Scale 1 : 12.) Made by the Admiralty, 1886. N. 1780.

This model shows the arrangement generally in use in H.M. Navy for carrying the bower anchors; it also shows the standard Admiralty anchor of 4 tons. The bill-board is similar to that of the earlier form, but is considerably smaller, while the chain by which the lower end of the anchor is secured is retained by a somewhat more compact arrangement of Blake's releasing levers. The "cat-head" is in the form of an iron davit, on the top of which is a similar releasing gear with a curved lever that extends to the bulwarks.

In getting the anchor up, the cable is continuously wound in until the ship is over it; the anchor then usually leaves its bed easily, and it is raised until above the water level. The small catting chain that is tied to the links of the cable for some distance is thus brought within reach, so that it can be passed through a block on the cat-head. By this chain the anchor can now be lifted higher, so that the fluke end can be hauled on to the bill-board by the "fishing" chain; this is provided with a large open hook by which the anchor is readily caught.

1096. Model showing method of carrying sheet and spare anchors. (Scale 1 : 16.) Presented by Sir C. Gage Brown, K.C.M.G., M.D., 1894. N. 2027.

The sheet anchor is the largest anchor carried, and owing to the limited space available is arranged abaft the fore rigging. In this position, however, some difficulty was experienced in lowering it clear of the ship until the arrangement shown, which was invented in 1842, by Capt. C. Brown, R.N., of Portsmouth Dockyard, was introduced, and which has since been universally adopted.

As shown in the model, the anchor is supported with its shank in a horizontal position, by two jaws carried by inclined rods which are hinged at their lower ends to the vessel's side. The anchor and these crutches are pulled toward the ship's side by two chains, retained by a trip gear by which both are simultaneously released: when this takes place the crutches, in lowering, throw the anchor from the ship's side before the shank leaves them. As the sheet anchor is but seldom used, temporary lashings are added by which the risk of accidental releasing is avoided.

1097. Chain cable and accessories. Lent by Messrs. Brown, Lenox & Co., 1892. N. 2003.

These are examples of the iron cable used for mooring, anchoring, or rigging purposes, together with the usual gear for manipulating, joining together, and temporarily securing the same.

Cables made of separate welded iron links were successfully introduced by Capt. Sir S. Brown, R.N., about 1812, and have now universally superseded those made of twisted cotton, hemp, or jute. The "stud-link" chain, formed by placing a cross bar or strut between opposite sides of each link, is the most approved pattern, being 10 per cent. lighter than the equivalent unstudded or close link type, without being any more liable to form that peculiar twist known as a "kink," which so reduces the strength of any chain or rope.

Mooring cables, secured by heavy anchors and sinkers, are placed at the bottom of harbours or roadsteads to form a permanent attachment for the buoys provided for vessels when ordinary anchorage is impracticable or undesirable.

Ships' cables, by which vessels are held at anchor, are usually made up of a number of lengths of chain of 12·5 fathoms each, connected together by "joining shackles" and to the anchor by an "anchor shackle." For convenience in making these connections the end links of each length are made without studs, but of increased diameter, to give equality of strength. Temporary attachments to cables are made by means of "slips," which also give facilities for readily disengaging.

(*a*) Examples of 2·6 in. and 3 in. mooring cable, and joining shackles for mooring cable.

(*b*) Single link of Admiralty pattern 4 in. mooring cable, square section.

(*c*) Piece of the largest size, 2·5 in., ship's cable.

(*d*) Example of 1 in. ship's cable, showing a flush pin in the shackle, to obviate fouling when passing through a hawse pipe.

(*e*) Permanent swivel as fitted to mooring buoys for the use of ships.

(*f*) Mooring swivel for attaching to ship's cables, to permit vessel to turn freely when riding with both anchors out.

(*g*) Chain swivel, fitted at each end of a ship's cable, and at intermediate positions if necessary, for taking out "twist" in the chain.

(*h*) Chain with cable slip attached.

(*k*) Deck stopper chain, with shackle for securing to stopper bolt and slip for temporarily attaching to cable.

(*l*) "Clear-hawse" chain, for supporting the weight of cable outside of the hawse pipe; this shows a roller shackle through which a rope may be rove, and a slip for attaching to cable.

An adjoining case contains other details of cable fittings and manufacture, together with tools, etc., used in the manipulation of chain cable.

1098. Chain cable. Presented by Messrs. Brown, Lenox & Co., 1906. N. 2426.

This is a tested sample of the cable manufactured by Messrs. Brown, Lenox & Co., for the quadruple-screw turbine steamer "Mauretania," a vessel of about 33,000 tons gross, built in 1906 for the Cunard Company by Messrs. Swan, Hunter and Wigham Richardson, Ltd.

The cable is the largest ever made for ships' use; its links are of iron, 3·75 in. diam. Each link is 22·5 in. long and 13·5 in. wide, and, with its cast steel stud, weighs 170 lb. The three links shown were tested at Lloyd's Proving House, Cardiff, and withstood a load of 350 tons without showing signs of fracture, although they were elongated six inches.

The total length of the cable for the steamer is 1,900 ft., and weighs, with the connecting shackles, about 130 tons.

1099. Joints for cable links. Lent by C. Martin, Esq., 1874. N. 1338.

These two models show:—(*a*) a forged link with its joint made by the usual scarf weld; (*b*) a link in which the joint is made with a stepped scarf, patented by Mr. Martin in 1872.

1100. Models of cable compressors. (Scale 1 : 8.) Presented by the Admiralty, 1864. N. 1001.

This compressor, of Admiralty pattern, is still used in both wooden and iron ships for checking the chain cable when running out round the riding-bitts after an anchor has been let go. The arrangement was invented by Capt. Chesman, when iron cables first came into general use about 1830, and subsequently improved.

The compressor, which is placed on the under side of the anchor deck, consists of a curved iron lever pivoted on a bolt at one end, and fitted at the other end with a tackle by which it can be caused to press the cable against the side of the chain pipe, thus causing considerable frictional resistance.

1101. Model of cable compressor. (Scale 1 : 12.) Presented by William Batten, Esq., 1858. N. 168.

This modification of the Admiralty compressor was patented by Mr. Batten in 1831. Greater closing pressure is obtained by the use of a combined lever and cam motion, while a stop is added which limits the travel.

1102. Model of cable compressor. (Scale 1 : 4.) Presented by the Rev. J. M. Kilner, 1878. N. 1506.

This breaking arrangement was patented by Mr. Kilner in 1871. It is in the form of a shackle which is fixed to a casting secured to the deck; the bow of the shackle is extended in the form of a lever by which it can be forced down upon the chain cable.

1103. Model of riding-bitt and compressor. (Scale 1 : 12.) Made by the Admiralty, 1887. N. 1779.

When lowering the anchor, the outgoing cable from the hold or locker passes upwards, through a deck-pipe fitted with a securing device called a "compressor," to the sprocket wheel of a winch or capstan; it then passes round a large fixed post or bollard, called a "riding-bitt," and over another securing device known as a "bow-stopper." When the anchor has reached the bottom and sufficient cable has been payed out, the cable is temporarily secured by a short chain called a "deck-stopper," while the inner end is taken one additional turn round the "riding-bitt," so as to obtain greater security while the ship remains at anchor; during this operation the weight of the hanging chain in the locker is carried by the adjacent compressor.

The model shows the riding-bitt of H.M.S. "Inflexible" (1876). The bitt is a hollow casting of iron or steel, secured to the anchor deck by a flange which receives bolts that pass up through a massive timber base built between the deck beams. To resist the severe local stresses on the deck, additional pillars are here fitted, while a strong central web extending to the deck below is also added. There is on one side of the bitt a nipping lever or compressor for temporarily holding the cable, but this part of the arrangement is not followed in later ships.

1104. Models of cable stoppers. (Scales 1 : 4 and 1 : 3.) Presented by Messrs. Bullivant & Co., 1902. N. 2285.

A cable stopper, or "compressor," for holding a wire rope at any point was patented in 1874 by Mr. W. M. Bullivant, when this class of rope was coming into nautical use and the importance of securely holding it without injuring it was realised. It consisted simply of a long trough fixed to the deck and provided with a semicircular groove fitting the rope, while a similarly shaped block could be pressed into the trough by a screw; in this way the frictional grip from a great total pressure was obtained, while, owing to the length of rope over which this was distributed, no injury was done to its material or structure.

The form of compressor, patented by Mr. Bullivant in 1874, is illustrated by the first two models shown, in which, to facilitate the insertion of the cable, one side of the trough is open; the closing block is mounted upon an eccentric formed on the back of a worm wheel moved by a worm or hand wheel by which the pressure was applied and maintained. At first the block had side guides, but the model shows how, by the use of two pins engaging in annular slots of the same throw as the eccentrics, these were dispensed with. In another example of this arrangement, two pressers were employed as shown, and the trough groove had a crest or undulation in it which added to the grip by slightly bending the rope.

In 1880 Mr. Bullivant patented two forms of compressor in which the pull on the rope tended to increase the grip, so that they became "automatic grippers," and these are the arrangements shown, to a scale of 1 : 3, in the two largest models. In one of these there are three shrouded toothed wheels, mounted eccentrically, and engaging with a shrouded rack formed on the under surface of a block which can be moved endways by another toothed wheel on a horizontal shaft arranged for taking capstan bars. When the rack is moved endways its teeth cause the eccentrics to revolve, so that they raise it and cause it to grip the rope between itself and the fixed framing, which, in the model, has been partly cut away to render the mechanism visible.

In the other automatic nipper, which is arranged horizontally and represents the later construction, there are seven inclined struts, or toggles, one end of each of which is notched into the framing and the other into the block, while there are a pair of pinned links which retain the movable block in position. The block is moved endways by a screw, fixed to it and traversing a nut fitted with a wheel, by which it can be turned, and carried in a spherical bearing which gives the necessary freedom. When the screw is forced inwards it pushes the block which, by the toggles, is thus caused to grip the rope between itself and the framing; the attachment of the screw to the block is by a pin in a slotted hole, so that the pull of the rope can automatically increase the grip without the screw being moved.

1105. Model of cable slip hook. (Scale 1 : 6.) Presented by the Rev. J. Hardie, 1866. N. 1115.

This is a cable holder introduced by Mr. R. F. S. Blake into the Royal Navy. The hook, which is attached to a chain secured by a shackle to the deck, is in two portions, hinged together and locked by an enclosing link. By knocking back the link everything is freed.

LOGS AND CLINOMETERS.

Many instruments used in nautical work will be found in the collection of scientific apparatus shown in the Western Galleries of the Museum, but those of specially marine application are retained in this collection.

For measuring the speed of a vessel some form of "log" is usually employed at intervals, although for determining the position of the ship astronomical observations are the only reliable means when land is invisible. The old-fashioned log consists of a teak float to which a light rope is attached; the float is thrown overboard and the line allowed to run freely from a reel so that the float remains nearly stationary. In this way the number of knots on the rope that run out in a certain interval of time, as determined by a sand glass, indicates the speed of the ship; when this interval has elapsed the line is stopped and hauled in again for future use. A trip arrangement on the log causes it to turn edgeways, and so reduce its resistance when being recovered.

Another means of measuring the velocity of a ship through the water depends upon the alteration in the pressure in a tube projecting through the bottom, as the speed varies, but this plan has never been extensively adopted.

The modern logs, however, do not attempt to give the speed, but the distance travelled, which is the important factor when sailing by "dead reckoning." Such a log consists of an elongated float provided with inclined vanes and connected by a plaited rope with a counting apparatus on deck. The float as it is dragged through the water rotates with a velocity that is proportional to the speed of the vessel, and the dial is graduated by experiment in such a way that it indicates the distance travelled in nautical miles. These instruments give reliable readings, but as they also register motion due to currents, etc., they may fail to indicate the true position of the vessel, particularly if there has been any considerable lateral drift.

For determining the angle of rolling, or even the list of a vessel, an observation upon the horizon gives the most accurate results, but is not always practicable or convenient, so that some form of pendulum or spirit level is generally resorted to. In these instruments arrangements are made to check or damp out oscillations, but all such gravity apparatus give results that are influenced by the motions of the vessel for the same reason that the surface of the water in the buckets of an overshot water-wheel does not remain level when the wheel revolves.

1106. Perpetual log. Presented by J. Taylor, Esq., 1857. N. 3.

This log, for measuring the distance travelled by a ship, was patented by William Foxon in 1772, and one was supplied to H.M.S. "Enterprise" in 1775.

It consists of two parts, a spiral log of sufficient weight to be just buoyant and the recording mechanism shown. The spiral log is towed after the ship by a line long enough to keep it out of eddy currents, and is connected with a train of toothed wheels in a case fixed on the taffrail. The train revolves at a speed proportional to that of the ship. An endless screw receives the motion, its arbor carrying a flywheel. Two dials are provided: one, with a single hand for frequent readings, shows small distances; the other has a large hand which revolves once for 100 revs. of the single hand, so that this dial will record 3,000 times the distance of the other. The log will register up to 18,000 knots.

1107. Propeller log. Presented by E. Massey, Esq., 1879. N. 2415.

In this log both the register and rotator, connected by a short rope line, are placed in the sea. In the original form, patented by Edward Massey in 1802, this connection was made by four lengths of cane rod, each about 17 in. long, joined together by a short length of chain. This arrangement avoided the friction of turning the long length of rope which would have been necessary had the registering gear been on board. The rotator is of the blunt-ended kind with four vanes; the register is an ordinary counter, the first wheel of which is set in motion by an endless screw on the shaft joined to the connecting rope. A universal joint is used to form the connection between the worm-shaft and the rope: in later forms of this log this joint is protected from the fouling action of weeds, etc., but here it is exposed. The whole of the wheelwork and dials are cased in brass; projecting side wings are also screwed on to prevent the register from rotating. The index is protected by a brass cap. Portions of a mile can be read off and distances up to 100 miles are recorded.

1108. Logs. Presented by A. Tolhausen, Esq., 1858. N. 60.

These logs were patented by Mr. A. Pécoul in 1854, and were intended both for measuring the distance travelled by the ship and for sounding without heaving-to. The smaller example appears to have been intended for measuring distance only, but the larger one has additional fittings for taking soundings. The log is of a conoidal shape, with the vertex pointing downwards, being kept in that position by a suitable weight attached to the end of the line. At a certain distance from the log, the line carries a cork; two ropes, attached to apices of the log, end in a pin (shown in the smaller example) which is inserted in this cork. There are thus three points of attachment of the metal log to the log line. The speed is determined by observing how much line runs off from a reel on the ship in a given time. When the record is taken, a check on the log line immediately withdraws the plug from the cork, the log assumes a horizontal position, and can then be hauled aboard easily.

1109. Harpoon log. Received 1906. N. 2425.

This propeller log, patented by Mr. T. Walker in 1861, has a blunt end with four vanes. In the details of its mechanism it resembles No. 1111, but the general arrangement is different. In this example the registering gear is directly attached to the log line and to prevent rotation a large harpoon-shaped fin of brass is fastened to the back of the body. The propeller end of the log is connected with the register by a collar, fastened by screws, which is prolonged to form a bearing for the shaft operating the registering gear. This shaft is fixed in the inner end of the rotating log. The end of the connecting collar forms one face for friction rollers working in the same way as in No. 1111, only in this log the shaft and attached pointer rotate and drive the wheel train through the carrier on the worm-shaft. Portions of a mile may be read off the indicator, and distances up to 100 miles are recorded.

1110. Dial log. Presented by Admiral F. Bullock, R.N., 1865. N. 998.

This log, for measuring the speed of ships, was patented in 1863 by Admiral Bullock.

The use of the instrument depends on the varying resistance to towing, at different speeds of the ship, of a float which is dragged through the water astern. The float, a metal cylinder closed at the ends, is about 12 in. long by 1·5 in. diam., and is attached to the recording indicator by a log line about 50 ft. long. A collar, to which is attached a pulley block, slides on a vertical rod fastened to the stern of the ship. The log line passes round the block, and can be thus regulated to give a suitable direction for towing the float. It is arranged that the portion of the line attached to the float is nearly horizontal, the sliding collar on the rod being only about 4 ft. above the surface of the water. The indicator, which is fixed within the ship, is an ordinary spring balance, and weighs the stress on the log line. It is graduated from a standard instrument which has been experimentally tested at known speeds. Only the indicator is exhibited.

1111. Propeller log. Presented by E. Massey, Esq., 1879. N. 2416.

This log was patented by Mr. J. E. Massey in 1865. By means of a four-bladed screw and worm gearing, contained within the body, a registering counter is actuated. The tube with its vanes, train of wheels, and indexes is caused to revolve round a stationary gun-metal worm-shaft geared into the first wheel of the train. The inner end of the log ends in a truncated cone through which this shaft passes; an outer cone, to which is attached a ring and thimble for turning the instrument, is fastened to the shaft. This outer cone does not touch the log, but acts as a protector against weeds, sand, etc. The inner cone, which is fixed to the instrument, is free to revolve on the shaft, and contains friction rollers working between two discs inside the cone, one fixed to the cone and the other screwed on the shaft. There are three rollers free to revolve, attached by screws to the faces of a triangular block fitting loosely on the shaft. By this means the friction and wear produced by the strain of the log dragging through the water are reduced to a minimum. The gun-metal shaft is held stationary by the attached log line, and is in contact by means of a pointer at its end with a carrier actuating the worm. The reading is taken by hauling the log on board and exposing the index by rotating the protecting sleeve. The index records fractions of a mile, and will read up to 100 miles.

1112. Self-registering ship's log. Presented by B. T. Moore, Esq., 1882. N. 1578.

This fan log was patented by Mr. Moore in 1873.

From the tail of the elongated body projects a four-bladed screw, which by means of worm gearing, rotates a counter contained within the body and registering from 0·25 of a knot to 100 knots. The reading is taken by hauling the log on board and holding it vertically. The index is protected by a sleeve.

1113. Deck log and speed gauge. Presented by E. Massey, Esq., 1879. N. 2417.

In this log the recording mechanism is kept distinct from the rotator, and in that respect it differs from others by the same inventor. It was patented in 1876 by Mr. J. E. Massey. The rotator is of the usual four-bladed kind with blunt end. It is connected with the recording mechanism by a cable-laid log line sufficiently long to keep the log out of eddy currents. Brackets are securely fastened to the top and side of the bulwark near the stern, one on each side of the ship. A stand arm, connected with the registering gear and dial by a swinging joint, can then be easily slid into a groove in the fixed bracket. In this position the recording mechanism is firmly held, but is free to turn in order to adjust itself to alterations in the ship's course.

The registering mechanism attached to the ship's quarter consists of a train of wheels with a graduated dial. Attached to the case of the dial is a cylinder containing a shaft or arbor ending in a circular face plate which operates the last wheel of the train by means of a pointer attached to its face. The inner face of this plate is hollowed out, and together with a similar but fixed plate forms a ball-bearing, the balls being of brass. This arrangement considerably reduces the friction of the gear. Between the fixed half of the bearing and the cylinder end a spring is threaded over the inner bush in order to give a more uniform motion. Outside this cylinder the shaft ends in an eye to which the hook on the end of the log line is attached. The dial is graduated so that the inner circle gives the distance travelled in miles, whilst the outer circle is divided into sixtieths of a mile. By observing the number of sixtieths travelled in one minute, the speed in miles per hour is obtained. The registering mechanism is shown separately in section.

1114. Electric log. Presented by Miss Clough, 1876.
N. 2421–2.

This log was patented in 1876 by Tito Visino, and consists of a recording mechanism placed on board, together with a rotator suspended from the side of the ship by iron bands, connection being made between the two by an electric cable. It was also the intention to use in conjunction with the recording mechanism an apparatus for tracing graphically the course of the ship. The rotator is a copper tube containing bearings in which a four-bladed propeller works. At the end of the tube, and external to it, is placed the wheelwork connected with the propeller by a single-toothed wheel on its axis. Water, entering the tube during the ship's motion, passes out through three copper pipes at its end. An outer tube, acting as a shield, covers this inner tube, and protects the wheelwork from contact with the water. The single tooth on the propeller shaft drives a wheel train and once in every 500 rotations of the propeller contact is made between two springs by projecting pins on the last wheel of the train, thus completing an electric circuit. The springs are terminals from which wires pass through the end of the copper tube, a cable being led thence to the recording mechanism on board.

This mechanism consists of a number of dials arranged in two circuits. In one are the three first dials, recording from hundreds of fathoms to thousands of knots. The first dial of this circuit is operated by the current which is completed by the contact of the springs described above. An electro-magnet controls one end of a lever, the other end rotating a ratchet-wheel on the dial shaft. The dial operates the next two by means of spring controlled levers and ratchet wheels. To connect the first series with the second and thus give continuous registration there is a commutator on the arbor of the last dial of the first series. When hundreds of knots are to be recorded springs resting on the commutator complete the second circuit, containing a separate electro-magnet, the mechanism being similar to that on the first dial. A ratchet and pawl then operate the dial placed on the top.

The advantages claimed for this log are that, as there is no towing line, violent jerks, which would affect the record, are avoided, and that its large size reduces the risk of its being seized by a fish, while, since it works fairly deep in the water, it is not exposed to surface obstructions.

1115. Speed indicator for ships. Lent by the Rev. E. L. Berthon, M.A., 1867.
N. 1165.

In this instrument, which was patented by the contributor in 1849, the velocity of the ship through the water is determined from the pressure produced in an open tube exposed to the passing stream. The original apparatus of this class, devised by Pitot, consisted of a tube passing through the bottom of the ship and having an opening in the direction of motion, so that the height above the sea level of the water column in the tube gave the pressure due to the velocity; but this height was only obtained after correction had been made for the draught and inclination of the vessel.

To obviate the necessity for making these allowances, Mr. Berthon introduced the use of two tubes: one with an opening in the direction of motion, and the other with two openings so situated that they received no pressure from the ship's motion; so that the difference between the pressure in the two tubes depended upon the speed only.

In the example shown the two tubes are combined into a single "way-tube" which passes through a stuffing-box in the bottom of the ship and projects a few inches beyond; the lower portion of this tube has two circular ports, with their axes inclined at 42 deg. with the line of motion, and a small pipe leading from it; while the upper portion has a port with its axis in the direction of motion. The two portions of the way-tube are connected to air vessels, from which pipes lead to the opposite ends of a mercury column in a bent tube. When the ship is in motion there is a displacement of the mercury column, by which the speed is indicated on a graduated scale.

Secured to the bottom of the way-tube is a collapsible vane, which keeps it in its required position, while an index on the handle of the tube indicates the lee-way being made by the ship.

1116. Registering clinometer. Constructed at Devonport Dockyard. Received 1897. N. 2126.

This instrument, for recording the number and the maximum amplitude of the oscillations of a ship, was introduced by Capt. A. G. Edye, R.N. In 1844 the Admiralty to some extent adopted it, and the Society of Arts awarded the inventor a medal.

The inclination is measured by a short massive pendulum, which is connected by spur wheels to a damping brake that prevents recoil oscillations. This brake is in the form of a pawl, which is thrown over at each reversal; the counting mechanism registers the reversals only, so that the vibrations are recorded independently of their amplitude.

Two light arms are separated by the pendulum when swinging, and so indicate the maximum swings since last closed together by the external knobs. The instrument is hung on a hinge in the plane of the motions to be recorded, and indicates on four decimally arranged dials.

1117. Bi-fluid clinometer. Lent by the Rev. E. L. Berthon, M.A., 1867. N. 1164.

This instrument for measuring inclinations, or the list of a vessel, was patented by Mr. Berthon in 1849. It consists of a glass bulb, containing mercury, connected by a horizontal capillary tube with a similar bulb terminating in a vertical index tube, which contains mercury and coloured water. As the area of each mercury bulb is 26 times that of the index tube a small change in level of the mercury causes 26 times as much movement of the water index. If the density of the mercury is 13 times that of the red water, which usually contains a little sulphuric acid, the change in level of the mercury caused by a certain inclination is only one-half of that when a simple U tube with legs of equal areas is employed; but as this change is multiplied 26 times in this instrument, it is 13 times as sensitive as the simple tube.

The connecting capillary tube damps out oscillation and insures a steady reading of the index scale, which in the example shown is graduated to show the trim of the ship carrying it.

1118. Bi-fluid clinometer. Lent by J. Wimshurst, Esq., F.R.S., 1902. N. 2297.

In this clinometer, patented by Messrs. J. and H. C. Wimshurst in 1896, two tubes containing mercury and a coloured liquid of low density, such as water or alcohol, are connected at their upper and lower ends. The bottom part, containing the mercury, has a greater area than the vertical index tubes in which the light liquid moves, consequently when the instrument is inclined the descent of the mercury on one side causes an exaggerated motion of the light fluid, which on the other side ascends into a reservoir situated above the zero point on the graduated scale.

In this example the lower tube has been contracted so as to check oscillation, but in other instances a glass cock was added so as to render the damping adjustable; also the length of the instrument has been reduced by bringing the index tubes close together.

DREDGING APPLIANCES.

Dredging has been resorted to from very early times to increase the depth of navigable channels or to remove obstructive shoals. The earliest means employed were drags or scoops worked by hand power from a boat; this arrangement still survives in the bag and spoon dredger, frequently used for cleansing locks and similar small areas. Steam power was first applied to dredging in 1796 in Sunderland harbour, where spoons with leather bags were in use; the engine fitted was supplied by Messrs. Boulton and Watt. The dipper type is best adapted for work in sheltered positions where the depth does not exceed 25 ft.; it is largely used on the North American lakes.

Ladder dredgers, in which an endless chain carrying buckets is supported on a ladder whose lower end can be adjusted to various depths, were first used in the Queen's Dock, Hull, in 1783, while steam power seems to have been first applied to drive the chain of buckets in 1811 at Sunderland; subsequently, additional auxiliary engines or shafting were added to perform the work of mooring and propelling. Ladder dredgers have at present the largest application, and are considered the best form for general purposes. Many are now so constructed that they can excavate their own flotation even through a solid bank, the ladder traversing forward so far that it projects beyond the bow. The disadvantage of bucket ladders is the height to which the spoil has to be raised in order to shoot it into hoppers alongside, also the great cost of repairs and the friction of the working parts.

Hopper dredgers of the ladder type carrying their own spoil have been largely constructed. They are ship-shaped in form, and the propelling power is sufficient to give a speed of about 10 knots, but they are most suited for cutting in an estuary where the spoil has only to be carried a short distance. In other cases the spoil is delivered into hopper barges which are towed away by a tug or the barges may be made self-propelling. If required the spoil may be delivered on adjacent land through a long shoot or a floating tube attached to the dredger.

The bucket of the "grab" or "clam-shell" dredger imitates the action of two spades; the two sides being driven into the earth have their lower edges brought together so as to lift the intervening material when raised: an early form was patented by John Gregory in 1744. It is most suitable for dealing with moderate quantities of gravelly material and may be used in confined situations, as nothing but vertical clearance is necessary. When used for clearing heavy rock or masonry, such as the débris of blasting operations, special buckets formed of interlocking bars or teeth are fitted. The orange-peel bucket, with four spade-like sides, is a variation of this type.

A form of "sand-pump" dredger was used in 1868 by Woodford, who placed a centrifugal pump close to the bottom, and drove it by a vertical shaft which passed through the discharge pipe. The water entering the pump carried the sand with it, and upon being delivered into a hopper was allowed to deposit the solid matter before returning into the sea. The advantages of the sand-pump are that the vertical lift is less than with a ladder, and that it can work, by the aid of telescopic pipes and flexible joints, where the ground swell is 2·5 ft. or more. The sphere of usefulness of this type has been largely extended during recent years: fitted with apparatus for cutting or loosening the subsoil a powerful suction dredger is capable of dealing with mud, clay and large shingle.

Owing to the rapid growth in the size of steamers during recent years, there has been a large increase in the dimensions and capabilities of dredging appliances.

1119. Whole model of double-ladder dredger. (Scale 1 : 24.) Contributed by Messrs. Thos. Wingate & Co., 1877.

N. 1469.

This is typical of three dredgers built of iron by Messrs. Wingate for the Tyne Commissioners in 1861–3, to the designs of Mr. J. T. Ure.

There are two ladders in independent wells, placed 20 ft. apart, amidships. Each chain of buckets is carried upon a plate girder fitted with bearing and guide rollers; one chain is shown with thirty-five buckets for working in clay with the chain tight, and the other has thirty-six buckets and a slack chain as for excavating in sand. The buckets have a capacity of 14 cub. ft., and the total capacity of the machine is 1,000 tons per hour. The depth to which the dredger will cut is 35 ft., and the cut is regulated by a 6-sheave chain block suspended from A-frames and worked by a winch. The spoil is discharged by shoots into hopper barges alongside.

The vessel is self-propelling, with capstans and winches by which it may be moved at its moorings as required; these appliances are also used in working the attendant barges. Power for all purposes is obtained from a side-lever engine of about 200 i.h.p., arranged aft, and connected by clutches with the screws, capstans, etc. The top tumblers, or square prisms, that drive the bucket chains are connected to the engine by gearing and V-grooved friction wheels, the latter being introduced to provide a slipping drive that shall limit the stress on the ladder chain.

Length, 158 ft.; beam, 39 ft.; depth, 11·5 ft.

1120. Whole model of dipper dredger. (Scale 1 : 24.) Presented by J. K. Rennie, Esq., 1893. N. 2019.

This single-bucket dredger was constructed by Messrs. J. and G. Rennie at Greenwich, in 1878, for dredging at the Mauritius to a depth of 10 ft. The capacity of each bucket is ·5 to ·75 ton of soil, and the vessel worked on trial at the rate of 43 buckets per hour, with an expenditure of 10 h.p.

Length, 40·5 ft.; 13·5 ft.; draught of water, 2·5 ft.

1121. Whole model of circular dredger. (Scale 1 : 32.) Lent by W. R. Kinipple, Esq., 1881. N. 1559.

This design by Mr. Kinipple is intended to reduce the time lost in mooring an ordinary hopper dredger, and also to secure greater accuracy in its position and feeding.

The dredger consists of an annular hopper around which can travel a framework carrying the machinery and two slewing bucket ladders. In the centre of the hopper is a well, through which passes a large screw pile that acts as a mooring post. The pile is hollow, so that when pumped out its buoyancy shall assist in lifting it at the completion of the work. Additional control is giving by two revolving anchors attached to legs that reach to the bottom, and may be used to give a circular feeding motion to the whole machine. The two bucket ladders may be worked in opposition so as to place the machine in equilibrium.

The dredger is provided with four screws, to enable her to steam to and be grounded on a river bar, then dredge till loaded, and afterwards float off, steam to sea with the flood tide, and discharge her spoil, without using any mooring appliances. When working alongside a quay the ladder-frame may be fixed and the circular hopper be rotated as the sections are loaded, or one ladder may be engaged in lifting spoil from the hopper on to the wharf.

The dimensions of the dredger are: Outside diam., 68 ft.; depth to deck, 17·5 ft.; draught, loaded, 14 ft.; displacement, loaded, 1,200 tons; and carrying capacity, 1,000 tons.

1122. Models of dredger buckets. (Scale 1 : 4.) Lent by W. R. Kinipple, Esq., 1881. N. 1559B.

These show methods of construction patented by Mr. Kinipple in 1879, with the object of reducing the cost of the bucket repairs necessary when dredging in hard ground.

The bucket is made of three distinct pieces; the "back," "body," and "lip," which are made to template, so that when any part is damaged it can be easily replaced.

The "back" of each bucket forms part of the link of the dredger chain, and has its rear end turned up so as to form a bottom also. Each end of the "body" is strengthened by a metal band, and the lower end is bolted to the turned-up end of the "back." The "lips" are made in shovel, spade, or claw form, according to the material to be dredged.

1123. Models showing methods of mounting dredger buckets. (Scale 1 : 8.) Lent by W. R. Kinipple, Esq., 1881. N. 1559A.

This shows the ordinary method of mounting the buckets on the ladder chain, and also a plan introduced by Mr. Kinipple in 1879 with the object of facilitating the emptying of the buckets when dealing with clayey material.

In the former method, each bucket is attached to a pair of links, and occupies a position about midway between their pins, so that it passes over the tumbler at the same rate as the chain. In the latter plan, the pins are under the centre of the bucket, so that when the bucket reaches the tumbler the front link has already cleared it, and the bucket, being pivoted on the connecting pin, tips its contents into the hopper-shoot in a manner similar to that of an ordinary tip-cart.

1124. Whole model of twin-screw hopper dredger. (Scale 1 : 48.) Lent by Messrs. W. Simons & Co., 1894. N. 2035.

This represents the dredger "Gefion," built in 1885 for the Danish Government by Messrs. Simons & Co.

It is a ladder dredger, with the chain of buckets carried over a four-sided tumbler or drum at the top, driven by reduced gearing from the steam engine. The returning buckets empty their contents into a large central hold or hopper, which is provided with large flaps or doors for its bottom. By releasing the closing-chains the doors open, and the contents of the hopper are deposited in the position selected. Side shoots are also arranged so that the spoil may be delivered into barges alongside when desired.

By means of a worm and rack-and-pinion gearing, driven by power, the ladder frame can be moved fore or aft, while the inclination and consequent depth of the ladder is adjusted by a heavy chain pulley attached to the dredger and to the lower frame of the ladder. The buckets will excavate 350 tons of spoil per hour, and the capacity of the hopper is 300 tons. The dredger works to a depth of 26 ft., and is so constructed that it can excavate in advance of itself, and thus clear its own channel.

Twin screws are provided by which the dredger propels itself to and fro the excavating and depositing grounds. Each screw is driven by a separate set of two-stage expansion engines, with cylinders 16 in. and 29 in. diam. by 21 in. stroke.

Length, 154·7 ft.; breadth, 29·6 ft.; depth, 13·4 ft.

1125. Whole model and photographs of sand-pump hopper dredger. (Scale 1 : 48.) Lent by Messrs. Lobnitz & Co., 1898. N. 2013.

This type of dredger is used for forming or deepening a channel when the bottom is of a loose sandy nature. The sand is carried up with the water lifted by a centrifugal pump, and quickly settles in a hopper, from the top of which the superfluous water is continuously overflowing. Such machines have been in use many years, and were employed in forming the Suez Canal.

The dredger represented, named the "Thyboron," was built by Messrs. Lobnitz for the Danish Government in 1892. She is constructed with raised fore-deck and quarter-deck; when loaded she carries 700 tons on a draught of 10 ft., and has been engaged in making a channel through a sand bar upon which there is only 7 ft. of water. She is propelled by twin screws, which are driven by two-stage surface condensing engines, with cylinders 16 in. and 30 in. diam. by 24 in. stroke; steam at 100 lb. pressure is supplied by two boilers 11 ft. diam.; her speed is 9 knots.

The dredger has two suction pipes, which may be used separately or together; they are connected to the centrifugal pumps which deliver into a discharge pipe placed over the hopper. Settling troughs are set below the discharge pipe to assist the precipitation of the sand, but the water carried into the hopper overflows along the coamings. The pumps are driven by the propelling engines.

On arriving at the scene of operations it is usual to drop anchor and pay out chain cable, so as to allow the dredger to drift with the wind or current until the cable is taut; if necessary one of the screws is kept running reversed; the cable then keeps the dredger sufficiently steady without the use of side or stern moorings. While the cable is being paid out a suction pipe is lowered, and as soon as the vessel is steady the pumping is commenced.

Directly the mouth of the suction pipe touches the bottom the vacuum, which when pumping water only is 6 in., increases to more than 12 in., and the fluid delivered is a mixture of sand and water.

The mixture is sampled from time to time in test tubes, 2 in. diam. and 12 in. long, graduated in percentages. The sample taken immediately the suction pipe touches the bottom will show from 5 to 10 per cent. of sand; after being at work five minutes the sample will probably show 15 to 20 per cent. of sand in the test tube, and during this time the man in charge of the winch to the suction pipe will have been gradually lowering the mouthpiece into the large hole excavated. As the hole deepens the vacuum increases, and the percentage of sand rises to 30, 40, and even 50 per cent.

A sand-dredger may be worked either by making a large hole in the sand each time she loads—the surface of the sand being levelled by the subsequent scour of the tide—or she can dredge to a given depth, leaving a level surface as she trails the suction pipe lowered to that depth.

Before leaving for Denmark, the "Thyboron" was tested on the Mersey bar, and after pumping for 20 mins. the hopper was filled to within 2 ft. of the top of the coaming, the quantity of sand deposited in the hopper being between 500 and 600 tons, at an expenditure of about 2·5 cwt. of coal. A feature in this dredger is her light draught, enabling her to work on an even keel at an immersion of 6·25 ft.

Length, 165 ft.; breadth, 34 ft.; depth, 12 ft.; carrying capacity, 700 tons.

1126. Rigged model of suction hopper dredger "Poulton." (Scale 1 : 48.) Lent by Messrs. Fleming and Ferguson, Ltd., 1905. N. 2372.

This twin-screw suction or sand-pump dredger was built of steel, and engined at Paisley in 1899, by Messrs. Fleming and Ferguson, to the joint order of the Lancashire and Yorkshire, and London and North Western Railway Companies, for the purpose of clearing the Fleetwood Bar.

The vessel is schooner-rigged, and has one steel deck, sheathed with wood. Her quarter-deck is 79 ft. long, and her forecastle 53 ft. She has a flat keel, and her hold is subdivided by seven bulkheads. There is a deep water ballast tank forward, which is 22 ft. long, and has a capacity of 200 tons.

The engines are of the three-stage expansion type, with six cylinders, of 13 in., 21 in., and 34 in. diam. by 24 in. stroke. Steam at 160 lb. pressure is supplied by two single-ended boilers, with four corrugated furnaces having a grate surface of 84 sq. ft., and a heating surface of 2,125 sq. ft. The speed of the vessel is 9 knots.

There is one suction pipe which is fitted with a flexible joint, and is connected to the centrifugal pump; the latter was made by Messrs. J. and H. Gwynne, and is capable of lifting 1,500 tons per hour. It delivers into two horizontal pipes running the full length of the hopper, these have adjustable apertures placed at intervals along their lower sides through which the mixture of sand and water passes into perforated troughs below, from which it is discharged into the hopper. This arrangement allows the spoil to be directed into any particular part of the hopper, and the water overflows over double coamings.

Auxiliary steam-driven machinery is provided for raising and lowering the suction pipe, and for opening and closing the hopper doors. On her load draught the vessel carries 1,250 tons.

Length, 204 ft.; breadth, 38·2 ft.; depth, 14·5 ft.

1127. Rigged model of steam hopper-barge. (Scale 1 : 48.) Lent by Messrs. Fleming and Ferguson, Ltd., 1908. N. 2490.

When the dumping ground is at a considerable distance from the locality where the dredging operations are being carried out, it is usual for the dredger to deliver its spoil into hopper-barges which, when filled, are taken by a tug to the dumping ground. By this course the dredging machinery can be kept at work for the maximum number of hours and the difficulty of recovering the moorings after each tide is avoided. For continuous and extensive operations of this nature, large self-propelled hopper-barges are frequently employed ; they possess good speed and sea-going qualities.

The model here shown is representative of four twin-screw steel hopper-barges, built and engined at Paisley in 1892–3 by Messrs. Fleming and Ferguson for the Clyde Navigation Trustees.

The large single hold or hopper is placed amidships and is framed internally, at the lower part, to carry twelve hinged doors opening downwards, for discharging the spoil. A strong arched middle-line girder connects the upper ends of the hopper and carries the fair-leads for the lift-chains to the hopper doors. For working these doors there are special steam windlasses, fitted with separate winding drums for each pair of doors.

For propulsion, two sets of three-stage expression engines are used with cylinders 15 in., 24 in., 37 in. diam., and 24 in. stroke; a speed of 10·5 knots is attained with 1,200 indicated h.p.

Gross register, 799 tons; length, overall, 200 ft.; breadth, 35 ft.; depth, 15·5 ft.; hopper capacity, 1,250 tons.

1128. Whole model of rockcutter. (Scale 1 : 48.) Lent by Messrs. Lobnitz & Co., Ltd., 1906. N. 2390.

Before removing sub-aqueous rock by dredging, some form of machinery is necessary to crush it to a suitable size. This shows a rockcutter patented in 1886 by Mr. H. C. Lobnitz and since improved by Mr. F. Lobnitz; it is, in this case, mounted on a steel pontoon, but is more usually mounted on two barges joined together by logs of wood or steel girders bolted across above their decks. In the present example, the pontoon has a central well provided with upright side timbers and struts, within which is a guide formed by a frame of cross beams. The guide has steel wearing-plates and can be raised by the hoisting rope to any height suitable to the depth of water in which the cutters are operating. Between the guide and the upright timbers are placed springs forming cushions to take any shock caused by the cutters striking an inclined face of the rock. The cutters fall freely through steel-lined holes in the guide.

The machine shown is a double one, having two steel cutters, each weighing 13 tons, fitted with renewable points whose hardness increases from the point to the inside. These cutters are graduated in feet and inches painted on their surface and are attached at the top to a wire rope of about 5 in. circumference, working over a pulley at the top of sheer legs fastened to the pontoon. The rope is operated by a hoisting winch, and the cutters are allowed to fall by their own weight on the surface of the rock, breaking it and partly pulverising it. The winch then hoists the cutters for another blow on the same spot until the desired depth of rock is broken up.

The hoisting winch is a powerful steam engine capable of giving about 2,000 blows per day of ten hours. The winch has a steel friction clutch which releases the barrel on which the hoisting rope is wound when the cutter is falling (the barrel then revolving independently of the driving shaft of the winch) but, immediately the tension on the rope is released as the cutter strikes the rock, the barrel engages with the driving shaft of the winch, thus raising the cutter for the next blow. In the early machines the levers for working the clutch were operated by hand, but in 1902 patent automatic gear was introduced to perform this operation. This gear consists essentially of a heavy weight operating a bell-crank lever, which tightens the coil clutch upon the shaft of the winch when the cutter strikes the rock. To operate the weight, advantage is taken of the fact that the rope slackens when the cutter strikes; a pulley resting on the rope is then released and the lever attached to it operates the weight.

The method of accurately manœuvring the pontoon to strike successive spots at the desired intervals of about 2 ft. is important. On the pontoon are set up two vertical rods, mounted in slots in a frame, which can be moved into other slots at intervals corresponding to fresh positions for the cutter. A base line is established on shore and square to it are set up two rods which are sighted in line with the rods on the pontoon and thus form sighting points. Moving the pontoon is performed by six manœuvring chains worked by a special steam winch upon which are six independent barrels; the four side chains are used to traverse the work, and the two remaining chains move the pontoon in a fore-and-aft direction. The winch is so arranged that the amount of chain taken in on the one side is equal to the amount given out on the other. Very accurate results can be obtained in this way. The rock having been broken up can then be dredged by an ordinary dredger, the bucket type being the most suitable.

The dimensions of the pontoon are:—Length, 100 ft.; breadth, 36 ft.; depth, 8 ft. The rockcutter shown is suitable for cutting to a depth of 40 ft.

1129. Suction dredger "Leviathan." (Scale 1 : 48.) Lent by Messrs. Cammell, Laird & Co., Ltd., 1910. N. 2555.

This represents an unusually large example of a self-propelled sand-pump dredger specially designed for deepening the sea approaches to the port of Liverpool. It is of the twin screw, hopper type and was built of steel by Messrs. Cammell, Laird and Co. at Birkenhead in 1908 for the Mersey Docks and Harbour Board.

The main structure is subdivided by eight transverse watertight bulkheads extending to the upper deck, and also by a continuous longitudinal bulkhead extending from the after end of the boiler room to the fore side of the buoyancy space in front of the hopper. The hopper space itself is 162 ft. long and 49 ft. wide subdivided into twelve compartments; structural strength in the way of these open areas is maintained by fore-and-aft deck girders and diagonal tie-bars; a deep steel coaming surrounds the hopper, and the buoyancy spaces on each side are 10 ft. wide.

Four suction tubes are used, of sufficient length to raise sand from a channel 70 ft. in depth: these are built up of steel plates, with cast steel flanges for connection with the swivel joints and nozzle; they are arranged to turn freely about a vertical or a horizontal axis and each tube is raised and lowered by two derricks worked by a single steam winch. Four Gwynne centrifugal pumps are used for lifting the spoil and delivering it into the two large rectangular ducts or "landers" which extend the full length of the hopper. This mixture of sand and water usually falls into the foremost hopper divisions at first and then overflows into adjacent divisions; the sand thus gradually settles to the bottom while the surface water is drained off by means of two weirs placed at the after end of the hopper.

The "dumping" or discharging of the sand is effected by large hydraulic valves or cylinders extending from the bottom of the hopper to the deck level and working at a pressure of 800 lb. per sq. in.

A full load of 10,000 tons can be raised in 50 mins. and discharged in 10 mins.

Two sets of three-stage expansion engines were fitted for propelling purposes by Messrs. D. Rowan and Co., Glasgow; they have cylinders 22·5 in., 37 in., 61 in. diam., and a stroke of 45 in. Steam is supplied at

180 lb. pressure by four boilers each 16 ft. diam. and 11·75 ft. long. On steaming trials an average speed of about 10·5 knots was realised.

The principal dimensions of the vessel are:—Length, between perps., 465·75 ft.; breadth, moulded, 69 ft.; depth, 30·6 ft.

AERIAL NAVIGATION.

A body may be supported in the air by flotation, as in ballooning, or gravitation may be resisted by the expenditure of mechanical energy in giving sufficient downward momentum to some of the surrounding air, as in flying. An important modification of the latter method is seen when a bird soars, an action in which it probably utilises the energy in air currents, although the cause of soaring flight is even now but little understood.

The introduction of the free balloon is generally attributed to the brothers Montgolfier who, in 1783, used a spherical balloon filled with heated air. Professor Charles of Paris, and others, in the same year substituted hydrogen gas as the lifting agent, and by this gas the first human ascent was made. At the present time hydrogen, or its cheaper compounds, is exclusively used for the inflation of balloons, although the violently explosive character of hydrogen when mixed with air in suitable proportions is a source of great danger. Its use has been greatly facilitated by the practice of compressing the gas into easily transportable steel cylinders.

The difficulty of guiding a free balloon has prevented the invention becoming of any great practical utility, although such balloons have been successfully employed in several wars, *e.g.*, during the siege of Paris in 1871. As not less than 13·4 cub. ft. of hydrogen, the lightest known gas, are required to give a lifting power of 1 lb., the size of a balloon causes the air to offer to its motion a considerable resistance, which can only be overcome by a corresponding expenditure of energy. As, however, the lifting power of a balloon increases with its dimensions at a greater rate than does the resistance of the air, and as the resistance can also be considerably reduced by adopting an elongated form, large dirigible balloons propelled by mechanical power have been produced. One of the earliest successful dirigibles was that of Henri Giffard, a Frenchman, who, in 1852, invented a spindle-shaped gas-bag, propelled by a 3 h.p. steam engine. Commandant Renard, of the French Army, in 1884–5 designed the dirigible balloon "La France," in which he employed an interior balloon called a ballonet, which, when filled with air, kept the outer or main gas-bag taut, power being provided by a Gramme electric motor developing 9 h.p. In 1901 A. Santos-Dumont commenced the construction of a series of successful dirigibles, with one of which he rounded the Eiffel tower, occupying 30 min. in going a distance of 9 miles. Until this period all dirigible balloons had been of the semi-rigid or non-rigid types. In the former the balloon is connected with the car by a trussed frame of steel or aluminium tubing, while in the latter the car is suspended from the balloon by suspension wires. In order to reduce the head resistance, Count Zeppelin, who began experimenting in 1898, greatly increased the length of the balloon in proportion to its diameter, and as the semi-rigid method of staying was obviously unsuited to balloons of great length, he employed a rigid framework of aluminium, strengthened by aluminium partitions which divided the balloon into 17 separate compartments. The whole framework was covered with rubbered fabric and each compartment contained a hydrogen balloon furnished with a separate automatic valve. Each of the two cars, suspended from the framework by tubes, contained a petrol motor, actuating two three-bladed propellers, the whole being constructed of aluminium. Zeppelin No. VII., which was completed in 1910, and in the same year wrecked in a storm while conveying passengers on a pleasure trip, had a capacity of 19,000 cub. metres, and could exert 340 h.p.

The term "aviation" is usually confined to systems of mechanical propulsion independent of buoyancy. There are three distinct types of flying-machines in this class:—

(*a*) Ornithopters, *i.e.*, those which depend upon the reciprocating action of wings, after the manner of birds. This type of machine dates back to the earliest times, but it has been almost uniformly unsuccessful.

(*b*) Helicopters, *i.e.*, those in which a direct vertical lift is provided for by propellers rotating on a vertical axis. This principle can be traced to Leonardo da Vinci about 1500 A.D. Notwithstanding the fact that this type of machine has been experimented with, a very limited amount of success has been attained up to the present.

(*c*) Aeroplanes, *i.e.*, those having inclined surfaces which when propelled horizontally deflect the air traversed, and so experience an upward pressure dependent upon the speed.

The attempts to solve the problem of aerial navigation by means of aeroplanes date back to the year 1842, when W. S. Henson and J. Stringfellow constructed a model (*see* No. 1130), which, although unsuccessful, bears a striking resemblance to the monoplane of to-day. Stringfellow, in 1846, designed a model which actually performed a free flight (*see* No. 1132). Subsequently Otto Lilienthal, of Berlin, with the assistance of his brother Gustave, thoroughly investigated bird flight, and, in 1889 and the following years he investigated the conditions of the maintenance of equilibrium in flight.

Professor Langley, of the Smithsonian Institution, after many experiments, constructed, in 1896, a double monoplane model, which flew over the Potomac river. Sir H. Maxim, in his famous experiment in 1894, employed large supporting surfaces which were propelled horizontally by twin-screws driven by a powerful steam engine (*see* Nos. 1133–4). He found that 1 h.p. expended upon the air propellers give a lifting effort of 130 lb., while his motor arrangements weighed but 13 lb. per indicated h.p. The first experimenters to achieve successful flight in a power machine were Messrs. Wilbur and Orville Wright of Dayton, Ohio, U.S.A. (*see* No. 1137). Profiting by the valuable researches of Lilienthal, the brothers Wright succeeded, in 1903, after much preliminary gliding, in making a free flight with power in a biplane. Subsequently they patented in America the method of securing lateral stability by warping the wing tips. In France the brothers Voisin designed the box-kite type of biplane with which excellent flights were made in 1907–8. Mr. Henri Farman modified this form, and designed a biplane which has been very successful. He used hinged flaps or ailerons, on the rear corners of his main planes, to secure lateral stability, in place of the warping mechanism of the brothers Wright. Mons. L. Blériot developed the monoplane by constructing a series of successful machines (*see* No. 1136), while M. Santos Dumont with his famous "Demoiselles" (*see* No. 1135) made great advances with regard to cheapness, lightness, and speed.

The only machine which has a special starting device is the Wright; all others start by running along the ground on wheels until the necessary speed for lifting has been attained.

The triplane has been experimented with, but so far as has been at present ascertained no advantage results from increasing the number of superposed surfaces.

The rapid development of aeroplanes in the last few years has been due in a great measure to the reduction in weight of the motor owing to the adoption of the internal combustion engine. Since 1903, the attention of engineers has also been directed to the construction of light-weight motors capable of running for a long continued period without attention.

1130. Model of proposed flying machine. (Scale 1 : 7.) Presented by P. Y. Alexander, Esq. and C. H. M. A. Alderson, Esq., 1907. Plate XII., No. 5. N. 2430.

This model, the design for which was patented in 1842 by Mr. W. S. Henson, was built in 1844–5 by Messrs. Henson and J. Stringfellow. Henson's proposal to utilise the fixed surfaces of an aeroplane to obtain support from the air was regarded at the time as a possible solution of the problem of flying. Henson's idea was to imitate soaring birds, all previous attempts being based on vibrating or rotating surfaces, after the manner of flapping birds. It was intended that the actual machine should be used as a conveyor of letters, goods, and passengers.

The model consists of an extended surface or aeroplane of oiled silk or canvas stretched upon a bamboo frame made rigid by trussing, both above and below. A car is attached to the under side of the aeroplane to contain the steam engine, passengers, etc. It has three wheels to run freely upon when it reaches earth. Two propellers 3 ft. diam. are shown with their blades set at 45 deg.; they are operated by endless cords from the steam engine (*see* No. 1131). Behind these is a fan-shaped tail stretched upon a triangular frame capable of being opened out, closed, or moved up and down by means of cords and pulleys. By this latter arrangement ascent or descent was to be accomplished. A rudder for steering sideways is placed under the tail, and above the main aeroplane a sail (not shown) was to be stretched between two masts rising from the car to assist in maintaining the course. When in motion the front edge of the plane was to be raised in order to obtain the required air support. To start the model it was proposed to allow it to run down an incline, *e.g.*, the side of a hill, the propellers being first set in motion. The velocity gained in the descent was expected to sustain it in its further progress, the engine overcoming the head resistance when in full flight. Experiments were eventually made on the downs, near Chard, and the night trials were abandoned, as the silk became saturated from a deposit of dew. After many day trials, down wide inclined rails, the model was found to be deficient in stable equilibrium for open air experiments, little puffs of wind or ground currents being sufficient to destroy the balance. The actual machine was never constructed, but in 1847–8 J. Stringfellow built a model which is supposed to be the first flying machine which performed a successful flight (*see* No. 1132).

The dimensions of the model shown are 20 ft. from tip to tip of wings, by 3·5 ft. wide, giving 70 sq. ft. sustaining surface to the wings and about 10 sq. ft. in the tail. Its weight is about 25 lb. The actual machine was to weigh about 3,000 lb., with 4,500 sq. ft. surface in the wings, and 1,500 sq. ft. in the tail. A lithograph of the proposed machine is shown.

1131. Engine for Henson-Stringfellow flying machine model. Presented by C. H. M. A. Alderson, Esq., 1907. N. 2429.

This steam engine was constructed to provide power for propelling the model shown suspended from the ceiling (*see* No. 1130). It was placed inside the car, at the after end, in a vertical position, and was connected with the propellers on the flying machine by endless cords running over the wooden pulleys shown. The engine is direct-acting and has a single cylinder 1·5 in. diam., by 3 in. stroke. On the crank-shaft is fixed the grooved pulley for driving the propellers. The framework consists of an angle-iron structure containing the bearings for the crank-shaft and supporting the cylinder.

The boiler consisted of 50 inverted truncated cones arranged around and above the furnace, and connected with a steam drum; they presented 100 sq. ft. of heating surface. The air-cooled tubular condenser gave a vacuum of from 5 to 8 lb. The speed of this model engine was to be 300 revs. per min., and the actual engine was intended to develop 25 to 30 h.p.

1132. Portions of Stringfellow's flying machine model of 1846–8. Presented by Sir J. H. Heathcoat-Amory, Bart., P. Y. Alexander, Esq., and C. H. M. A. Alderson, Esq., 1909. N. 2467.

The model, of which the wings, tail, engine and boiler are shown, was constructed by Mr. J. Stringfellow in 1846 and was designed for indoor experiments. The sustaining planes were shaped liked the wings of a bird and were slightly curved on the underside. They were also feathered at the back edge, in order that the yielding of the feathers might automatically regulate the fore and aft stability. It is stated that during the experiments the model rose after leaving the sustaining wire as much as 1 in 7, and a free flight of about 40 yds. was eventually made with the model. The sustaining surface was 17 sq. ft. and the planes measured 10 ft. over the tips.

The motive power was supplied by a steam engine placed inside a car between and underneath the wings. It had a cylinder ·75 in. diam. by 2 in. stroke. The boiler was of the water-tube type as used by Henson and Stringfellow, and consisted of inverted truncated cones arranged around and above the furnace and connected with a steam drum. The propeller speed was increased in the ratio of 3 : 1 by bevel gear on the crank-shaft. The two propellers were 16 in. diam. and were four-bladed.

The weight of the model, including the engine, was 6 lb., and with water and fuel 6·5 lb.

The engine and boiler, which have since been used to work a small lace machine, are not now in their correct relative position as used by Stringfellow.

1133. Model of Maxim's flying machine. (Scale 1 : 12.)
Presented by Sir Hiram S. Maxim, 1907. N. 2092.

This is a complete model of the flying machine constructed and experimentally tried by Sir Hiram Maxim in 1894; by its own effort it more than supported its weight and that of its crew. It never soared aloft, however, as its rise was limited by inverted rails to a few inches only, and an accident when running under these at a speed of 40 miles per hour brought the experiments to a premature conclusion. The total weight of the machine was 7,700 lb., and it exerted in the trials a total lifting effort of 10,000 lb.

The machine consists of a braced structure of steel tubes and wires connected to large inclined surfaces, called aeroplanes, that possess a total area of 5,400 sq. ft., and slope at an angle of 7·25 deg. with the horizontal. The extreme width of the machine is 120 ft., and the length 104 ft.

1134. Engines and propeller for Maxim's flying machine.
Presented by Sir Hiram S. Maxim, 1907. N. 2092.

One of the two-stage expansion engines patented in 1889, and the two-bladed propeller which it drove, on Sir Hiram Maxim's flying machine, are shown. The engine weighs only 300 lb. and exerts 180 h.p., or over ·5 h.p. for every pound of weight. The high-pressure cylinder is 5·05 in., and the low pressure 8 in. diam., with a stroke of 12 in. Steam is distributed by piston valves with a travel of 3 in.; the high-pressure cut-off is at ·75 of the stroke, and the low pressure at ·625. The speed of the engines is 375 revs. per min.

Steam at 300 lb. pressure is supplied from a tubulous boiler of the Thornycroft type, fired by naphtha delivered through hollow firebars as 7,650 spray jets under a pressure of 50 lb. The boiler has a heating surface of 800 sq. ft. and a grate area of 30 sq. ft.; its weight is 900 lb., and with feed-heaters, burners, and water 1,200 lb.

The propeller is 17·83 ft. diam., of the two-bladed type, 16 ft. pitch, and 5·16 ft. wide; the two engines and propellers have driven the machine along at the speed of 40 miles per hour, and obtained a horizontal thrust of 2,000 lb. from the air passing them.

1135. Model of Santos-Dumont monoplane. (Scale 1 : 10.)
Made in the Museum, 1910. N. 2542.

As the lightest practical machine that has successfully flown, the "Demoiselle" represented by the model is of considerable interest. With it M. Santos-Dumont rose from the ground after travelling 230 ft. in the record time of 6·2 secs. and attained the high speed of 60 miles per hour in free flight.

The introduction of bamboo as the material for the main framework, the wings and the tail, and the system of staying adopted have conduced to make this type of machine exceedingly light and simple in construction. The main frame is a girder of triangular section formed of three bamboos, about 2-in. diam. at the larger ends, connected by steel struts of oval section.

When stationary the machine rests on two bicycle wheels at the front end and a skid near the rear; these wheels are inclined in order to minimise the stresses should the machine land sideways. At the forward end of the chassis are the main planes or wings, the two chief supporting members of which are transverse spars of ash, which taper slightly in depth, becoming thinner where they join the central bamboo. Firm connections are made between the central bamboo and these spars by fitting them into rectangular sockets brazed to bosses on the framework. The fabric which encloses the spars and bamboo ribs is double, and is formed of silk. The leading and trailing edges of the planes are quite sharp, and are supported by wires held in claws at the ends of the bamboo ribs. The fabric envelops the wire at the leading edge, but at the trailing edge it is laced to the wire, thus ensuring that the wings are stretched tightly. The greatest camber of the planes is slightly in front of the centre and is approximately 4 in.

The tail is built up of fabric stretched on a bamboo frame, and moves as a whole about a universal joint formed at the after end of the chassis. The lever on the right hand of the aviator elevates or depresses the tail, while the steering wheel moves it sideways, both the motions being controlled by steel wires kept taut by springs. The lever at the back of the aviator controls the warping or flexing of the wings; it is attached at its upper end to his coat, so that by leaning over sideways in either direction the wings are warped as required. The aviator sits beneath the engine, on a strip of canvas stretched between the two lower bamboos of the main frame.

The engine represented is a twin-cylinder Darracq motor of 25–30 h.p. The cylinders are placed horizontally on opposite sides of the crank-case and are 130 mm. (5·12 in.) diam. by 120 mm (4·72 in.) stroke. The engine is coupled directly to the propeller, which acts as a flywheel. Water cooling is employed, and the radiator, consisting of numerous small copper pipes, is placed beneath the main plane on each side. The water enters the tubes from the cylinders at the top, and after traversing them is pumped back again. The weight of the engine is taken at the centre by the central bamboo, and at the cylinder ends by the transverse spars of the main planes, which are themselves supported at these points by oval steel struts connected with the chassis. In addition, two tie rods connect the engine at the rear with the top bamboo of the main frame. The petrol tank is placed above the motor and is shown on the model, but the water tank, which is also placed above the motor, is not represented. The propeller, 6·66 ft. diam., is of the Chauvière type built up in walnut, and makes 1,500 revs. per min.

Length over main planes, 18 ft.; breadth of planes, 6·4 ft.; total length of machine, 20 ft.; main supporting surface, 115 sq. ft.; aspect ratio, 2·8; total weight of machine without pilot, 242 lb.

1136. Model of Blériot monoplane (cross-Channel type). (Scale 1 : 10.) Made by Messrs. T. W. K. Clarke & Co., 1910. Plate XII., No. 6. N. 2541.

The earliest experiments of Mons. L. Blériot were made in 1901 with a flapping-wing machine which failed. His first successful flight was accomplished in July 1907, when the monoplane principle was adopted, and the steady development of this type of machine has resulted in the successful form shown by the model, the most notable achievements of which were a cross-country flight of 25 miles, and the crossing of the English Channel from Calais to Dover on July 25th, 1909. The model shown represents the machine known as No. XI. with which the Channel crossing was made. It is of the single-passenger type, and, with the exception of the monoplane of M. Santos Dumont (*see* No. 1135), is the smallest which has met with any success.

The main frame or chassis of the machine is of rectangular section, and consists of four main members of poplar or ash supported at intervals by vertical struts; the whole is trussed by diagonal wires, all of which contain strainers. In plan the frame tapers to an edge at the rear, and there is a slight taper from front to rear when viewed sideways.

The main wings, which are removable, are attached to the sides of the frame at the forward end. The framework of each wing consists of two stout wooden spars placed athwartships, crossed by a large number of curved ribs, the construction of which can be seen in the model. The front edges of the wings are rigidly stayed by flat steel tapes to the chassis. The wings are double-surfaced, and have a camber of about 3·5 in. in a fore-and-aft direction, while their extremities are rounded off. In order that the wings shall be easily removable, the inner ends of the spars extend some inches beyond the wings and are bolted into sockets fixed to the chassis.

The auxiliary vertical steadying plane which was originally placed above the wings has been dispensed with. The steel frame of this auxiliary plane, however, is retained, and to it are fastened the stays which support the main wings from the upper side.

The auxiliary surfaces consist of a tail having separate tips pivoted about a horizontal axis, and a vertical rudder. The tail is built up in a similar manner to the wings, but its main transverse member is a steel tube which is carried by the lower members of the main frame and is supported in bearings formed by aluminium clips. The tips can be inclined at will by the aviator, but the central portion of the tail remains fixed in the position in which it was placed at starting. Its angle of incidence can be adjusted before leaving the ground by means of a drilled metal quadrant and a bolt. The vertical rudder is controlled by a pedal in front of the aviator's seat whilst the tips of the tail are operated by a vertical lever terminating in an inverted cup-shaped fitting—a method of control patented by Mons. Blériot in 1908. The cup is free to rock about its centre, and wires may be attached to points on its circumference. Any two such wires diametrically opposite to one another will form one control. The warping of the wings is effected by this means, as is also the control of the tail.

The starting and alighting arrangement consists of a pair of bicycle wheels at the front of the machine and a single wheel at the rear. The wheel forks are provided with springs, and also with leather straps which act as stops. In passing over uneven ground the wheels rise and fall and can also incline sideways, but have springs in their connections tending to restore them to their normal positions.

The Channel flight was accomplished with a three-cylinder Anzani motor of the semi-radial air-cooled type, developing 24 h.p. It had a bore of 100 mm. (3·94 in.), and a stroke of 150 mm. (5·9 in.). The propeller, 6·66 ft. diam., was by Chauvière, built up in walnut, and made 1,400 revs. per min.

Length over main planes, 28 ft.; breadth of planes, 6 ft.; total length of machine, 25 ft.; main supporting surface, 150 sq. ft.; aspect ratio, 4·65; total weight of machine without pilot, 462 lb.

1137. Model of Wright biplane. (Scale 1 : 10.) Made by Messrs. T. W. K. Clarke & Co., 1910. Plate XII., No. 7. N. 2563.

The early experiments of Messrs. Orville and Wilbur Wright, of Dayton, Ohio, were made with soaring machines, which were abandoned, however, in 1903 in favour of power-driven aeroplanes. In 1906 the brothers took out a U.S.A. patent, claiming the essential features of their improved machine.

The model represents the biplane used by Mr. W. Wright on the race-course of Hunaudières, near Le Mans, in the autumn of 1908. It consists of two horizontal superposed planes, nearly rectangular in plan, the greater length being in a direction at right angles to the line of flight. At the rear is a double vertical rudder for steering in a lateral direction, and in front of the main planes two smaller superposed horizontal planes serve to control the vertical flight path of the machine. These front and rear rudders are nearly balanced, so that they can be easily moved by the control levers. The small semi-circular plane between the elevators is connected with the rear rudders and is designed to act exclusively as a tell-tale.

The aeroplane is mounted upon two wooden runners or skids, which extend forward and form supports for the front rudder. The whole structure is braced with wooden struts and wire ropes, the vertical wooden struts between the main planes being spaced at about 5 ft. intervals. The planes are constructed of cotton fabric stretched over ribbed frames; in the model the port side of the planes and the port rudder are uncovered in order to show the construction of the framing. Two seats are shown, that on the left is for the aviator, the other one being for a passenger or pupil. Only two levers are used by Mr. Wilbur Wright, one on either side, the one on his left being duplicated on the right-hand side of the passenger. The left-hand lever controls the front rudder only, whilst the other one has two controls. A fore-and-aft motion operates the rear rudder, and a motion sideways operates the plane-warping mechanism of the machine. Side balance is maintained through the warping of the wings; moreover, it is stated that the vertical rudder is never used alone in changing the direction of the machine.

The motor, which was designed by Messrs. W. and O. Wright, is mounted on the lower main plane, and is of the 4-cylinder vertical type, using petrol as fuel. It weighs about 200 lb., and develops about 24 brake h.p. at 1,200 revs. per min. It is water-cooled, the radiator consisting of flat vertical piping stowed between the main planes. Two wooden propellers are employed, about 8·5 ft. diam., and are mounted on parallel shafts 11·5 ft. apart. These propellers are driven in opposite directions at about 400 revs. per min., by chains direct from the motor shaft, one chain being crossed. For the greater part of their length these chains are protected by steel tubes packed with thick grease. The propeller shafts are slightly above the middle line between the main planes, in order to prevent any risk of the blades striking the ground. The aviator, pupil, and motor form a load symmetrically disposed about the centre line of the machine.

The starting apparatus consists of a derrick, and a wooden rail 75 ft. long with a flat bar of iron on the top. A starting beam, just long enough to reach from one runner of the aeroplane to the other, is attached at its centre by a swivel joint to a frame containing two ball-bearing wheels placed one in front of the other. These wheels are placed on the starting rail, small flanges keeping them in position. This arrangement allows the aeroplane to be easily turned on the starting rail. When about to start, the weight is drawn up to the top of the derrick, and the rope is attached to a release catch at the front of the machine. With its own motive power, and the impetus obtained from the falling weight, a high speed on the rail is produced. Immediately the aeroplane rises from the rail, the starting beam drops off.

The chief dimensions of the machine are:—Length of each main plane, 40 ft.; width, 6·5 ft.; space between them, 6 ft.; total supporting surface, about 500 sq. ft.; front auxiliary planes, 16 ft. long; width, 2·5 ft.; total surface, about 75 sq. ft.; weight of machine, about 800 lb.; total weight with two persons and supplies, about 1,150 lb.

APPENDIX.

The following objects were included after this volume was in the press. Their numbers, however, indicate their serial positions in the catalogue.

53a. Rigged model of 40-gun frigate (about 1800). (Scale 1 : 120.) Lent by the Executrices of the late Mrs. B. J. Colvin, 1911. N. 2592.

This represents the French frigate "Armide," which was captured, with three similar vessels, off Rochefort in 1806 and added to the British Navy, without changing her name.

In the above action she carried 44 guns: long 18-pr. guns on the main deck and long 8-pr. with 36-pr. carronades, on the quarter deck and forecastle.

Her burden was 1,104 tons—practically the same as British 50-gun frigates—and her approximate dimensions were:—Length, 154 ft.; breadth, 40 ft.

249a. Rigged model of S.S. "Glenartney" (1873). (Scale 1 : 48.) Presented by Allan McGregor, Esq., 1911. N. 2591.

This schooner-rigged vessel was one of the earliest successful steamships regularly employed in the London and China tea trade *viâ* the Suez Canal. She was built of iron at Glasgow in 1873 by the London and Glasgow Engineering and Iron Shipbuilding Co., and is typical of a number of the Glen Line steamers owned by Messrs. McGregor, Gow & Co., and employed on similar service.

In the years 1874 to 1876 the "Glenartney" was the earliest vessel to arrive in London with the new season's teas; her first homeward passage was accomplished in 44 days.

Her engines, made by the builders, were of the two-stage inverted type, using steam at 70 lb. per sq. in. in cylinders 44 in. and 79 in. diam. by 45 in. stroke.

Gross register, 2,100 tons; length, 330 ft.; breadth, 35·35 ft.; depth, 24·7 ft.

320a. Rigged model of turbine S.S. "Londonderry." (Scale 1 : 48.) Lent by the Midland Railway Company, 1911. N. 2590.

This Channel steamer was built at Dumbarton in 1904 by Messrs. W. Denny and Bros., from designs of Messrs. Biles, Gray & Co.; she is chiefly employed in the Midland Railway Co.'s service between Heysham and Belfast.

The hull is subdivided by eight transverse watertight bulkheads, and there are three complete decks, in addition to a shade deck 216 ft. long amidships. A total of 1,600 passengers may be carried, and cabin accommodation is provided for about 250 of these; for heating and ventilating the living apartments the "thermo-tank" system of humid air is fitted. The anchor cables are worked by Baxter's capstan windlass.

In 1903 the Midland Railway Co., when approving designs for four new steamers, decided that two of these, "Antrim" and "Donegal," should be fitted with reciprocating engines, and two, "Londonderry" and "Manxman," with turbines. The dimensions and general structural features of the four vessels were to be similar, so that direct comparisons could be made as to the merits of the two systems of propulsion. A special feature of the "Manxman" was, however, the use of steam at 200 lb. per sq. in., whereas the "Londonderry" used steam at 150 lb. with smaller turbines. In initial cost and weight the turbine engines gave some advantages, while the official trials showed a further superiority in speed, coal consumption, and general economy; these advantages were also emphasised by the first year's record of actual service. The "Manxman" proved 1 knot faster than either the "Antrim" or "Donegal," and about ·75 knot faster than the "Londonderry." The turbines are of the Parsons type, arranged for driving three separate shafts (*see* No. 866); the high-pressure turbine drives the central shaft, and the two low-pressure the wing shafts, to which are also attached the two "astern" turbines. Cylindrical boilers are used, with a total of 15 furnaces and a heating surface of 12,461 sq. ft. On measured mile trials the speed of the "Londonderry" was 22·3 knots, while on a six-hours' trial a speed of 21·6 knots was maintained.

Gross register, 2,100 tons; length on water-line, 330 ft.; breadth, moulded, 42 ft.; depth to promenade deck, 25·5 ft.

673a. Sectional model of cantilever-framed vessel. (Scale 1 : 48.) Lent by Messrs. Sir Raylton Dixon & Co., Ltd., 1910. N. 2557.

This shows the fore-body of a modern cargo steamer of about 4,000 tons, framed on the "cantilever" system, the principal features of which were patented by Mr. W. Dixon and Mr. G. M. Harroway, in 1905; the model is sectioned through one of the main holds, so as to illustrate structural details of the system as well as its adaptation to the stowage of coal cargo.

When at sea in light condition the full-bodied type of cargo vessel is liable to roll violently if ballasted only in the double bottom spaces. One successful means of moderating this defect is by using side or wing water-ballast tanks placed well above the centre of gravity of the unloaded vessel; to provide an efficient method of incorporating these side tanks into the hull structure is one of the important objects of the cantilever system of framing. Each cantilever frame-bar, instead of conforming to the ship's side from bilge to bulwarks, is bent sharply inboard at the lower edge of the side tank position and is ended at a continuous longitudinal deck girder in line with the hatchway coamings. A broad diagonal plate is then worked all fore-and-aft upon the inclined portions of the frames and thus forms, with the ordinary side and deck plating, a water-ballast compartment of nearly triangular section along each side of the ship; the deck edge is supported by the addition of short bars and bracket plates. Externally, therefore, the cantilever-framed vessel presents no striking departure from ordinary form; wide hatchways are possible and the full breadth of ship is preserved for deck cargoes. Internally, however, the hold spaces provide similar self-trimming facilities for bulk cargoes as in the Priestman designs. Further, owing to the deck support and general increase of longitudinal strength given by the continuous tank structure, no hold pillars or stanchions are necessary, and the side stringers and deck beams are of relatively small scantlings.

The model also shows details of the deck erections and fittings usually adopted in this class of vessel. A vertical mast or derrick post is placed between the two foremost holds and is used in conjunction with the four steam winches for working the cargo; the derrick booms are heeled upon a special steel-built platform, instead of upon the mast itself.

A considerable number of vessels of this character have been built; they are particularly suitable for carrying cargoes in bulk, but, with the addition of a shelter deck, they are used also for passenger or cattle traffic.

825a. Model of engines of H.M.S. "Arrogant" (working). (Scale 1 : 12.) Received 1909. N. 2504.

This represents generally the engines and adjacent ship-structure of H.M.S. "Arrogant," a wooden-built auxiliary screw frigate of 47 guns, completed about 1849.

Her dimensions were :—Displacement, 2,615 tons ; length (b.p.), 200 ft. ; breadth, 45·7 ft. ; draught, 20 ft.

The "Arrogant," together with her sister ship "Encounter," was fitted by Messrs. John Penn and Son with horizontal trunk engines, and was one of the earliest vessels so fitted. A later example of Penn's trunk engine having the same general arrangement is shown in No. 845.

The engines represented had two simple cylinders, equivalent in area to 55 in. diam. by 36 in. stroke, and drove a propeller 15·5 ft. diam. by 15 ft. pitch. The cranks were forged in one piece with the shaft, and the model shows balance weights. The air-pumps were double-acting and were situated within the condenser.

On trial in 1853, H.M.S. "Arrogant," with 61 revs. per min. of the engines, developed 774 indicated h.p., which gave the vessel a speed of 8·6 knots.

LIST

OF

DONORS AND CONTRIBUTORS.

Queen Victoria, H.M. - - - - - - - - - 12, 13, 15, 16, 126

PAGE

Admiralty, The 172, 180, 181, 194, 195, 197–201, 203–209, 213, 215, 216, 219, 220, 227, 299, 306–310, 330, 336, 348, 349, 351, 352, 360, 365, 367.
Ailsa Shipbuilding Co., Ltd., The 93, 122, 279
Airtight Smoke Box Door Syndicate - - - - - - 311
Alderson, C. H. M. A., Esq. - 383, 384
Alexander, P. Y., Esq. - - 383, 384
Amazon Steam Navigation Co., The - - - - - - 101
Amory, Sir John H. Heathcoat, Bart. - - - - - - 384
Anderson, J. G. S., Esq. - - 276
Anderson, J. S., Esq. - - 116
Andrews, W., Esq. - - - 338
Armstrong, Sir W. G., Mitchell & Co., Messrs. - - 40, 42, 89, 95
Arts, The Society of - - - 332
Aspinall's Patent Governor Co. - 288
Aylen, J., Capt., R.N. - - 361

Babbage, H. P., Maj.-Gen. - 235
Babcock and Wilcox, Ltd., Messrs. - - - - - - 302
Baird, G., Esq. - - - - 135, 248
Barclay, Curle & Co., Messrs. 45, 59, 77, 79
Barnett, J., Esq. - - - 130
Barrow Shipbuilding & Engineering Co., The - - 82, 86, 87
Bates, Austin & Co., Messrs. - 348
Batten, A., Esq. - - - - 150
Batten, W., Esq. - - - - 367
Baxter, H. C., Esq. - - - 357, 363
Belcher, Adm. Sir E., K.C.B. - 360
Berthon, Rev. E. L. - - 134, 372, 373
Bigger, C. J., Esq. - - - 59
Birnie, W. R., Esq. - - - 153
Blyth Shipbuilding Co., The - 93
Bodmer, R., Esq. - - 263
Bompas, G. C., Esq. - 129–132, 138–140
Bompas, Mrs. - - - - - 155
Bonney, F. A. B., Esq. - - 18
Bow, M'Lachlan & Co., Messrs. 354
Boyle, R. & Son, Messrs. - - 214
Bracey, J., Esq. - - - 138
Brassey, The Rt. Hon. Earl, K.C.B. - - - - - - 49, 119
Bridson, A. H., Esq. - - - 110
Brooke, J W. & Co., Ltd., Messrs. - - - - - - 122
Brown Bros., & Co., Messrs. - 287
Brown, Sir C. Gage, K.C.B. - 365
Brown, John & Co., Ltd., Messrs. 311
Brown, Lenox & Co., Messrs. - 364, 366
Brunet, J. J., Esq. - - - 319, 321
Bucknall, H. C., Esq. - - 129, 141
Bullivant & Co., Messrs. 249, 251, 252, 291, 319–322, 329, 332, 339, 356, 358
Bullock, Adm. F., R.N. - - 371

PAGE

Bund, J. Willis, Esq. - - - 125
Burgess, W. S., Esq. - - - 115, 116
Burgoyne, H. T., Capt., R.N. - 77, 170
Burke, H., Esq. - - - - 20
Burns, G. & J., Messrs. - - 98
Burrell, H., Esq. - - - 218
Buss, T. O., Esq. - - - 313
Byers, W. L., & Co., Messrs. - 364

Caird & Rayner, Messrs. - - 314
Cammell, Laird & Co., Ltd., Messrs. - - - - - - 380
Campbell, A. J., Esq. - - 223, 225
Campbell, J., Esq. - - - 55, 58
Camper & Nicholsons, Messrs. 110, 111, 115, 120
Canadian Commissioners to the Fisheries Exhibition - - 154
Carron Co., The - - -214, 215, 218
Caudwell, H., Esq. - - - 196
Cayzer, Irvine, & Co., Messrs. - 88, 100
Chance Bros. & Co., Messrs. - 236
Chaplin, A., Esq. - - - - 346
Child, Walter, Esq. - - - 128, 333
Chinese Commissioners to the Fisheries Exhibition - - 162, 163
Christy, Thos., & Co., Messrs. - 226
City of Cork Steam Packet Co. - 61
Civil Engineers, Institution of - 250, 251, 280, 281, 340
Clark, J. A. R., Esq. - - - 151
Clark & Standfield, Messrs. - 224
Clarke, Hyde, Esq. - - - 18
Clarke, F. C. Pickering, Capt., R.N. - - - - - - 232
Clarke, T. W. K. & Co., Messrs. 165, 166
Claxton, C., Capt., R.N. - - 64
Clough, Miss - - - - - 372
Coates, T. & C. J., Messrs. - - 300
Cochran & Co., Messrs. - 51, 142, 297
Cochrane, Cooper & Schofield, Messrs. - - - - - - 142
Colvin, Mrs. B. J. - - - - 389
Commerell, Lady - - - - 346
Commissioners of the 1851 Exhibition, The - - - 240, 343, 361
Congalton, W., Lieut., R.N.R. - 171
Conservators of the River Thames - - - - - - 227
Cooper, Sir D. - - - - - 159
Cory, Wm., & Son, Ltd., Messrs. 101, 228
Coryton, J., Esq. - - - 146, 362
Cox & Co., Messrs. - - - - 149
Craggs, R., & Sons, Ltd., Messrs. 202
Creswell & Co., Messrs. - - 229
Crispin, W. H., Esq. - - - 334, 340
Crossley, C. W., Esq. - - - 334
Culley, W. R., Esq. - - - 87
Cunard Steamship Co., Ltd., The - - - - - 61, 62, 86, 79
Cunningham, H. D. P., Esq. - 171

PAGE

Currie, Donald, & Co., Messrs. - 56, 80
Dafforne, J. J., Esq. - - - 11
Daft, T. B., Esq. - - - - 197
Darlington Forge Co., The - 208–212
Davis, Elisha, Esq. - - - 25
Davis, H., Esq. - - - - 54
Denny & Co., Messrs. - - 261
Denny, W., & Bros., Messrs. 77, 80, 81, 102, 272
Denton, W., Esq. - - - 216
Des Vignes, G. F. G., Esq. - - 263
Dewrance & Co., Messrs. - - 314
Dickinson, J., Esq. - - - 296
Dickson, Dr. Oscar - - - 132, 140
Dixon, J., Esq. - - - - 7, 8, 143
Dixon, Sir Raylton, & Co. - - 390
Dodd, T. F., Esq. - - 159
Downie, T. - - - - - 312
Doxford, William, & Sons, Messrs. 99, 202
Duncan, Bros., Messrs. - - 149
Duncan, Robert, & Co., Messrs. - 82, 194
Dundonald, Earl of - - - 295
Dunleath, Lady - - - 110
Dunraven, Earl of - - - 113, 114
Dunstan Engine Works Co., The 350

Edenborough, H., Esq. - - 21
Edwardes, T. Dyer, Esq. - - 9, 11
Egyptian Commissioner to the Paris Exhibition of 1867 - 158
Emanuel, H., Esq. - 152, 292, 345, 348
"Engineer, The" - - - 249
Ericsson, J., Esq. - - - 30, 268
Evans, S. T. G., Esq. 13, 14, 106, 125

Fairbridge, R. T., Esq. - - 239
Fairfield Shipbuilding & Engineering Co., The 44, 47, 48, 60, 83, 94, 96, 100, 121
Farnley Iron Co., The - - 310
Fawcus, G., Esq. - 128, 150, 151
Fay, J. G., & Co., Messrs. - - 113, 114
Ferguson Bros., Messrs. - - 104
Fife, Wm., & Son, Messrs. - 111, 113, 115
Finn, H. E., Esq. - - - 127
Fitzmaurice, Hon. J. T., Capt., R.N. - - - - - - 347
Flannery & Fawcus, Messrs. - 88
Fleming & Ferguson, Ltd., Messrs. - - - - 121, 378, 379
Foreign Office, H.M. - - - 121
Forrester, G., & Co., Messrs. - 255
Forrestt & Son, Messrs. - 113, 118, 133, 134, 147, 148
Foster, Rev. A. J. - - - 157
Fothergill, Rev. P. A. - - 337
Fox, Samson, Esq. - - - 297
Froude, W., F.R.S. - - - 179

Gaines Reversible Propeller Co., Ltd., The - - - - - 338
Gibbs, Bright & Co., Messrs. - 261, 292
Gibbs, Mrs. - - - - - 13
Gibson, T. D. E., Esq. - - 159
Gifford, A. G., & Co. - - - 142
Gill & Sons, Messrs. - - - 137
Gleichen, H.S.H., Count, Capt., R.N. - - - - - - 127
Godlee, Arthur, Esq. - - - 326
Gorman, W. A., Esq. - - - 228
Gray, W., Esq. - - - - 295
Gray, Dawes & Co., Messrs. - 92
Great Eastern Railway Co., The 90
Great Western Railway Co., The 96
Green, R. & H., Messrs. - - 148
Green, W. S. Clayton, Esq. - 279
Grendon, Thomas, & Co., Messrs. 57, 58, 121
Griffiths, R., Esq. - - - 335, 337
Griffiths, W. J., Esq. - - - 337, 341
Groves, Prof. J. W. - - - 118
Guppy, T. R., Esq. - - - 62

Halpin, D., Esq. - - - 226, 286
Halsted, E. P., Adm., R.N. - 427
Hamilton, J., Esq. - - - 248
Hamilton, Wm., & Co., Messrs. - 59
Hardie, Rev. J. - 170–172, 186–189, 192, 214, 218, 345, 346, 365, 368
Hardwicke, Earl of - - - 19
Harfield & Co., Messrs. - - 353, 357
Harland, H. S., Esq. - - - 239
Harrison, G. H., Esq. - - 76
Harrison Patent Steering Engine Co., The - - - - 351
Harvey, R. F., Esq. - - - 20
Hawthorn, R. & W., Messrs. - 295
Hayes, E., Esq. - - - - 159
Heathcoat-Amory, Sir John H., Bart. - - - - - 384
Heathorn, T. B., Capt., R.N. - 347
Henderson, D. & W., & Co., Messrs. - - - - - 59
Hepple & Co., Messrs. - - 84, 149
Hewett, R., Esq. - - - 112
Hewitt, W., Esq. - - - 337
Hick, Benjamin, & Son, Messrs. 292
Hill & Clark, Messrs. - - - 151
Hill, Laurence, & Co., Messrs. - 56, 171
Hirsch, Hermann, Esq. - - 179
Hodd, F. H., Esq. - - - 331
Hodges, E., Esq. - - - 222
Holloway, W. H., Esq. - - 155–158
Holt, H. P., Esq. - - - 289
Hooper, H. L., Esq. - - - 118
Hooper & Nickson, Messrs. - 198
Hope, Linton, Esq. - - - 114
Hope, Linton, & Co., Messrs. - 20
Horne, A. T., Esq. - - - 259
Howard, James & Frederick, Messrs. - - - - 296
Howden, James, & Co., Messrs. - 280
Hoyes, J., Lieut. Col., R.A. - 159
Hughes, J., Esq. - - - 26
Humphreys, A., Esq. - - - 118
Humphry, Mrs. - - - - 11
Humphrys, Tennant & Co., Messrs. - - - - - 270, 304
Hunter, S., Esq. - - - 362
Hurst, Capt. J. W. - - - 239

India Office, H.M. - - 158, 160, 161
Inglefield, E. A., Adm., R.N. - 350
Inglis, A. & J., Messrs. 79, 80, 87, 121
Inman, W., Esq. - - - 78
Inman & International Steam Ship Co., The - - - 88
Institution of Civil Engineers, The - - 250, 251, 280, 281, 340
Ismay, Imrie & Co., Messrs. - 92, 102

Jackson & Watkins, Messrs. 291, 312, 318, 322, 325, 326, 328, 329, 339

PAGE

Japanese Board of Lighthouses - 234
Japanese Bureau of Fisheries - 166
Japanese Bureau of Mercantile Marine - - - - - 165, 166
Jessop, W., & Sons, Messrs. - 208
Jex, E., Esq. - - - - - 139
Jones, J., Esq - - - - - 30
Joy, David, Esq. - - - 286, 287

Kew Museum of Economic Botany, The - - - - - 56, 74
Kilner, Rev. J. M. - - 151, 340, 367
Kincaid & Co., Messrs. - - 94
King, J., & Co., Messrs. - - 123
Kinipple, W. R., Esq. - - 376
Kirk, A. C., Dr. - - - - 314

Laing, Andrew, Esq. - - - 287
Laird Bros., Messrs. - - 74, 81–83
Lambert, Mrs. S. - - - - 120
Lapraike, D., Esq. - - - 64, 318
Lawrence, W., Esq. - - - 130
Life-boat Institution, The Royal National - - - - 146-148
Liggins, H., Esq. - - - - 108
Lighthouse Board, U.S.A. - - 236, 237
Liquid Fuel Engineering Co., The - - - - - - 364
Lloyd's Register of British & Foreign Shipping 189, 190, 193, 194, 200
Lobnitz & Co., Ltd., Messrs. - 377, 379
London & Glasgow Engineering & Iron Shipbuilding Co., The - 81, 90
London & South Western Railway Co., The - - - - - 98
London, Brighton, & South Coast Railway Co., The - - 83
London County Council, The - 92
Loveridge, Ltd., Messrs. - 352
Lumley, H., Esq. - - - - 347
Lune Valley Engineering Co., The - - - - - - 306

McClellan & Owen, Messrs. - 318
McCool, J., Esq. - - - - 229
MacFarlane, Sir D. H. - - 21
McGregor, A., Esq. - - - 389
Mackellar, Campbell D., Esq. - 64
Mackie, G., Esq. - - - - 80
Mackrow, G. C., Esq. - - 129
McLean Museum, Committee of the - - - - - - 247
McMillan, A., & Son, Ltd., Messrs. - - - - - - 86, 103
Mallory Propeller Co., The - 341
Manning, A., Esq. - - - 112
Marshall, F. C., Esq. - - - 286
Martin, C., Esq. - - - 363, 367
Martinez, Gassiot & Co., Messrs. 128
Mason, F. H., Esq. - - - 7, 8
Massey, E., Esq. - - - 370, 371
Maudslay, J., Esq. - - - 256
Maudslay, Sons & Field, Messrs. 60, 252, 254, 289, 291, 300, 336, 339
Maudslay Collection - 28, 44, 249, 253–255, 264, 265, 267, 269, 274–276, 318, 320, 333, 336, 339, 343
Maxim, Sir Hiram S. - - 385
Mechan & Sons, Ltd., Messrs. - 215
Melville, P., Esq. - - - 58
Merrifield, Prof. C. W., F.R.S. - 348, 362

Midland Railway Co., The - 389
Miller, Miss - - - - - 245
Miller, J. J., Esq. - - - - 22
Millwall Ironworks and Shipbuilding Co. - - - - 33
Mitchell, W. - - - - - 31
Moore, B. T., Esq. - - - 371
Morgan, Wm., Esq. - - - 317, 321
Muir, Mrs. Campbell - - 248
Muntz, W. H., Esq. - - - 317, 356
Murray, A., Esq. - - - 349
Museum Workshop 202, 218–220, 227, 246, 259, 290, 291, 299, 301, 303-305, 317, 319, 352–354, 385

Nance, R. Morton, Esq. - - 9, 10
Napier, R., & Sons, Messrs. 32-36, 75, 78, 135, 191, 196, 212, 213, 274, 314, 349
Napier, Shanks, & Bell, Messrs. - 89, 91
Nasmyth, G., Esq. - - 313
Nelson Dock Co., The - 189, 190, 192
Newall, R. S., & Co., Messrs. - 150
New Palace Steamers, Limited, The - - - - - - 98
New South Wales Commissioners to the Fisheries Exhibition, The - - - - - - 133
New Zealand Shipping Co., Ltd., The - - - - - - 217
Nippon Yusen Kabushiki Kaisha, The - - - - - - 99
Nunn, Ridsdale & Co., Messrs. - 236

Orient Steam Navigation Co. 84, 85, 90, 95
Oswald & Co., Messrs. - 57, 77, 79
Oubridge, J. B., Esq. - - 332

Pacific Steam Navigation Co. - 101
Palmers Shipbuilding & Iron Co. 41, 43, 50, 277, 303
Parsons Marine Steam Turbine Co., Ltd., The - - - 284
Patents, The Commissioners of 312, 322, 360
Payne, A. E., Esq. - - - 113
Peacock, Capt. G. - - - 332, 362
Peek, Miss M. A. - - 9, 143, 218
Pendred, Vaughan, Esq. - - 19, 266
Peninsular & Oriental Steam Navigation Co. 54, 60, 69, 75–81, 217, 265, 271
Phillips, L. P. C., Esq. - - 389
Pickering, C. L., Esq. - - 29
Pilkington, Sir Geo. A. - - 111
Porteous, D. S., Esq. - - - 350
Powell, H. Y., Esq. - - - 20
Prince Line, Limited, The - 104
Pritchard, L. H., Esq. - - 162
Pritchett, R. T., Esq. - - 111, 114
Pybus, J., Esq. - - - - 160, 163

Ramage & Ferguson, Messrs. - 278, 298
Rankine, W. H., Esq. - - 246
Ravenhill, Hodgson, & Co., Messrs. - - - - - 258, 268
Ravenhill, Salkeld & Co., Messrs. 254
Reed, Sir E. J., K.C.B. - - 36
Reid, John, & Co., Messrs. - - 58
Rennie, G., Esq. - - - 317, 330
Rennie, J. & G., Messrs. - 37, 38, 42
Rennie, J. K., Esq. 33, 82, 264, 271, 275, 330, 335, 376

PAGE

Rettig, E., Esq. - - - - 362
Ricardo, A. R., Esq. - - - - 111
Richardson, Duck & Co., Messrs. 59
Roberts, R., Esq. - - - - 361
Robins, T. S., Esq. - - - - 13
Robinson, R. L., Esq. - - 284
Rodger, Wm., Lieut., R.N. - 361
Rodway, Maj. H. B. - - - - 240
Ross & Duncan, Messrs. - - 285. 335
Rowe, A. T., Esq. - - - - 58
Rowe, M. E., Esq. - - - - 282
Royal Mail Steam Packet Co. - 90, 278
Royal National Life-Boat Institution, The - - - - - 146–148
Royal United Service Institution, The - - 134, 154, 161, 229
Royden, T., Esq. - - - - 59, 186
Rubie, G. P., Esq. - - - - 248
Russell & Co., Messrs. - - 59
Russell, John Scott, & Co., Messrs. - - 65–68, 70, 72, 73, 257
Russell, J. Scott, F.R.S. 23, 26, 29, 62, 71, 73, 75, 108, 109, 118, 119, 177, 178, 196, 256, 257, 267
Russian Embassy, The - - 37

St. Petersburg Agricultural Museum - - - - - - 132
Samuda Bros., Messrs. - - 37, 39
Sandford, Sir H. - - - - 85
Saxe-Coburg-Gotha, H.R.H. the Duke of, K.G. - - 29, 147, 161
Scott Bros., Messrs. - - - 308
Scott, Capt. G. J. - - - - 297
Scott, G., Esq. - - - - - 149
Scott, Michael, Esq. - - - 179
Scott, Mrs. - - - - - 19
Searle & Sons, Messrs. - - 127, 137
Seaward, J., Esq. - - - 253, 338
Settle, W. F., Esq. - - - - 23
Shell Transport & Trading Co., The - - - - - - 103
Sheward, R., Esq. - - - - 319
Short, Sir Frank - - - - 16
Short Bros., Messrs. - - - 97, 193
Silver, T., Esq. - - - 66, 69, 288
Simons, W., & Co., Messrs. - 89, 377
Simson, Lieut. E. Spicer, R.N. - 164, 165
Sisson, W., & Co., Messrs. - - 281
Skinner, A. M., Capt., R.N. - 332
Slade, F. W., Esq. - - - - 189
Slader, S. E., Esq. - - - - 81
Smith, Sir F. P. - - - 328, 331
Smith, D. Ramsay, & Co., Messrs. 335
Smith, Geo., & Sons, Messrs. - 94
Smith, N. H. J., Esq. - - 239
Smith, James A., Esq, - - 191
Smith, W., Esq. 35, 225, 239, 269, 313, 323
Smith, W. Wasteney. Esq. - 363
Stephen, Alex., & Sons, Ltd., Messrs. - - - - - - 101, 298
Stephenson, Robert, & Co., Messrs. - - - - - - 278, 298
Steven & Struther, Messrs. - 237
Stewart, C., Esq. - - - - 346
Summers & Payne, Ltd., Messrs. 110, 112, 114, 116
Swan, Hunter & Wigham-Richardson, Ltd., Messrs. - 181
Swedish Commissioners to the Fisheries Exhibition - - 132

PAGE

Sweeting, F. J.. Esq. - - - - 150
Swinburne, T. A., Capt., R.N. - 363

Taplin, R., Esq. - - - - 312
Tasmanian Commissioners to the Fisheries Exhibition - 133, 140, 141
Taylor, F., Esq. - - - 111, 112
Taylor, Dr. J., M.D. - - - 179, 228
Taylor, J., Esq. - - - - - 369
Teasdel, J. E., Esq. - - 130, 145, 146
Telegraph Construction and Maintenance Co. - - - 88, 235
Thames Ironworks & Shipbuilding Co., Ltd., The - - - 42, 118
Thompson, Joseph L., & Sons, Messrs. - - - - - - 90
Thomson, A., Esq. - - - 179
Thomson, J. & G., Messrs. - - 83
Thornycroft, John I., & Co., Ltd., Messrs. 39, 41, 42, 45, 281, 300, 305, 352
Tolhausen, A., Esq. - - - 370
Trinity House, Corporation of the - - - - - - 233–235
Trotman, J., Esq. - - - - 361
Tucker, J. S., Esq. 21, 127, 170, 177, 187, 192, 347
Tudor, J. R., Esq. - - - 129, 130
Turk, R. J., Esq. - - - - 115
Turk, R. J., & Sons, Messrs. - 141
Turnbull, T., Esq. - - - 131, 139
Turner, G., Esq. - 30, 32, 144, 191
Turner, R., Esq. - - - - 172

Union Steam Ship Co., The - 85, 95
U. S. A. Lighthouse Board, The 236, 237

Vansittart, Mrs. H. - - - 329, 334
Vaughan, E. P. H., Esq. - - 151
Vickers, Sons & Maxim, Messrs.- 51
Vines, R., Esq. - - - - - 322

Walduck, H., Esq. - - - - 332
Walters, R., Esq. - - - - 160
Watkins & Co., Messrs. - - 111, 142
Watson-Höwen, Count - - 153, 159
Watson, Henry, & Sons, Messrs. 314
Watson, John L., Esq. - - 112, 113
Watt, James, & Co., Messrs. - 266
Watts, Ward, & Co., Messrs. - 91, 93
Weir, G. & J., Messrs. - - 313
Welin, A., Esq. - - - - 151
West India & Pacific Steam Ship Co., The - - - 76, 78
Westgarth, English, & Co., Messrs. - - - - - - 251
Westwood & Baillie, Messrs. - 29
Wilesmith, John, & Co., Messrs. - 123
Willis, W., Esq. - - - - 296
Wimshurst, H., Esq. - - - 327, 328
Wimshurst, J., Esq. - - - 340, 374
Wingate, Thos., & Co., Messrs. - 375
Wiseman, F., Esq. - - - - 138
Wolseley Tool & Motor Car Co., Ltd., The - - - - - 282
Woodcroft Bequest 24, 64–66, 83, 117, 232, 244, 245, 247, 262, 318, 325-327, 330, 331, 335, 336

Yarrow & Co., Messrs. - 46, 84, 301
Young, J., Esq. - 54, 131, 144, 170
Yuill, G. S., & Co., Messrs. - 228

Zohrab, J., Esq. - - - - 158

INDEX.

PAGE
"Aaron Manby," P.S. (1822) 52, 242, 256, 320
Accra canoe - - - - - 155
"Achilles," H.M.S., steering gear of - - - - - - 350
"Active," proposed turret ship - 35
Adjustable propellers - - 335–338
"Admiral Popoff," warship - 37
"Admiral" class, battleship 199, 208, 352
Admiralty cruisers - - - 97, 100
Admiralty yacht - - - 31
"Agamemnon," H.M.S. (1852) - 26, 27
"Agincourt," H.M.S. (1864) - 28
"Agincourt," H.M.S. (1864), engines - - - - - - 274
"Ajax," H.M.S. (1798) - - 19
"Ajax," H.M.S. (1848) - 27, 30, 264
"Alabama," privateer (1862) - 30
"Alacrity," H.M.S. (1885) - 41
"Alarm," Yt. (1830) - - 105, 107
"Albatross," P.S. (1878) - - 149
"Alberta," S. Yt. (1896) - - 122
"Albion," H.M.S. (1842) - - 23
"Alecto," H.M.S. (1843) - - 330
"Alert," cutter (1755) - - 13
"Aline," Yt. (1860) - - - 110
"Alma," S.S. (1894) - - - 98
"A. Lopez," S.S. (1865), engines 272
"Aloungpyah," P.S. (1875) - 82
Ambulance surf boat - - 134
"Ambuscade," H.M.S. (1773) - 15
"America," Yt. (1851) - 105, 108, 109
American river steamers - 64, 66, 69, 74, 77, 80, 84, 101, 247, 259
American war-vessels - 30, 196, 268
American whaling boat - - 134
"Amethyst," H.M.S. (1811) - 187
"Amphion," H.M.S. (1844) 27, 242, 268, 329
Anchor, Baxter's - - - - 363
Anchor, Byers' - - - - 364
Anchor, Hawkins's - - - 360
Anchor, Hunter's - - - 362
Anchor, Lenox - - - - 364
Anchor, Martin's - - 47, 362, 363
Anchor, Porter's - - - 359, 361
Anchor, Rodger's - - - 361
Anchor, stowage of, etc. - - 47, 365
Anchor, Trotman's - - - 361
Anchor, Wasteneys Smith's - 363
Anchor, wedge clump - - 364
"Anglo-Egyptian," steam launch - - - - - - 143
"Annette," S.S. - - - - 75
"Antelope," brig - - - 54
"Apollo" class, cruiser - - 208
Arab trading vessels - - - 158
"Arbib Brothers," S.S. (1888) - 91
"Arctic," P.S. (1850) - - 66
Archer's steering gear - - 350
"Archimedes," S.S. (1838) 323, 327, 328
"Ariadne," H.M.S. (1816) - 21
"Ariel," S. (1865) - - - 56
"Arizona," S.S. (1879) - - 83

PAGE
Armed cutters - - - 13, 20, 22
"Armide," frigate - - 389
Armour plating - - - 185, 196, 200
Armour belt - - - - 43, 48, 200
"Arrogant," H.M.S. (1849) - 391
"Arrow," H.M.S. (1871) - - 37
"Arundel Castle," S. (1864) - 56
"Aska," S.S. (1889) - - - 93, 279
Assisted draught for boilers - 310
"Athenian," S.S. (1881) - - 85
"Atlantic," P.S. (1850) - - 66
Auger, screw - - - - - 192
"Augusta," H.M.S. (1733) - 176
"Augusto Montenegro," S.S. (1900) - - - - - - 101
"Austral," S.S. (1881) - - 85
"Australia," S.S. (1892), stern frame - - - - - - 209
Australian fishing boats - 133, 140, 141
Australian lifeboats - - - 147
Auxiliary screw propellers 76, 328, 337–340
"Avni Illah" (1869) - - 32
"Avon" class, gunboat - - 194
"Azizea," frigate (1866) - - 32

Babcock and Wilcox boiler - 303
"Bacchante," H.M.S. (1876), engines - - - - - - 275
"Baggala," Arab - - - 158
Balance-chambers, water - - 181
Balance-rudder 44, 208, 210, 212, 347, 348, 353
Balancing engines - - 263, 281–283
Balloons - - - - - - 381
"Baltic," P.S. (1850) - - 66
Baltic trading steamers - - 70, 79
"Bann," H.M.S. (1856) - - 29
Barbette ships - - - 7, 43, 50, 185
"Barfleur," H.M.S. (1768) - 15
Barge, hopper - - - - 379
Barge, sailing - - - - 137
Barge, State - - - - 126
Barges, Thames - - - 137
Bar-keels - - - - - - 203
"Baron Osy," P.S. - - - 71
Barque (1850) - - - - 55
"Barrow Express," P.S. (1882) - 87
"Basilisk," H.M.S. (1845) - - 331
"Batello," Arab - - - 158
Battery, floating - - - 35–37
Battery, proposed main deck - 212
Battleship, Elizabethan - - 9
Battleship, four-decked (1809) - 21
Baxter's anchor - - - - 363
Baxter's cable windlass - - 357
Beam engine, American - - 259
Beam engines - - - - 248–251
Beam knees - - 182, 187, 190, 206
Bearings, lignum vitæ - - 292, 324
"Belleisle," H.M.S. (1876) - - 39
"Bellerophon," H.M.S. (1865) 28, 31, 197
Belleville boiler - - - 300
Bell-Rockcliffe plating - - 202

PAGE
Belt, protective - - 43, 48, 189, 200
"Benbow," H.M.S. (1888) - 32, 42
"Benedict," S.S. (1888) - - 91
Bengal pilot brig - - - - 55
Bengalese boats - - - 160, 161
Bermuda floating dock - - 223
Berth fittings - - - - - 218
"Bezan" rig - - - - - 106
Bi-fluid clinometer - - - 373. 374
Bilge valves, boats - - - 152
Birchbark canoe - - - - 154
Bishopp's disc engine - - 264
"Black Eagle," H.M.S. (1831) - 27
"Blake," H.M.S. (1889) - - 44
Blake's screw - - - - - 192
Blake's stopper - - - - - 368
"Blenheim," H.M.S. (1847) - 27, 339
"Blenheim," H.M.S (1890) - 32
Blériot flying machine - - 386
"Bleville," S.S., boiler of - - 298
"Boadicea," H.M.S. (1876), engines - - - - - - 275
Boat construction - - - 124
Boat chocks - - - - - 151
Boat davits - - - - - 151
Boat disengaging gear - 125, 150, 151
Boat lowering apparatus - 125, 150, 151
Boats, collapsible - - - 134
Boats, ferry for disembarking - 143
Boats, fishing 125, 128–133, 136, 138–141
Boats, ice - - - - - 116, 117
Boats, life - - - - - 144–148
Boats, man-of-war's - - - 127, 135
Boats, method of stowing - - 128, 151
Boats, racing and rowing - - 127, 128
Boats, surf - - - 134, 146, 155
Boiler, Babcock & Wilcox - - 302
Boiler, Cochran's - - - 297
Boiler, Dundonald's - - - 295
Boiler fittings - - - - 306–310
Boiler furnaces - - - - 310, 311
Boiler, Gray's - - - - 295
Boiler, Hawthorn's - - - 295
Boiler, Kemp's - - - - 298
Boiler, Niclausse - - - 304
Boiler, Perkins's - - - 293, 306
Boiler, Reed - - - - 303
Boiler, Scott's - - - - 297
Boiler, Thornycroft - - - 294, 300
Boiler, Thornycroft-Schulz - 305
Boiler, Yarrow - - - - 294, 301
Boilers, Belleville - - - 294, 300
Boilers, box - - - - 295
Boilers, forced draught for - 307–309
Boilers, Scotch - - - - 299
Boilers, Serve tubes for - - 311
Boilers, vertical - - - 297
"Bokhara," S.S. (1873) - - 80
"Bolivar," S.S. (1862) - - 76
Bombay fishing boat - - 161
"Bonetta," H.M.S. (1871) - 37
"Bonita," Yt. (1876) - - 111
"Botter" Dutch - - - 136
Bow castings and forgings - 209–212
Bow framing - - 186, 194, 199, 201
Bowsprit, fids for - - - 170
"Boyne," H.M.S. (1776) - - 16
Bracket framing - 184, 197, 201, 204
Brackets for shaft - - - 209, 211
Bramah's screw propeller (1785) 325

PAGE
Brazilian gunboats - - 38
Brazilian jangada - - - 153
Bremme valve gear - - - 285
"Braunschweig," battleship (1904) - - - - - - 49
"Brighton," P.S. (1878) - - 83
Brigs, merchant - - - 54, 55
"Britannia," Yt. (1893) - - 105
"Britannia," P.S. (1840) - - 61, 251
"Britannia," telegraph S.S. - 88
"Britannic," S.S. (1874) engines 275
"Brooke II.," motor boat - - 122
"Brotherly Love," brig - - 54
"Brune," H.M.S. (1856) - - 29
Buchanan's paddle-wheel - - 319
Buffer for tiller chain - - 352
Bulkheads, double - - - 179
Bulkheads, watertight 79, 92, 180, 181, 206, 207
"Bullfinch," H.M.S. - - - 347
Bulwarks - - - - - 207
"Bunnie," Yt. (1906) - - 116
Buoys, bell - - - - 231, 237
Buoys, life - - - - 238–240
"Buttercup," Yt. (1880) - - 112
Burmese boats - - - - 161
Byers's anchor - - - - 364

Cable stoppers - - - - 368
Cables - - - - - 360, 366
Cables, compressors for - - 367, 368
Cables, slips for - - - 368
"Cabral," gunboat (1866) - - 33
Caissons for docks - - - 222, 225
"Calcutta," H.M.S. (1831) - 28
"Caledonia," H.M.S. (1808) - 20, 21
"Caledonia," H.M.S. (1862) - 191
"Cambria," Yt. (1868) - - 110
"Cambridge," S.S. (1886) - - 90
"Campania," S.S. (1892) - - 97
Canadian river steamers - - 74, 77
"Candia," S.S. (1854) - - 69, 265
Canoe, Rob Roy - - - 141
Canoes - 152, 154–156, 158, 159, 167
"Canterbury," H.M.S. (1741) - 176
Cantilever-framed ship - - 390
Capstans - - - - - 355, 357
"Captain," H.M.S. (1869) - - 28, 174
Cargo discharging float - - 228
"Caribo," P.S. (1860) - - 74
"Carmarthenshire," S. (1865) - 57
"Carnatic," S.S. (1863), engines 271
Carrack, 15th century - - 8
Catamarans - - - 152, 153, 167
"Cathay," S.S. (1872) - - 80
Cathead - - - - - - 365
"Cedric the Saxon," S. (1875) - 58
"Cedric," S.S. (1902) - - 102
Cellular construction 184, 197, 201, 204, 205
"Celt," fishing boat (1883) - 138
"Celtic," S.S. (1901) - - - 102
Centre-board vessels 56, 105, 114–116
"Cevic," S.S. (1894), castings for - - - - - 209
Chain cables - - - - - 366
Channel steamers 71, 79, 80, 83, 96, 98, 252
"Charkieh," S.S. (1864) - - 77
"Charlotte Dundas," P.S. (1801) 246

PAGE
"Chazalie," Yt. (1875) - - 120
"Cheshire," P.S. (1863) - - 76
"Chester," H.M.S. (1691) - - 11
Chilian war-vessel - - - 40
Chinese junks - - - - 163–165
Chinese life-boats - - - 164
"Ching-ping," S.S. (1890) - 93
Cingalese outrigger canoe - - 159
Circular armour clads - - 35, 37
"City of Chicago," S.S. (1883) - 88
"City of Dundee," S.S. (1890) - 280, 308
"City of London," ketch - 139
"City of Paris," S.S. (1866) - 78
"City of Paris," S.S. (1889) - 92
"City of Richmond," S.S. (1874) 81
"City of Rome," S.S. (1882) - 86, 290
"City of Vienna," S.S. (1890) - 94
"Clan Colquhoun," S.S. (1899) - 100
"Clan MacArthur," S.S. (1883) - 88
"Cleopatra," H.M.S. (1779) - 17
"Cleopatra," S. Yt. (1858) - 19
"Cleopatra," obelisk vessel (1877) 143
"Clermont" P.S. (1807) - - 247
Clifford's boat lowering - - 150
Clinometers - - - - 373, 374
Clipper race (1866) - - - 54
Clipper sailing ships - - 53–58, 107
Clipper schooner - - - 57
Clutch for propeller shaft - 292
Clyde passenger steamers 79, 102, 104, 247, 248
"Clyde," P.S. (1841) - - 62
Coamings, hatchway - - 216
Coble, fishing - - - - 131
Cod's head and mackerel's tail lines - - - - - - 177
Coffer dam to screw - - - 229
Cold storage arrangements - 217
Collapsible boats - - - 134
Collier, steam - - - - 97, 101
"Collingwood" class, details of - 199
Collins Line steamers - - 66
Collision bulkhead - 75. 194, 199, 201
"Colombia," S.S. (1899) - - 101
"Colombo," S.S. (1853) - - 69
"Colombo," gunboat (1866) - 33
"Columbia," P.S. (1861) - - 75
"Columbia," S.S. (1894) - - 98
"Comet," P.S. (1811) - - 247, 248
"Commerce de Marseille," (1793) 19
Composite ship construction 53, 183, 192, 195
Compressors for chain cables - 367, 368
Condensers, surface and jet - 243, 285
"Confiance," H.M.S. - - - 321
"Connaught," P.S. (1860) - - 74
Conoidal screw propeller - - 330
"Conqueror," H.M.S. (1859), engines - - - - - - 268
Coracle - - - - - - 9, 125
Cornish fishing boats - - 131, 138
"Corolla," Yt. (1895) - - 115
Corrugated boiler flues - - 297
"Corsair," Yt. (1832) - - 107
"Corsair," Yt. (1892) - - 114
Corvettes - - - 23, 25, 29, 30, 198
"County of Selkirk," S. (1878) - 59
Cranks, disconnecting - - 258, 291
Crank-shafts, built-up - - 290, 291
"Craster Hall," S.S. (1909) - 203

PAGE
"Creole," Yt. (1890) - - - 113
"Crescent," H.M.S.(1894), engine framing - - - - - - 281
"Cricket," steam launch - - 142
"Crocus," S.S. (1885) - - 88
"Cruiser," H.M.S. - - - 264
Cruiser, Chilian (1884) - - 40
Cruiser, Japanese - - - 40
Cummerow's screw propeller - 326
"Cupica," barque (1888) - - 59
Curragh, Irish - - - - 125
Curves of warships, 18th century 176
Cutters, Revenue - - 13, 22, 23
Cutters, steam, etc. - - 135, 147, 148
Cycloidal paddle wheel - - 317, 318
"Cygnet," S. - - - - - 58

"Dahabeeyah," Nile boat - - 158
"Dakahlieh," S.S. (1865) - - 77
"Damascus," S.S. (1887) boilers of - - - - - - - 314
"Dantzig," warship - - - 26
Danube river steamer (1846) - 66
"Daring," H.M.S. - 45, 281, 352
"Dauntless," proposed turret ship - - - - - - 34
Davits - - - - - 12, 18, 151
Deadeyes - - - - - - 171
"De Buffel," war-vessel (1868) - 36
"Deccan," S.S. (1868) - - 79
Deck fastenings 187, 188, 194, 206. 207
Deck log - - - - - - 371
Decks, wood and iron - - 206–208
Decks, protective - 40, 185, 200, 208
"Dee," H.M.S. (1827) - - 249
"Defence," proposed turret ship (1866) - - - - - - 35
"Delhi," S.S. (1864) - - - 77
"Democrata," gunboat - - 38
"Deptford," H.M.S. (1719) - 176
Deptford Dockyard - - - 13. 221
Derrick, Turnbull's - - - 228
Despatch boat - - - - 150
"De Tyger," war-vessel (1868) - 36
"Devastation," H.M.S. (1840), engines - - - - - - 24, 254
"Devonia," S.S. (1876) - - 82
"Dewsbury," steam launch - 143
Dhow, Red Sea - - - - 153, 158
Dhow canoe - - - - - 158
"Diadem," H.M.S. (1896) - 47, 301
Diagonal bracing - - 183, 189, 191
Diagonal framing - - - 190
Diagonal planking 124, 146, 190, 191, 250
Dial log - - - - - - 371
Dickinson's crank-shaft - - 290
"Dictator," U.S.A. warship (1863) - - - - - - 30
Dioptric lighthouse apparatus - 231
Dipper dredger - - - - 374, 376
Disc engines - - - - 262, 264
Disconnecting cranks, etc. - 258, 291
Disengaging gear, boat - 125, 150, 151
Diving bell and helmet - - 228
Docks, dry, graving, floating, and depositing - - - 221–224
Docks, apparatus for - - - 225
Dockyards - - - - 6, 13, 221
Door, smoke box - - - 311
Door, watertight - - - 215

PAGE
Double-bottoms, construction of 197, 199, 200, 201, 204–206
Double-ended vessels - - 79
Double-hulled vessels - - 159, 245
Douro wine boat - - - 128
"Dragon," H.M.S. (1733) - - 176
Drainage of battleships - - 216
"Drake," H.M.S. (1899), castings 212
"Dreadnought," hospital ship - 20
"Dreadnought," proposed turret ship - - - - - - 34
"Dreadnought," H.M.S. (1906) 7
Dredgers - - - - - - 374–380
Drogue or floating anchor - - 362
"Dromedary," H.M. tug (1894) - 45
"Dryad" class, destroyer - - 45
"Dryad," Yt. (1846) - - - 118
"Duchess of Edinburgh," fishing boat - - - - - - 140
Dugout canoes - - 152, 154–156, 167
"Duke," H.M.S. (1776) - - 14
"Duke of Edinburgh," H.M.S. - 49
"Duke of Kent," proposed battleship (1809) - - - 21
"Duke of Wellington," H.M.S. (1852) - - - - - - 27
"Duncan," ferry steamer - - 92
"Dunottar Castle," S.S. (1890) - 94
"Durham," S. (1866) - - 57
Dutch galliot - - - - 136, 177
Dutch men-of-war - - - 10, 11
Dutch sloop - - - - - 107
Dutch yachts - - - - 104, 106
"Dwarf," H.M.S. (1842) - - 336

"Eagle," S. (1851) - - - 54
"Earl Balcarres," S. (1815) - 54
East Indiamen - - - 54, 56, 189
"Echo," H.M.S. - - - 321
"Eclipse," P.S. (1844) - - 319
"Eclipse," American river steamer - - - - - - 69
"Eclipse," Yt. (1884) - - 112
"Edinburgh," P. vessel (1786) - 245
"Edinburgh Castle," S.S. (1872) 80, 274
"Egeria," Yt. (1865) - - 110
Egyptian dahabeeyah - - 158
Electric log - - - - - 372
"Elizabeth," river steamer (1815) - - - - - - 248
Elizabethan warship - - - 9
"Ellora," S.S. (1855) - - 69
Embarkation of Henry VIII., print - - - - - - 8
"Empire," P.S. (1843) - 64, 66, 318
"Empress of China," (1891) - 209
"Emulator," fishing boat - - 138
"Enchantress," H.M.S. (1885) - 31
"Encounter," H.M.S. (1845) - 27
"Endeavour," P.S., engines of - 256
"Endymion," H.M.S. (1797) - 20
Engines, atmospheric - - 246, 252
Engines, diagonal - - - 261, 265
Engines, disc - - - 262, 264
Engines, flying machine - - 384, 385
Engines, half beam - - - 248, 251
Engines, horizontal direct-acting 264, 266, 270, 276
Engines, inverted 271, 272, 274, 277–284
Engines, oscillating - - - 256–259

PAGE
Engines, return connecting-rod - 252, 253, 268, 269, 271, 274
Engines, Siamese - - - 254
Engines, side lever - - - 248–251
Engines, steeple - - - 253, 263
Engines, steering - - - 351, 354
Engines, trunk - 265, 266, 268, 271, 273, 390
Engines, vibrating piston - - 249
"Enterprize," H.M.S. (1775) - 16
"Erebus," H.M.S. (1856) - - 6
Ericsson's screw, engines and propeller - - - - 268, 328
"Ermack," S.S. (1898), castings 211
Eskimo canoes - - - - 154, 155
"Esmeralda," cruiser (1884) - 40
Evaporator for boiler - - 314
"Evelyn," P.S. (1864) - - 77
"E. W. Morrison," American schooner - - - - - 58
"Excellent," H.M.S. (1810) - 28
"Exeter," H.M.S. (1700) - - 176
"Experiment," H.M.S. (1774) - 16

"Fair American," brig - - 16
"Fairy," H.M. Yt. (1844) - - 117, 118
"Falls of Earn," S. (1884) - 59
Falua - - - - - 141
"Fantôme," H.M.S. (1838) - 22
Faroese fishing boat - - - 129
Farnley boiler flue - - - 310
"Fauber" class, motor boats - 123
"Fay," Yt. (1845) - - - 108
Feathering paddle-wheels - - 319–322
Feed water regulator - - - 314
Feluccas - - - - - - 19, 141
Ferrando's forced draught - - 308
Ferry steamers - - 76, 79, 88, 89, 104
"Finnieston, No. 1," ferry boat - 104
Fiddles for ships' tables - - 218
Fids, Blake's - - - - - 170
"Fiery Cross," S. (1855) - - 55
"Fiery Cross," S. (1861) - - 55, 56
Fiji double canoe - - - 159
"Firm," mortar boat - - 24
Fishbourne's designs - - - 23, 66
Fishing boats, African - - 155–157
Fishing boats, Australian - 133, 140, 141
Fishing boats, Chinese - - 162, 163
Fishing boats, Cornish and S. Coast - - - - - 131, 138
Fishing boats, Guernsey - - 138
Fishing boats, Heligoland - - 129, 131
Fishing boats, Isle of Man - 139
Fishing boats, Japanese - - 166
Fishing boats, North Sea - - 130, 131, 138–140, 142
Fishing boats, Orkney and Shetland - - - - - - 129, 130
Fishing boats, oyster and shrimp 138, 139
Fishing boats, Portuguese - - 128, 129
Fishing boats, Russian and Scandinavian - - - 132, 140
Fishing boat, Scotch - - - 130, 140
Fishing boats, seal - - - 132
Fishing boats, Siamese - - 162
Fishing boats, steam - - - 142
Fishing boats, Yorkshire - - 131, 139
Fish carrying boats - - 130, 132, 136, 139–141

PAGE
Fishing rafts - - - - - 153, 166
"Flamboro" S.S. (1885), engines of - - - - - - - 277
"Flamer," mortar boat - - 24
Fleet at anchor (1854), lithograph - - - - - - 27
Fleets becalmed (1854), lithograph - - - - - - 27
Fleetwood lighthouse - - 232
Floating batteries - - - 35–37
Floating docks - - 221, 224, 226
Floating wharf - - - - - 228
Floor-timbers - - - - - 188
"Fly-by-Night," steam launch - 142
Flying machines - - - 382–387
Fog-horns - - - - - - 237
Forced draught for boilers - 307–309
"Formidable," H.M.S. (1898) - 211, 353
"Formidable," proposed turret ship - - - - - - 35
"Formosa," Yt. (1878) - - 111
"Forte," H.M.S., machinery - 280
Foster's crank-shaft - - - 291
"Four Brothers," schuyt - - 136
Fox's corrugated flues - - 297
Frames, radiating - - - 190
Framing, bracket and longitudinal - - - 197–199, 201–204
Framing, wooden vessels - - 186–191
"France," S. (1890) - - - 59
"Francis B. Ogden," S.S. (1836) 328
"Francis Smith," S.S. (1836) - 327
Fraser river steamboats - - 74
"Freda," Yt. (1880) - - - 112
French ships-of-war - 11, 16, 19, 20, 176, 389
"Fuji," battleship (1896) - - 32
Fulton's steamboat - - - 241. 247
Funnels, telescopic - - - 312
"Fu-ping," S.S. (1890) - - 93
Furnaces for marine boilers - 312
Furnace front - - - - - 312
Futtock timbers - - - 187

"Galatea," S.Yt. (1868) - - 296
Galley, Maltese - - - - 9
Galliots, Dutch - - - - 136, 177
Galloway's engine - - - 249
Galloway's paddle-wheel - - 321
Galway line steamers - - 75
"Ganges," H.M.S. (1821) - - 170
Ganges river steamers - - 60
"Gaul," S.S. (1893) - - - 209
Geared capstan - - - - 356
"Gefion," dredger - - - 377
"General Troquilla," P.S. (1879) 84
German armour-clad (1869) - 36
"Gibraltar," H.M.S., engine framing - - - - - - 281
Gig, man-of-war's - - - 127
"Gladiator," H.M.S. (1896) - 210, 354
"Gladiator," S. Yt. (1886) - 278, 298
"Glatton," H.M.S. (1872) - 28
"Glenartney," S.S. (1873) - 389
"Glengyle," P.S. (1864) - - 77
"Glengyle," S.S. (1886) - - 99
"Glenshiel." S.S. (1886) - - 99
"Glückauf," S.S. (1886) - - 95
"Golconda," S.S. (1863) - - 76
Gondola, Venetian - - - 126

PAGE
"Good Hope," H.M.S. (1900) - 48
Goodwin Sands lightship - - 234
"Gordon," ferry steamer - - 92
"Gorgon," H.M.S. (1838), engines of - - - - - - - 251
"Goth," S.S. (1893) - - - 209
"Governor Douglas," river steamer - - - - - - 74
Governors, marine engine - - 288
"Grace Darling," S. Yt. (1887) - 121
"Grafton," H.M.S. (1892) - 32
"Gratitude," trawler - - 139
"Great Basses" lighthouse - 233
"Great Britain," S.S. (1843) 53, 62, 64, 261, 331
"Great Eastern" (1857) - 72, 73, 78, 344
"Great Eastern," engines of - 257. 266
"Great Harry," H.M.S. (1514) - 89
"Great Western," P.S. (1838) - 53. 61
"Greek," S.S. (1893) - - 209
Greenland kayak - - - 154, 155
Griffiths's screw propeller - 335, 337, 341
"Guadiana," S.S. (1874) - - 81
Guard boat, mine fields - - 42
Guernsey fishing boat - - 138
"Guinevere," Yt. (1868) - - 110
Gunfleet lighthouse - - - 233
Gunwale for boats - - - 191

"Hadley," S.S. (1901) - - 101
Halsted's proposed warships 34, 35, 135, 196
"Hankow," P.S. (1873) - - 80
"Han Kwang," S.S. (1876) - 82
"Harbinger," S.S. (1851), engines 265
"Hardy," mortar boat - - 24
Harfield's steering gear - - 345, 353
Harfield's windlass - - - 357
Harpoon log - - - - - 370
Harwich barge - - - - 137
Hatchways - - - - - 216
Hatchways, self-trimming - - 202, 216
"Hawk," steam trawler - - 142
Hawkins's anchor - - - 360
"Hebe," S. Yt. (1856), engines - 267
"Helen McGregor," P.S. (1843), engines - - - - - 255
"Helicon," H.M.S. (1865) - - 31
Heligoland fishing boat - - 129, 138
"Henri Grâce à Dieu," H.M.S. (1514) - - - - - - 89
Henson's flying machine, 1842 - 383, 384
"Hercules," H.M.S. (1868) - 28
"Her Majesty," P.S. (1850) - 67
"Héros," French warship - - 19
"Hibernia," P.S. (1843) - - 62
"Highflyer," H.M.S. (1851) - 25
"Himalaya," H.M. troopship (1853) - - - - - - 26
Hirsch's propeller - - - 333
Holes in ships, stopping - - 229
Holland's submarine - - - 51
"Ho-nam," P.S. (1882) - - 87
Hopper barge - - - - 379
Hopper dredgers - - 374, 376–378
Horizontal screw engines - 264, 266, 270, 276
Horse stalls for troopship - - 218
"Hound," S.S. (1893) - - 98

	PAGE
"Hounslow," S.S. (1890) - -	93
House boat - - - -	162, 164
Howden's forced draught - -	308
Hoy, Southampton - - -	20
"Huascar" (1866) - - -	28
"Hubbuck," S.S. (1886) - -	90
Hudson river steamers -	64, 66, 247
Hulls's steam boat - - -	241, 244
"Hyacinth" class, cruiser -	195
"Hydaspes," S.S. (1872) - -	80
Hydraulic propulsion -	148, 342, 343
Hydraulic steering gear - -	349, 350
Hydro-kineter - - - -	313
Hydroplane motor boat - -	123
"Ibex," S.S. (1891) - - -	96
Ice boats - - - - -	116, 117
Ice-breaker, "Ermack" - -	211
Ice chambers, ship's - - -	217
"Imperieuse," H.M.S. (1853) -	27
"Inca," S.S. (1856) - - -	243
"Inconstant" class, corvette -	198
"Inconstant," H.M.S. (1868) -	28
Indiamen - - - -	54, 56, 189
Indian river steamers	60, 73, 82, 253, 347
Indian troopships - -	26, 28, 101
Induced draught for boilers -	310
"Inez Clarke," P.S. (1879) -	84
"Inflexible," H.M.S. (1881)	306, 351, 367
"Intrepid," H.M.S. (1770) -	15
"Invincible" (1747) - - -	14
"Iona," P.S. (1864) - - -	248
Irawadi river boats - -	82, 153, 161
"Iris," H.M.S. (1876), engines -	276
Irish curragh - - - -	125
Iron and steel construction -	196-212
"Iron Duke," H.M.S. (1871) -	28
"Irrawaddy," S.S. (1874) - -	81
Isherwood's framing - - -	203
"Islander," S.S. (1888) - -	91
Isle of Man fishing boats - -	139
"Isle of Thanet," P.S. (1844) -	319
"Isolde," Yt. (1895) - - -	115
"Iverna," Yt. (1890) - - -	113
"Ivy," S. Yt. (1895) - - -	121
"Jackdaw," steam launch -	142
"James Duckett," Sr. (1865) -	57
"James Nicol Fleming," S.(1869)	194
"James Watt," P.S. (1822) -	60
Jangada, Brazilian - - -	153
"Janus," H.M.S. (1844) - -	295
"Japanese," S. - - - -	59
Japanese cruisers (1886) - -	40
Japanese junk - - - -	166
Japanese yacht - - - -	165
"Javary," P.S. (1874) - -	81
"J. B. Eminson," S.S. - -	216
"Jeanne and Louise," steam launch - - - - -	143
"Jersey," H.M.S. (1733) - -	176
"John Wesley," Sr. (1867) -	57
Jouffroy's steamboat, sketch of -	244
Joy's valve gear - - -	286, 287
"Jullanar," Yt. (1875) - -	105, 111
"Jumna," P.S. (1832) - -	60
Junks - - - - -	161, 163-166
"Juno," H.M.S. (1757) - -	13
Jury-rudders - - - -	345, 346

	PAGE
"Kamakura Maru," S.S. (1897)	99
"Kashgar," S.S. (1874) - -	81
"Kate," yawl (1869) - -	118
"Kathleen," S.S. tug - -	149
Kayak, Eskimo - - - -	154, 155
"Kearsarge," man-of-war - -	30
Keels and keelsons - - -	203-205
"Kenia," P.S. (1890) - -	94
"Keying," junk - - -	164
"Khiva," S.S. (1874) - -	81
"King Edward VII.," H.M.S.(1905)	49
"King Edward," S.S. (1901) -	102
"Kingfisher," H.M.S. (1769) -	15
"King George" (1867) - -	32
King's Ship, 11th century -	7
"Kingston," H.M.S. (1736) -	176
Kingston valves - - -	218, 219
Kirk's evaporator - - -	314
Knees, built-up wood - -	187, 188
Knees, iron - - - -	190, 206
"Koh-i-noor," P.S. (1892) - -	98
"König Wilhelm," frigate (1869)	32
"Korniloff," S.S. (1865) - -	76
Kroo canoes - - - - -	156
Ladder dredger - - -	374-377
"Lady Daly," lifeboat - -	147
"Lady Nan," Yt. (1888) - -	113
"Lady Torfrida," S.Yt. (1886) -	121
Lafargue's steering gear - -	349
Lagos fishing boats - - -	156
"Lahloo," S. (1867), lithograph -	57
"La Hogue," H.M.S. (1848) -	339
Laing's valve gear - - -	287
"Lammermoor," S. (1874) -	58
Lamp, marine - - - -	236
Lancashire shrimping boat -	139
Launch at Deptford, painting -	13
Launch of H.M.S. "Royal Albert" (1854) - - -	26
Launches - - - -	123, 127, 142
Launches, engines for -	259, 281, 282
Launching ships and boats	12, 17, 22, 58, 66, 125
Lawson's bracket rudder - -	348
"Laying off" of vessels - -	175, 177
"Lazareff," S.S. (1865) - -	76
"Leah," sailing punt (1896) -	115
"Leinster," P.S. (1860) - -	74, 258
Lenox anchor - - - -	364
"Leopard," H.M.S. - - -	27
"Leopard," Yt. (1807) - -	107
"Le Sceptre" (1778-82) - -	16
"Leven," P.S., engines - -	249
"Le Vengeur" (1794) - -	19
"Leviathan" (1857) - - -	71
"Leviathan," dredger - -	380
"Liberty and Property," S. (1754) - - - - -	54
Lifeboat apparatus - - -	147, 239
Lifeboat carriages - - -	146, 147
Lifeboat, hydraulic steam - -	148
Lifeboats - - -	124, 144-148, 239
Lifeboats, Chinese - - -	164
Life rafts - - - - - -	239
Life-saving apparatus - -	237-240
Lighter, Thames - - -	137, 227
Lighthouses - - - -	229, 234
"Lightning," H.M.S. (1854) -	27
"Lightning," H.M.S. (1876) -	39

PAGE
Lights, side - - - - 215, 236
Lightships - - - 230, 234, 235
Link-drive for screw shaft - 289
"Little Haste," Yt. (1902) - 116
"Livadia," Russian Yt. (1880) - 120
Lloyd's Coffee House - - 53
Logs, ships' - - - - 369–372
"London," H.M.S. (1840) - - 27
"London Engineer," P.S. (1818) 249
"Londonderry," S.S. - - 389
Longitudinal framing - 72, 184, 202
"Lord Nelson," H.M.S. (1908) - 49, 50
"Lord Warden," H.M.S. (1865), screw of - - - - - 333
"Lord W. Bentinck," P.S. (1832) 60
Lowe's screw propeller - - 329
"Lucania," S.S. (1892) - - 97
"Lyons," P.S. (1856) - - 71
Lyttleton's screw propeller (1794) - - - - - 325

"Mab," S.S. (1874) - - - 135
Madras surf boats - - - 159
"Maggie," Yt. (1878) - - 111
"Magicienne," H.M.S. (1888) - 44
"Maiden City," barque (1887) - 59
"Majestic," H.M.S. (1853) - 27
"Majestic," H.M.S. (1895) - 210
"Majestic," S.S. (1889) - - 279
"Malabar," H.M. troopship (1866) - - - - 33
"Malabar," S. (1860) - - 56
Malacca lighthouse - - - 233
Malayan proa - - - - 153, 160
Mallory's propeller - - - 341
Maltese vessels - - - - 9, 126
"Malwa," S.S. (1873) - - 80
Man-of-war's gig - - - 127
Manx fishing boats - - - 139
Maplin lighthouse - - - 232
Marine boilers (*see* boilers) - 292
Marine engines (*see* engines) - 241
Marine engine governor - - 288
"Marlborough," H.M.S. (1852) - 28, 267
"Marquis of Bute," P.S. (1868) - 79
"Martaban," S.S. (1874) - - 81
Martin's anchor - - 47, 362, 363
Martin's assisted draught - - 310
"Mary Taylor," pilot boat (1850) 108
Masoolah boat, Madras - - 153, 159
"Massilia," P.S. (1860) - - 75
Masting sheers - - - - 227
Masts and fittings - - 168, 170–172
Mat for stopping holes in ships - 229
Maudslay's engines - - 252, 256, 267
Maudslay's screw - - - 336, 339
"Mauretania," S.S. (1907) - 181
Maxim's flying machine - - 385
"Mayflower," river steamer - 69
"Medea," H.M.S. (1833) - - 321
"Medway," S.S. (1865) - - 77
"Megna," P.S. (1832) - - 60
"Meleager," H.M.S. (1785) - 18
"Mercury," H.M.S. (1876), engines - - - - - - 276
"Merlin," S. (1851) - - - 54
"Mersey," H.M.S. (1885) forced draught - - - - - - 309
"Mersey," P.S. (1859) engines - 258
"Mersey," Yt. (1877) - - 111

PAGE
Mersey ferry steamers - - 76, 89
"Messoudiyé" (1874) - - 32
"Meteor," Yt. (1887) - - 112
Mevagissey fishing boat - - 131
"Mexico," gunboat (1875) - 38
"Midge," steam launch - - 143
Midship section of battleship 189, 196, 197, 199
Midship section of corvette 194, 195, 198
Midship section of merchantmen 192-195, 201–203
Midship section of proposed warships - - - - - 196
Miller's double-hulled vessels - 245
Miller's marine engine (1788) - 241, 245
Mine fields, guard boat for - 42
"Minnow," Yt. (1885) - - 112
"Minotaur," H.M.S. (1866) 28, 32, 196
"Minx," H.M.S. - - - - 264
"Miramar," P.Yt. (1872) - - 119
Mississippi river steamers - - 69
Mitchell's screw piles - 232, 233, 364
"Mona's Queen," P.S. (1885) - 87
"Monarch," H.M.S. (1868), engines - - - - - 270
"Monarch," telegraph ship (1883) - - - - - - 87
"Monitor," (1862), engines of - 268
Morgan's paddle wheel - - 321
Mortar boats (1855) - - - 24
"Mosquito," Yt. (1848) - - 105, 108
Motor boat planking - - - 191
Motor boats, petrol - - 106, 122, 123
"Mule," fishing boat - - 131
"Muleta," fishing boat - - 129
Multiplying gear for screw engines - - - - 262, 263, 289
"Munster," P.S. (1860) - - 74
"Muriel," Yt. (1869) - - - 110
"Mystery," Yt. (1841) - - 107

"Nachimoff," S.S. (1865) - - 76
"Naniwa," cruiser (1886) - - 40
"Napier," S. (1869) - - 194
Napier's paddle wheel - - 319
"Narciso Deulofeu" - - - 149
"Narcissus," H.M.S. (1859) - 28
Nasmyth's screw-propeller - 326
"Natchez," river steamer - - 69
"Nautilus," lifeboat - - - 145
Navigation lights - - - 236
"Nelson," H.M.S., engines of - 268
"Nelson," mast of - - - 170
"Nembo" class, torpedo b. d. - 48
"Neptune," H.M.S. (1876) - 28, 37
"Neptune," Yt. (1875) - - 111
Neva river steamers - - - 135, 248
"New World," P.S. (1849) - 66
"New York City," S.S., boiler of 308
"Niagara," steering wheel - 349
Niclausse boiler - - - 304
"Niger," H.M.S. (1845) - - 331
Nigerian canoes - - - 156
Nile boats - - - - 41, 156–158
"Nix" gunboat - - - 25
"Norman Isles," S.S. (1896) - 99
North Isles fishing boat - - 130
North Sea trawler - - - 139, 142
"Northumberland," H. M. S. (1868) - - - - - - 33

PAGE

"Northumberland," H.M.S. (1868), engines - - - 273
"Notting Hill," S.S. (1883) - 332
"Novelty," S.S. (1840) - - 328
"Novorossisk," S.S. - - - 150
"Nyanza," S.S. (1890) - - 142

"Octavia," H.M.S. (1849), engines - - - - - 269
Oil boat, Burmese - - - 161
Oldham's paddle-wheel - - 320
"Omrah," S.S. (1899) - - 100
"Onyx," H.M.S., machinery - 280
"Ophir," S.S. (1891) - - - 95
"Orient," S.S. (1879) - - 84, 276
"Orinoco," S.S. (1886) - - 90
"Orinoco," S.S. (1886), engines - 278
"Orion," H.M.S. (1876) - - 39
"Orkhanea," frigate - - - 32
"Orlando," P.S. (1885) - - 89
"Orlando," H.M.S. (1888) - - 43
"Ormuz," S.S. (1886) - - 91
Oscillating engines - - 242, 256–259
"Osman Ghazy," or "Osmanea," frigate (1866) - - - 32
"Otago," sailing ship (1869) - 194
Outer Gabbard lightship - - 235
"Outlook," Yt. (1902) - - 115
Outrigger boats - - 153, 159, 167
Oyster dredging boat - - 138
"Ozone," P.S. (1886) - - 89

"Pacific," P.S. (1850) - - 66
"Pacific," P.S. (1854) - - 68, 257
Paddle-chain, Spurgin's - - 343
Paddle engines (*see* engines) - 244
Paddle frigates - - - - 24–27
Paddle-wheel, Buchanan's (1813) 319
Paddle-wheel, disconnecting apparatus - - - - - 258, 291
Paddle-wheel, Galloway's (1829) 316, 321
Paddle-wheel, Morgan's (1830) - 316, 321
Paddle-wheel, Oldham's (1827) - 320
Paddle-wheel, Poole's (1829) - 320
Paddle-wheel, Rennie's (1839) - 317
Paddle-wheel, Seaward's (1833) - 321
Paddle-wheels, cycloidal floats - 317, 318
Paddle-wheels, feathering floats 258, 261, 319–322
Paddle-wheels, fixed floats - 317, 318
Paddle-wheels, reefing floats - 319
Paddle-wheels, weighted floats - 319
Paddle *v.* screw, trials of - - 330, 331
"Palgrave," S. (1884) - - 59
"Paouting," S.S. (1873) - - 179
"Papanui," S.S. - - - 217
"Paris," S.S. (1889) - - - 92
Parsons steam turbine - - 243, 284
"Pass of Melfort," S. (1891) - 60
"Pattamar," Bombay - - 161
"Paul Paix," (1908), oil steamer 202
"Pearl," Yt. (1820) - - - 107
"Pendennis," P.S. (1885), engines - - - - - 251
Penn's oscillating engines - - 242
Penn's trunk engines - - - 242, 273
"Pera," S.S. (1855) - - - 71
"Périere," S.S. (1866) - 77, 333, 349
Perpetual log - - - - 369
Petrol engine - - - - 282

PAGE

Petroleum bulk steamer - 95, 103, 202
"Philadelphia," S.S. (1889) - 92
Pillars, ships - - - - 182, 202
Pilot boat, "Mary Taylor" - 108
Pilot brig - - - - - 55
"Pinken," Dutch - - - 136
Pinnaces, steam - - - 135
Planking, shell and deck 186, 187, 190, 191, 193, 194
Plating, shell and deck 198, 199, 201–203
Plugs, bilge - - - - 152
"Pomone" frigate - - - 20, 242
Pontoon, life raft - - - 239
Pontoon, ship-raising - - 226
"Popovka," Russian warship - 37
Porter's anchor - - - - 359, 361
"Portland," H.M.S. (1770) - 15
Ports, ships' - - - - 189
Portuguese boats - - 128, 129, 141
Portuguese warship - - - 32, 38
"Poulton," dredger (1899) - 378
"Powerful," H.M.S. (1896) - 46, 301
"Powerful," proposed warship - 34
Price's self-trimming hatchways 216
"Prince Albert," H.M.S. (1864), engines - - - - 270
"Prince Regent," H.M.S. (1823) 21, 27
"Princesa de Asturias" (1895) - 210
"Princess Alice," P.S. (1843), engines - - - - - 255
"Princess Mary," H.M.S. (1737) 176
"Princess Royal," H.M.S. (1854) 27
"Princess Royal," S.S. (1841) - 62
"Princesse Henriette," P.S. (1888) - - - - - - 261
"Prinzessin Charlotte," P.S. (1816) - - - - - - 248
Proa, Malayan - - - - 153, 160
"Prometheus," S.S. (1886) - 278, 298
Propeller log - - - - 370, 371
Propellers, paddle (*see* paddle-wheels) - - - - - 315
Propeller, reciprocating - - 343
Propellers, screw (*see* screw propellers) - - - - 323
"Propontis," S.S. (1874) - - 243
Protected screw - - - 340, 341
Protective belt - - 43, 48, 189, 200
Protective deck of warships 40, 185, 200, 208
"Puck," Yt. (1880) - - - 121
Punt, sailing - - - - 115
Purves's ribbed flue - - - 311

Quadrant boat davits - - 151
Quadruple piston-rod engine - 253
Quartermaster, steam - - 351
"Quebec," P.S. (1864) - - 77
"Queen," H.M.S. (1840) - - 27
"Queen Alexandra," S.S. (1902) 102
"Queen Charlotte," H.M.S. (1790) - - - - - - 18

Racing boats - - - - 127, 128
"Racoon," H.M.S. (1857) - - 29
"Ramillies," H.M.S. (1892) - 281
Rapson's slide - - - - 344, 352
Ratchet gear for stays - - 172
"Ratcliff," S.S. (1892) - - 97
"Rattler," H.M.S. (1843) - - 6, 330

PAGE

"Rattlesnake," H.M.S. (1886) - 45
Reciprocating propeller - - 343
"Recruit," H.M.S. (1846) - - 23
"Recruit," H.M.S. (1851) - - 25
Red Sea dhow - - - - 153, 158
Reed boiler - - - - - 303
Reefing sails - - - - - 71
Refrigerating chamber - - 217
"Regina," S.S. (1907) - - 103
"Reindeer," H.M.S. (1860) - 271
"Renard," H.M.S. (1893), machinery - - - - - - 280
Rennie's paddle and screw - 317, 330, 335
"Republique" - - - - 49
Resistance of ships - - - 174, 179
"Resurgam," submarine boat - 51
"Retribution," H.M.S. (1844) engines - - - - - 254
Return connecting-rod engines 252, 253, 268, 269, 271, 274, 275
Revenue cutter (1810–1830) - 27, 33
"Rêverie," Yt. (1891) - - 113
Reversible propeller - - 283, 334, 338
Rice boats - - - - - - 162
Riding-bitt - - - - - 367
Rigging-model - - - - - 170
Rigging plans, 18th century - 170
Rigg's guide blade propellers - 333
"Rippon," H.M.S. (1730) - - 176
"Robert F. Stockton," S.S. (1838) - - - - - 329
"Rob Roy," canoe - - - 127, 141
"Rob Roy," fishing boat - - 142
Rockcutter - - - - - 379
Rocket apparatus - - - - 238
Rodger's anchors - - - - 361
"Rodney," H.M.S. (1833) - - 189
"Romney," H.M.S. (1762) - - 14
Rope drive for screw shafts - 289
"Rosalind," steam launch - - 143
"Rose," P.S. (1876) - - - 82
"Rouen," P.S. (1853) - - 68
Rowing boats - - - 107, 124–134
"Royal Albert," H.M.S. (1854) - 26
"Royal Alfred," H.M.S. (1864) - 28, 229
"Royal Arthur," H.M.S. (1891) - 280, 281
"Royal Charles," H.M.S. (1672) 11
"Royal Charter," S.S. (1859) - 71, 292
"Royal George," H.M.S. (1756) - 9, 13
"Royal George," H.M.S. (1788) - 18
"Royal George," H.M.S. (1853) - 27
"Royal James," H.M.S. (1675) - 9
"Royal Oak," H.M.S. (1769) - 15
"Royal Oak," H.M.S. (1892) - 281
"Royal Sovereign," H.M.S. (1637) - - - - - - 10
"Royal Sovereign," H.M.S. (1891) - - - - 199, 200, 209
"Ruby," P.S. (1836), engines - 250
Rudder, balanced - 44, 208, 210, 212, 347, 348, 353
Rudder, construction of 208–212, 346, 348
Rudder, jury - - - - 345, 346
Rudder, screw - - - - 341
Rudder, twin - - - - - 347
"Rupert," H.M.S. (1736) - - 176
Russian fishing boats - - - 132
Russian ships of war - - - 37, 46
Russian Yt. "Livadia" - - 120
Ruthven's hydraulic propulsion 342, 343

PAGE

"Safa-el-bahr," S.Yt. (1894) - 121
Sail plans, 18th cent. - - 170
Sails, flat surface - - - 171
Sails, reefing - - - - 171, 172
Salvage vessels - - - 149, 150, 227
"Saint," schooner (1870) - - 58
"St. George," H.M.S., lithograph (1854) - - - - - - 24
"St. Jean d'Acre," H.M.S. (1853) 27
St. Lawrence river steamers - 77
St. Thomas floating dock - - 222
"Salamander," H.M.S. (1832) - 6
"Salamander," H.M.S. (1851) - 25
"Salamis," H.M.S. (1865) - - 31
Salinometers - - - - - 313
Sand pump dredger - - - 377, 378
"Sanspareil," H.M.S. (1774) - 19
Santos-Dumont flying machine - 385
"Sarah" of Lewes - - - 326
"Sarah Sands," S.S. (1845) - 65
"Sardinian Prince," S.S. - - 104
"Sarcea," S.Yt. (1886) - - 285, 335
"Satanita," Yt. (1893) - - 114
Scandinavian fishing boats - 140
Scarfs, hooked and tabled - - 195
"Scot," S.S. (1891) - - - 95
Scotch boiler - - - - - 299
Scotch fishing boats - - - 130, 140
"Scotia," P.S. (1861) - - 75, 251
Scott's boiler - - - - - 297
Screw engines (*see* engines) - 261
Screw propeller, Bramah's (1785) - - - - - - 325
Screw propeller, Cummerow's (1828) - - - - - - 326
Screw propeller, De Bay's (1879) 334
Screw propeller, Ericsson's (1836) - - - - - - 328
Screw propeller, Griffiths's (1849–59, 1880) - - - - 335, 337, 341
Screw propeller, Hirsch's - - 333
Screw propeller, Mallory's - - 341
Screw propeller, Maudslay's (1848-53) - - - - - 336, 339
Screw propeller, Lowe's (1834–52) - - - - - - 329, 334
Screw propeller, Lyttleton's (1794) - - - - - - 325
Screw propeller, Rennie's (1839–40, 1879) - - - - - 330, 335
Screw propeller, reversible 283, 334, 338
Screw propeller, Rigg's guide blade (1864) - - - - - 333
Screw propeller, Seaward's (1846–49) - - - - - 338, 339
Screw propeller, Shorter's (1800) - - - - - - 326
Screw propeller, Smith's (1836) - 327
Screw propeller, Vansittart's (1868–9) - - - - - 334
Screw propeller, Woodcroft's (1832–46) - - - - - 335, 336
Screw propellers, adjustable pitch - - - - - - - 335, 338
Screw propellers, disconnecting gear for - - - - - 283, 292
Screw propellers, folding - - 339
Screw propellers, lifting - 25, 338, 339
Screw propellers, increasing pitch - - - - - - 325, 335

PAGE
Screw shaft bearing - - - 292, 324
Screw shaft coupling - - - 292
Screw *v.* paddle, trial of - - 330, 331
Scuttles, deck and side - - 215
Sea inlet valve - - - - - 220
"Sea King," S. (1863) - - 30
Seal hunting boats - - - 155
Seat, pivot, for saloon - - 218
"Secret," oyster fishing boat - 138
Seine fishing boats - - 128, 131, 133
Serve boiler tubes - - - 311
"Servia," S.S. (1881) - - - 86
Service yacht - - - - - 22
Shackles, chain cables, etc. - 366
Shaft brackets - - - - 209–211
"Shah," H.M.S. (1873) - - 28
Shallow draught steamers 41, 60, 73, 82, 84, 94, 346
"Shamrock," P.S. (1876) - - 82
"Sharpshooter" class (1886) - - 45
Sheathing for ships - - - 197, 198
Sheer draughts, 18th cent. - 20, 176
Sheers for masting ships - - 227
Sheet anchor, stowing of - - 365
"Shenandoah," S.S. (1863) - 30
Shetland fishing boats - - 130
Shields coble - - - - - 131
Ship-raising apparatus - - 226, 227
Shorter's screw propeller - - 326
Shrimping boat - - - - 139
Shrouds, Blake's plans for - - 172
Siamese boats - - - - - 162
"Siamese" engines - - - - 254
Side-lever engines - - 242, 249–251
"Sidon," H.M.S. (1846) - - 27
"Silverlip," S.S. (1903) - - 103
"Simla," S.S. (1854), engines - 263
Siren, steam - - - - - 237
"Sir John Lawrence," S.S. - 179
"Sirius," P.S. (1837) - - 52, 61
"Sisceepe," steam launch - - 142
Skiff, Thames - - - - - 127
Slip-hook for cables, etc. - 172, 368
Slip-ways - - - - - - 17, 220
Sloop, Dutch - - - - - 107
Sloop-of-war - - - - - 13, 17
Smalls Rocks lighthouse - - 232
Smith testimonial plate - - 328
Smoke-box door - - - - 311
"Snowdrop," S.S. (1885) - - 88
"Sokol," ice-boat - - - - 116
"Sokol," Russian destroyer (1895) - - - - - - - 46
Solid of least resistance - - 178, 179
"Sorceress," Yt. (1894) - - 114
South Coast fishing boat - - 131, 138
Southport fishing boat - - 139
"Sovereign of the Seas," H.M.S. (1637) - - - - - - 10
Speed indicator - - - - - 371, 372
"Speedy," H.M.S. (1892) - 45, 281, 300
"Sphinx," H.M.S. (1775) - - 16
Starting engine - - - - 261, 287
State barge - - - - - 126
Stays, setting up - - - - 172
"Stealers," method of working - 205
Steam boilers (*see* boilers) - - 292
Steam engines (*see* engines) - 241
Steam trawlers - - - - - 142
Steam turbines - - - - 243, 284

PAGE
Steam windlass - - - - - 357
Steeple engines - - - - 241, 253
Steering arrangements, warships 350–353
Steering gear - - - - - 344–354
Stem forgings and castings - 208–212
Steps for masts - - - - - 171
Stern bush - - - - - 71
Stern forgings and castings - 208–212
Sterns, iron and steel ships 201, 208, 353, 354
Sterns, wooden ships - - 186, 187, 189
Stern-wheel steamers 74, 84, 94, 246
Stévart's valve gear - - - 286
Stevens's cut-off gear - - 260
"Stonehouse," S. (1866) - - 57
Stoppers for anchors - - - 368
Stopping holes in ships - - 229
"Strafford," H.M.S. (1714) - 176
"Strafford," H.M.S. (1733) - 176
Stringers, deck - - - - - 206
Stringfellow's flying machine, 1846–8 - - - - - - - 384
Submarine boats - - - - 51
Submarine-cable gear - - 358
Suction dredgers - 375, 377, 378, 380
"Sudbourne," S. (1881) - - 59
"Sunbeam," S.Yt. (1874) - - 119
"Sunk," lightship - - - - 235
"Superbe," H.M.S. (1710) - - 176
"Surat," S.S. (1866) - - - 78
Surf boats and rafts - 134, 146, 152, 153, 155, 159, 166, 167
"Surprise," H.M.S. (1885) - 41
"Swallow," S. (1788) - - 54
"Swedish Arrow," ice yacht - 117
Symington's engines (1788 and 1801) - - - - - - 245, 246
"Syria," S.S. (1901) - - - 101

Tables for shipboard - - - 218
"Taeping," S. (1863) - - 56
"Takachiho," cruiser (1885) - 40
Tank steamer - - - - 95, 103, 202
"Tara," Yt. (1883) - - - 112
"Taroba," S.S. (1888) - - 92
Tasmanian fishing boats - 133, 140, 141
Telegraph cable-laying steamers 75, 87, 88
Telescopic funnels - - - 312
Telescopic rudder - - - 346
Telescopic tiller - - - 348
"Terne," Yt. (1860) - - - 110
"Terrible," H.M.S. (1845) - - 24
"Terrible," H.M.S. (1896) - - 301
"Terror," H.M.S. (1856) - - 7
"Teviot," P.S. - - - - - 62
"Thames," P.S. (1832) - - 60
Thames barges - - - - - 137
Thames lighter - - - - 137, 227
Thames river steamers - 88, 92, 98
Thames skiff - - - - - 127
"Thelma," barge (1901) - - 137
"Themis," Yt. (1851) - - 109
"Thetis," S.S. (1858) - - 243
"Thistle," Yt. (1887) - - 112, 113
Thornycroft boiler - - - 300
Thornycroft-Schulz boiler - - 305
"Thunderbolt," H.M.S. (1856) - 7, 332
"Thyboron," dredger (1892) - 377
"Tilbury," H.M.S. (1730) - - 176

PAGE
Tillers and gearing, etc. - - 344, 348
"Titania I.," Yt. (1851) - - 109
"Titania II.," Yt. (1852) - - 109
Tonnage measurement 105, 109, 112, 173
"Tootsie," Yt. (1885) - - 112
Topmast, Turnbull's - - - 171
Topsides, method of forming - 207
Torpedo boats - - - 39, 42, 45, 51
Torpedo boat destroyers - 42, 45, 48, 50
Torpedo boat, forced draught for 307
Torpedo boat, screw propeller for 335
"Trafalgar," H.M.S. (1841) - 18
"Trafalgar," H.M.S. (1887), boiler of - - - - - 299
"Trafalgar," H.M.S., forced draught for - - - - - 309
Transport boat - - - - 143
"Travancore," S.S. (1868) - 79
Trawlers - - - - 139, 140, 167
Triple screws - - - - 243, 284
"Triumph," H.M.S. (1764) - 14
Troopships - - - 26, 28, 101
Troopships, fittings - - - 218
Trotman's anchor - - - 361
Trunk engines - 242, 265, 266, 268, 271, 273, 390
Tugs, paddle and screw - - 124
Turbines, steam - - - - 243, 284
"Turbinia," S.S. (1894) - - 243
Turkish frigates - - - 32
Turnbull's derrick - - - 228
Turnbull's topmast - - - 171
Turret deck steamer - - 99, 100, 262
Turret, Napier's - - 34, 35, 213
Turret ships - - 7, 30, 36, 37, 42
Turton's crank-shaft - - - 290
"Tutty," Yt. (1898) - - - 115
"Twickenham," S.S. (1888) - 91
Twin-hull vessels - - - 159, 245
"Tynwald," S.S. (1891) - - 96

"Ulster," P.S. (1860) - - 74
Umiak, Eskimo - - - 155
"Undine," Yt. (1856) - - 119

"Valiant," H.M.S. (1861) engines 269
"Valkyrie I.," Yt. (1889) - - 113
"Valkyrie II.," Yt. (1893) - - 114
"Valkyrie III.," Yt. (1895) - 114
"Valparaiso," S.S. (1856) - - 243
Valve gear - 261, 278, 285–287, 355
"Vanguard," H.M.S. (1835) - 22
"Vasco da Gama," ironclad (1875) - - - - - 32, 38
"Vedette," proposed turret ship 35
"Vendetta," Yt. (1893) - - 114
"Venetia," S.S. (1873) - - 80
Venetian gondola - - - 126
"Venezuelan," S.S. (1865) - - 78
"Vengeance," H.M.S. (1898), stem of - - - - - 212
Ventilators, ships' - - - 213, 214
Vertical boiler - - - - 297
"Vestal," S.S., lifeboats for - 148
Vibrating piston engines - - 249, 268
"Victor," steam tug (1884) - 149

PAGE
"Victor," S.S. (1845) - - 65
"Victoria and Albert," H.M.Yt. (1842) - - - - - 117
"Victoria and Albert," H.M.S. (1855) - - - - - 28, 361
"Victoria," H.M.S. (1859) - 29
"Victoria," H.M.S. (1887) - - 42
"Victoria" frigate (1865) - - 32
"Victoria," P.S. (1878) - - 83
"Victoria," S.S. (1852) - - 67
"Victory," H.M.S. (1737) - - 12
"Victory" (1765) - - - 28
"Victory," S. (1863) - - - 56
"Vigilant," proposed turret ship 35
"Viking," H.M.S. (1910), turbine destroyer - - - 50
"Ville de Paris," S.S. (1866) - 78, 349
"Vindobala," S.S. (1879) - - 84
"Violet," P.S. (1879) - - - 83
"Vittorio Emanuele," warship - 49
"Volage," H.M.S. (1874) - - 28
"Volunteer," Yt. (1887) - - 113

Walschaerts valve gear - 261, 278, 286
"Wanderer," H.M.S. (1855), engines - - - - - - 265
"Wanderer," Yt. (1878) - - 120
"Warrior," H.M.S. (1860) 7, 28, 32, 183, 196
Warships, proposed - 21, 29, 32, 34, 35
Wasteneys Smith's anchor - 363
Water-balance chambers - - 181
Water circulator - - - 313
Watertight bulkheads 79, 92, 206, 207
Watertight compartments - - 180, 181
Watertight doors - - - 215
Watertight joint - - - 207
Watertube boilers - - 293, 300–306
Waterways - - - - 188, 190
"Waterwitch," H.M.S. (1866) - 343
"Waterwitch," Yt. (1880) - - 111
Wave lines - 23, 29, 65, 67, 68, 70, 72, 118, 119, 175, 178
"Wave Queen," P.S. (1852) - 68
Wedge clump mooring anchor - 364
Well-decked vessel - - - 83, 91
Well vessel - - - - 139–141
"Weser," H.M.S. (1851) - - 25
"Weymouth," H.M.S. (1733) - 176
Whaling boats - 129, 133, 134, 155, 167
Whitby fishing boats - - - 131, 139
"William Fawcett," P.S. (1837) 60
"Winchester," H.M.S. (1717) - 176
Windlass, Baxter's - - - 357
Windlass, Chinese - - - 163
Windlass, elastic - - - 356
"Windsor," S.S. (1890) - - 93
Wine boat, Douro - - - 128
"Wizard," S.S. (1838) - - 329
Wooden ship construction - - 186–191
Woolwich ferry, 1888 - - 92
Woolwich steam packets - - 61
"Worcester," H.M.S. (1733) - 176
Wreck-raising appliances - - 226, 227
Wright flying machine - - 387

Yacht, Japanese - - - 165

	PAGE
Yacht measurement	105, 109, 112, 114, 116
Yachts, cruising	117-122, 161
Yachts, Dutch	104, 106
Yachts, racing	106–116
"Yale," U.S. cruiser	92
"Yama," Yt. (1890)	113
"Yarmouth," H.M.S. (1745)	12
Yarmouth fishing boats	138
Yarrow boiler	301
Yawls	111, 113, 130
Yorkshire "coble" and "mule"	131
Zeppelin airship	382

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CONTENTS.

PLATE I.

No.
1. King's ship.
2. 15th century carrack.
3. Elizabethan warship.
4. Maltese galley.
5. Dutch war vessel (1650–75).
6. H.M.S. "Royal Charles," 1672.
7. H.M.S. "Triumph," 1764.

PLATE II.

1. English frigate, 1750.
2. H.M.S. "Juno," 1757.
3. 64-gun ship, 1764.
4. Sloop-of-war, 1780.
5. 64-gun ship, 1780–90.
6. H.M.S. "Ajax," 1795.
7. H.M.S. "Vanguard," 1835.
8. H.M.S. "Fantôme," 1839.

PLATE III.

1. H.M.S. "Highflyer," 1851.
2. Turkish frigate, 1864–6.
3. Mexican gun-boat, 1875.
4. "Vasco da Gama," 1876.
5. H.M S. "Victoria," 1887.
6. H.M. tug "Dromedary," 1894.
7. Russian destroyer "Sokol," 1895.
8. H.M.S. "Lord Nelson," 1904–8.

PLATE IV.

1. Bengal pilot brig.
2. Barque, 1850.
3. S. "Stonehouse," 1863–6.
4. Schooner "John Wesley," 1867.
5. Barque "Pass of Melfort," 1891.
6. P.S. "Hibernia," 1843.
7. S.S. "Great Britain," 1839–43.
8. P.S. "Empire," 1843.

PLATE V.

1. "Great Eastern," 1853–8.
2. Stern-wheeler "Inez Clarke," 1879.
3. Petroleum steamer.
4. S.S. "Omrah," 1898–9.
5. Turbine S. "Queen Alexandra," 1902.

PLATE VI.

1. Yt. "Jullanar," 1875.
2. American yacht "Outlook," 1902.
3. S. Yt. "Livadia," 1880.
4. Obelisk ship "Cleopatra."
5. Sailing life-boat.
6. Egyptian yacht.
7. Bombay pleasure boat.

PLATE VII.

No.
1. Section of H.M.S. "Rodney."
2. Section of H.M.S. "Royal Sovereign."
3. Section of "turret-deck" vessel.
4. Large sea inlet valve.
5. Bermuda floating dock, 1868.
6. Wreck-raising lighter.
7. Malacca lighthouse, 1874.

PLATE VIII.

1. Patrick Miller's paddle ship, 1787.
2. Original marine steam engine, 1788.
3. "Charlotte Dundas," 1801.
4. P.S. "Comet," 1811.
5. Engines of P.S. "Comet," 1811.
6. Engines of P.S. "Ruby," 1836.
7. Engines of H.M.S. "Devastation," 1840–4.

PLATE IX.

1. Paddle engines of the "Great Eastern."
2. Beam engine for American steamer.
3. Engines of S.S. "Great Britain."
4. Engines of H.M.S. "Ajax," 1848.
5. Engines of H.M.S. "Wanderer," 1855.
6. Screw engines of the "Great Eastern."
7. Engines of S. Yt. "Hebe," 1856.
8. Engines of H.M.S. "Northumberland."

PLATE X.

1. Engines of S.S. "Britannic," 1874.
2. Engines of S.S. "Britannic," 1874.
3. Engines of S.S. "Flamboro," 1885.
4. Two-stage expansion launch engine.
5. Parsons marine steam turbine.

PLATE XI.

1. Brown's steam starting engine.
2. "Scotch" boiler and setting.
3. Belleville water-tube boiler.
4. Yarrow water-tube boiler.
5. Niclausse water-tube boiler.
6. Thornycroft - Schulz water - tube boiler.

PLATE XII.

1. Rapson slide steering gear.
2. Harfield's steering gear.
3. Steam steering engine.
4. Overlead cable windlass.
5. Henson's proposed flying machine.
6. Blériot monoplane.
7. Wright biplane.

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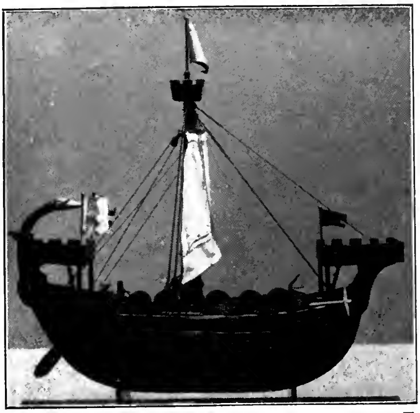
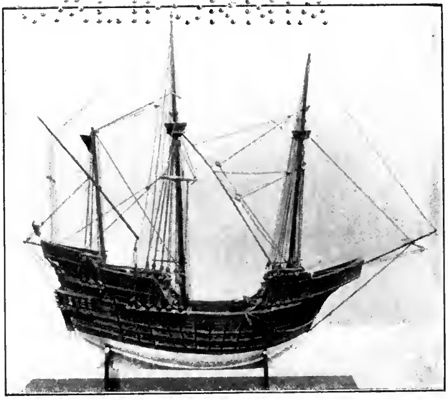
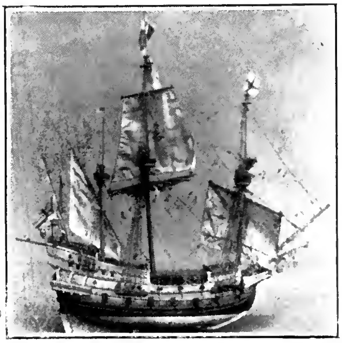
Plate I.



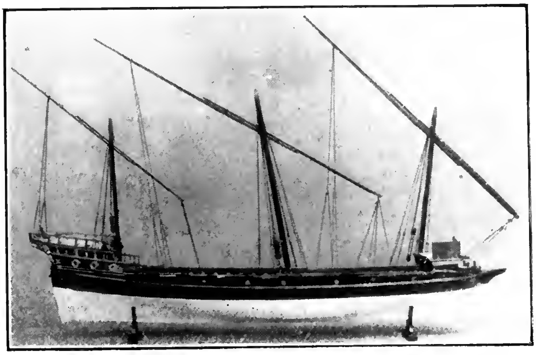
1. King's ship, p. 7.



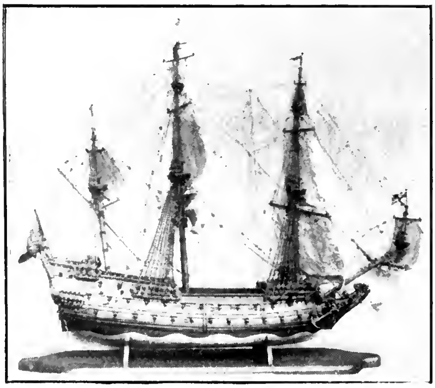
2. 15th century carrack, p. 8.



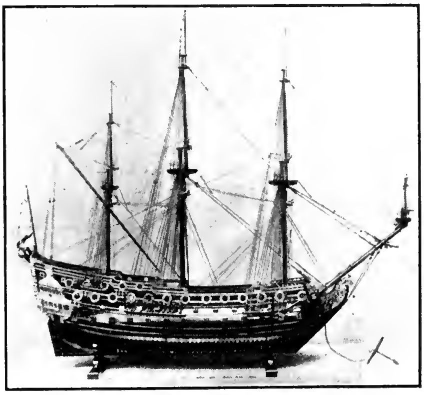
3. Elizabethan warship, p. 9.



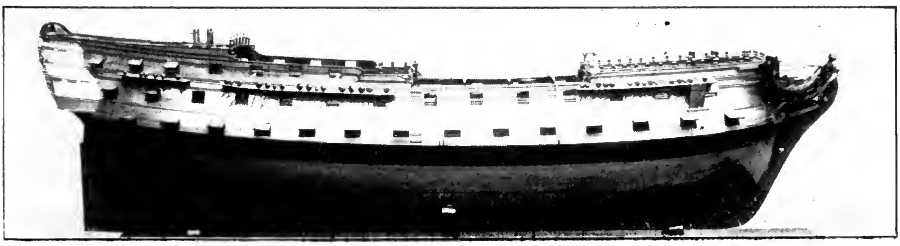
4. Maltese galley, p. 9.



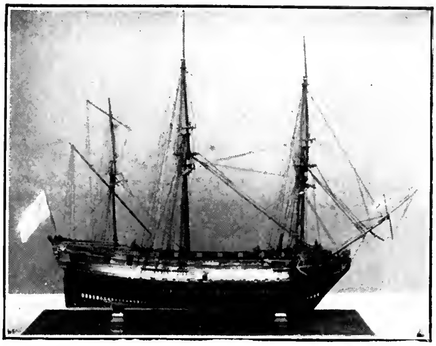
5. Dutch war vessel, p. 10.



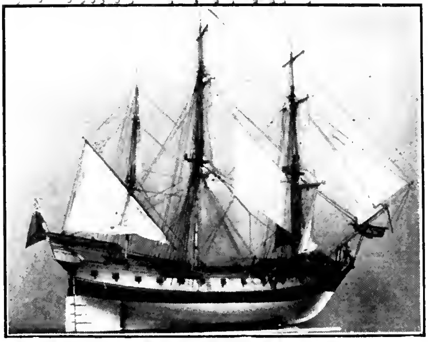
6. H.M.S. "Royal Charles," p. 11.



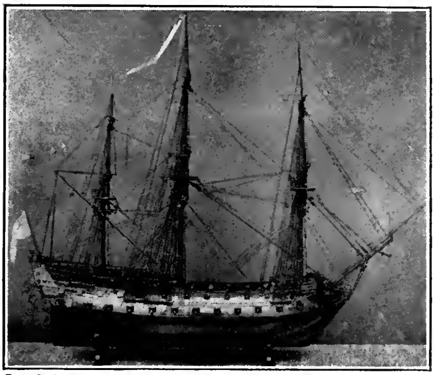
7. H.M.S. "Triumph," 1764, p. 14.



1. English frigate, 1750, p. 13.

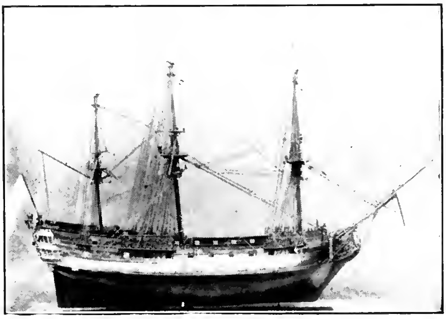


2. H.M.S. "Juno," 1757 p. 13

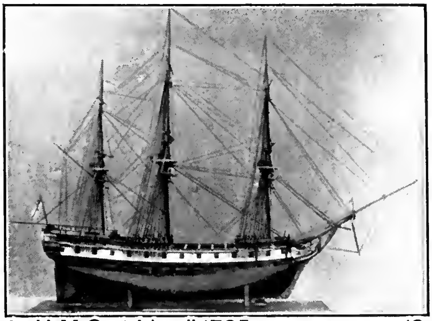


3. 64-gun ship, 1764, p. 14.

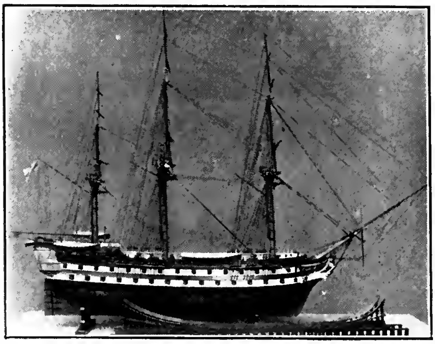
4. Sloop-of-war, 1780, p. 17.



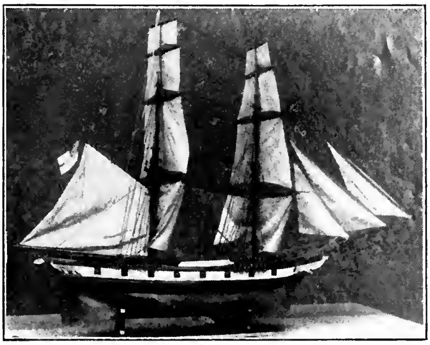
5. 64-gun ship, 1780–90, p. 18.



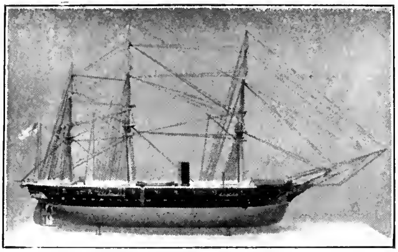
6. H.M.S. "Ajax," 1795, p. 19



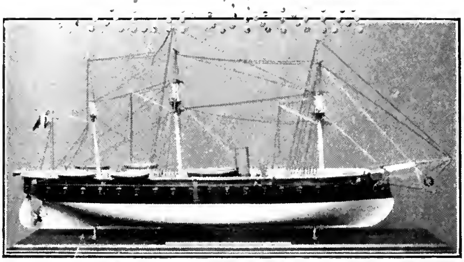
7. H.M.S. "Vanguard," 1835, p. 22.



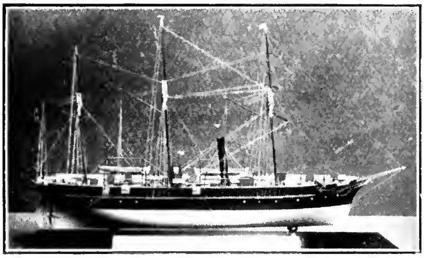
8. H.M.S. "Fantôme," 1839, p. 22.



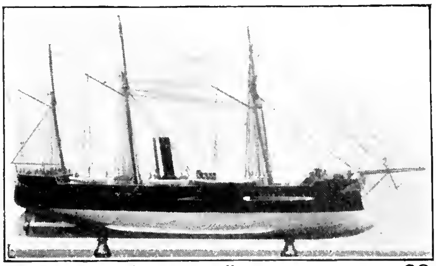
1. H.M.S. "Highflyer," p. 25.



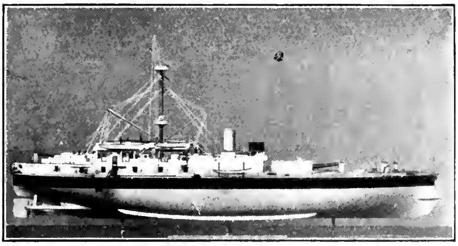
2. Turkish frigate, 1864-6, p. 32.



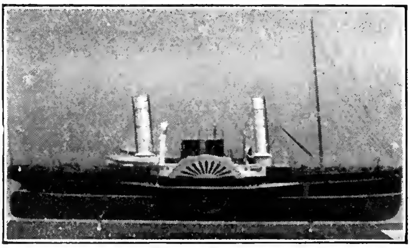
3. Mexican gun-boat, p. 38.



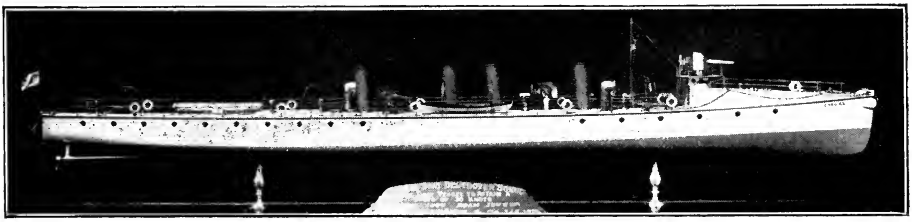
4. "Vasco da Gama," p. 38.



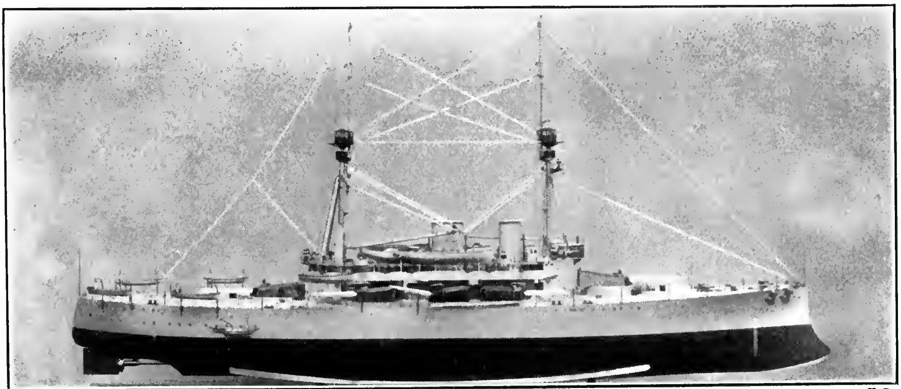
5. H.M.S. "Victoria," p. 42.



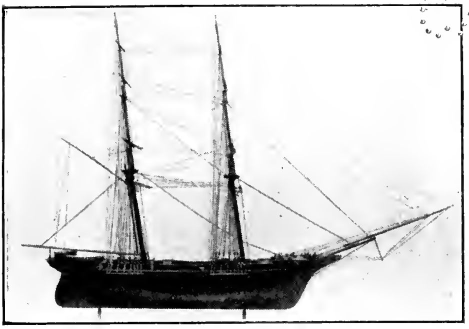
6. H.M. tug "Dromedary," p. 45.



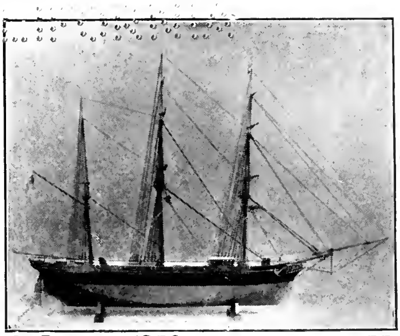
7. Russian torpedo boat destroyer "Sokol," p. 46.



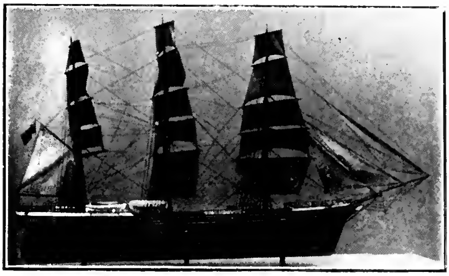
8. H.M.S. "Lord Nelson," 1904-8, p. 50.



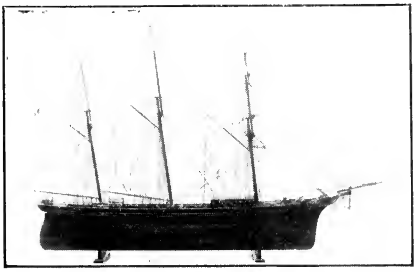
1. Bengal pilot brig, p. 55.



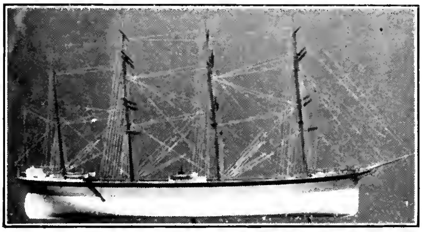
2. Barque, 1850, p. 55.



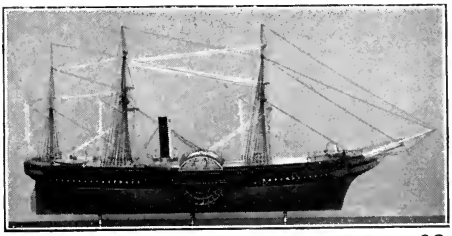
3. S. "Stonehouse," 1863-6, p. 57.



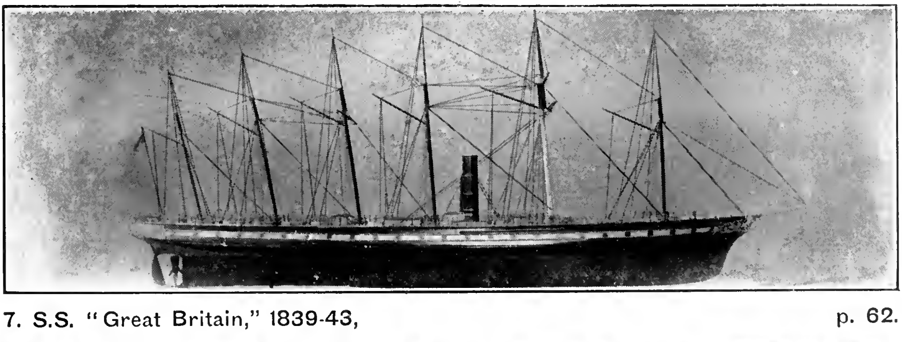
4. Schooner "John Wesley," p. 57



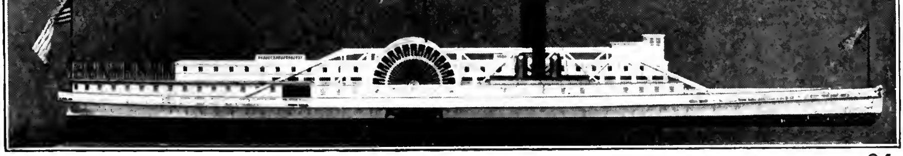
5. Barque "Pass of Melfort," p. 60.



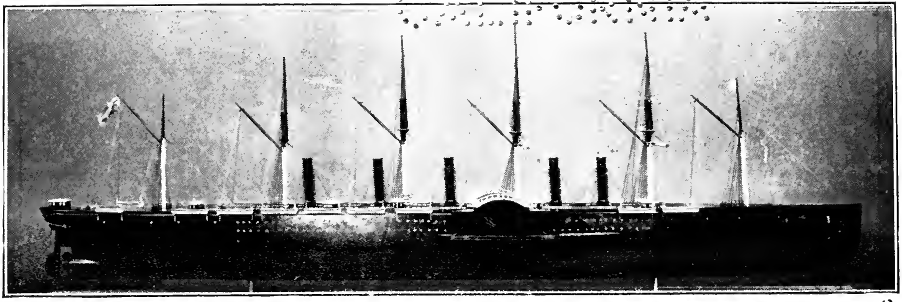
6. P.S. "Hibernia," 1843, p. 62.



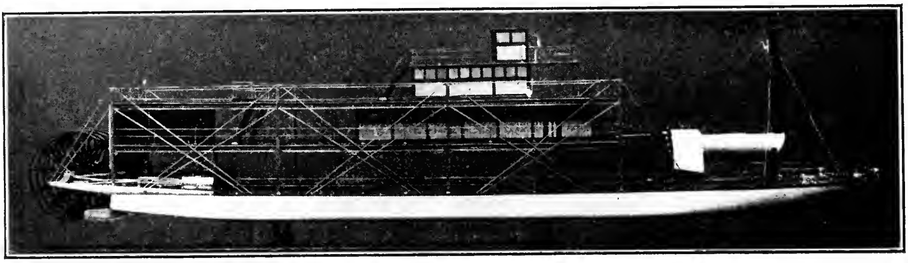
7. S.S. "Great Britain," 1839-43, p. 62.



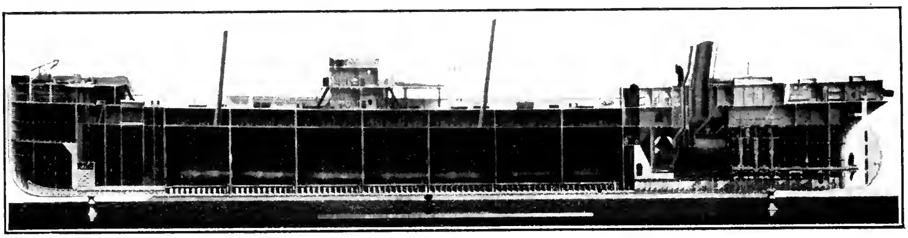
8. P.S. "Empire," 1843, p. 64.



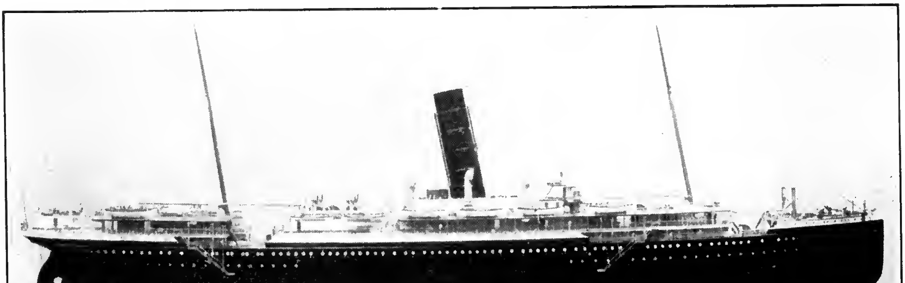
1. "Great Eastern," 1853-8, p. 73.



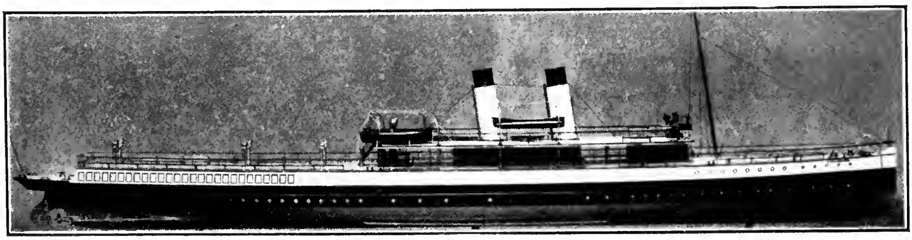
2. Stern wheel steamer "Inez Clarke," 1879, p. 84.



3. Petroleum steamer, p. 95.

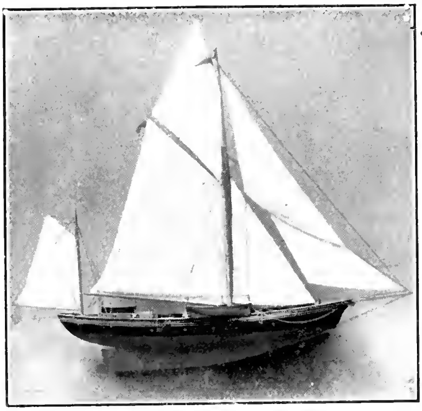


4. S.S. "Omrah," 1898-9, p. 100.

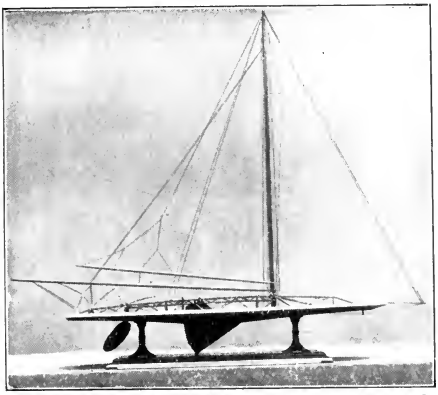


5. Turbine steamer "Queen Alexandra," 1902, p. 102.

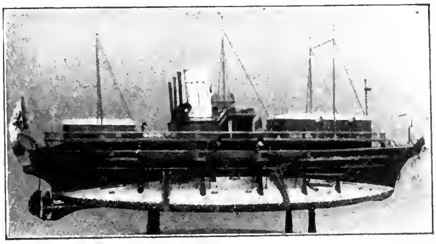
Plate VI.



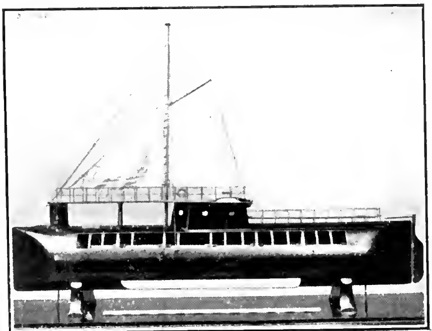
1. Yt. "Jullanar," 1875, p. 111.



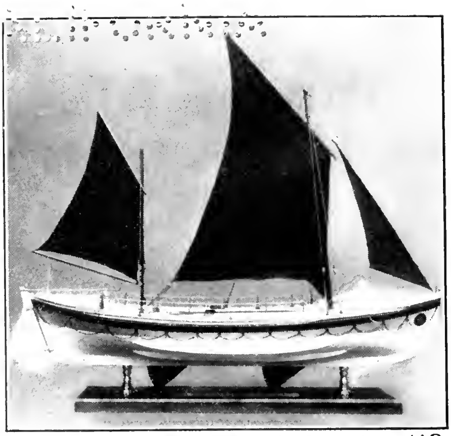
2. Yt. "Outlook," 1902, p. 115.



3. S. Yt. "Livadia," 1880, p. 120.

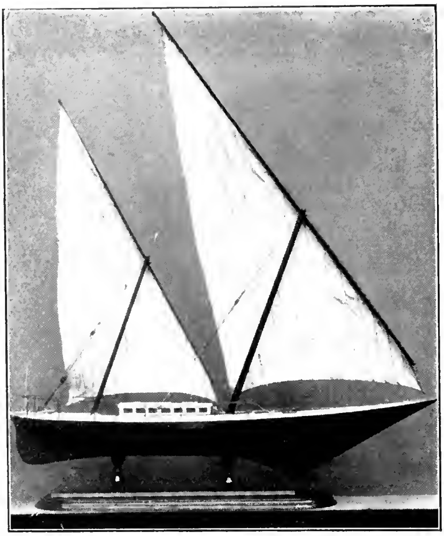


4. Obelisk ship "Cleopatra," p. 143.

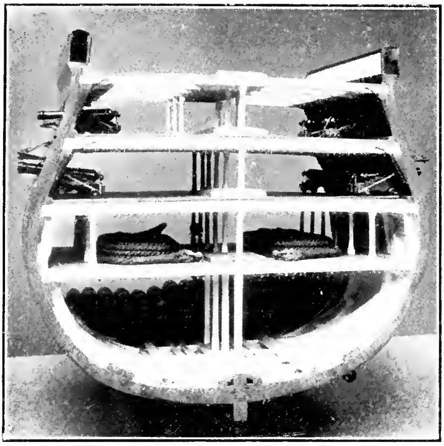


5. Sailing life-boat, p. 148.

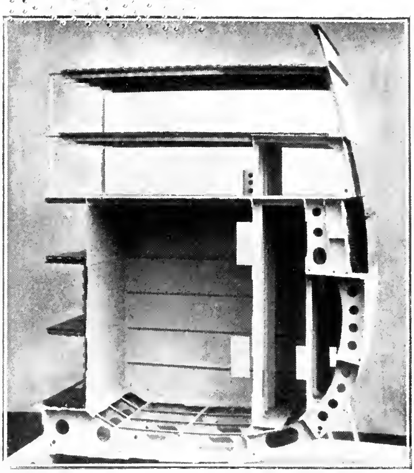
6. Egyptian yacht, p. 158.



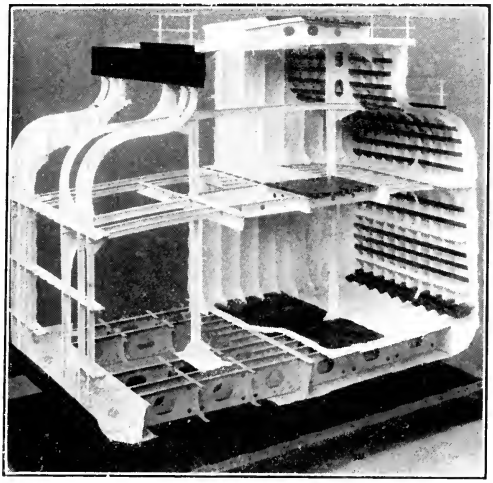
7. Bombay pleasure boat, p. 161.



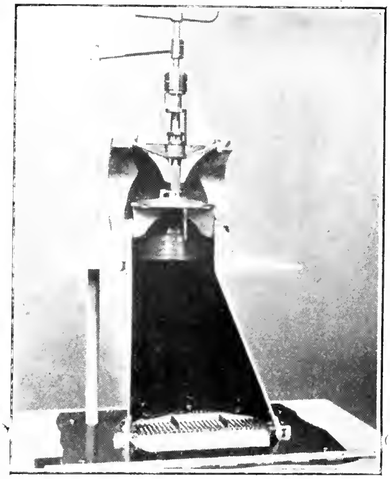
1. Section of H.M.S. "Rodney," p. 189.



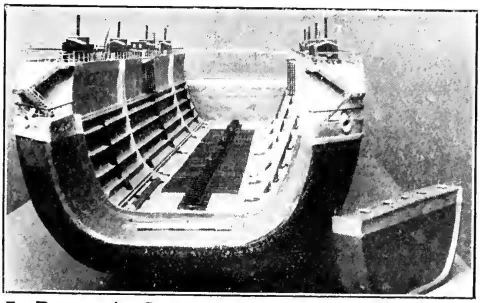
2. H.M.S. "Royal Sovereign," p. 199.



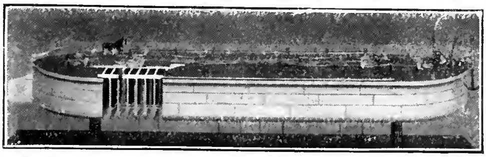
3. "Turret-deck" vessel, p. 202.



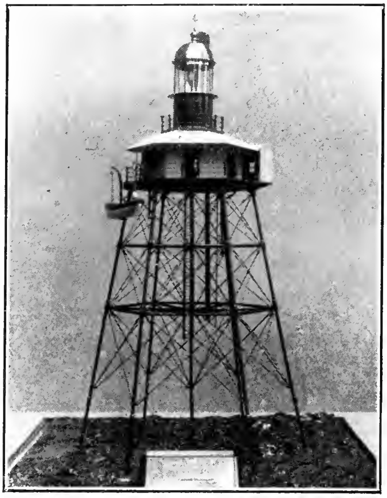
4. Sea inlet valve, p. 220.



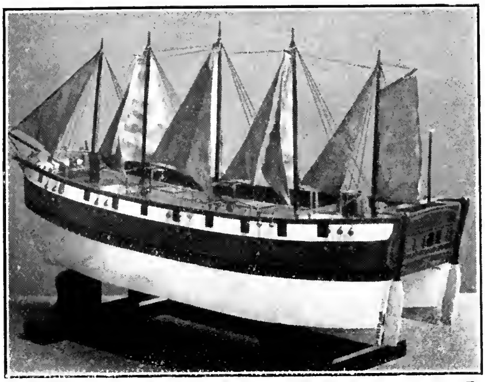
5. Bermuda floating dock, p. 223.



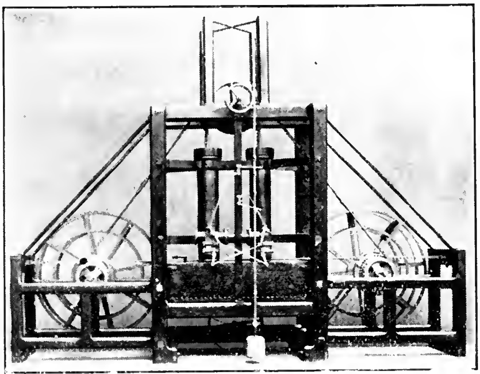
6. Wreck-raising lighter, p. 227.



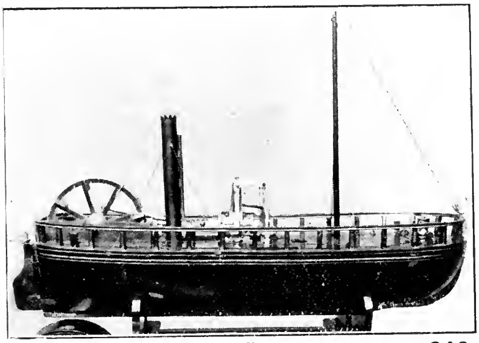
7. Malacca lighthouse p. 233.



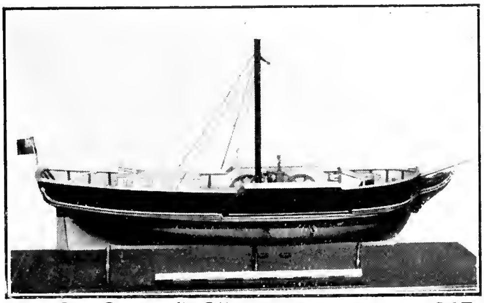
1. Miller's paddle ship, p. 245.



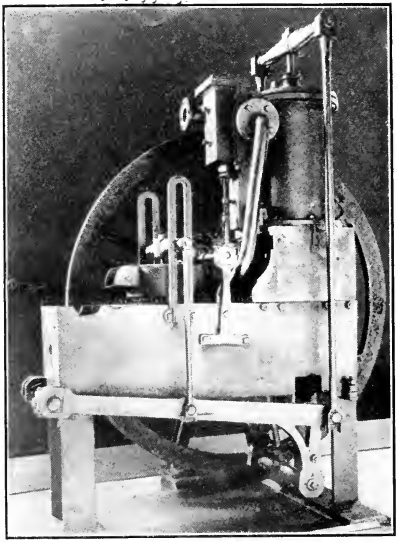
2. Original marine steam engine, p. 245



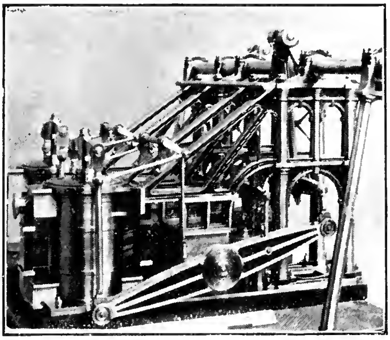
3. "Charlotte Dundas," p. 246.



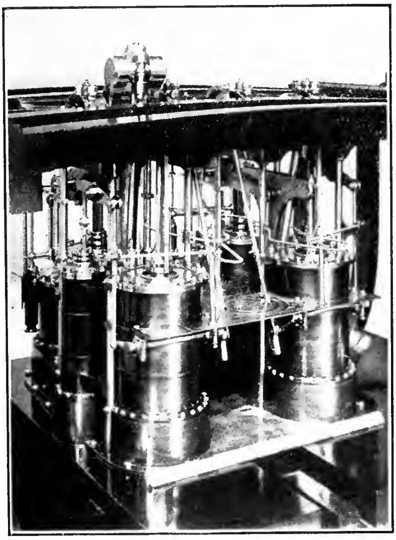
4. P.S. "Comet," 1811, p. 247.



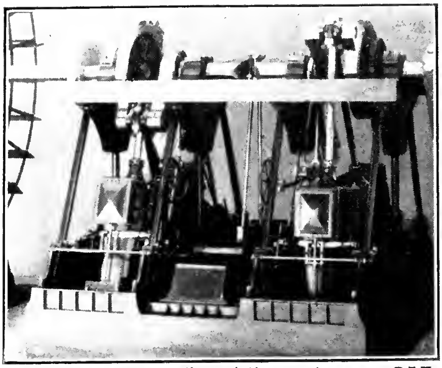
5. Engines of P.S. "Comet," p. 248.



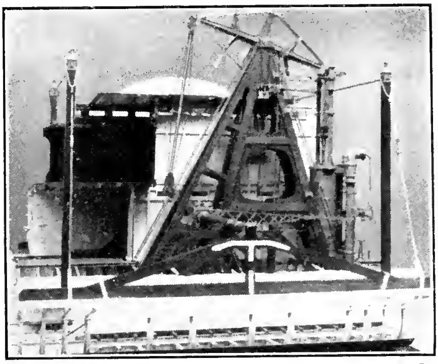
6. Engines of P.S. "Ruby," p. 250.



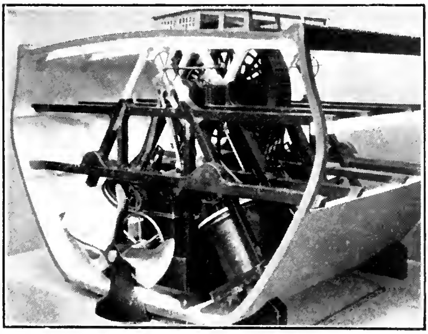
7. Engines of "Devastation," p. 254.



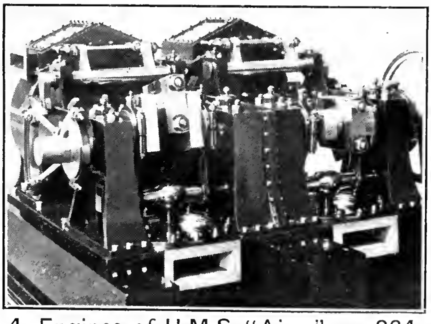
1. "Great Eastern" paddle engines, p. 257.



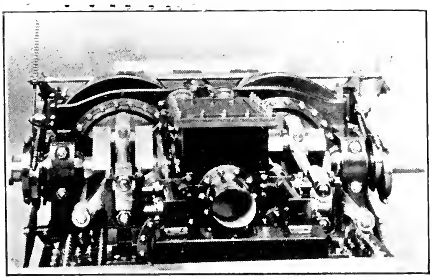
2. American beam engine, p. 259.



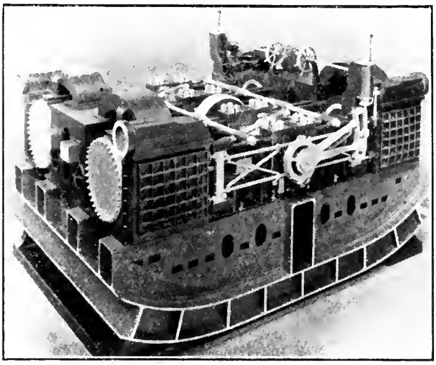
3. Engines of "Great Britain," p. 261.



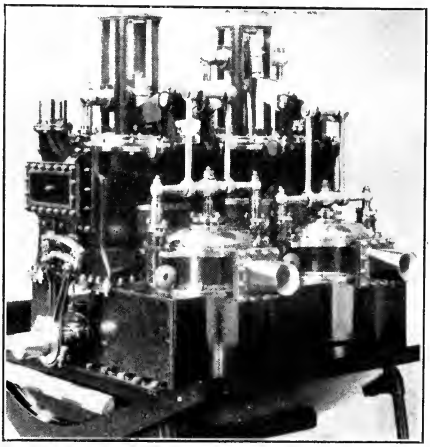
4. Engines of H.M.S. "Ajax," p. 264.



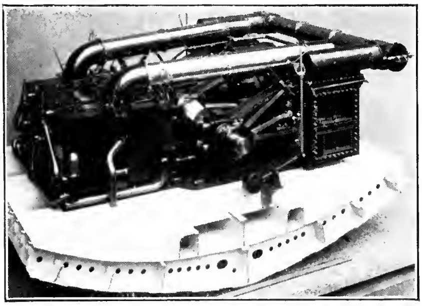
5. Engines of "Wanderer," p. 265.



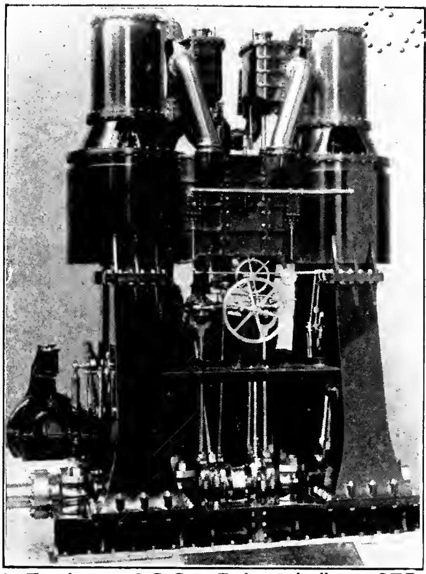
6. "Great Eastern" screw engines, p. 266.



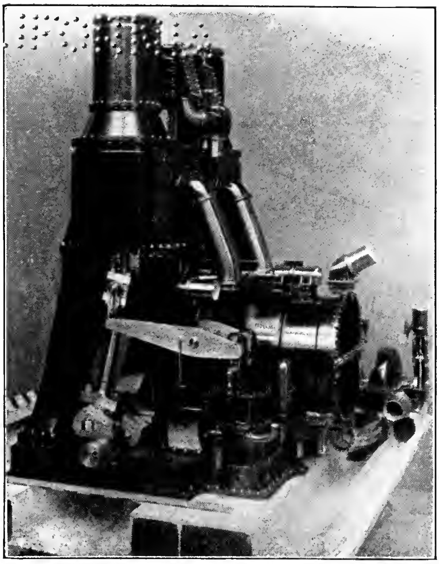
7. Engines of S. Yt. "Hebe," p. 267.



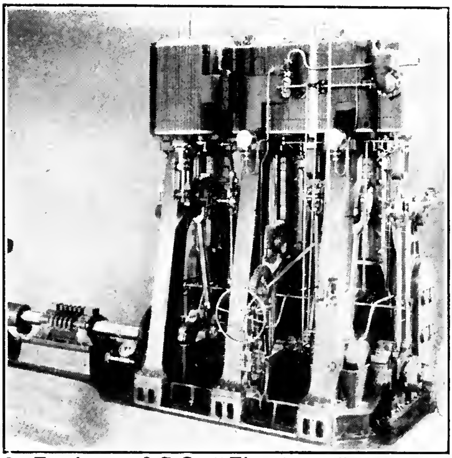
8. Engines of "Northumberland," p. 273.



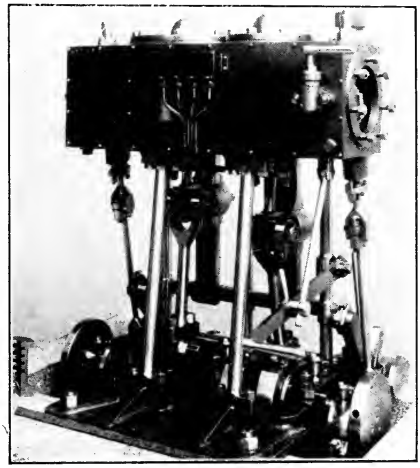
1. Engines of S.S. "Britannic," p. 275.



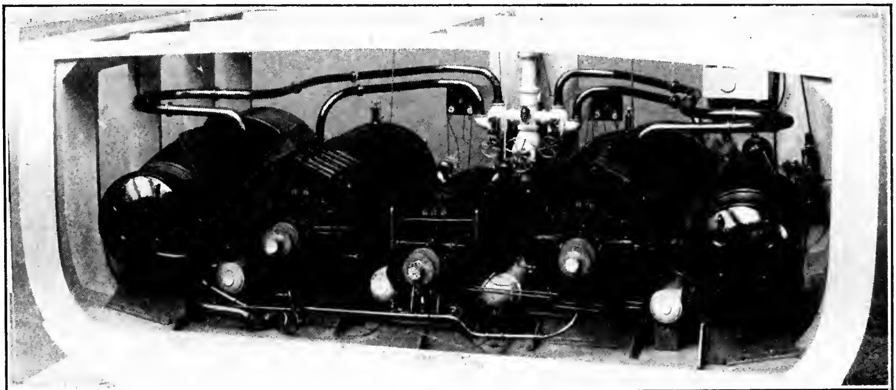
2. Engines of S.S. "Britannic," p. 275.



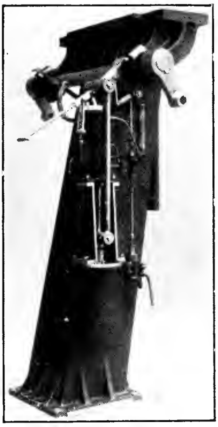
3. Engines of S.S. "Flamboro," p. 277.



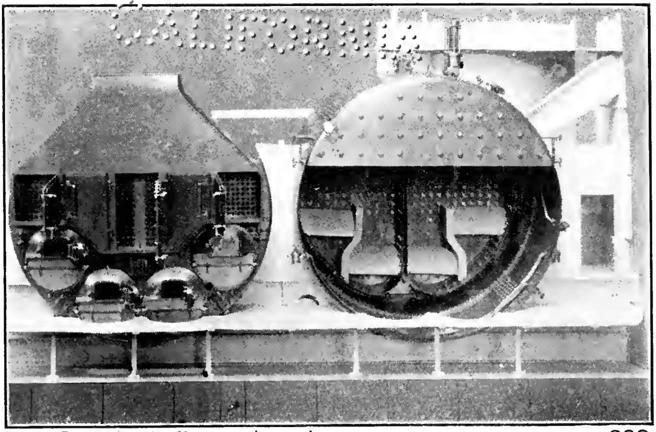
4. Launch engine, p. 281.



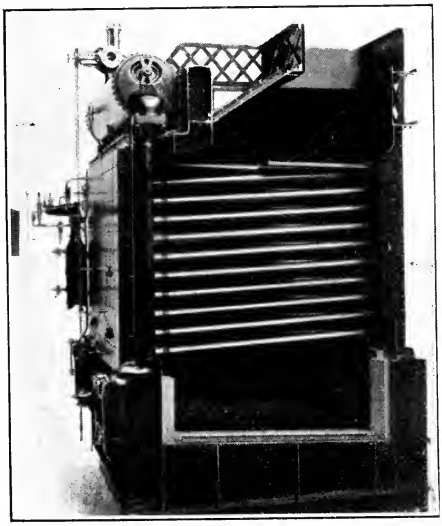
5. Parsors marine steam turbine, p. 284.



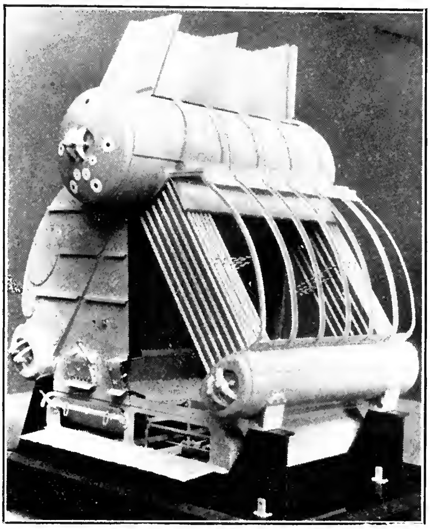
1. Starting engine, p. 287.



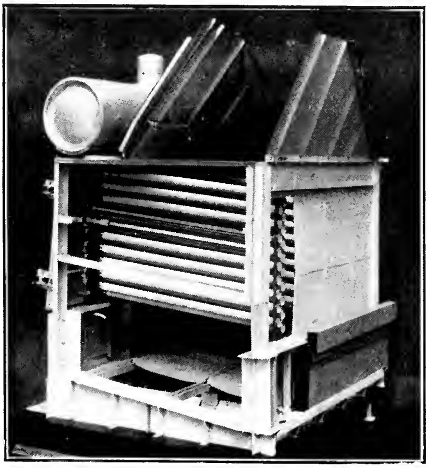
2. "Scotch" boiler and setting, p. 299.



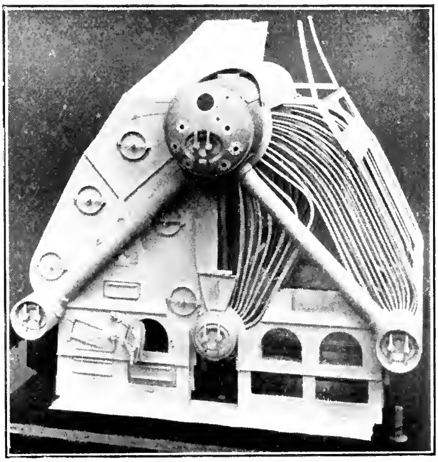
3. Belleville boiler, p. 300.



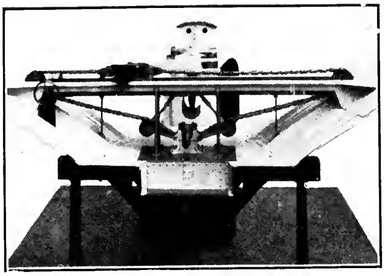
4. Yarrow boiler, p. 301.



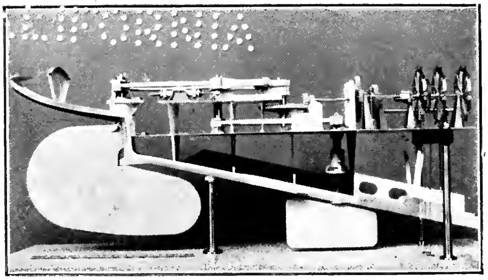
5. Niclausse boiler, p. 304.



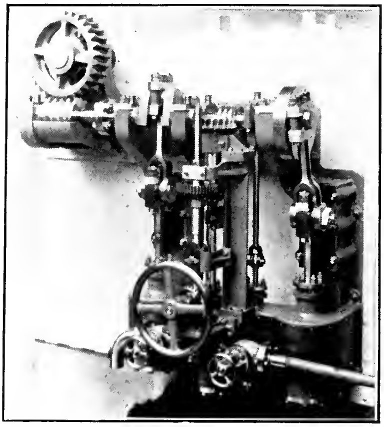
6. Thornycroft-Schulz boiler, p. 305.



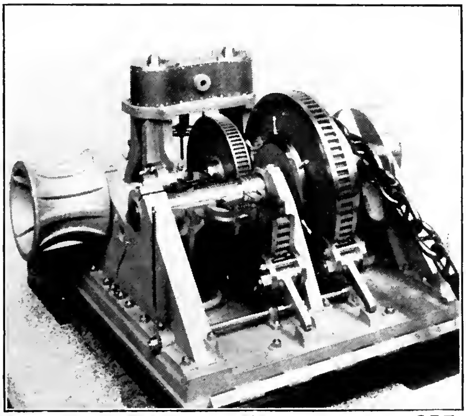
1. Rapson slide, p. 352.



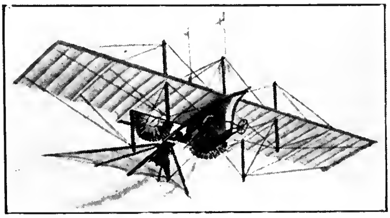
2. Harfield's steering gear, p. 353



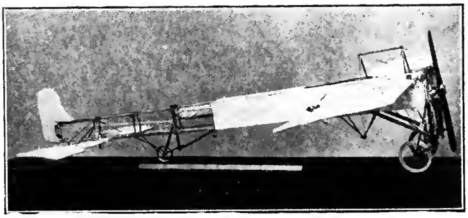
3. Steam steering engine, p. 354.



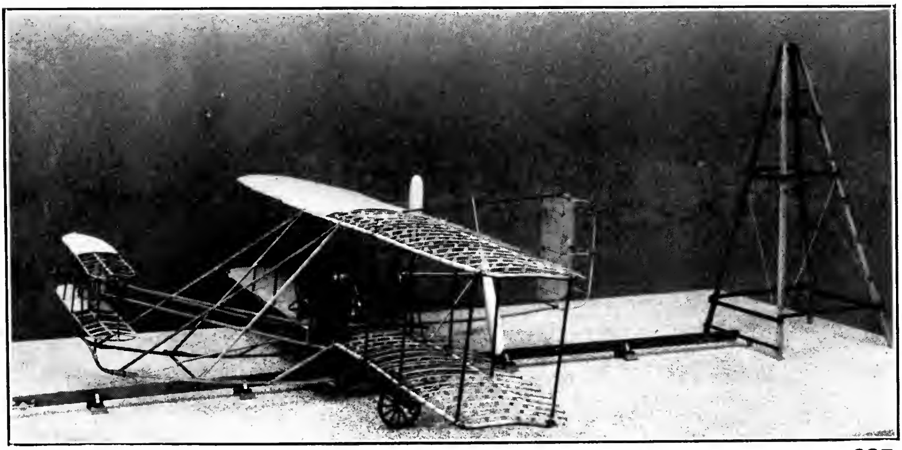
4. Overlead cable windlass, p. 357.



5. Henson's flying machine, p. 383.



6. Blériot monoplane, p. 386.



7. Wright biplane, p. 387.