TWO CENTURIES OF SHIPBUILDING

SCOTTS' SHIPBUILDING & ENGINEERING Cº Lᵀᴰ
GREENOCK

TWO CENTURIES

OF

SHIPBUILDING

H. M. S. "Colossus" firing big Guns.

TWO CENTURIES OF SHIPBUILDING

BY THE

SCOTTS AT GREENOCK.

[SECOND AND REVISED EDITION.]

[*Partly Reprinted from "Engineering."*]

"Take it all in all, a ship of the line is the most honourable thing that man, as a gregarious animal, has ever produced. . . . . Into that he has put as much of his human patience, common sense, forethought, experimental philosophy, self-control, habits of order and obedience, thoroughly wrought hand-work, defiance of brute elements, careless courage, careful patriotism, and calm expectation of the judgment of God, as can well be put into a space of 300 feet long by 80 feet broad."—RUSKIN.

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1920.

Contents.

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List of Illustrations.

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Author's Note.

The first edition of this book, published in 1906, has long been out of print, and as numerous enquiries for copies have been made by shipowners and by those interested in the history of naval architecture, it is advisable to issue a new edition. In the preparation of this second edition it has been decided to retain those parts dealing with the early contributions of Scotts to shipbuilding and marine engineering, as these will assist the student of the evolution of iron and steel shipbuilding and of engineering. Additional information of historical interest has since been discovered and is included.

The chapters on modern work have been re-written, as this was necessary in view of the progress made in the past ten years and of the influences of the great European War. That Scotts have played no insignificant part in these recent years is suggested by the fact that they built the first Dreadnought and the first submarine constructed on the Clyde—our premier shipbuilding river; that for the Merchant Service they built the first ocean liner to be propelled by geared turbines, and that for the war and during the war they contributed vessels of practically every type required for the fleets of the British Navy.

September 1st, 1920.

Personalia and Memorabilia.

♣ ♣

John Scott (I) founded the firm in 1711, and engaged in the building of herring busses and small craft, being also a "hammerman." He was closely associated with the father of James Watt in several schemes for the improvement of Greenock. There is, unfortunately, no engraving of him extant, so that our series of portraits on Plates II and III, adjoining page 1, is to this extent incomplete.

William Scott (I), his son, born 1722, died 1769, succeeded him, and with his brother James, constituted the firm of "James and William Scott." They extended the business, alike as regards the capacity of the works and the types of vessels built. Their first square rigged ship, of 1765, was the first vessel built on the Clyde for owners out of Scotland.

John Scott (II), born 1752, died 1837, greatly developed the works, and built the dry dock and basin until recently included, with the original yard, in the establishment lately owned by Messrs. Caird and Co., Ltd. Under his *régime* many ocean-going sailing ships were constructed and ship-building work for the Navy was undertaken. He was an early student of Watt's inventive work, and, directing his practical attention to engineering, acquired the Greenock Foundry in 1790. This was but a preliminary step to the construction of steam engines for ship propulsion which was started by the firm in 1825. The Greenock Foundry was carried on as a separate but correlated concern under the designation of "Scott, Sinclair and Co.," and Admiralty orders were undertaken for the machinery of Dockyard-built, as well as Greenock-built, frigates. John Scott (II) built the Custom

House Quay at Greenock in 1791, bought, in 1810, the estate of Halkshill, which is still in possession of the family, was a partner in the Greenock Bank, and otherwise promoted the industries of the town.

His brother William Scott (II), born 1756, was associated with him in his earlier years, the title of the firm being then "John and William Scott," but in 1802 it became "John Scott and Sons," as William a short time before had gone to Barnstaple, where he carried on an extensive shipbuilding industry, obtaining engines for most of his steamships from the Greenock Works. The engineering extension to the Greenock business was pushed with energy and considerable progress was made. It is recorded that in 1829 the firm had in hand, for a ship built in Bristol, "the largest engine ever made." It was early in the nineteenth century, in 1803, that the Scotts built their first warship, the *Prince of Wales*, a sloop of war, and since that date the firm have maintained their connection with naval construction for the British Admiralty. Although the manufacture of marine engines was not taken up until 1825, the succession of steamships built before that date included the *Waterloo*, in 1819, the *Superb*, in 1820, and the *Majestic*, in 1821, the largest steamships built in Great Britain in their respective years. As to the yard in which these vessels were built, the following is a quotation from Weir's "History of the Town of Greenock," published in 1829: "The building yard of Messrs. Scott and Sons is allowed to be the most complete in Britain, excepting those which belong to the Crown."

Charles Cuningham Scott (I), born 1794, died 1875, son of John Scott (II), along with his elder brother John Scott (III), born 1785, died 1874, carried on the business as "John Scott and Sons," developing still further the progressive policy of their father, who had been responsible for the works for about half a century. The Cartsdyke Yard was commenced in 1850 by Charles Cuningham Scott (I) and his son John, under the style of "Scott and Co." In 1859 the name of the correlated engineering firm was changed from "Scott, Sinclair and Co." to "The Greenock Foundry Co.," the principal partner of the latter being John Scott (IV); and under this title it was known till 1904 when the shipyards and engine works were combined under one name, referred to later. The engine works were further developed during this era, and it is interesting to note here that H.M.SS. *Hecla* and *Hecate*, engined in 1838–39 by Scotts, were the first ships built at Royal Dockyards to have their machinery constructed in Scotland. Among the vessels turned out in this period may be noted the *Tagus*, in 1837, one of the first Peninsular and Oriental liners, and the largest steamer constructed on the Clyde up to that date; the *India*, in 1839, being the first steamer to trade with India *viâ* the Cape; and the *Dee*, the first Royal West India mail steamer. The firm also had the credit of building the first steam frigate constructed on the River Clyde for the British Navy, named H.M.S. *Greenock*, and launched in 1849. This vessel was the largest iron warship of her day. The machinery represented one of the earliest attempts to drive the screw propeller by means of gearing, which was adopted in those days to increase the revolutions of the propeller. It was a noteworthy feature that the ship's figurehead was a bust of John Scott (II). This compliment by the naval authorities of the time was well merited, not only on account of his labours for the advancement of naval architecture, but also for the development of the town of Greenock.

John Scott (IV), born 1830, died 1903, and Robert Sinclair Scott, born 1843, died 1905, sons of Charles Cuningham Scott (I), were responsible for the progress for nearly forty years, and the former was created a Companion of the Bath (C.B.) in 1887. During their *régime* the firm took a large part in the introduction of the steamship for oversea voyages; in the building of steamers for the coast and river trade of China; in the development of high steam pressures and of the multiple-expansion engine, which greatly improved the economy of the steam engine; and in naval work, with its incidental advancement. They completely reconstructed the Cartsdyke Works, and acquired the iron shipbuilding yard and graving dock of Messrs. Robert Steele and Sons, on which site they established the Cartsburn Dockyard, which was laid out and equipped for naval construction. The co-partnery was, for family reasons, registered in 1900 under the Limited Liability Company law. In 1904 the firms known as the "Greenock Foundry Company" and "Scott and Co.," being identical in partnership and interests, were merged into one company, under the title of "Scotts' Shipbuilding and Engineering Company, Ltd."

Charles Cuningham Scott (II), son of John Scott, C.B., born 1867, died 1915, succeeded his uncle in 1905 as chairman of the Company, and during his occupancy of this position the firm continued to advance in influence. They built the first "Dreadnought" battleship and the first submarine constructed on the Clyde, and completed many fighting ships which did brilliant service in the Great War. They had the distinction of being the first to fit steam turbines to submarines, an innovation—since adopted for many of these vessels—resulting in greatly increased size and speed. The first geared turbine Atlantic liner was also built by the firm, and many important ships were added to the Merchant Service.

Robert Lyons Scott, the only surviving son of John Scott, C.B. (IV), succeeded to the chairmanship of the Company in 1915, and associated with him are James Brown, C.B.E., as Managing Director, and J. B. Hutchison, Colin C. Scott, Cedric C. S. Scott, and Lawrence D. Holt, as Directors.

William Scott
(1722-1769)

John Scott
(1752-1837)

William Scott
(born 1756)

Charles C. Scott
(1794-1875)

John Scott
(1830 - 1903)

Sinclair Scott
(1843 - 1905)

C. C. Scott
(1867 - 1915)

R L Scott

The Era of the Sailing Ship.

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THE maintenance of an industry for two hundred years by one family, in the direct line of succession and in one locality, is almost unique in the history of western manufactures. Such a record indicates the maintenance of a high standard of workmanship as well as integrity and business capacity; because time is the most important factor in proving efficiency and in establishing credit for durability of work, without which no reputation can be retained for a long period.

The Scotts began the building of ships in Greenock in 1711. To-day, their descendants of the sixth generation worthily maintain the high traditions of the intervening years. To give an adequate impression of the service rendered by the firm to the science of marine construction we should require to review in detail the successive steps: firstly, in the perfection of the sailing ship, from the sloops and the brigantines of the eighteenth century, to such beautiful clippers as Scotts' *Lord of the Isles*, which in 1856 made the record voyage from China, and did much to wrest from the Americans the "blue ribbon" of the ocean; secondly, in the development of the merchant steamship from its inception early in the nineteenth century to the leviathans of to-day; and, thirdly, in the increase in fighting efficiency of all types of warships, from the submarine —the first vessel of which class fitted with steam turbine machinery was built by them for the British Navy, to the modern super-Dreadnought, of which they contributed examples to the British fleet which won a glorious victory in the great European war of 1914–1918.

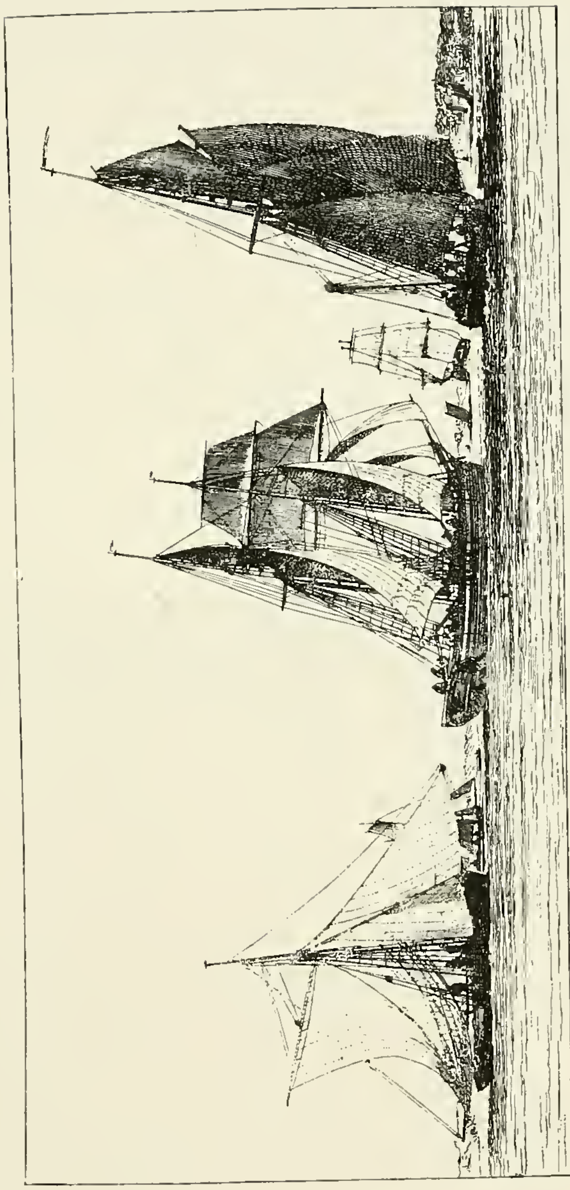
In successive epochs in the history of naval architecture the Scotts have played a creditable part, and to some of the more important improvements initiated or advanced by the firm reference will be made in our brief survey of the work done during the past two centuries. Unfortunately, some years ago, most of the old-time records were destroyed by a fire at the shipyard, so that our review of the early work is largely from contemporary publications, and is unavoidably incomplete.

The beginnings were small, for Scotland had not yet attained to industrial importance, and had little oversea commerce. The first trans-Atlantic voyage by a Clyde ship was made in 1686, when a Greenock-built vessel was employed on a special mission to carry twenty-two persons transported to Carolina for attending conventicles and "being disaffected to Government."[1] American ships were most numerous on the western seas. The East India Company had a monopoly of the eastern seas, so far as Britain was concerned, and preferred to build their ships in India, although many were constructed on the south coast of England. This monopoly checked progress. There was little or no incentive to improvement in merchant ships, and the naval authorities were too busy fighting Continental nations to risk extensive experimental work. We have it on the authority of the late Sir Nathaniel Barnaby, K.C.B.,[2] that neither Government nor private builders made much progress in improving methods

[1] Campbell's "Historical Sketches of the Town and Harbour of Greenock," vol. i, page 18.

[2] Sir Nathaniel Barnaby's "Naval Development in the Century," page 23.

Plate IV.



[*From an Engraving by E. W. Cooke, R.A.*

THE BEGINNINGS.

of construction. The first letters patent granted for improvements relating to ships bear the date January 17th, 1618, but the result of a thorough investigation of all patents between 1618 and 1810 discloses no improvement worth recording, except in the manufacture of sheathing and the construction of pumps.

The Scotts, like a few other shipbuilders on the Clyde, were concerned for the greater part of the eighteenth century in the building of fishing and coasting boats. There belonged to Greenock, in 1728, as many as nine hundred of such fishing boats, locally built, each carrying from twenty to twenty-four nets and manned by a crew of four men. For many years the business of the firm consisted almost entirely in the building of herring busses and small craft employed in the fishing trade, the first establishment being at the mouth of the West Burn, on land leased from the Shaw family. The shipbuilding industry was then carried on intermittently; the Scotts were the first to give it stability and continuity. In 1752, the Greenland whale fisheries were engaged in, and this led to a development in the size of craft. The first square-rigged vessel built in the port was a brig, named *Greenock*, constructed in 1760, for the West Indian trade. In 1765, James and William Scott, who had succeeded the original founder—their father, John Scott—built a large square-rigged ship[1] for some merchants of the town of Hull, the timber for which came from the Ducal woods at Hamilton. This ship is notable as being probably the first ship built on the Clyde for owners out of Scotland.[2] To take a fairly representative year (1776), eighteen vessels, ranging up to 77 tons, and of a total of 1073 tons burden, were constructed in Greenock, and of the number six were built by the Scotts.[3] Although the work could be more cheaply done on the Clyde than in London or

[1] Weir's "History of the Town of Greenock" [1829].
[2] Brown's "Early Annals of Greenock," page 136.
[3] Williamson's "Memorials of James Watt," 1856.

Bristol, there was for a long time a strong prejudice against English owners ordering vessels from the north, and against Scotch vessels taking any part in the oversea trade.

The Jacobite risings had also affected the industry, but the War of Independence in America had far-reaching beneficial results. It is true that prior to this the rich fields of the English colonial possessions, as well as the English markets, had been opened to the commerce of Scotland, and that the merchants of Glasgow had developed extensive commercial operations with the West Indies and British North America. But, although there was thus a considerable oversea trade between the Clyde and the Western hemisphere, all the large vessels trading to the Clyde were built in America.[1] The shipbuilding industry in the States was thus a very extensive one; and, in 1769, there were launched, in the North American Colonies, three hundred and eighty-nine vessels of 20,000 tons burden, which was far in excess of the annual British output.[2] This was largely owing to the limitless supply of timber in America, and to the import duties on constructional material imposed in this country to suit the English growers of oak, the price of which advanced in the eighteenth century from £2 15s. to £7 7s. per load.[3]

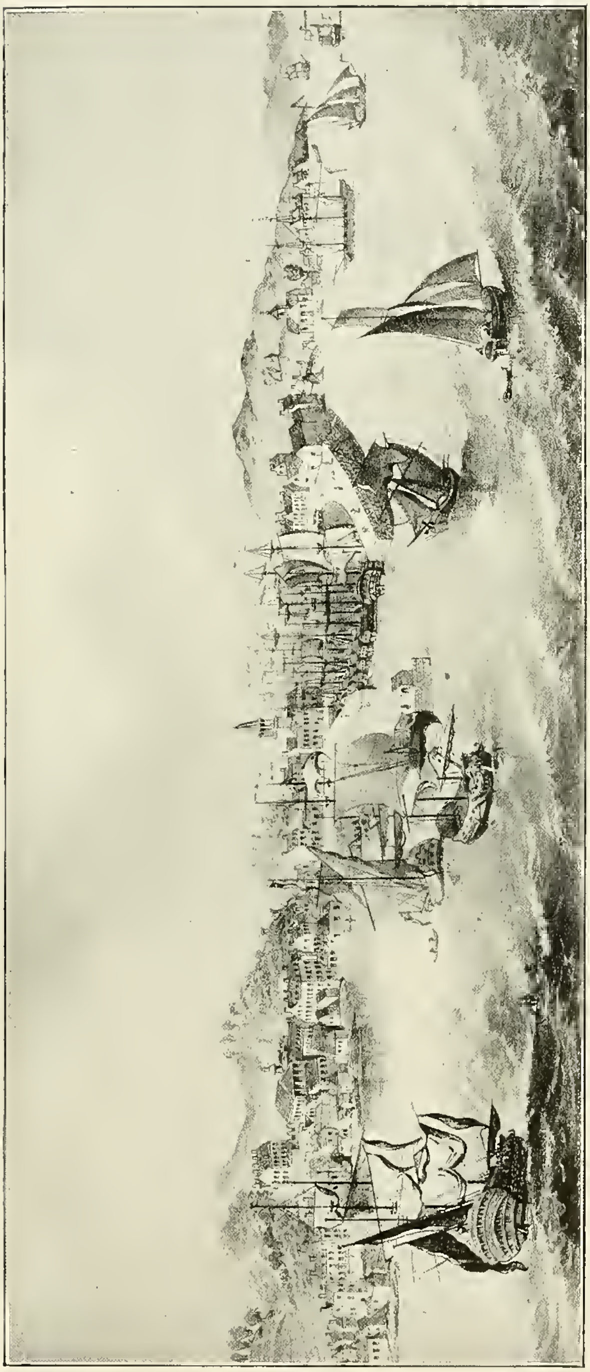
The *Brunswick*, of 600 tons, carpenters' measurement, to carry 1000 tons real burden, built by the Scotts in 1791 for the Nova Scotia trade; and the *Caledonia*, of 650 tons, built by the Scotts in 1794, for the carriage of timber for the Navy yards—each the largest ship built in Scotland of its respective year—signalised the beginning of a period of greater activity, especially in respect of large ocean ships. Some years before—1767—the Scotts had feued ground for a building yard on the shore east of the West Burn. They added now a

[1] "The Gazetteer of Scotland," 1842, vol. i, page 709.

[2] "Journals of the House of Commons," 1792, page 357.

[3] Holmes's "Ancient and Modern Ships," page 152.

Plate V.



EARLY VIEW OF GREENOCK, 1768.

graving dock of considerable size, and the inaugural proceedings included a dinner held on the floor of the dock. Other developments contributed to the prosperity of the port of Greenock, the chief of the establishment at this period being John Scott of the third generation, who was born in 1752, and died in 1837. His brother, William, the second of that name, migrated to Barnstaple, where he carried on an extensive trade as a shipbuilder. The latter was the father of James M. Scott, who was long remembered as a benefactor because he was the founder, about 1847, of the Artisans' Club and of penny banks in Greenock. John Scott, after his brother's departure, carried on the business under the name of John Scott and Sons and did great service not only for the town, but also for the advancement of the business. In three successive years, 1787, 1788, and 1789, he bought large plots of ground from the ninth Lord Cathcart, for the extension of the works.[1] These then extended almost from the West Quay to the West Burn. He also, in 1791, constructed the old steamboat or custom-house quay,[2] and played a large part in developing the banking facilities of the town. He bought, in 1810, Halkshill, near Largs, which has continued the residence of the family. In view of the association of the firm with the town, it may be worth interpolating here a statement of the growth of the population of Greenock, with the sources from which the figures have been taken.

Year.		Population.		Source.
1700	...	1,328	...	Campbell's History, page 23.
1801	...	17,458	...	Weir's History, page 120.
1901	...	68,142	...	Census Returns, vol. i, page 212.
1911	...	75,140	...	Census Returns, vol. i, p. 212.
1920	...	92,000	...	Estimated.

Shipbuilding work, however, was still in craft which to-day would be considered insignificant. The increase of

[1] Williamson's "Old Greenock," page 148.

[2] Campbell's "Historical Sketches of the Town and Harbour of Greenock," page 68.

the mercantile fleet of England throughout the eighteenth century was only fivefold in respect of numbers, and sixfold in tonnage; the average size shows an augmentation from 80 tons to 100 tons, and there was no improvement in labour-economising appliances for the working of the ship, as the ratio of men to tonnage was at the beginning of the century practically 1 to every 10 tons, and at the close, 1 to 13 tons.[1]

In the nineteenth century, the tonnage increased sevenfold, but in view of the adoption of steam the actual carrying capacity was augmented between twenty-five and thirty-fold; the average size of ship increased to 722 tons. Practically, every ship in the eighteenth century carried guns, the average being two per vessel. It was not until 1853 that there was omitted from the mail contracts the clause which provided that each mail vessel must be built to carry guns of the largest calibre in use. The practice of carrying guns on merchant vessels came again into force during the great European war for the purpose of warding off attack from the submarines of Germany and Austria.

The nineteenth century brought every incentive to the development of shipbuilding. Nelson taught the lesson, never to be forgotten, that sea-power is essential to the commercial expansion—even to the existence—of our island kingdom, with its corollary, that the merchant fleet is as necessary to

[1] The following figures are taken for 1701 from "Chambers' Estimates," pages 68, 69, and 90; for 1793 from Lindsay's "History of Merchant Shipping"; for 1803 from "Porter's Progress of the Nation," page 626; and for 1901 and 1917 from the "Statistical Abstract for the United Kingdom."

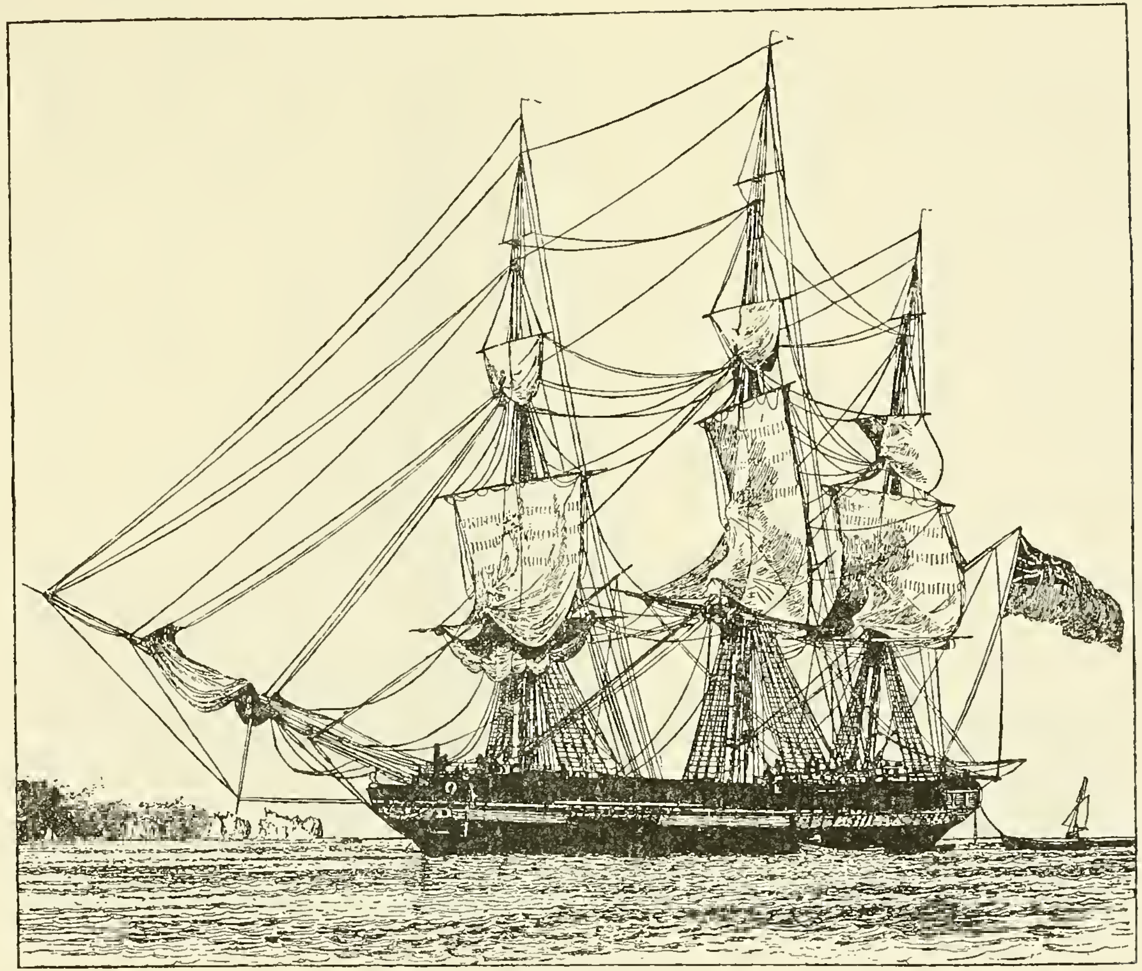
	1701.	1793.	1803.	1901.	1911.	1917.
No. of ships	3,281	16,079	20,893	14,574	21,072	18,720
Tonnage ...	261,222	1,540,145	2,167,863	9,524,496	18,803,469	16,559,635
Seamen ...	27,196	118,286	—	247,973	281,300	—

The Scottish fleet, which is not included for 1701 and 1793, was much smaller, alike in the size of units and aggregate tonnage.

Plate VI.

[*From an Old Engraving.*

GREENOCK AND SCOTTS' YARD EARLY IN THE NINETEENTH CENTURY.



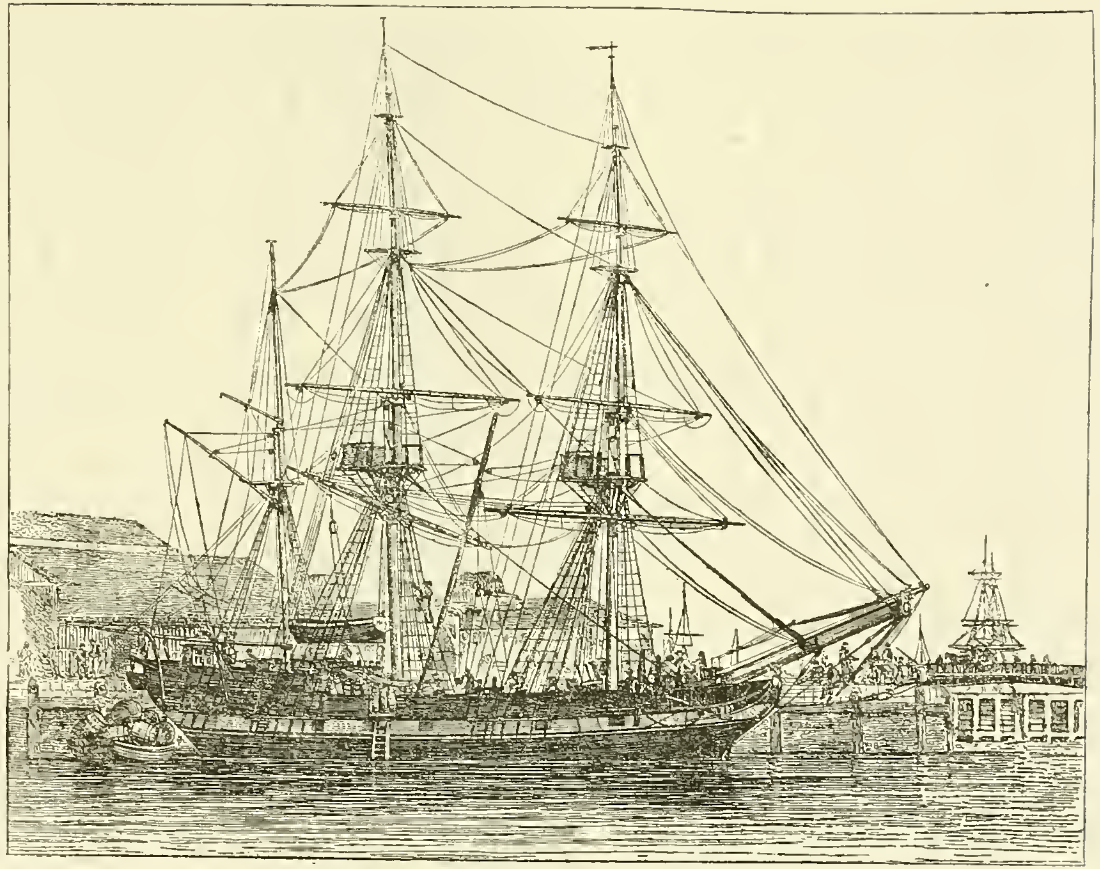
A TYPICAL EAST INDIAMAN. (*See page* 11.)

this mastery of the sea as fighting squadrons. This lesson was still more forcefully established during the recent war. The sea became our home; there arose a renewed love of exploration, and an ambition for colonisation. Success brought the chastening influence of responsibility, with a higher appreciation of the advantage of a conciliatory policy towards foreign nations. Contemporaneously with the growth of this conception of empire there arose a war of retaliation in shipping with the newly-formed United States of America, which continued for half a century. Although not without its regrettable incidents, it stimulated a rivalry in the shipping and shipbuilding industries which was ultimately as beneficial as it had been pronounced. The monopoly of the East India Company in the Eastern shipping trade terminated, so far as India was concerned, in 1814, and as regards China in 1834. This removed an influence which had hitherto retarded enterprise in naval construction—especially on the Clyde—due to the Company's preference for building their ships in India, and in the south of England ports. Private owners, too, entered more vigorously into competition with American clippers which had first commenced trade with China in 1788.

With the widening of the maritime interests and the intensification of competition there was awakened a general desire to increase the strength of ships. In this respect, as in others, there had been little advance either in the Navy or in the mercantile marine. It was exceptional for a ship of the eighteenth century to continue in service for more than twelve or fifteen years. This was due partly to defective constructional details, and partly to the ineffective methods of preserving timber.

Ships were then built up[1] of a series of transverse ribs, connected together by the outside planking and by the ceiling. There was no filling between the ribs. The ship's structure

[1] Holmes's "Ancient and Modern Ships," page 130.



A WEST INDIAMAN. (*See page* 11.)

thus suffered severely from hogging and sagging stresses. The French tried to improve this by introducing oblique iron riders across the ceiling, or by laying the ceiling and the outside planking diagonally, while in other instances the whole was strengthened with vertical or diagonal riders; but none of these systems gave complete satisfaction. The Sepping system was introduced about 1810, and was early adopted by the Scotts. The bottom of the ship was formed into a solid mass of timber. The beams were connccted with the side of the ship by thick longitudinal timbers below the knees, and by other stiffening members. A trussed frame was laid on the inside of the transverse frame in the hold of the ship, and the decks were laid diagonally. These members bound the ship in all dircctions, so as to resist thc stresses due to thc ship working in a seaway.

The method of preserving the timber adoptcd at thc beginning of the eighteenth century was to char the inner surface of the log, while the outer surface was kept wet; but this was superseded early in the century by the stoving system, which consisted in placing timber in wct sand, and subjecting it to the action of heat, for such time as was necessary to extract the residue of the sap and bring the timber to a condition of suppleness. This process continued until 1736, after which the timber itself was steamed. Copper sheathing was first employed on warships in 1761; prior to this lead had been used, but only occasionally.

American shipbuilders held an important position, even in the British trade, for some time after the Declaration of Independence; but there was then developed a pronounced spirit of emulation amongst the British firms, which had a marked effect on competition in western seas. At the beginning of the nineteenth century much of the oversea work done by the Scotts was for the West Indian trade. The vessels were not often of more than 600 tons, but the firm continued steadily to develop their business.

Between 1773 and 1829, the period of expansion under the second John Scott, to which we have already referred, the output was 16,800 tons.[1] This output included a succession of fine ships for the West India trade, to the order of some of the old Glasgow companies, amongst the number being Stirling, Gordon and Company; J. Campbell and Company; James Young and Company; and Muir and Fairlie. We may mention as typical ships, the *Grenada*, of 650 tons burden, and the *John Campbell*, of 446 tons, built in 1806, the first ships launched on the Clyde with all rigging in position.

Thus early, too, the Scotts had entered upon the construction of that long series of yachts, sailing and steam, which has brought them considerable repute, and even more pleasure, since they were in successive generations noted yachtsmen. In 1803 they launched the 45½-ton cutter for Colonel Campbell, of the Yorkshire Militia, which was pronounced one of the most complete of the kind ever built in Scotland up to that time. It may be incidentally mentioned, that the Scotts also showed thus early their practical sympathy with the auxiliary forces of the Crown by being at the head of the volunteer Sea Fencibles formed on the Clyde in the stormy years of the Napoleonic wars.

As soon as the monopoly of the East India Company was removed in 1814, private shipowners entered the lists, and the Scotts were early occupied in the construction of Indo-China clippers. In 1818 they built the *Christian*, and in 1820 the *Bellfield*, the latter, of 478 tons register, for the London and Calcutta trade. She was one of the first of a long series. The *Kirkman Finlay*, of 430 tons, built in 1834, suggests the name of a firm long and honourably associated with the development of trade in our great Eastern dependency. The effect of competition was a reduction in the average rate of freight per ton from India to Britain from £32 10s. about 1773 to £10 in 1830.

[1] Weir's "History of Greenock."

The East India Company about the year 1813 paid £40 per ton for their ships, as against about £25 per ton by other traders; the latter sum was about the same as that paid in America. The East Indiaman had a crew in the ratio of 1 to 10 or 12 tons, while 1 to 25 tons sufficed for the West Indiaman. The speed of the western ship was greater, largely by reason of the difference in proportions and lines. The clippers built on the Clyde and in America had a length equal to five or six times the beam, against four times the beam in the case of the East India Company's ships. In the design of these clippers the Scotts took an important part. An ingenious method of making model experiments in the graving dock at the works was evolved in the 'forties, whereby the firm were able to arrive at the most satisfactory form of hull to give the minimum of resistance, and at the same time a large capacity for cargo per registered ton. In this latter respect they were more successful than the designers of the East Indiamen, notwithstanding the bluff form of the latter.

As rapidity in answering the helm was a most important element in tacking, and therefore in speed, the firm about this time prepared full-rigged models, about 5 ft. long, for experimental trials to test the ship's form and rudder, on Loch Thom, situated on the hill above Greenock in an exposed place where the conditions of wind were analogous to those at sea. The results proved satisfactory. In fact, in these years, when the *Minerva*, *Acbar*, and other noted clippers were built, the care used in design and construction was almost as great as that now devoted to the case of racing yachts.

The Scotts, in the first half of the nineteenth century, continued to produce a long series of successful sailing ships, while at the same time taking a creditable part in the evolution of the steamship. Steam, however, was not possible in long-distance voyages until pressures had been increased, and coal consumption reduced to moderate limits; and thus it came that, although the steam engine was used in the early years of

Plate VII.

THE "LORD OF THE ISLES"

the nineteenth century in river, and later in coasting, craft, the sailing ship continued supreme almost until the middle of the century. We do not propose, however, to refer to all of the later sailing ships built by the Scotts, but it may be interesting to give some details of the construction.

American rock elm was largely used. The frames were in three sections with scarfed joints, bolted together, the scantlings being reduced towards the top, so as to lower the centre of gravity. Inside the frames there were at various heights longitudinal timbers to add to the fore-and-aft strength. The top sides were of greenheart, the beams of oak or greenheart, with wrought-iron knees; the height between the beams was made to admit of two hogsheads of sugar being placed in the hold. There were side-stringers, sometimes 10 in. thick, between the floor and the beams, which were half-checked into the stringers. On the top of the beams there were deck-stringers. There was a most effective transverse and longitudinal binding, brass bolts being extended right through the knee, stringer, frame, and skin of the ship. The decks were of yellow or Dantzig white pine. An 800 or 1000-ton West Indiaman took about nine months in construction. The last wooden ship built in Greenock was the *Canadian*, completed by the Scotts in 1859.[1]

The highest conception of the iron sailing ship, as built by the firm, was probably embodied in the *Lord of the Isles*, completed in 1856 and illustrated on Plate VII, facing page 12. She had a length, between perpendiculars, of 185 ft., a breadth of 29 ft.—the proportion being thus 6.4 of length to 1 of beam —with a depth of hold of 18 ft. Her registered tonnage was 691 tons, and her builders' measurement 770 tons. Although a fine-ended ship she carried a large cargo on board, and made her first trip to Sydney in seventy days, which had not then been surpassed.[2] She made the passage from Shanghai to

[1] Brown's "Early Annals of Greenock," page 138.

[2] Murray's "Shipbuilding in Iron and Wood," page 60.

London in eighty-seven days, with 1030 tons of tea on board. In one trip she averaged 320 nautical miles for five consecutive days. When engaged in the celebrated race for the delivery of the season's teas from Foo-chow-foo to London, in 1856, the *Lord of the Isles* beat two of the fastest American clippers, of almost twice her tonnage. She "delivered her cargo without one spot of damage, and thus British ships regained their ascendency in the trade which their American rivals had far too long monopolised."[1] From that time the British sailing ships gradually gained a complete superiority over the American vessels, and carried all before them, until they in turn were supplanted by the British steamship.

From time to time an occasional sailing ship was constructed of steel; the latest, the *Archibald Russell*, is illustrated on Plate VIII, facing this page. Built for Messrs. John Hardie and Company, this vessel had a length, between perpendiculars, of 278 ft., a beam of 43 ft., and a depth, moulded, of 26 ft., and carried 3930 tons of deadweight cargo on a draught of 21 ft. 7½ in. But less than 1 per cent. of ships now constructed depend upon the unbought but uncertain winds, and then only for special trades. On regular routes the steamer is now almost paramount, and it was, therefore, appropriate in the highest degree that the first vessels to steam regularly to China, *viâ* the Cape, should, like the *Lord of the Isles*, be built by the Scotts; but that belongs to another story.

[1] Lindsay's "Merchant Shipping," vol. iii, page 294.

Plate VIII.

THE "ARCHIBALD RUSSELL."

The Development of the Steamship.

♣ ♣

A CLOSE association existed between the Scotts and the family of James Watt, the inventor of the steam engine: the founder of the Scotts' shipbuilding firm and the father of Watt were identified with several schemes for the improvement of Greenock; and the signature of John Scott, of the third generation, whose portrait is the second reproduced on Plate II, is taken from a document in connection with some intromissions of town's funds, to which also is adhibited the signature of Watt's father.

It is not surprising, therefore, that the Scotts were early close students of Watt's inventive work, and among the first to enter upon the building of steamships while, at the same time, as we have shown in the preceding pages, building many of the fine sailing ships which established British shipping supremacy in the early half of the nineteenth century, and raised Greenock by 1829 to a port having trade with every part of the world.

Miller and Taylor commenced their experiments at Dalswinton in 1788, with a steam engine driving paddle-wheels on boats.[1] Symington's steam tug, *Charlotte Dundas*, by its success in 1802 on the Forth and Clyde Canal,[2] removed

[1] Woodcroft's "Steam Navigation," page 20, etc.

[2] *Ibid.*, page 54.

any remaining doubt; but it was not until 1812 that Henry Bell, with his *Comet*, proved the commercial utility of the steam system, although without profit to the promoter.[1] The building of steamships, evolved by experiments by various workers in Britain—and in America also—was readily adopted on the Clyde. Within four years of the completion of the *Comet*, it was not unusual for five hundred or six hundred passengers to enjoy in the course of one day water excursions on the river.[2] The fares were five times those prevailing before the war. Among the earliest of the Clyde steamers were the *Active*, of 59 tons, and *Despatch*, of 58 tons, built by the Scotts. In calculating the tonnage in those early days, an average allowance of one-third was deducted for the machinery. In 1816 the firm built the *Shannon*, of a length, between perpendiculars, of 77 ft. 7 in., of a beam of 15 ft. 3 in., and of a depth moulded of 9 ft. 1 in. She had fore-and-aft cabins. Her engines were of 14 horse-power nominal. She plied on the Shannon between Limerick and Kilrush. By 1818—six years after the completion of the *Comet*—thirty-two steamers were running on the Clyde, and some of these were sent ultimately for traffic on the coast and on other rivers.[3] The largest of these was of 112 tons, with engines of 40 nominal horse-power.

The Scotts had built many sailing craft for the Clyde and Belfast trade, for the Glasgow and Liverpool service, and for the Liverpool and Drogheda, and other coasting routes; and it was natural when steam was introduced that the same firm should supply the side-paddle boats.

In three successive years—from 1819 to 1821—the largest steamer in the kingdom came from Scotts' Works. The record was marked in 1819 by the *Waterloo*, of over 200 tons,

[1] Deas' "Treatise on the Improvements and Progress of Trade on the River Clyde" (1873), page 24.

[2] Muirhead's "Life of Watt," pages 428 and 429.

[3] Williamson's "Clyde Passenger Steamers," pages 348 to 351.

with engines of 60 nominal horse-power; in 1820, by the *Superb* of 240 tons register, with engines of 72 nominal horse-power, which cost about £37 per ton, and steamed 9 miles per hour, using 1670 lb. of Scotch coal per hour; and in 1821, by the *Majestic*, of 345 tons register, with engines of 100 horse-power, which cost over £40 per ton, and steamed 10 miles per hour for a consumption of 2240 lb. of Scotch coal. Although the modern steamer is more than one hundred times the size of these pioneers, with a cost per ton of less than one-fourth, and a fuel consumption per unit of work done of not more than a seventh, the records of these and other early ships are worthy of full reference.

The advantage of steam navigation for channel service was at once recognised. A Parliamentary return issued in 1815 showed that for the space of nine days in the previous year only one mail packet could sail between Holyhead and Dublin owing to adverse winds, and even then the average passage was twenty-four hours. Lord Kelvin, in his memorable Address as Chancellor of the University of Glasgow, in 1905, recalled the fact that early in the century his father often took three or four days to cross from Belfast to Greenock in a smack, as she was frequently becalmed. With favourable winds, rapid passages were made, a revenue cutter occasionally doing the Belfast and Greenock run in ten hours.

The Greenock and Belfast route was among the first around the coast to come under the influence of the mechanical system of propulsion. The *Rob Roy*, which was the outcome, so far as form of hull was concerned, of probably the first model experiments ever made—undertaken by David Napier in the Canal at Camlachie[1]—was in 1818 the pioneer in the Glasgow and Belfast steam service, and later in the Dover and Calais steam service.

There followed in 1819 three notable vessels from Scotts

[1] James Napier's "Life of Robert Napier," page 21.

Works: the *Waterloo*,[1] the *Robert Bruce*, and the *Sir William Wallace*. The particulars and performances of these vessels, taken from contemporary records, principally the "Greenock Advertiser," which faithfully reported each incident in the development of the steamship, are especially interesting as illustrative of early work.

The *Waterloo*, which, as we have already said, was the largest steamer of her year (1819), had a beam equal to one-fifth of her length, the measurement between perpendiculars being 98 ft. 8 in. In addition to a large number of passengers, she carried under ordinary conditions a cargo of 100 tons, on a draught of 8 ft. 6 in. against 7 ft. 3 in. without cargo. Three months were required, between the launch of the ship and her trials, for the fitting on board of the engines which were each of 30 nominal horse-power, and gave her a speed of between 8 and 9 miles per hour. Sails, however, were still carried to assist in driving the ship, and this vessel was of schooner rig. She inaugurated the steam service between Belfast and Liverpool.

The *Robert Bruce* was the first steamer to trade between the Clyde and Liverpool.[2] She was followed by the *Sir William Wallace*. Both were built by the Scotts, and had engines of 60 nominal horse-power. They began service in the summer of 1819; and the record of the maiden voyage of the former,

[1] This was the second of the name—a favourite one after the Duke of Wellington's great victory—and gave rise to the following poetic effusion:—

And now amid the reign of peace,
  Art's guiding stream we ply;
That makes our wheels, like whirling reels,
  O'er yielding water fly.
As our heroes drove their foes that strove
  Against the bonnets blue;
On every side the waves divide
  Before the *Waterloo*.

—Millar's "Clyde from Source to Sea," page 179.

[2] Millar in "Lectures on Naval Architecture and Marine Engineering at Glasgow Exhibition, 1880–81," page 138.

Plate IX.

EARLY STEAMBOATS AT GREENOCK, 1820.

in August, 1819, showed that two and a half hours were occupied in the run from Glasgow to Greenock, about 22 miles; and within 26 hours thereafter the vessel took on her pilot at the north-west lightship outside the Mersey Bar. The return voyage was equally satisfactory. To quote again from contemporary records, "the passengers, both out and home, were so highly gratified with the performance of this vessel and their treatment on board that they unanimously expressed their entire satisfaction with Captain Paterson's exertions to render them comfortable and happy, their conviction of the seaworthiness of the vessel, and their admiration of the powers of the engines, capable of propelling so large a body at the rate of 7 knots per hour, in the face of a strong north-north-west wind and high sea for at least two-thirds of the way from Liverpool, her rate thither being nearly 9 knots."[1]

In 1820, the *Superb*, of 240 tons and 72 horse-power, followed the *Sir William Wallace*, and marked a still further improvement. She had a copper boiler, and in the three cabins sleeping accommodation was provided for sixty-two passengers. She was "the finest, largest, and most powerful steam vessel in Great Britain.[2] The average duration of the passage from the Clyde to Liverpool did not exceed 30 hours."

The *Majestic*, also for the Clyde and Liverpool service, was built in 1821, and was 134 ft. 11 in. long between perpendiculars, 22 ft. 8 in. beam, and 14 ft. 5 in. depth, moulded. Her draught, 10 ft. 6 in. forward and 12 ft. aft, was too great for the navigation of the upper reaches of the Clyde, and passengers were conveyed between Glasgow and Greenock in a tender. In her four cabins there was greatly-increased accommodation for the passengers. She was probably the first steamer with a sleeping apartment exclusively for ladies. The copper boiler worked at a pressure of 4 lb. per square inch,

[1] "Greenock Advertiser," August 6th, 1819.

[2] "Steamboat Companion" for 1820.

and the engines ran at 56 revolutions. The fares[1] to Liverpool in those days were £2 15s., as compared with 17s. pre-war rate; of course, very much better accommodation is provided.

The *City of Glasgow* was built in 1822 for the Liverpool service. This vessel, which cost £15,000, had a speed of over 10 knots, and was reputed the fastest afloat. Her length was 110 ft. 4 in., beam 22 ft. 4 in., and depth, moulded, 13 ft. She was arranged like the *Majestic*, and the two were long the most important vessels in the Clyde and Liverpool trade. She was subsequently bought by McIver, and inaugurated the competition with the Burns line, commenced in 1829.[2] The McIver and Burns lines were subsequently combined.

The Scotts rendered similar service in the development of the mail route between Holyhead and Dublin. The first vessel built by them for this service was the *Ivanhoe*, constructed in 1820. The steam service had been opened between these two ports in 1819 by the *Talbot*, the first steamer fitted with feathering floats.[3] The *Ivanhoe*,[4] a larger steamer than the *Talbot*, was of 170 tons burden, her length between perpendiculars being 97 ft. 4 in., beam 19 ft., and depth, moulded, 14 ft. 6 in. She had various improvements in her machinery, which was of 60 nominal horse-power. She left Scotts' yard in May, 1820, and made the voyage to Howth (200 miles), in 26½ hours.

The Scotts continued thus to improve on each successive ship, and to widen the area of their influence. The Clyde continued largely to monopolise the industry of steam shipbuilding, and it was not until the summer of 1822 that a steamer —not built in Scotland—appeared on the Clyde. This was the *Saint George*, from Liverpool. The *City of Glasgow*, already

[1] Millar, "On the Rise and Progress of Steam Navigation." Lectures at the Glasgow Exhibition (1880–81), page 138.

[2] Hodder's "Life of Sir George Burns, Bart.," page 161.

[3] Williamson's "Clyde Passenger Steamers," page 32.

[4] Lindsay's "History of Merchant Shipping," vol. iii., pages 78 to 80.

referred to, was her competitor and proved much faster in races to Liverpool.

One of the first steamers to trade in the Mediterranean was the *Superb*, sent thither in 1824, and the *Trinacria*, also built by the Scotts, followed in 1825. These ran between Naples and Palermo. The last-named vessel was 135 ft. long overall, and 113 ft. 6 in. between perpendiculars, 39 ft. 6 in. broad over the paddle-box, and 21 ft. 10 in. net beam, 14 ft. deep (moulded), and of 300 tons burden. The vessel was especially well-equipped, and cost £15,000. The engines, the first manufactured by the Scotts at their Greenock foundry, were of 80 nominal horse-power, and the boilers, which were of copper, weighed 40 tons. The speed was 10 miles per hour. Later this steamer became the *Hylton Joliffe*, and was employed by the General Steam Navigation Company on their London and Hamburg service.

As to the yard in which these several vessels were built, suggestion is afforded of the state of efficiency by the following quotation from a history published in 1829.[1] "The building yard of Messrs. Scott and Sons is allowed to be the most complete in Britain, excepting those which belong to the Crown. It has a fine extent of front from the West Quay to the termination of the West Burn, and has a large dry dock, which was altered lately to the plan of the new dock. All the stores and lofts are entirely walled in, and, independently of the building premises, they have an extensive manufactory of chain cables."

The majority of the engines for these early steamers of the Scotts were constructed by Napier or Cook, and were of the side-lever or beam type. In 1825, however, John Scott, who had done so much for the progress of the firm, decided to commence building machinery, and acquired workshops for that purpose at an outlay of £5000. Originally a brass and iron foundry, commenced in 1790 by Burrow and Lawson, this business had been sold in 1796 or 1797 to William Brownlie,

[1] Weir's "History of Greenock," page 89.

and was purchased from him by the Scotts. It was carried on with progressive success under the title Scott, Sinclair and Co., became the Greenock Foundry Company in 1859, and finally was absorbed into Scotts' Shipbuilding and Engineering Company in 1904, without in any instance material variation in co-partnery.

This establishment when begun, on a very small scale, about 1790,[1] included in its equipment, which was considered thoroughly efficient, a large cupola. Some idea is given of the extensions which took place by reference to Weir's "History of Greenock" (1829), page 94, where it is stated that in the few years that had elapsed since the taking over of the works by the Scotts "they have manufactured some splendid engines, and—what is more to be looked for than the appearance—they have wrought well. They have in hand the largest engine ever made, which is of a size of 200 horse-power, and is intended for a vessel building at Bristol. The number of men employed amounts to about two hundred and twenty, while the weekly distribution of wages is £180." As a contrast it may be said here that there were, in 1918, in the engine works alone, well over 2000 men earning roughly £7500 in wages per week, and engaged upon the construction of machinery of all classes for vessels of the British Navy. These figures are, of course, independent of those connected with the shipbuilding yards.

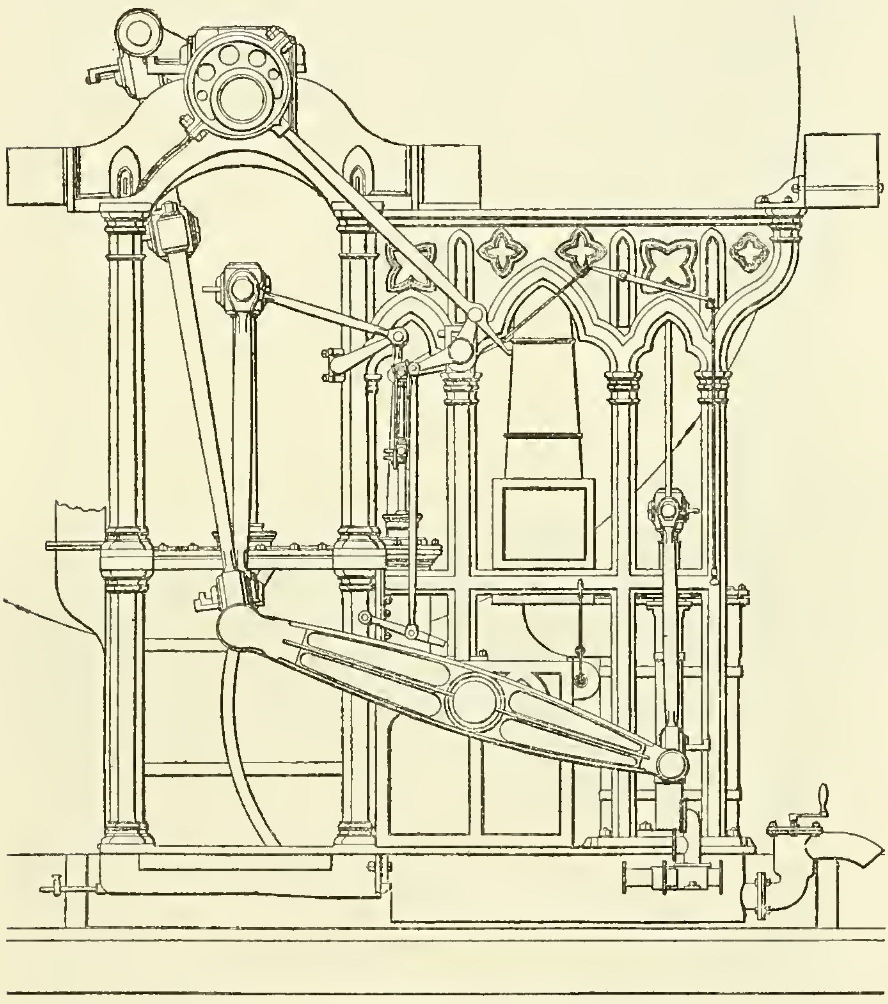
From 1825, the Scotts continued to do very satisfactory engine work, much of it of an original character, not only for vessels built by themselves, but for ships constructed on the Thames and other English rivers, and also for the series of warships built for the British Navy at their works and for others constructed at the Royal Dockyards.

The naval engine work began with H.M. Ships *Hecla* and *Hecate*, engined in 1838–9, and the first warships built in the dockyards to be sent to Scottish works to receive machinery.[2]

[1] Williamson's "Memorials of James Watt" (1856), page 228.

[2] "Greenock Advertiser," July 5th, 1839.

And here it may be noted, too, that the first warship built by the Scotts was the *Prince of Wales*, in 1803, and also that the firm had the credit of building the first steam frigate constructed on the River Clyde for the British Navy, H.M.S.



A SIDE-LEVER ENGINE OF 1831.

Greenock, launched in 1849. They also built the first compound engines fitted to a French warship. With these naval ships and engines we deal in our next Chapter, and may therefore continue our narrative regarding merchant steamers.

We reproduce on page 23 a drawing illustrating an early type of engine built by the firm. This is an engine constructed in 1831. The steam cylinder is $52\frac{1}{4}$ in. in diameter, and the crank-shaft is actuated, through connecting-rods, from the ends of the levers operated by the piston-rod, while the air-pump is placed at the opposite ends of the levers.

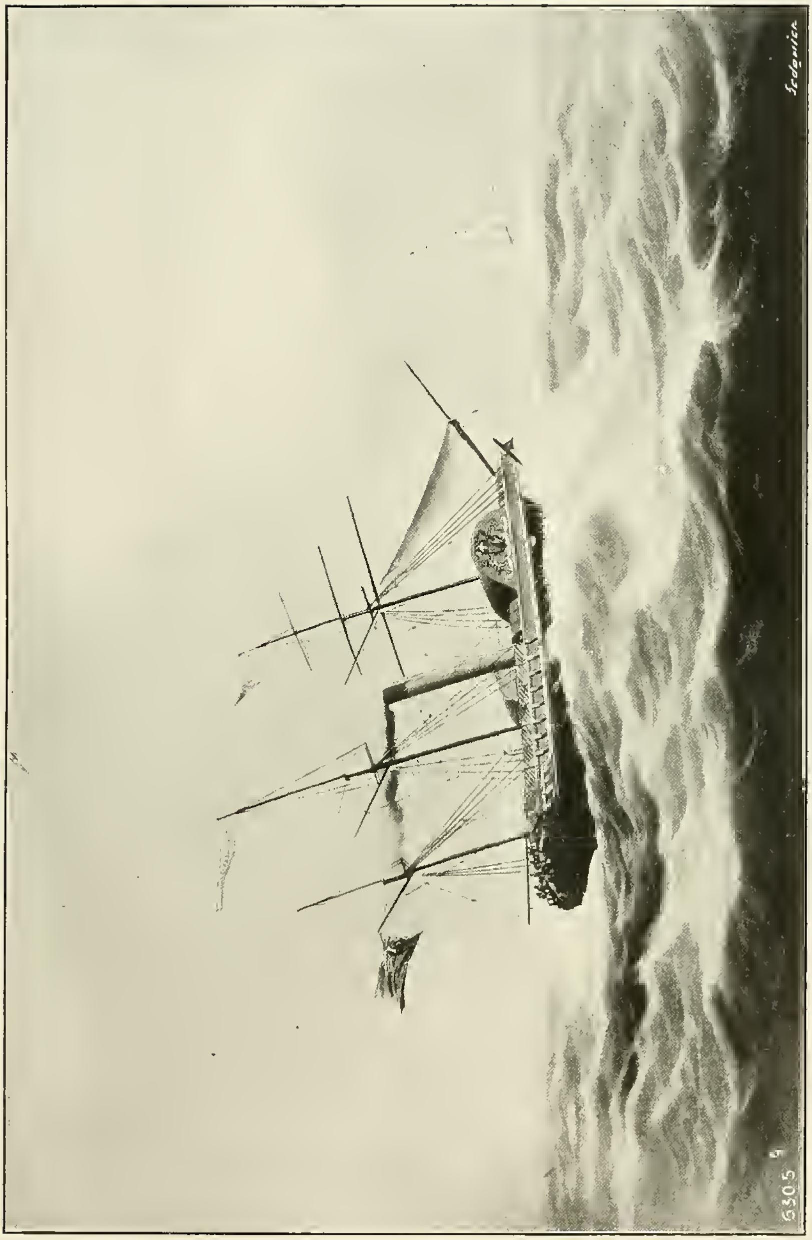
A different type of engine, constructed in the following year (1832), is illustrated on page 25. In this case the cylinder operates the opposite end of the levers to that connected with the crank-shaft. In both engines the lever-gudgeon passes through the jet-condenser.

The records we have given are historically interesting, because they tell of the beginnings of a great epoch in British shipping. We do not propose to follow in such detail subsequent steamships, built for other services, between London and Aberdeen, the Clyde and Dublin, etc. The *City of Aberdeen*, built in 1835 for the first-named, marked noteworthy progress. She measured 187 ft. over the figure-head, and was of 1800 tons, including the space for the machinery. Her poop was 60 ft. long, and 45 ft. broad. According to contemporary testimony, she was, in her day, the strongest steamer built, having solid frames from gunwale to gunwale. She had additional bracing with African oak stringers; oak and iron trussings alternately bolted to the stringers formed a complete system of diagonal fastenings and bindings from stem to stern. The whole of the cabins, saloons and state rooms, were on one deck, and there was the important innovation of hot and cold baths. The speed was 12 miles per hour.[1] An interesting feature was the arrangement of the boilers, described in contemporary records[2] as "an entirely new plan." "The boilers are placed in two heights, three below and two above. The three lower ones are fired in the usual way, and the two upper from an iron platform. Besides the saving of room in the length of the vessel, the boilers

[1] "Greenock Advertiser," February 5th and May 25th, 1835.

[2] "The Morning Chronicle," May 29th, 1835.

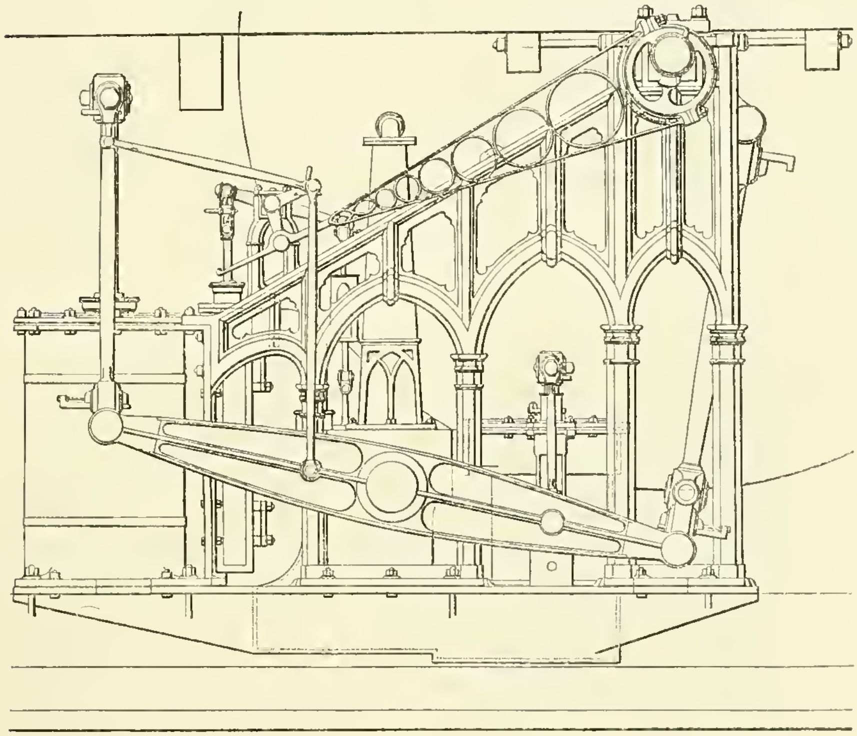
Plate X.



THE "CITY OF ABERDEEN," 1835.

being much shorter than usual, four additional fires have been obtained."

The *Jupiter*, of 439 tons and 210 horse-power, built in 1836 for the Clyde and Dublin trade, cost £20,000, and established a record in speed, making the voyage in sixteen hours six minutes, at the rate of 13 miles per hour; formerly the voyage took twenty-four hours.



AN ENGINE OF 1832.

In the late 'thirties and the early 'forties there was a great development in oversea trading steamers, the Clyde taking, then as now, the foremost place. Several epoch-marking voyages had been made with the steam engine used intermittently. The *Savannah* had thus crossed the Atlantic from the United States in 1819, and the *Royal William* from Quebec in 1833.

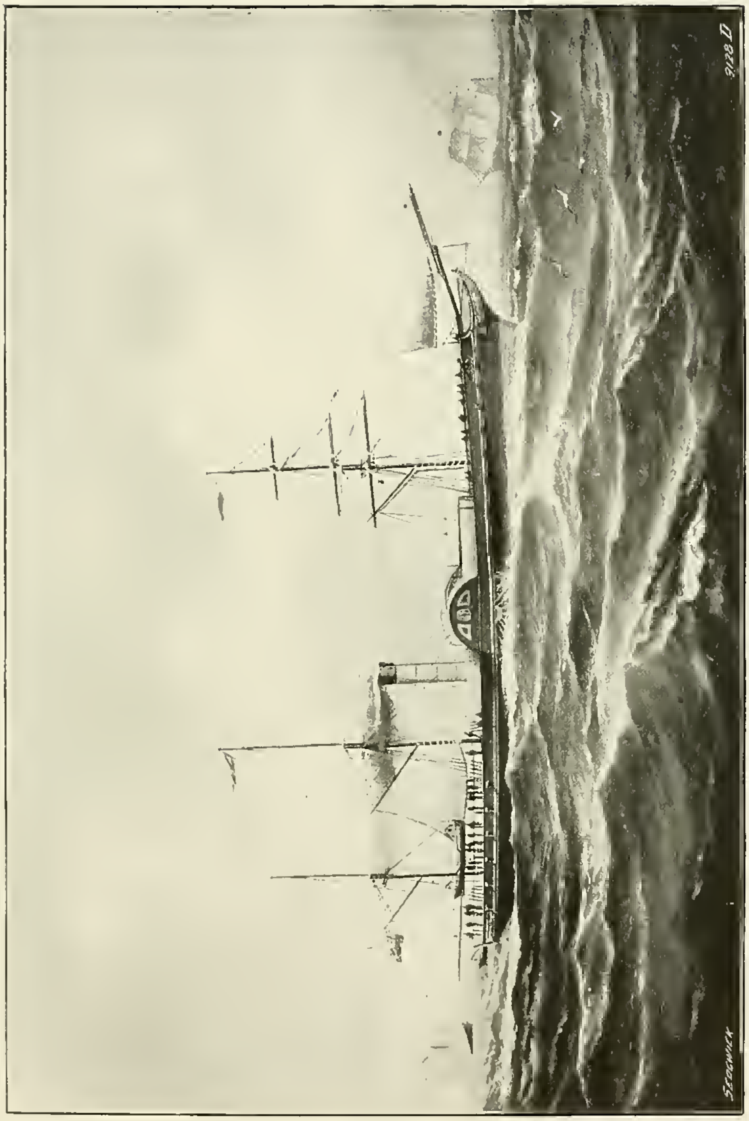
The barque *Falcon*,[1] 84 ft. in length, and of 175 tons, had on the voyage to India in 1835 utilised engines which, however, were removed on her arrival in our Eastern dependency. Later in the same year the *Enterprise*, of 470 tons and 120 horse-power, also rounded the Cape of Good Hope to India. In all these cases, however, sails were utilised whenever possible, and there was still great hesitancy in accepting the steam engine even as an alternative on occasions to the use of the " unbought wind." The advantage, however, of a rate of speed which, while low, would be constant, soon asserted itself, and there followed within a few years regular mail steamship services on the North and South Atlantic Oceans, in the Mediterranean Sea, in the Indian Ocean, and the China Seas. In the beginning and development of these services the Scotts took a prominent part.

One of the first notable steamship lines to be organised for oversea service was that which ultimately became the Peninsular and Oriental Company. It had its origin[2] in steamship service from Falmouth to Oporto, Lisbon, Cadiz, and Gibraltar. Four steamers were built in 1836–37, the *Tagus*, *Don Juan*, *Braganza*, and *Iberia*. The first-named was built by the Scotts, and the third was engined by them. These ultimately carried the mails as far as Alexandria, whence they were conveyed overland to Suez, and from thence by the East India Company's vessels to Bombay. This service developed into the Peninsular and Oriental service, when, in 1840, the Company took over the mail service on the Indian Ocean; in 1847 they extended their operations to China. The overland service continued until the Suez Canal was opened in 1869, and many of the vessels for the Mediterranean service, as well as for the eastern route, were built by the Scotts.

[1] Fincham's " History of Naval Architecture," page 294.

[2] Sir Thomas Sutherland, in the " Pocket Book of the P. and O. Company " (1890), page 15.

Plate XI.



SCOTTS' FIRST P. AND O. LINER, THE "TAGUS."

The *Tagus*,[1] which was thus one of the first quartette of P. and O. steamers, was built in 1837. She had a length of 182.1 ft., a beam of 26 ft., and a depth of 17 ft. 4 in., the burden tonnage being 709 tons. When carrying 265 tons of coal in her bunkers and 300 tons of cargo, the draught was 14 ft. 6 in. The side-lever engines which were fitted to her had a cylinder 62 in. in diameter, with a 5-ft. 9-in. stroke, developed 286 horse-power, and operated paddle-wheels 23 ft. 6 in. in diameter. Two of the other early steamers, the *Jupiter* and the *Montrose*, were also constructed by the Scotts.

The conveyance of cargo and passengers across the Isthmus of Suez not only involved inconvenience and expense, but was a cause of great delay. There was still, however, a strong prejudice against steamships being utilised for long sea voyages, partly because of vested interests in sailing ships. Sir John Ross, C.B., who, in 1818 and in 1829 to 1833, made Arctic explorations, was one of the strongest advocates for a service to India by way of the Cape of Good Hope ; and, in order to establish the feasibility of the undertaking, made experiments with the *City of Glasgow*, built by the Scotts in 1821. This vessel, of 283 tons, had in the interval been fitted with new boilers, with special safety appliances, and they worked at 4-lb. pressure ; they gave the high evaporation in those days of 9 lb. of water per pound of coal.[2]

This vessel made the trip from London Bridge to the light-ship off Spithead (246 miles) in thirty-one hours five minutes, on a consumption of 6 lb. of fuel per indicated horse-power per hour. These facts were utilised by Sir John Ross in his advocacy of the route, and a new company was formed, under his chairmanship, in 1837.

The first vessel of the fleet, named the *India*, was built and engined by the Scotts, and was a few years later transferred

[1] Fincham's " History of Naval Architecture," page 235.

[2] Sir John Ross's " Steam Communication to India by the Cape of Good Hope " (1838), page 31.

to the Peninsular and Oriental Company. The *India*, launched in 1839, was the largest steamer built on the Clyde up to that date, being 206 ft. 6 in. long, 30 ft. 9 in. beam, or 48 ft. wide over the paddle-boxes. The gross tonnage was 1206 tons. Accommodation was provided for eighty cabin passengers, and provision made for 400 tons of cargo. A feature of her construction was the provision of two strong bulkheads of iron across the engine-room, in order to avoid accidental outbreak of fire, and also to prevent water from a leak in one part spreading to another.[1] This was probably the beginning—nearly seventy years ago—of the system of division by watertight bulkheads, now universal. Its compulsory adoption was advocated by the Institution of Naval Architects in 1866, and enforced by Lloyds in 1882, and by the Board of Trade in 1890. The machinery was of 320 horse-power, and had surface-condensers. The *India* was launched on the anniversary of the birth of James Watt, and a salute of twenty-one guns was fired as the vessel left the ways.

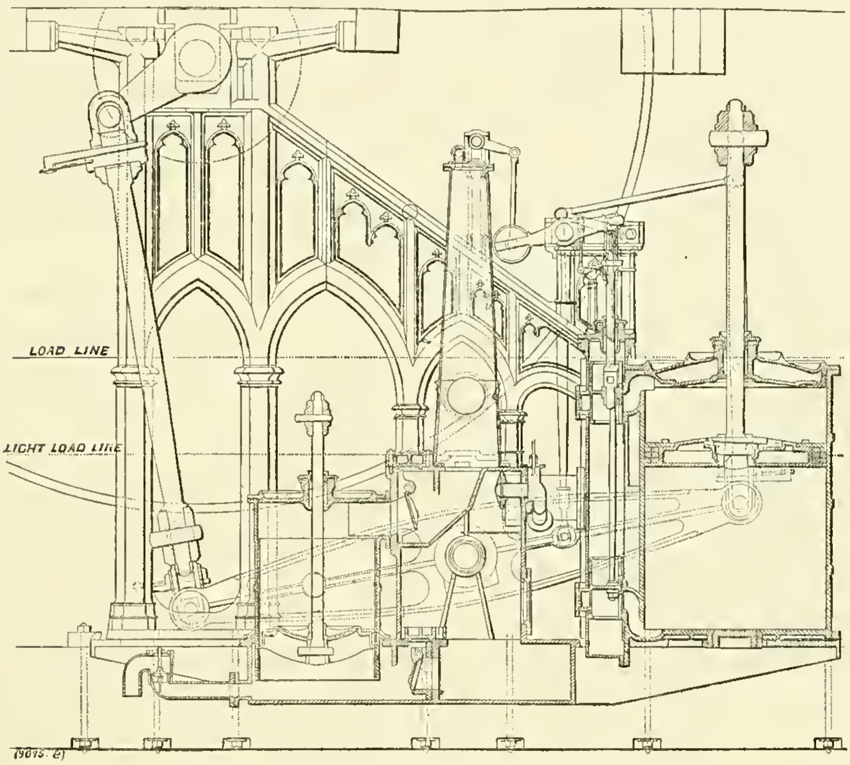
Five other steamers were built for the service, and the voyage took from fifty-five to sixty days, as compared with the one hundred and thirteen days occupied by the *Enterprise*. A monthly service was thus rendered possible. At the same time the Scotts built steam vessels for the coasting trade of India and of South Africa.

The type of machinery in use at this period is illustrated on the opposite page. This particular engine was constructed in 1838. The piston was connected to one end of the side-levers, while the crank was operated from the other. The paddle-wheel of this engine was 25 ft. $0\frac{1}{2}$ in. in diameter, with seventeen floats. For about thirty years this was the standard type of marine engine for paddle steamers.

The Gothic architectural design for the main framing was gradually abandoned for something less ornamental and perhaps more in accord with the principles of mechanics.

[1] "Greenock Advertiser," January 22nd, 1839.

The Royal West India Mail Company's Service, still one of the best known of British lines, was commenced in 1841. Some of the steamers were purchased, but amongst those built originally for the service was the *Dee* by the Scotts. She was 213 ft. 9 in. long, 30 ft. 4 in. beam, and 30 ft. in depth, the burden tonnage being 1848 tons. On a draught of 17 ft. 6 in.



TYPE OF SIDE-LEVER ENGINE OF 1838.

she carried 700 tons of cargo; and, as with most of the oversea liners of the period, the average speed was only about 8 knots. The voyage of 13,650 miles occupied then one hundred and nine days, including stoppages; and the consumption of fuel was 25½ tons per day. The engines, which had cylinders 73 in. in diameter with a stroke of 7 ft., were of 450 horse-power, driving side paddle-wheels 28 ft. 6 in. in diameter.[1]

[1] Fincham's "History of Naval Architecture," pages 320 and 321.

In the thirty years from the first commercial British steamer, the *Comet,* there had not been much advance in the steam engine, excepting in size, power, and, perhaps, reliability. Wood had continued to be the constructive material for all but the smallest ships. The size of vessels had grown steadily to the 1848 tons of the West Indian mail liner, which began a regular steamship service almost contemporaneously with the inauguration of the Atlantic mail line by the Cunard Company in 1840. Speeds on service, even on the shortest routes, were seldom over 13 knots, and on the long routes under 8 knots. But this was in excess of the average attained by all but exceptionally fast clippers. The Table on the opposite page shows the progress made in these years.

We enter now upon the period when iron took the place of timber as a constructional material. It was first used in part in the construction, on the banks of the Monkland Canal as far back as 1818, of a canal barge named the *Vulcan,* a vessel which continued at work for over sixty years.[1] But the first vessel built entirely of iron was a small craft constructed in 1821 in England. It was not, however, until 1832 that the first sea-going vessel was built of iron. Progress in the adoption of iron was slow, largely because timber had proved so serviceable, and, with lessened restriction upon its importation, had become much cheaper. It was not until the higher strength and greater ductility of steel were demonstrated in the 'eighties that timber was finally superseded. The last wooden ship built by the Scotts was completed in 1859.

Though the first successful application of the screw propeller was made about 1837, it was not till 1845 that a screw steamer crossed the Atlantic. This was the *Great Britain,* which was fitted with oscillating engines arranged to drive a large spur-wheel which engaged with a spur-pinion on the propeller shaft. From this time onwards the screw propeller gradually took the place of side paddle-wheels for ocean-going vessels.

[1] Lindsay's "Merchant Shipping," vol. iv., page 86.

The Scotts built several of the early Atlantic liners, and we reproduce on page 33 a drawing showing the geared double engines constructed early in the 'fifties for an iron screw steamer of

TABLE I.—EPOCH-MARKING STEAMERS BUILT BY THE SCOTTS, 1819 TO 1841.

Year.	Name.	Tonnage.	Horse-power.*	Speed (Miles per Hour).	Remarks.
1819	*Waterloo*	200	60	9	Largest steamer of 1819 (page 18).
1820	*Superb*	240	72	9	Largest steamer of 1820 (page 19).
1821	*Majestic*	345	100	10	Largest steamer of 1821 (page 19).
1835	*City of Aberdeen*	...	200	12	Strongest steamer of 1835 (page 24).
1836	*Jupiter*	439	210	13	Record speed (page 25).
1837	*Tagus*	709	286	10	Largest constructed on Clyde, 1837, and an early P. and O. liner (page 26).
1839	*India*	1206	320	10	First steamer to India *viâ* the Cape and the first Indian liner; largest launched on Clyde (page 27).
1841	*Dee*	1848	450	10	First Royal West India Mail liner (page 29).

* It is difficult to determine in all cases the basis on which horse-power was computed. The figures given represent nominal horse-power, and in Sennett and Oram's "Marine Steam Engine" (page 3), the indicated horse-power is, for this early period, recorded as 1.8 times the nominal horse-power.

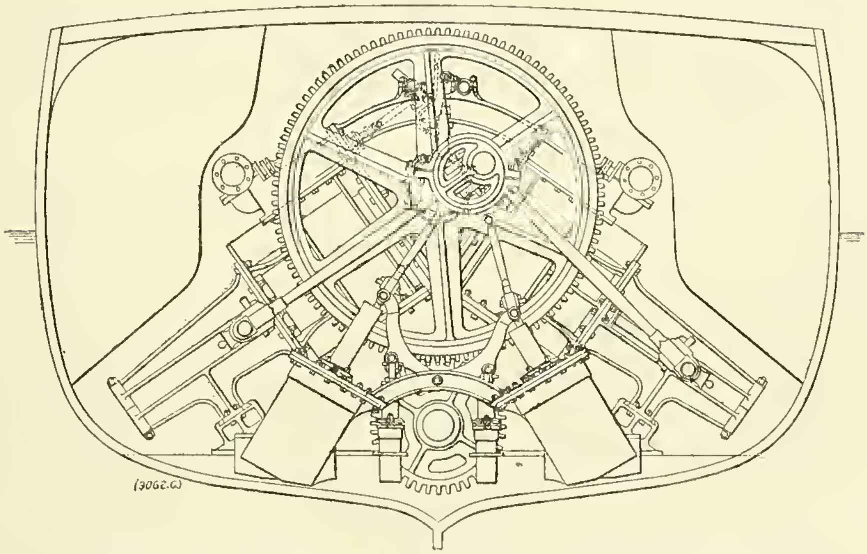
1190 tons, built for the Glasgow and New York service. This engine was pronounced at the time "the most compact specimen of its type then in existence,"[1] for although the power

[1] "Practical Mechanic's Journal," vol. i., 1853.

developed was 250 horse-power, and the ship was 260 ft. in length, only 12 ft. 6 in. of the fore-and-aft length was taken up by the machinery. "Every weight was well balanced, the working parts were clear and open, and the combined whole was stable, firm, and well bound together." The cylinders were 52 in. in diameter, were arranged diagonally, and worked at right angles to each other, with a stroke of 3 ft. 9 in. The piston-rods projected through the lower covers to allow of long return connecting-rods. Each cylinder had two piston-rods, for greater steadiness, their outer ends in each case being keyed into a crosshead, fitted at each end with slide-blocks, working in a pair of inclined open guide-frames, bolted to the bottom cylinder cover, and supported beneath by projecting bracket-pieces, recessed and bolted down upon pedestal pieces on the engine sole-plate. From each end of this crosshead, immediately outside the guide-frame, a plain straight connecting-rod of round section passed up to actuate the main first-motion shaft. The upper ends of the connecting-rods were jointed to side-studs, or crank-pins, fixed in two opposite arms of a pair of large spur-wheels, which gave motion to the screw-shaft by means of a pair of corresponding spur-pinions, fixed on the shaft.

The main spur-wheels were 11 ft. 5½ in. in diameter, and the pinions on the screw-shaft 4 ft. 6 in.; so that the screw propeller made 2½ revolutions to each rotation of the engine. The arrangement ensured that each piston was directly coupled to both of the large wheels, and the increased length of the crossheads, which the plan involved, was counterbalanced by the effect of the double piston-rods, for by this division of the pressure the cross-strain leverage was proportionately diminished.

Experience showed that there was great loss of efficiency in such gearing, and the engineers soon overcame the difficulty by speeding up the engine to conform to the required speed of the propeller. It is a remarkable coincidence that early in the twentieth century gearing had to be adopted in connection with the propulsion of ships by the steam turbine, as will be explained later. In this latter instance, however, the aim was directly opposite to that for which gearing was introduced in the middle of the nineteenth century. Now the idea is to reduce the speed of the propeller relative to that of the turbine, as it was found that the turbine, in order to achieve high thermodynamic efficiency, should revolve at a much greater speed than the propeller, if the latter was to attain



GEARED DOUBLE ENGINE FOR EARLY ATLANTIC LINER.

high propulsive efficiency. Consequently the gearing was required to reduce the speed of the propeller instead of to increase it, as in the engines of fifty or sixty years ago. Mechanical experience, however, enabled a different form of gearing to be introduced. Instead of a spur-wheel and pinion, with the teeth on the periphery of both at right angles to the plane of rotation, the teeth cut in turbine gearing take a spiral form, while, at the same time, there is much closer contact, and therefore great reduction in the loss in transmission. Details will be given later of geared turbines.

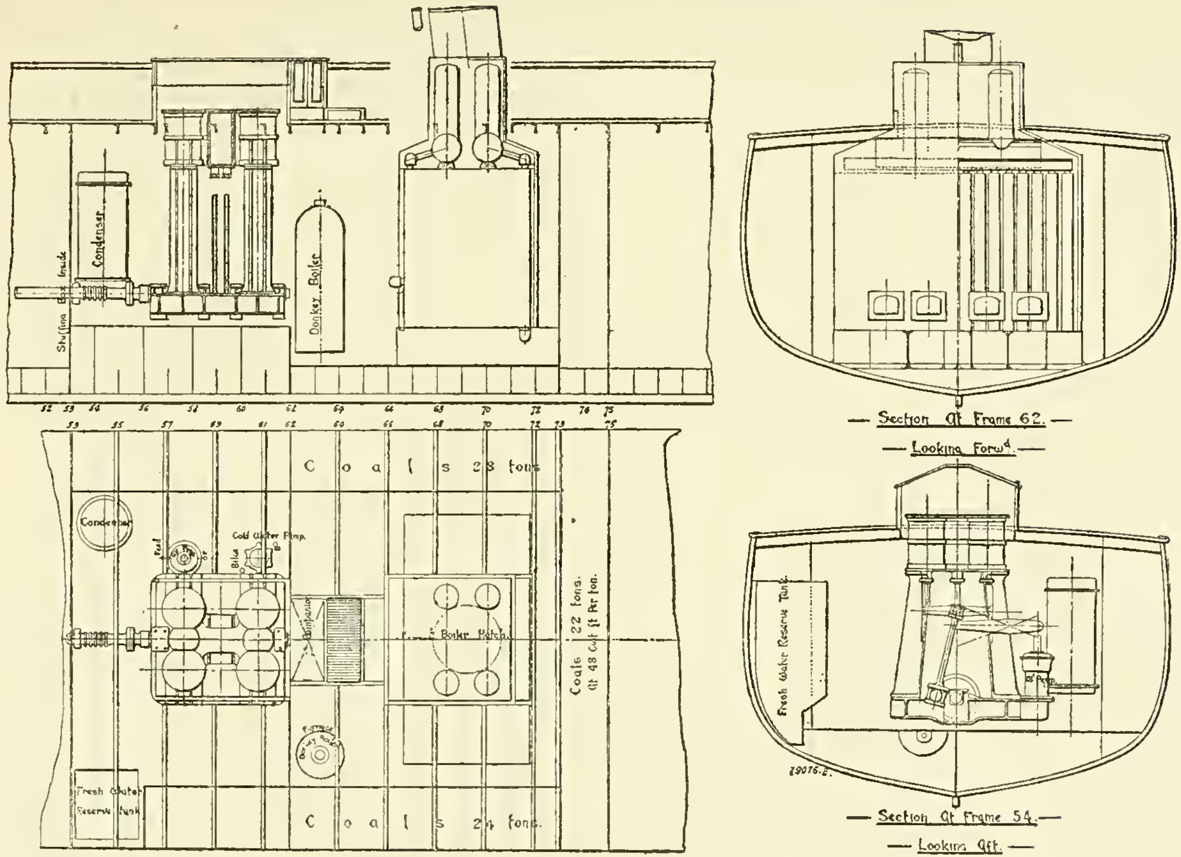
To return to our historical narrative, the use of steam expansively in multiple-cylinder engines was, however, the most important factor in the development of the steamship during the latter half of the nineteenth century.[1] With low steam pressures and simple engines the coal consumption, even for moderate-sized ships, was a serious item in a long sea voyage ; and, early in the 'fifties, engineers, recognising the economy which would result from a successful compounding of steam, tackled the problems of steam-generation plant to enable the necessary high initial pressure to be employed with safety. John Elder had fitted several ships, but was, for a long time, content with an initial pressure of from 50 lb. to 60 lb. per square inch.

The late John Scott, C.B., was so convinced of the economy of steam at higher pressures in the compound system that he decided to build, largely at his own expense, a vessel which would enable him to put the system to a thorough test. This steamer, constructed of iron in 1858, was the *Thetis*, which was, undoubtedly, an epoch-marking ship, as her machinery was operated at an initial pressure of 115 lb. to the square inch—exceptionally high for those days.

For the first time, surface condensers were used in association with the compound marine engine. There were, as shown on page 35, six cylinders, arranged in two groups, each with one high- and two low-pressure cylinders. The three pistons of each group worked one cross-head, connecting-rod, and crank. Each group had two slide-valves, one for the high-pressure, and one for the low-pressure, cylinders, and both were attached to one valve spindle and one reversing link.[2] The engines worked up to 51 revolutions

[1] The number of steam vessels belonging to the United Kingdom in 1849 was only 1142, of 158,729 tons ; Sweden, which was second among the nations of the world in this respect, had only about one-tenth of this tonnage.—Porter's " Progress of the Nation," page 626.

[2] Holmes' " Marine Engineering," page 74.



HIGH-PRESSURE MACHINERY IN THE "THETIS."

per minute—equal to a piston speed of 255 ft. per minute—and the maximum indicated horse-power was 256. The engines were tested by the late Professor Macquorn Rankine, F.R.S., who certified that the coal consumption on trial was 1.018 lb. per indicated horse-power per hour ; an extraordinary result, even in the light of modern improvements.[1]

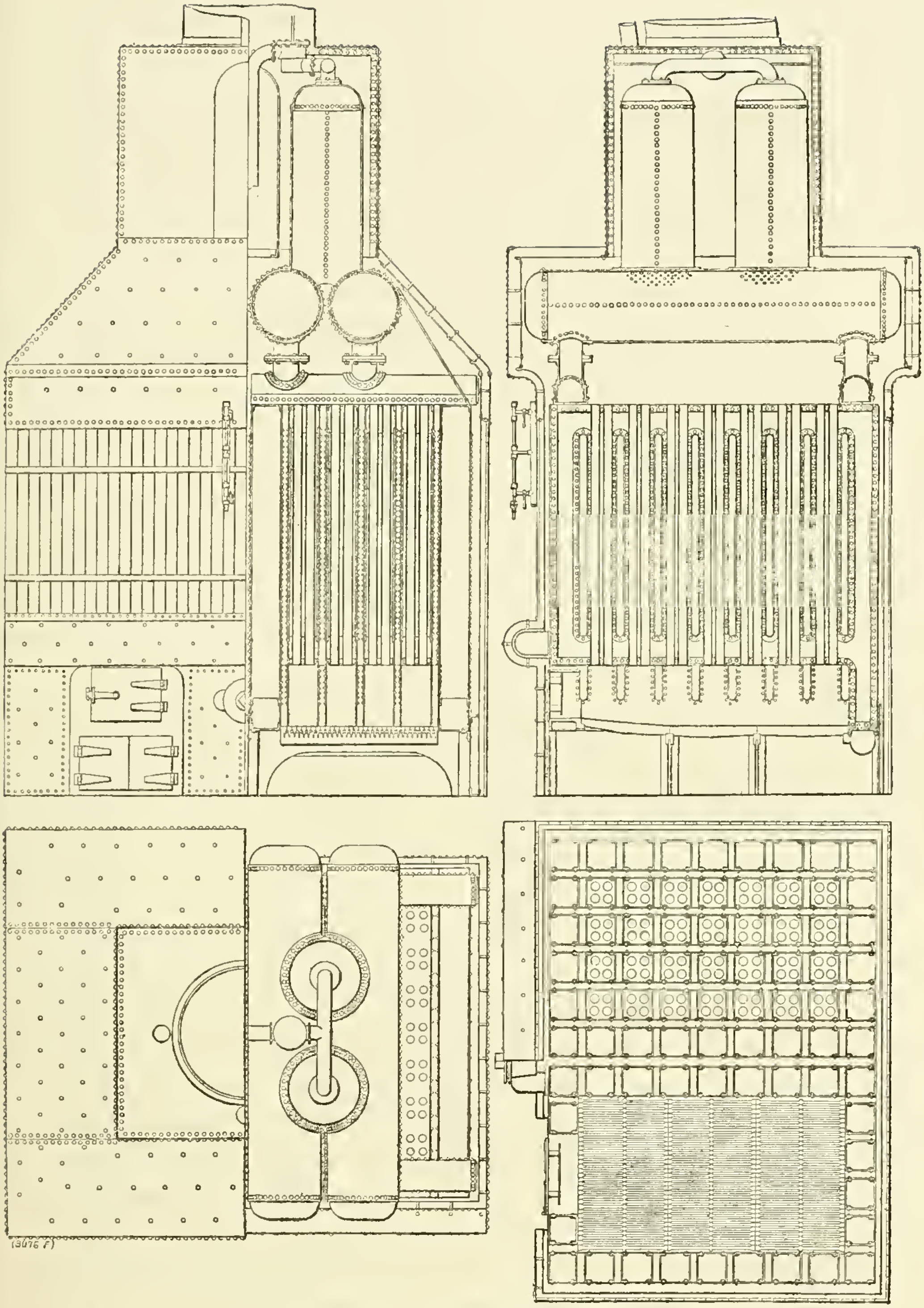
A large part of this efficiency was due to the boilers, which were of the Rowan water-tube type, and are illustrated on the opposite page. They had square vertical water-tubes, and through each of these there passed four hot-gas tubes. They evaporated 11 lb. of water per pound of coal, which was 30 per cent. higher than was attained with the best marine boilers of those days. The coal consumption at sea was about 1.86 lb. per indicated horse-power per hour.

Unfortunately, there soon developed small holes in the boiler-tubes, owing to erosion of the external surface, probably the consequence of the chemical action set up by the steam for cleaning the tubes mixing with the soot and other deposit.[2] Although for this reason this early water-tube boiler did not succeed, there is no doubt that the performances suggested improvements which have since brought complete success to this type of boiler. At the same time, the efficiency of high steam pressures was completely established and resulted in very considerable progress in the size and power of steamships.

Another innovation which suggested future developments was the fitting at the base of the funnel in the *Thetis* of a series of water-tubes for the purpose of utilising the waste heat from the boilers to heat the feed water before it was passed to the boilers. The time was not ripe for such a utilisation of the waste gases ; but now various schemes are applied for thus absorbing the waste heat in the uptake to heat air for furnace draught and to superheat steam.

[1] Rankine's "Steam Engine," page 502.

[2] "Transactions of the Institution of Naval Architects," vol. xxviii., page 141 ; and vol. xxx., page 278.



A PIONEER IN WATER-TUBE BOILERS.

A number of water-tube boilers were made, and a set was fitted into a corvette built for the French Navy. This vessel, completed in the early 'sixties, was the first ship in the French fleet to be driven by compound engines, and will fall to be described with other vessels in our next Chapter dealing with the work of a century for the Navy.

Perhaps the most significant indication of the success of the compound engine by Scotts is found in the results of its application to the early Holt steamers. The late Mr. Alfred Holt commenced in 1855 his now famous fleet to trade with the West Indies, while his brother, the late Mr. George Holt, became associated with Mr. Lamport in the River Plate trade in 1865. Both lines continue among the most successful in British shipping.

The Holt steamship line to China was commenced in 1865, and was the only one *viâ* the Cape of Good Hope which proved at once successful. Built and engined by the Scotts, the early Holt liners, starting from Liverpool, never stopped till they reached Mauritius, a distance of 8500 miles, being under steam the whole way, a feat until then considered impossible.[1] Thence the vessels proceeded to Penang, Singapore, Hong Kong, and Shanghai. Unaided financially by any Government grants, they successfully performed this long voyage with great regularity.

The three vessels which inaugurated the Holt line were named *Agamemnon*, *Ajax*, and *Achilles*, and were built of iron by the Scotts in 1865-6. They were each 309 ft. in length between perpendiculars, 38 ft. 6 in. beam, and 29 ft. 8 in. in depth, with a gross tonnage of 2347 tons—dimensions which were then deemed too great for the China trade, but which experience soon proved to be most satisfactory. Sails were fitted to the vessels, as shown in the engraving on the Plate facing page 42.

It is interesting to note that thirty-five years later the Scotts built for the Holt Line three vessels having the same

[1] Lindsay's "Merchant Shipping," vol. iv., page 434.

names, and as indicative of progress it may be stated that they were each 440 ft. in length between perpendiculars, 52 ft. 6 in. in beam, 35 ft. in depth, with a gross tonnage of 7040 tons. But more important still, the coal consumption per 100 ton-miles was very much reduced. These later vessels are also illustrated in the Plate facing page 101.

The late Mr. Alfred Holt was the first to apply the compound engine to long voyages, and his vessels were the earliest of the type built for the merchant service by the Scotts. It is true the Pacific Company had compound engines fitted to one or two ships prior to this, but these were only used in the coasting trade. The engines of these Holt liners are therefore of historical interest, and drawings are reproduced on the next page, and on page 41 is given a general arrangement of the machinery of the *Achilles*. A feature in these liners was that the propeller was abaft the rudder, which worked in an aperture in the deadwood corresponding to that for the propeller in single-screw modern ships.

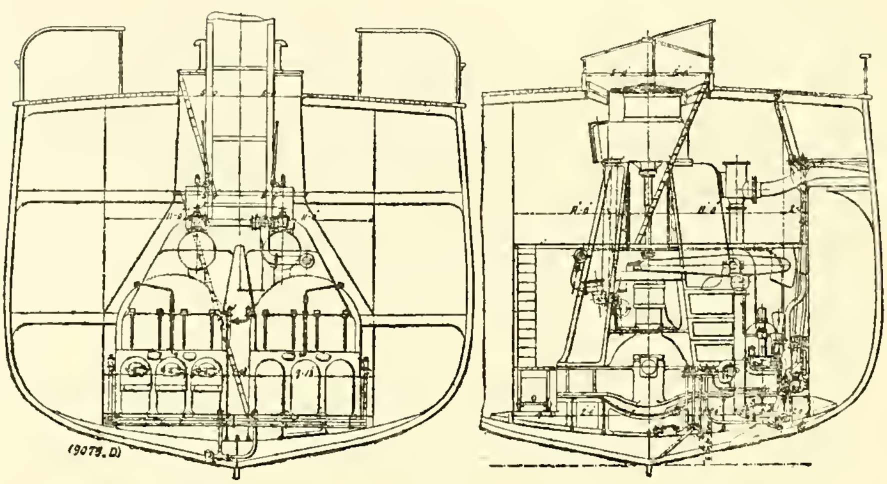
A detailed description from the specification of the early machinery may be reproduced, as it indicates the practice of the Scotts for a considerable time. Indeed, this type of compound engine, with slight modifications, was the standard engine for Holt liners until the advent of the triple-expansion engine. The details follow :—

The cylinders were : high-pressure, 30 in. in diameter ; low-pressure, 62 in. in diameter, with 4-ft. 4-in. stroke, arranged vertically in tandem fashion, with the low-pressure cylinder on the top. There were two connecting rods, but a common crosshead for the tandem cylinders, and a common crank-pin.

The crankshaft was 13½ in. in diameter, with a bearing 30 in. long at the aft end of the bedplate, which took the propeller thrust. The propeller was three-bladed, 17 ft. in diameter, with 26-ft. 6-in. pitch ; with 46 revolutions per minute the piston speed was 400 ft. per minute. To ensure smooth working with the single crank, a heavy flywheel was fitted, and the pump levers carried a massive weight to help to balance the weight of pistons and rods.

The condenser had 420 tubes 1½ in. in diameter, giving a cooling surface of 1375 square feet. The tubes were arranged in three nests, the water circulating through the top one first and the bottom one last. The circulating pump, instead of forcing water through the tubes, as was usual in such case, sucked from the condenser and discharged directly overboard. There were: one air pump, 24 in. in diameter; one circulating pump, 24 in. in diameter; two feed pumps, 4¾ in. in diameter and one bilge pump 7 in. in diameter; all the pumps were single-acting, with 17-in. stroke. The diameters of the principal pipes were: main steam, 7½ in.; to low-pressure cylinder, 12 in.; circulating inlet, 10 in.; discharge, 12 in.; air-pump discharge, 10 in.; main feed, 3¾ in.; and waste steam, two at 6-in. diameter.

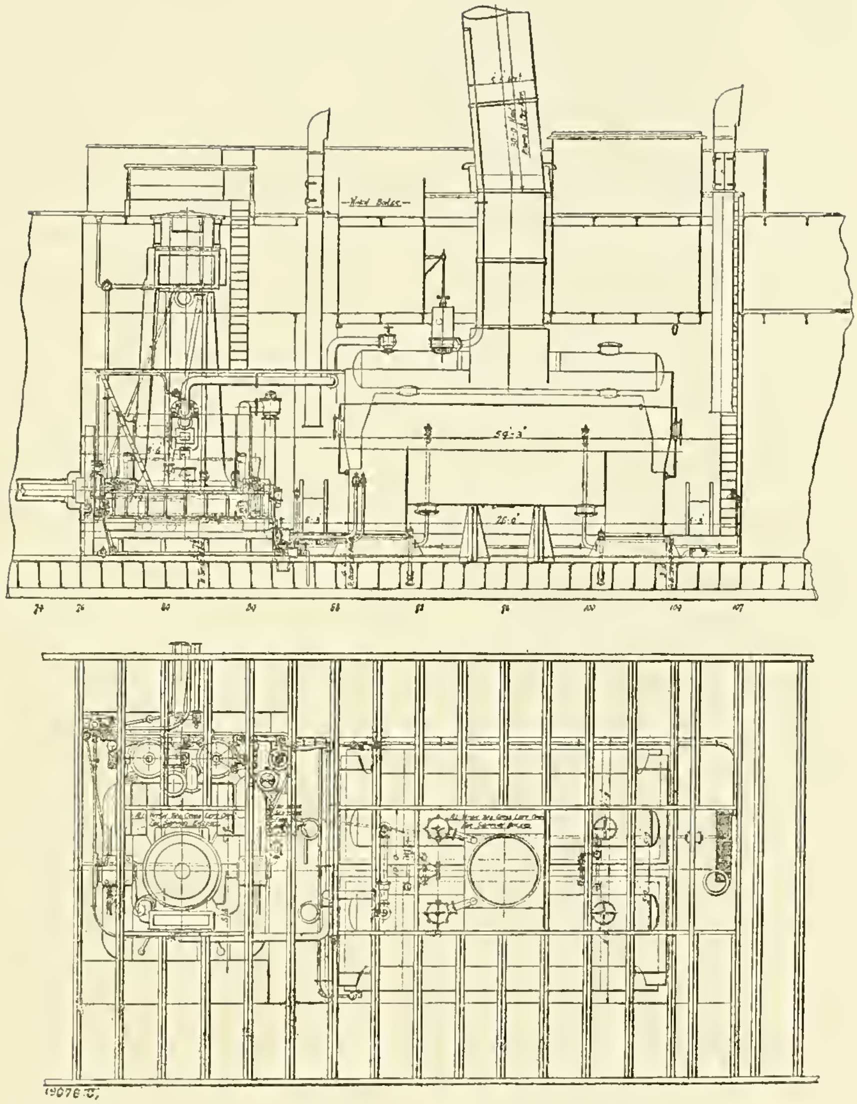
The two boilers were double-ended, of the locomotive type, with wet-bottomed furnaces. The centre was cylindrical, but the ends were rectangular with semi-cylindrical tops, the total weight, without water, being 78 tons.



THE MACHINERY OF THE "ACHILLES."

Each boiler had a long receiver passing through the uptake to dry the steam. On the receiver was a deadweight safety-valve 6¼ in. in diameter, to suit a working pressure of 60 lb. per square inch. The grate surface was 112 square feet, and the total heating surface 4506 square feet, there being 328 iron tubes 4 in. in diameter.

The three pioneer ships of the Holt Line—the *Agamemnon*, *Ajax*, and *Achilles*—proved most economical. The *Achilles* came home from China in fifty-seven days eighteen hours net steaming time, or, including the stoppages at ports, sixty-one days three hours. She travelled during this period a distance of 12,352 miles, on a consumption of coal which



GENERAL ARRANGEMENT OF THE MACHINERY OF THE "ACHILLES."

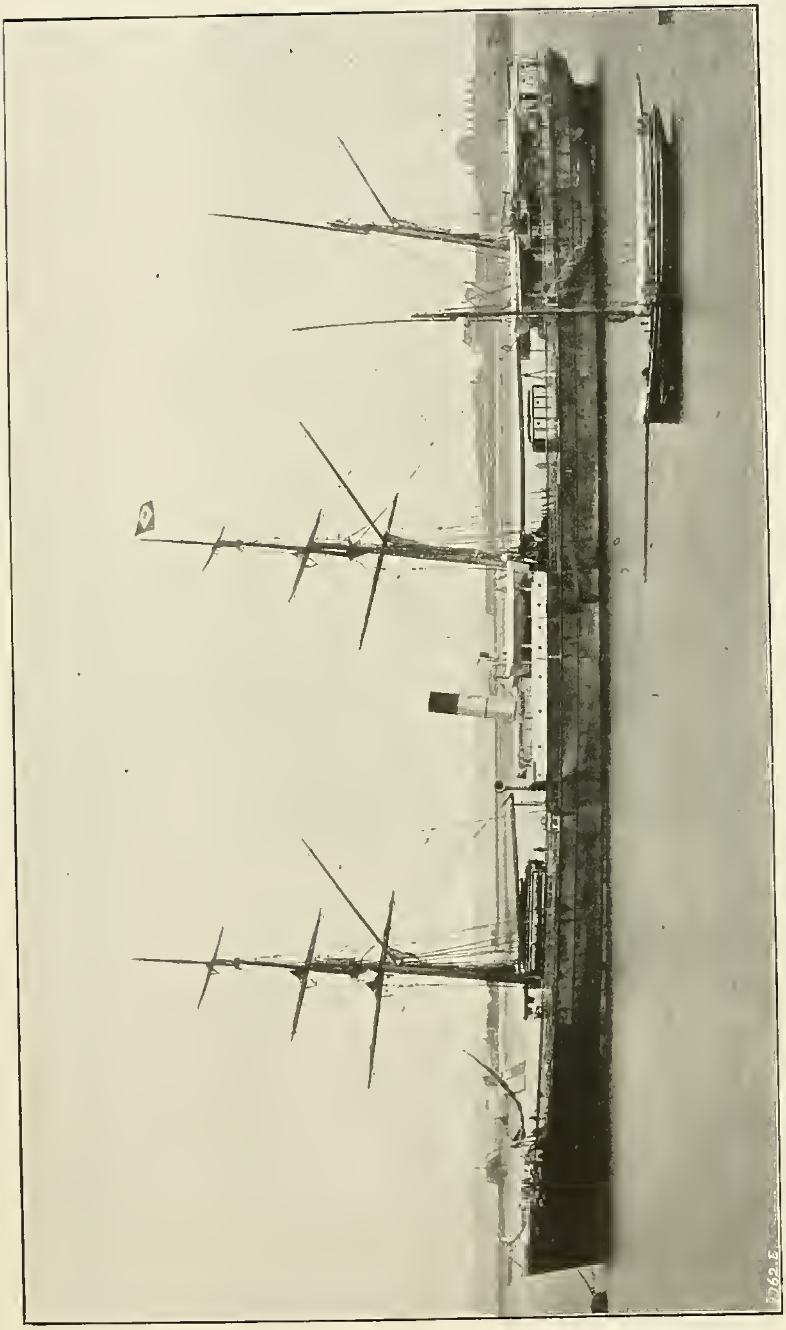
did not exceed 20 tons per day for all purposes,[1] equal to $2\frac{1}{4}$ lb. per unit of power per hour, which for those early days, with comparatively low steam pressures, must be regarded as a highly satisfactory result.

The non-stop voyage between Liverpool and Mauritius was made as early as 1866 in thirty-seven days, equal to 10 knots speed, with a number of passengers and a fairly large cargo. The higher economy established for the compound engine on long voyages resulted in the ultimate supersession of the sailing ship.[2] Thus the Scotts, while still enjoying the credit of the splendid performance of the *Lord of the Isles* in the early 'sixties, produced at their foundry the Holt compound engine, which sounded the death-knell of the clipper. The compound system had at once an influence on the size of ships. Up till 1862 no ship of over 4000 tons had been constructed, with the exception of the *Great Eastern*; by 1870 there were fifteen; by 1880, thirty-seven.[3]

The Scotts, aided by Holt, continued their research towards higher economy, and a large fleet of steamers was built, with engines having flywheels which, it was found by experience, considerably improved the turning moment of the engine up to a certain stage, although with increased pressure the advantage was not commensurate with the weight of the wheel, and the three-cylinder three-crank engine was ultimately adopted.

It is interesting to observe here that in the modern reciprocating heavy oil engine we have a reversion to the use of the flywheel for marine propelling machinery. Owing to the fact that the oil engine is usually single acting and works on the two-cycle or four-cycle principle, it is found necessary to adopt a flywheel, in order to produce the even turning moment on the shaft required for satisfactory starting or manœuvring.

[1] "Proceedings of the Institution of Naval Architects," vol. xi., page 152.
[2] Lindsay's "Merchant Shipping," vol. iv., page 435.
[3] Pollock's "Modern Shipbuilding, and the Men Engaged in it," page 199.



THE "ACHILLES" OF 1865 OFF GRAVESEND.

The Scotts throughout the century continued to have a close association with the China trade, constructing a long series of successful steamers for the Holt and other lines with services from Britain to the Far East, and carrying out very extensive work in the building up of the coasting trade of Asia and Oceana. For the India and China services there have, in the past fifty years, been completed over one hundred and fifty steamers.

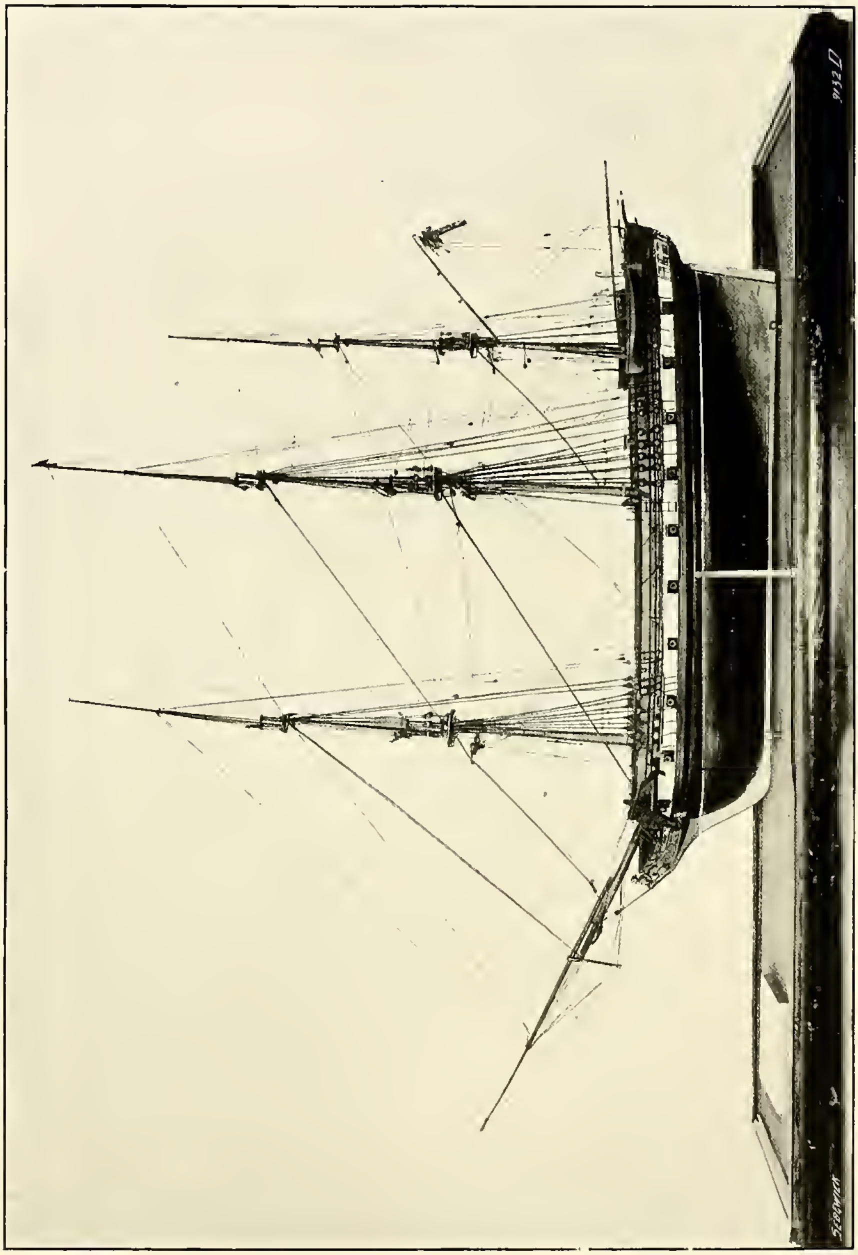
The China Navigation Company, Limited, was formed in 1873 by Messrs. John Swire and Sons, of London, for trading in China, and the first steamers built for them by the Scotts were two vessels of 1200 tons gross, completed in 1876.

Since then the Scotts' yard has rarely been without a vessel for one or other branch of the Eastern trade, and particularly for the China Navigation Company, which runs steamers from China as far south as Australia, as far west as the Straits, and as far north as Vladivostock and the Amur river. This company also have ships trading up the Yangtsze Kiang for more than 1000 miles from the sea. For this service the twin-screw steamer was adopted in 1878, much earlier than in many other trades, largely owing to the strong advocacy of the late John Scott, C.B. Up to that time most of the Yangtsze steamers were propelled by paddle-wheels driven by walking-beam engines. The first of the twin-screw steamers was a vessel of 3051 tons and there has been constructed since then a long succession of very serviceable steamers of this type.

But having in our brief historical sketch come to times within the recollection of the reader, it may be more satisfactory to depart from the purely chronological review of the company's operations, and leave for later chapters an analysis of the progress made, and a review of typical modern merchant steamers.

The direct-acting vertical engine, with inverted cylinders, almost as we know it to-day, and as illustrated in connection with the work of the twentieth century, was introduced in the late 'fifties. The compound engine, introduced in 1854, was developed into the triple-expansion system in 1882, and later into the quadruple-expansion type. There followed the direct driving steam turbine, then the geared turbine, but the greatest of these advances belong to the twentieth century, and it is appropriate that a separate chapter should be devoted to them.

Plate XIII.



MODEL OF H.M.S. "PRINCE OF WALES," 1803.

A Century's Work for the Navy.

♣ ♣

THE work for the Navy by the Scotts began with the building, in 1803, of a sloop-of-war named *The Prince of Wales ;* a photograph from the model of this vessel is reproduced on Plate XIII. Since the construction of this ship the firm have carried out many important Admiralty contracts, including the first machinery made in Scotland for a dockyard-built ship, the first steam frigates built in the North, the first " Dreadnought " battleship, and the first submarine boat to be built on the Clyde. The Scotts were also pioneers in the design and construction for the British Navy of submarines propelled by turbines. Thus they had contributed many important ships, representative of each of the various classes, to the British Fleet, which after one hundred and ten years of peace upon the sea was called upon again to defend our Empire. With its traditional efficiency, alike in *materiel* and *personnel,* the Navy once more established the supremacy of Britain on all seas.

If in this connection we devote more attention to *materiel,* it is not because we underrate the strategical and tactical skill displayed in the many engagements with the enemy or the heroism proved by officers and men in combat. Those deeds of imperishable memory belong to other records : here we are concerned with the developments by which such firms as the Scotts were able to place at the disposal of the officers and men of the Navy ships of individual excellence, which collectively constituted a Fleet unsurpassed in every material requirement for executing the multifarious duties of a great prolonged war, and for the final overthrow of the enemy.

Even the most cursory review of such development suggests a brilliant record of research and invention, not only on the part of the naval architect, but also of the chemist, the metallurgist and the engineer; a triumph far greater than that reviewed in the case of the Merchant Marine. An enormous advance in speed in capital ships—even equal to 100 per cent.—has been achieved, notwithstanding that the problems to be solved in its attainment have been intensified by the limitations imposed upon the size of ship to reduce the target presented, and by the necessity of providing in the displacement weight for armament and ammunition, for heavy armour against gunfire, and for protection against submarine and aerial attack.

When a comparison is made of the Navy ships at the beginning of the nineteenth century with those of a hundred years earlier, it is found that little progress had been made, either in design or in gun-power. The largest vessel in 1700 was of 1809 tons burden, with a hundred guns. A century later, the size had increased only to 2600 tons, with a hundred and twenty guns.[1] But even this was then considered an exceptionally large vessel. The British ships were, as a rule, smaller, and perhaps slower, than the French ships; but then—as now and always—skill in strategy, courage in combat, and devotion to duty were the most powerful factors in action. No fault in these respects could be found with the work of our Navy in the various engagements which terminated in the epoch-marking victory in Trafalgar Bay.

The peace following the Napoleonic wars was not conducive to advancement, as there was little incentive to pursue the

[1] Charnock's "History of Marine Architecture," vol. iii., page 245.

Plate XIV.

LAUNCH OF THE FIRST CLYDE-BUILT STEAM FRIGATE, THE "GREENOCK," 1849.

sciences which contributed to the development of destructive weapons. Steam as a motive power and iron as a constructive material were not so readily adopted in the Navy ship as in the Merchant Marine. Progress in the utilisation of iron was not continuous. The first application of steam was belated and its popularity was not unalloyed.

The Admiralty ordered their first ship of iron in 1839—a small, non-fighting boat for the Dover station—and there followed other vessels for the exploration of the River Niger. But the first iron fighting ship was not built until 1843. In 1848–9 the Scotts constructed the iron steam frigate *Greenock*, the largest iron warship of her day, and the first steam frigate built on the Clyde. The over-all length of this vessel was 213 ft., the beam 37 ft. 4 in., and the depth of hold 23 ft. She was of 1413 tons burden, and carried ten 32-pounder smoothbore muzzle-loading guns. The illustration on Plate XIV. is a reproduction from an old engraving of the launch of the vessel. It is a noteworthy feature that the figure-head was a bust of John Scott, the second of that name. This compliment by the Naval authorities of the time was well merited, as he did much not only for the advance of naval architecture, but also for the development of Greenock.

As a writer of the day put it, this vessel was the *experimentum crucis* of the principle of constructing fighting ships of iron.[1] By 1850 there were six large iron vessels, ranging downwards from the 1980 tons of the eighteen-gun ship *Simoon* with eleven smaller vessels; but they were all condemned because it was found by experiment[2] that the 32-pounder gun at short range could perforate the side of the iron ship, and that the projectile carried its "cloud of langrage" with great velocity into the interior of the ship, so that men could not stand against it. Tests were also made with sixteen wrought-iron

[1] The "Greenock Telegraph," May 4th, 1849.

[2] Sir Nathaniel Barnaby's "Naval Development of the Century," page 140.

plates superposed, to give a total thickness of 6 in., but these also were perforated by the 32-pounder projectiles at 400 yards range ; so that the adoption of iron on the main structure of the ship was practically delayed until armour-plates were first rolled in 1859.

The obstacle to the adoption of steam was the unsuitability of paddle-wheel machinery for fighting ships. The wheel was exposed to gun-fire, and the whole of the machinery could not be located below the water line. Moreover, the side wheel limited the number of guns which could be utilised for broadside fire. The first steam craft ordered by the Admiralty was a small vessel of 210 tons and 80 nominal horse-power, built in London in 1820.[1] Several other non-fighting steamships followed. By 1837, the largest steam vessel in the fleet was a sloop of 1111 tons and 320 horse-power.[2] In 1839 five steam vessels were built, and two of them—the *Hecate* and *Hecla*—were engined by the Scotts. These wooden steamers were the first Naval vessels sent to Scotland to have their machinery fitted on board. They were of 817 tons and 250 horse-power. The paddle-wheels had a diameter of 25 ft. $\frac{1}{2}$ in., and there were seventeen floats. The main engines, illustrated on page 29, represent the type adopted, not only in the Naval, but in the Merchant service of this time. The steam pressure was then about 3 lb. per square inch.

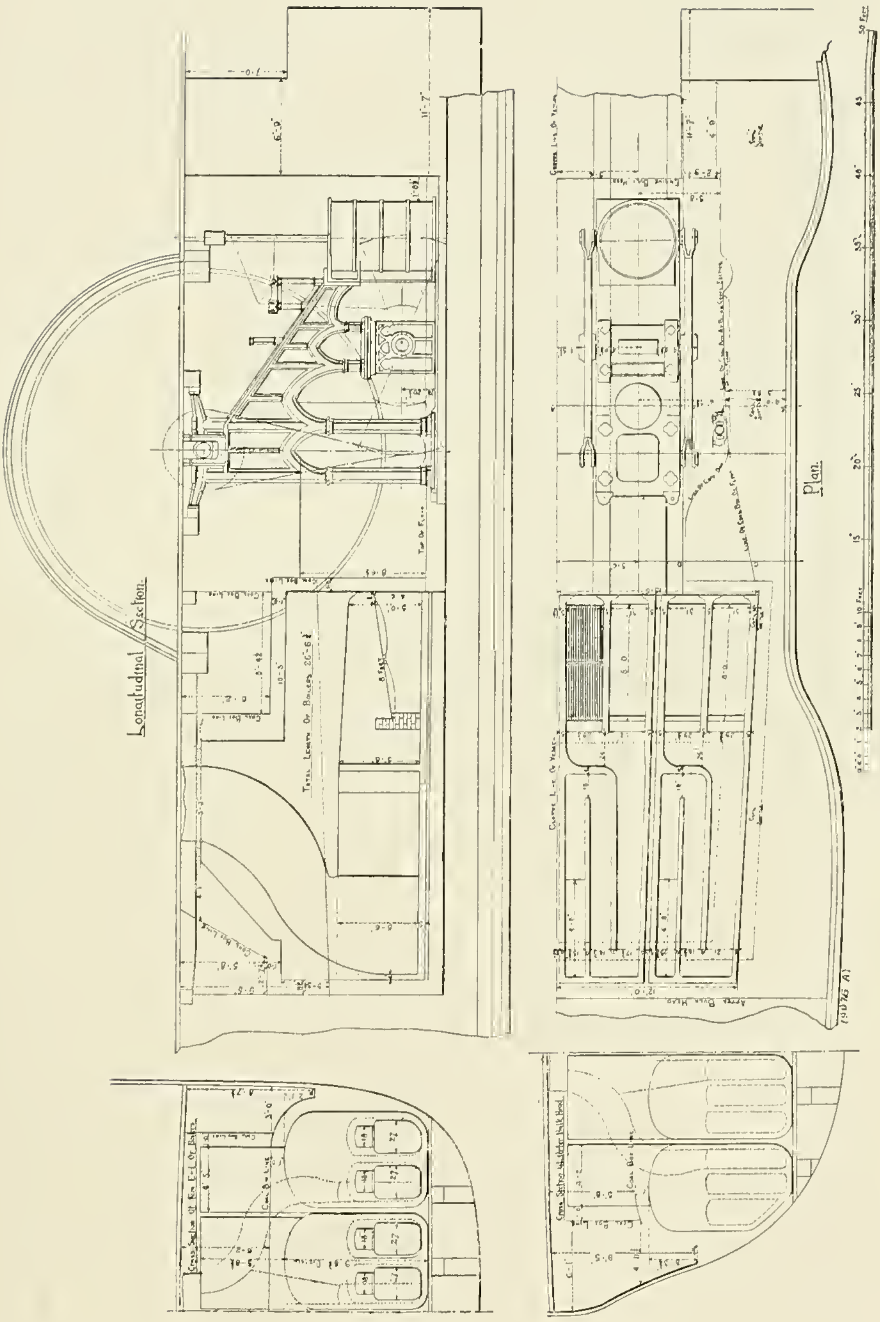
On Plate XV. we illustrate the general arrangement of the machinery in the *Hecate* and *Hecla*. There were four boilers of the rectangular type, each with two wet-bottomed furnaces at one end and large return flues at the other end. The uptakes passed up inside the boilers through the steam space, uniting in one funnel.

Smith's screw-propeller was tried experimentally in 1837, and Ericsson's about the same time. The comparative trials of the *Archimedes* fitted with Smith's screw against

[1] Sennett and Oram's " Marine Steam Engine," page 3.

[2] Fincham's " History of Marine Construction," page 332.

Plate XV.



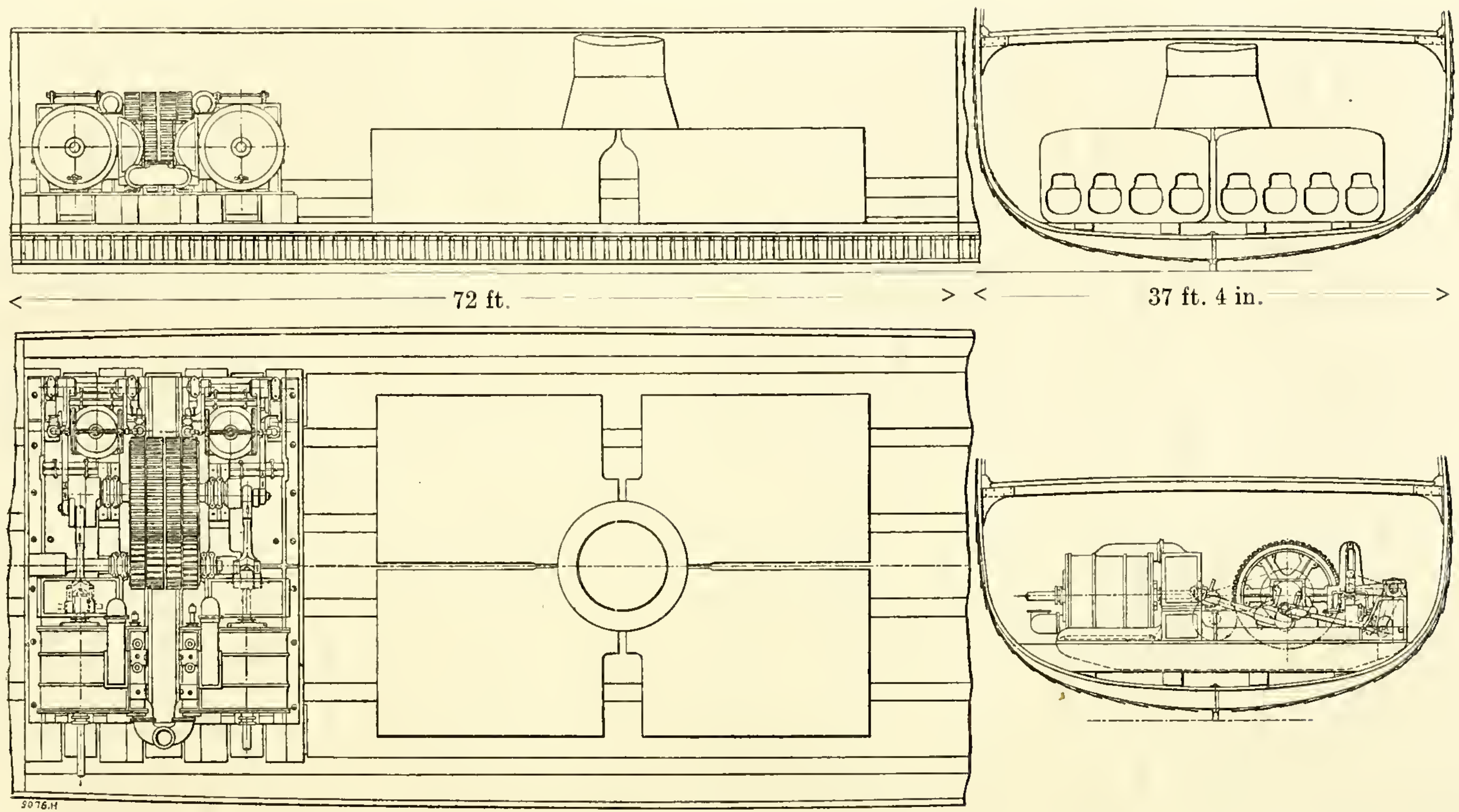
MACHINERY OF H.M.SS. "HECLA" AND "HECATE," 1839.

existing paddle-steamers did much to prove the efficiency of the new system.[1] The screw-ship excelled the performance of paddle-steamers on the service, and the screw-propeller was adopted by the Admiralty in 1845; twin-screws followed twenty-five years later.

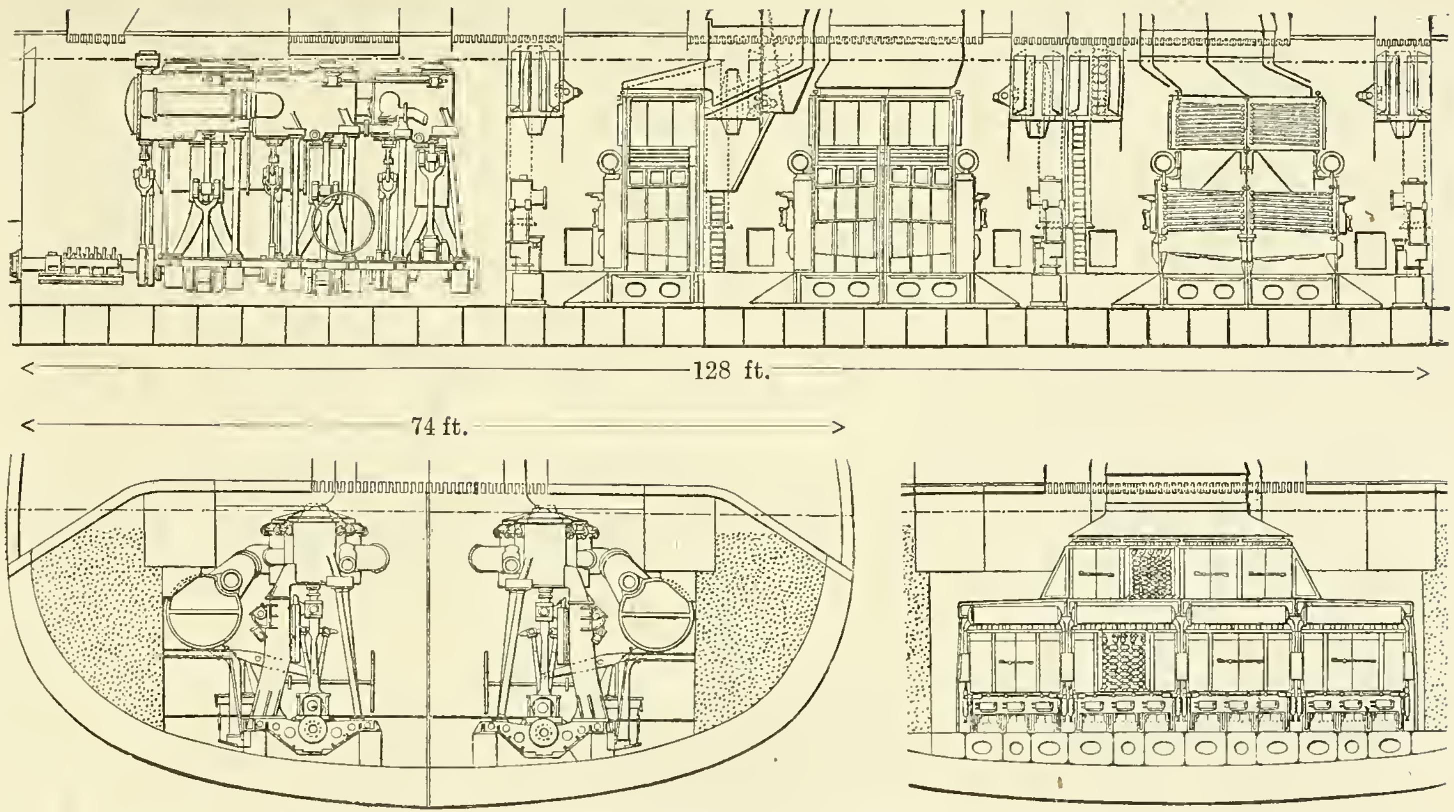
The *Greenock*, built in 1848, was the first war vessel by the Scotts fitted with the screw-propeller. We have already referred to her construction in iron, and to her launch. She had a displacement of 1835 tons, and her engines were of 719 indicated horse-power. The speed realised on the trial was 9.6 knots. The *Greenock's* machinery, which is illustrated on the next page, is specially interesting, as it represents one of the earliest attempts to drive the screw-propeller by gearing. Two horizontal cylinders were fitted, each 71 in. in diameter, with a stroke of piston of 4 ft. The gearing consisted of four sets of massive spur-wheels and pinions, in the ratio of 2.35 to 1, so that 42 revolutions per minute of the engines give 98.7 revolutions to the propeller-shaft. The propeller was 14 ft. in diameter, and was so fitted that it could be detached and raised to the deck. There were four rectangular brass-tube boilers, each with four wet-bottomed furnaces, and all the internal uptakes united in one funnel, which was telescopic, so that when it was lowered and the propeller raised out of the water, the vessel had the appearance, as well as the facility, of a sailing frigate.

As will be seen from the drawings, both the engines and boilers were arranged very low in the hull, to be safe from the enemy's fire. The engine and boiler compartment occupied 72 ft. of the length of the ship—about one-third of the total length—and the seating for the machinery was specially constructed, with a very close pitch of frames which were only 1 ft. apart. For comparison with the drawings of the machinery in the *Greenock*, and to illustrate the progress of the second half of the nineteenth century, we give on page 51 a

[1] Fincham's "History of Marine Construction," page 344.



MACHINERY OF THE FRIGATE "GREENOCK," 1849,—719 I.H.P.



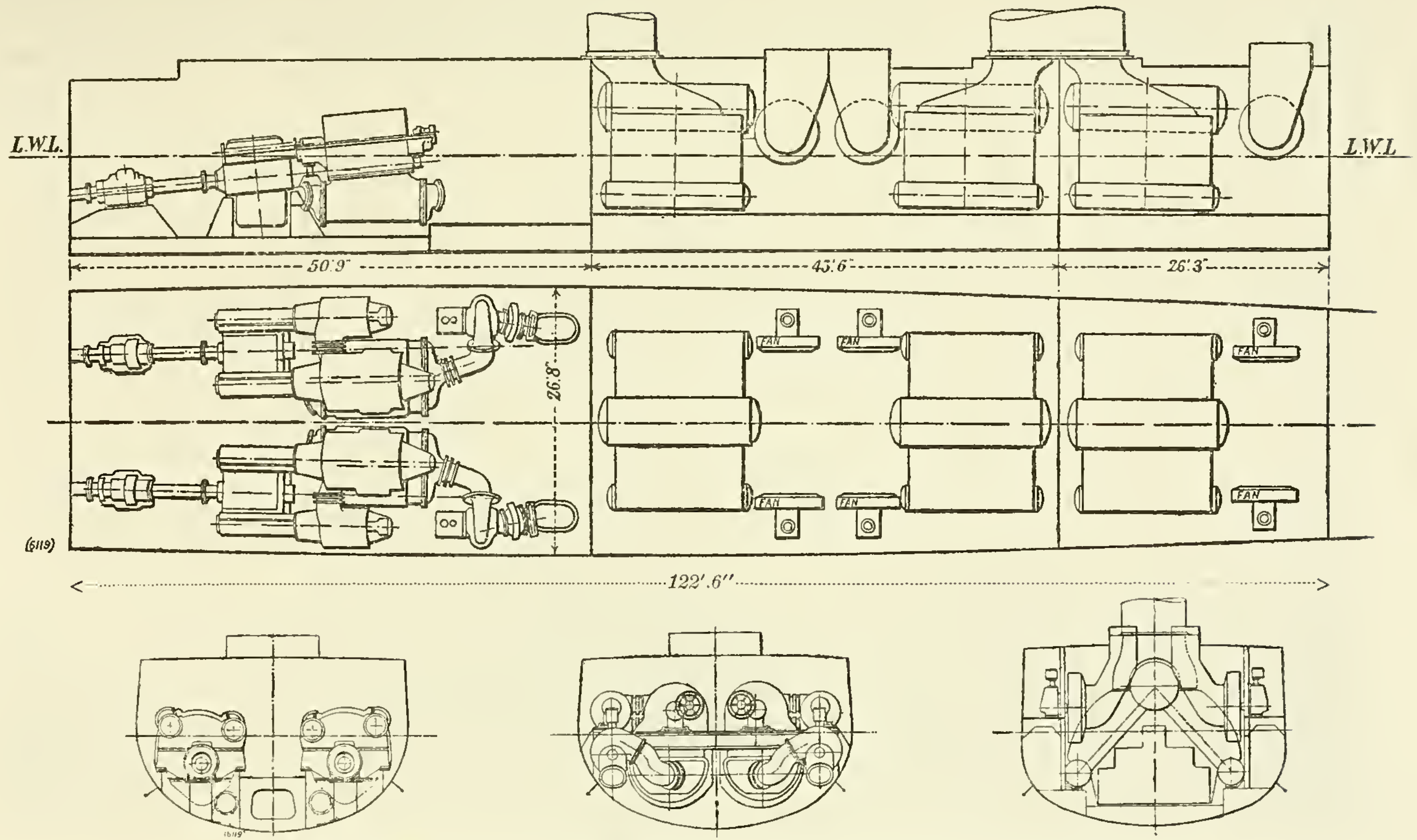
MACHINERY OF THE BATTLESHIP "CANOPUS," 1900,—13,500 I.H.P.

similar drawing of the machinery of the *Canopus*, completed in 1900 and of 12,956 tons displacement, seven times that of the *Greenock*. To double the speed the power of the machinery had to be multiplied twenty times, and yet the space occupied is only about trebled. As a further contrast there is given on the opposite page a corresponding diagram of the geared turbine machinery of a recent torpedo-boat destroyer, to show the progress made in the equivalent of the old time frigate. As compared with the *Greenock*, of 1848, the destroyer has engines of more than thirty-five times the power; yet the machinery occupies little more space. The speed of the vessel of to-day is nearly four times that of the *Greenock*.

In 1850 the largest of the steam vessels in the Navy[1] had a displacement of 3090 tons, but the most noted was the *Dauntless*, of 2350 tons displacement, with engines of 1347 indicated horse-power to give a speed of 10 knots. It is true that there were three smaller vessels of greater speed, one of 196 tons steaming 11.9 knots; but this was the highest rate reached in the Navy Service. By this time some of the fast mail steamers made 13½ knots. These latter were suited for war service, but we have already dealt with them in the preceding chapter.

Following the advance in engine design consequent upon the adoption of the screw propeller in warships came the abandonment of gearing for the engines, only to be revived in another and more efficient form fifty years later, but for an exactly opposite purpose, viz., to decrease the speed of the propeller relatively to that of steam turbines, as is explained on page 33 *ante*. For many years various forms of horizontal engines were used; first with return-connecting rods, and subsequently with direct-acting rods. Steam pressures steadily increased, largely owing to stronger materials being available. It was, however, not until the 'seventies that the cylindrical boiler, the

[1] Sir Nathaniel Barnaby's "Naval Development of the Nineteenth Century," page 113.



MACHINERY OF A TORPEDO BOAT DESTROYER, 1918—27,000 S.H.P.

compound engine, and the surface condenser admitted of an increase to 60 lb. per square inch[1]—several years after these improvements had been introduced in the Merchant Marine.

The Scotts had worked steadily at the solution of the problem from their trials with the *Thetis* in 1858 (see page 34 *ante*). In 1860 the late John Scott, C.B., laid before the Admiralty a system of water-tube boilers and compound engines, but objection was raised to the system. The French Naval authorities, with whom the Scotts then had close business connection, took up the scheme, largely because of the favour with which it was viewed by the late M. Dupuy de Lôme, then the head of the Constructive Department. The first ship fitted was a corvette of 650 tons displacement; the boilers worked at a pressure of 140 lb., while the initial pressure at the compound three-cylinder engines was 120 lb. These were the first engines of the compound type in the French Navy.

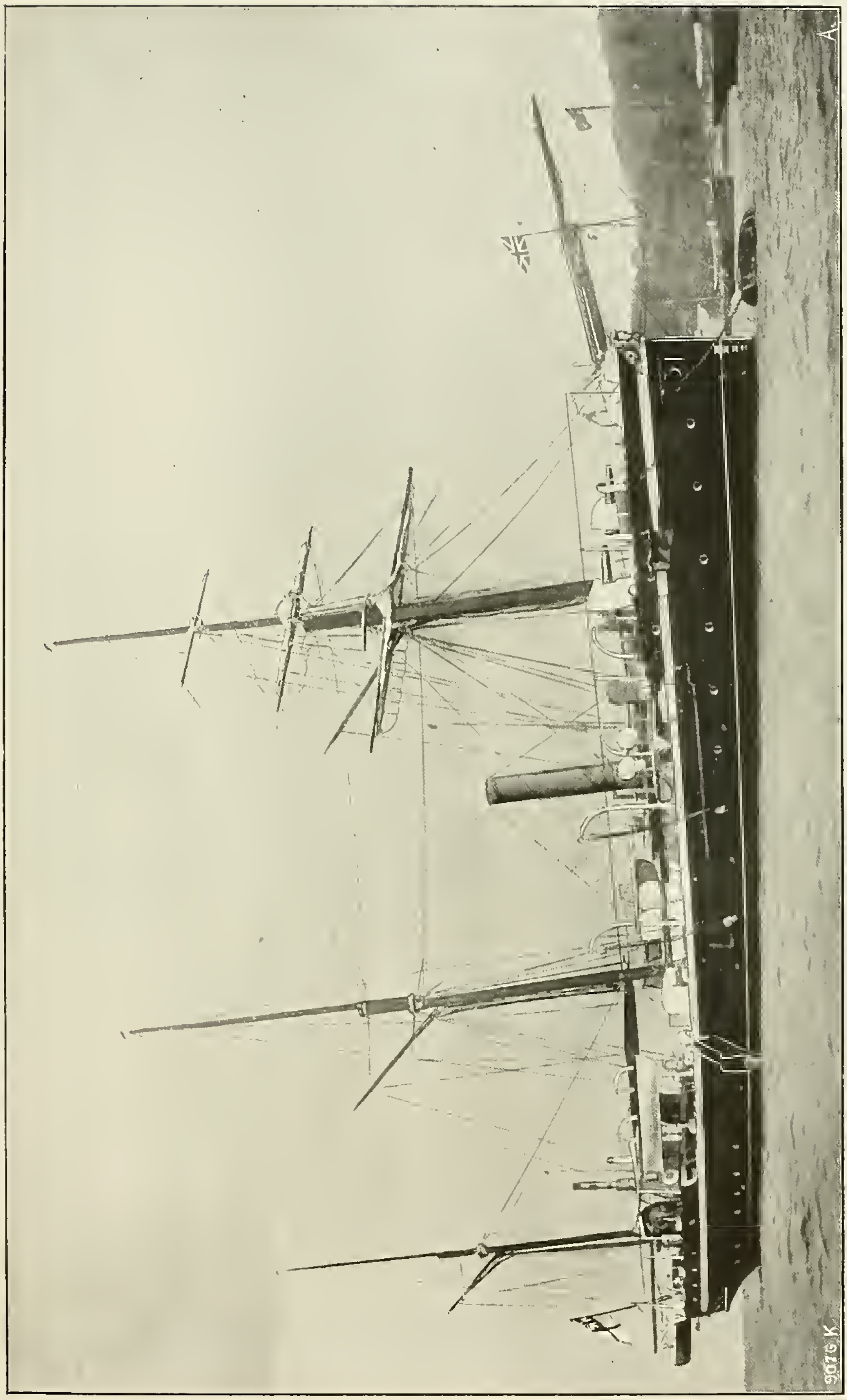
The Scotts were at the time building engines for four corvettes under construction at the Woolwich and Deptford yards for the British Navy; and the Admiralty agreed to have fitted in one of them water-tube boilers and engines similar to those built for the French boats. The boilers may be said to have belonged to the same general type as the Thornycroft and Normand water-tube steam generators of later years. It was found impossible, however, to ensure that the top of the boilers should be at least 1 ft. under the load-line—a condition then enforced in steam vessels for the Navy—and the adoption of the water-tube boiler was deferred, the ordinary machinery of the period being fitted to work at 25-lb. pressure instead of 120-lb.[2]

This was unfortunate, as it removed the incentive to continued research needed to make the water-tube boiler a really satisfactory steam generator. The Scotts, however,

[1] Sennett and Oram's "Marine Steam Engine," page 10.

[2] "Proceedings of the Institution of Naval Architects," vol. xxx., page 278.

Plate XVI.



[From a Photograph by Symonds and Co., Portsmouth.

H.M.S. "THRUSH," 1889.

continued to work for the successful application of high pressures, and it was this that brought them into contact with the late Mr. Samson Fox, with whom they were closely identified for many years in connection with the development of the corrugated flue and the cylindrical steam boiler.

Opinion being adverse to the water-tube boiler, notwithstanding its acceptance by many foreign Navies, there was a strong agitation fostered by engineers to induce the societies for the registry of shipping, and also the Board of Trade, to increase the ratio of the working to the test pressure in boilers. The British Admiralty allowed the boiler to be worked up to within 90 lb. of the test pressure, whereas in the Merchant Service the working pressure was limited to one-half of the test pressure. In 1888 the Scotts, being convinced that the Admiralty system afforded quite a satisfactory factor of safety, undertook the experiment of submitting a warship boiler, then being built by them to Admiralty specification, to the highest possible pressure, even up to bursting-point. The boiler ultimately leaked to such an extent, after the pressure had been maintained for a long period at 620 lb. per square inch, that it was not considered necessary to proceed further. The stresses at this stage worked out to 48,130 lb. per square inch ; and the result proved that there was some justification for a reduction in the minimum scantlings of the shells of marine boilers to, at least, the scale adopted by the Admiralty.[1]

These suggestive experiments were carried out in connection with the boilers constructed in 1888–9 for two war vessels built by the Scotts. These vessels were the *Sparrow* and the *Thrush.* At the same time, the Scotts engined two other vessels of the same type, constructed at the Royal Dockyards. A view is given on Plate XVI. (facing page 54) of the *Thrush,* which was commanded by H.R.H. the

[1] "Proceedings of the Institution of Naval Architects," vol. xxx., page 287.

TABLE II.

PROGRESS IN WARSHIP MACHINERY FOR LIGHT FAST TYPES OF VESSELS 1890 TO 1918.

Year.	1890.	1895.	1900.	1905.	1910.	1918.
Type of boiler	Locomotive	Water tube	Water tube	Water tube	Water tube	Water tube
Kind of fuel used	Coal	Coal	Coal	Coal	Oil	Oil
Working pressure (lb. per sq. in.)	130	175	250	250	220	250
Horse-power per boiler....	1000	1040	1700	2200	2500	9000
Heating surface per horse-power (sq.ft.)	1·75	2·05	1·8	1·8	1·4	0·88
Approximate horse-power per ton of boiler-room machinery, including water	39·5	65·5	85	85	93	140
Type of engines	Vertical triple-expansion	Vertical triple-expansion	Vertical four-cyl. triple-expansion	Vertical four-cyl. triple-expansion	Direct steam turbines	Geared steam turbines
Number of propeller shafts	One	Two	Two	Two	Three	Two
Revolutions of propellers	400	380	390	390	750	340
Revolutions of main engines	400	380	390	390	750	H.P. 2900 L.P. 2200
Piston speed (ft. per min.)	1070	1100	1190	1190	—	—
Approximate horse-power per ton of engine-room machinery	72	80	90	92	82	130
Approximate horse-power per ton of engine and boiler-room machinery....	25·5	36	44	44	43·5	67
Horse-power	1000	4000	6500	8500	13,500	27,000

TABLE III.

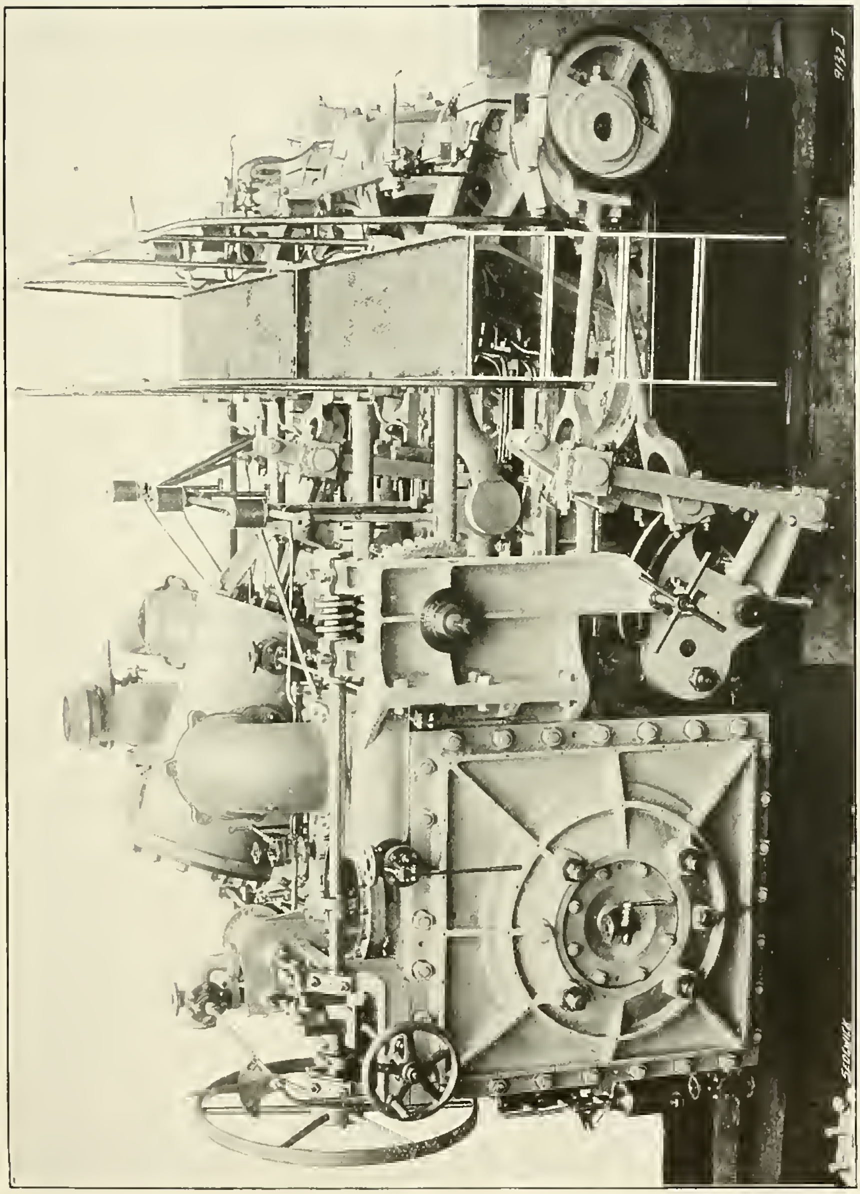
PROGRESS IN WARSHIP MACHINERY FOR HEAVY TYPES OF VESSELS 1850 TO 1918.

Year.	1850.	1865.	1875.	1885.	1895.	1905.	1910.	1918.
Type of boiler	Rectangular brass tube	Rectangular, tubular	Rectangular, tubular	Oval	Cylindrical, return tube	Belleville	Water tube, Babcock & Wilcox or Yarrow type	Water tube, Babcock & Wilcox or Yarrow type
Kind of fuel used	Coal	Coal	Coal	Coal	Coal	Coal	Coal and oil	Oil
Working pressure	15 lb.	30 lb.	30 lb.	65 lb.	155 lb.	300 lb.	235 lb.	235 lb.
Horse-power per boiler	175	520	670	700	1250	750	1500	3100
Heating surface per horse-power (sq. ft.)	About 6·0	4·0	2·9	2·7	2·0	2·4	2·1	1·4
Approximate horse-power per ton of boiler-room machinery, including water in boilers	—	9·1	10·8	12	16·25	24	29·5	44·0
Type of engines	Horizontal engines & gearing	Horizontal trunk	Horizontal	Vertical triple-compound	Vertical triple-expansion	Vertical triple-expansion	Parsons reaction steam turbines	Parsons or Brown Curtis steam turbines
Number of propeller shafts	One	One	One	Two	Two	Two	Four	Four
Revolutions of propellers (per min.)	99	74	70	88	97	113	320	275
Revolutions of main engines (per min.)	42	74	70	88	97	113	320	275
Piston speed, feet per minute	336	590	600	615	825	960	—	—
Approximate horse-power per ton of engine-room machinery	—	10	14·5	14·5	17·0	20	26·25	38·0
Approximate horse-power per ton of engine- and boiler-room machinery	About 4	4·8	6·2	6·6	8·3	11	12·4	20·5
Horse-power of main propelling engines	700	4700	6700	7000	10,000	15,000	25,000	75,000
Horse-power of auxiliary engines, approximate	—	500	1200	1200	3,400	4,200	6,000	—

Duke of York (now His Majesty King George V.), on the North American and West Indian stations in 1891, and it is perhaps permissible to say that in visiting Scotts' works in 1916, His Majesty was specially interested in the model and, in narrating reminiscences, referred to changes made in the rig. She was a vessel of composite build of 805 tons displacement, with machinery of 1200 horse-power, to give a speed of 13 knots ; but, as is shown by the illustration, she was fitted as a three-masted schooner, and utilised her sails when the wind was favourable. In this respect, she marks the transition stage between the days of the sailing craft and the modern ship depending entirely on steam for propulsion. Indication is afforded of the progress towards this transformation by Tables II and III on pages 56 and 57, which shows the improvement in economy in the machinery of warships at various stages in their development, in the one case for light craft and in the other for large vessels.

The figures in the tables are average results rather than highest attainments during the periods. For 1890–95 we have taken the *Barfleur*, the engines of which were constructed by the Scotts in 1894 ; whilst the particulars for 1895–1900 refer to the *Canopus*, engined by them in 1900. In 1902 they also supplied the machinery for the battleship *Prince of Wales*, and commenced the construction of the armoured cruiser *Argyll*. In 1907 they began the building of machinery for the Dreadnought battleship *St. Vincent*, and in 1909 laid down the super-Dreadnought battleship *Colossus*. Subsequently they built the battleship *Ajax*, several high-speed light cruisers, and many destroyers. But before referring in detail to the later ships in the next chapter on Work for the Great War Fleet, 1914–1918, we may briefly review the advances in applied mechanics, metallurgy and chemistry, which have contributed largely to the perfection of modern fighting ships in respect of offensive and defensive qualities.

Plate XVII.



ENGINES OF H.M.S. "THRUSH."

The gun most in favour at the close of the eighteenth, and at the opening of the nineteenth, centuries was the cast-iron, smooth-bored, muzzle-loader: first the 32-pounder and later the 68-pounder. Carronades were used for "smashing" rather than for penetrating the skin or structure of ships. Although the 68-pounders were improved by a lining of wrought iron being inserted in the bore, whereby the energy at 1000 yards range was increased from 290 to 600 foot-tons, little progress was made until after the Crimean War, when chemists undertook the investigation of the action of explosives and metallurgists sought to produce stronger metals.

The general idea as regards the powder used as a propellant was that the ignition was instantaneous, and that the more violent the explosion the greater would be the velocity of the projectile. Under such conditions short weapons naturally found favour; and indeed, with a light, spherical, ill-fitting projectile, there was very little advantage to be gained by lengthening the bore. But with the introduction of rifled cannon, much heavier and better-fitting shot became possible, and a rapid-burning powder gave rise to dangerous pressures in the gun. It was then realised that it was not an explosion that was wanted, but a continuous pressure acting on the base of a shot for a relatively considerable period. This needed a slow-burning explosive, and led to the manufacture of powder as pebbles or prisms; the enlargement in the late 'seventies of the chamber of the gun, and the provision of air spaces for the expansion of the powder, greatly added to the velocity with which the shot left the gun, and therefore augmented its carrying power.[1]

Gun-makers had meanwhile improved the strength of the weapon by a recognition of the fact that wrought iron was twice as strong in the direction of the fibre as across it; and thus in the 'sixties they began to coil the central tube, surrounding it by hoops, welded or shrunk on. The full

[1] "Encyclopædia Britannica" (1898 edition), vol. xi., page 288.

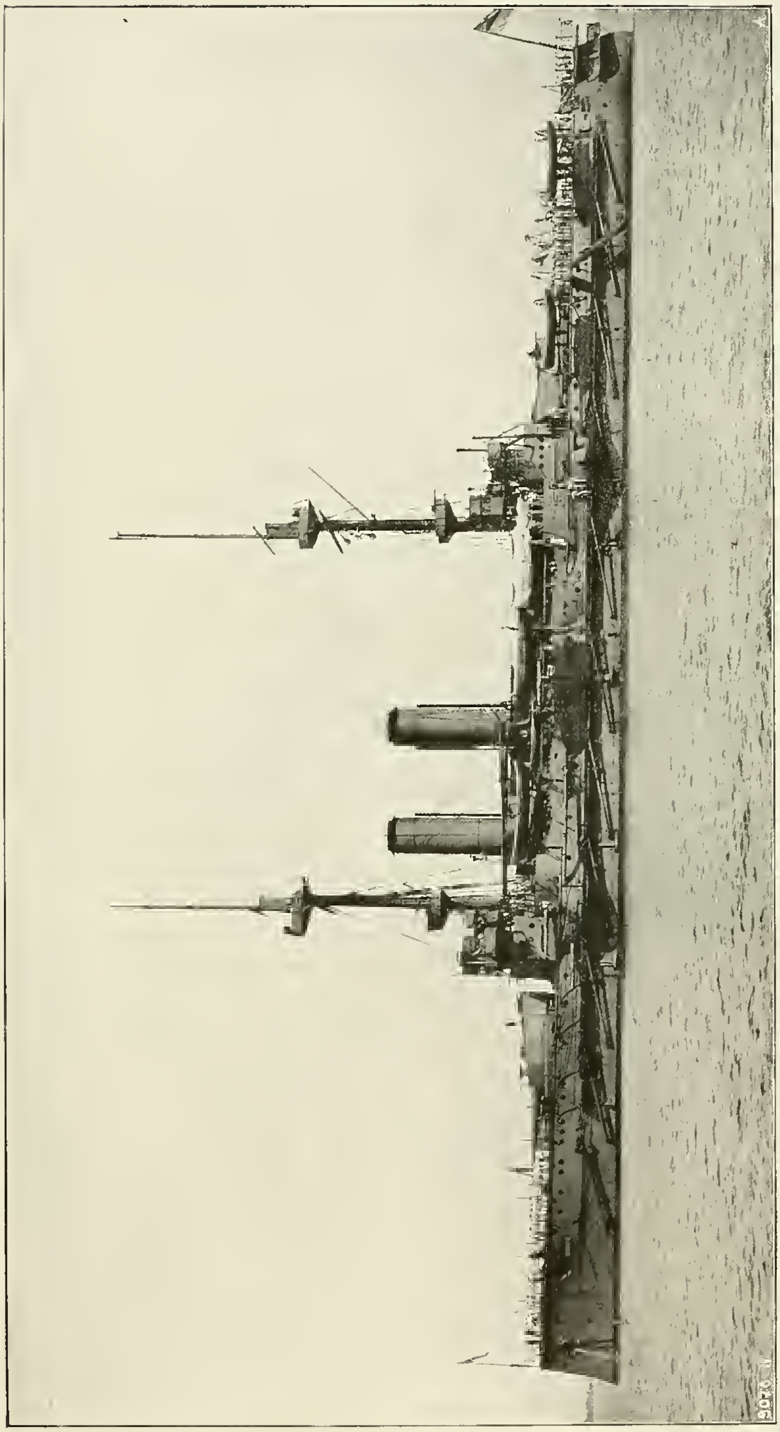
advantages of fibre were thus secured for resisting circumferential strain. The bore was rifled to give the shot that rotatory motion which prevents irregularity in flight and conduces to accuracy of fire at long range. The smooth-bore gun was effective up to only 1000 yards range, as compared with the 18,000 yards and 20,000 yards for the modern weapon. Breechloading was first introduced into the Navy in the 'sixties, but discarded because the details for closing the breech end proved unsatisfactory. Finally, it was reintroduced in 1878, a satisfactory breech block and operating mechanism having been devised.

These various improvements gradually increased the power of the gun. The length and weight had enormously grown, as is shown by the particulars of successive large Naval guns, shown in Table IV, on the next page; but the increase in energy up till the 'eighties was not commensurate with the augmentation of the weights of the projectile and charge.

The advance from the 38-ton gun of 1870 to the 110½-ton gun in 1887 involved the multiplying by five of the charge of powder, which quadrupled the energy of the gun, but the carrying power of the shot was still deficient. The velocity had increased in twenty years from 1600 to 2000 ft. per second, slower-burning powder having been introduced.

Attention was further directed to the improvement of explosives; and ultimately, instead of gunpowder having a potential energy of 480 foot-tons per pound, modified guncotton was introduced, with an energy of 716 foot-tons per pound, and still later there were evolved explosive compounds of which the potential energy per unit of weight was fourfold greater than in the case of gunpowder, namely, 1139 foot-tons per pound. Finally, the explosive has taken the form of nitro-compounds, which ensure slow burning, great expansion, and, consequently, augmented propelling power behind the projectile, without material addition to the maximum strain upon the weapon. But in any case the constructional strength

Plate XVIII.



[*From a Photograph by West and Son, Southsea.*

HIS MAJESTY'S BATTLESHIP "PRINCE OF WALES," 1902.

of the modern gun is enormously superior to the earlier built-up weapons, as around the inner tubes there is coiled something

TABLE IV.

PARTICULARS OF THE SUCCESSIVE LARGE NAVAL GUNS, 1800 TO 1918.

Year.	Type.	Weight.	Length.	Calibre.	Weight of Projectile.	Weight of Charge.	Muzzle Energy.	Penetration of Wrought Iron at 1000 Yards Range.
		tons cwt.	in.	in.	lb.	lb.	ft.-tns.	in.
1800	Cast-iron smooth-bore	2 12	114	6·4	32	10	400	—
1842	Ditto ...	4 15	—	8·12	68	16	700	—
1865	Woolwich wrought iron	4 10	—	7	115	22	1,400	7
1870	Built-up muzzle-loader	38 0	200	12·50	810	200	13,900	17
1880	Ditto ...	80 0	321	16	1700	450	27,960	22½
1887	Built-up breech-loader	110 10	524	16·25	1800	960	54,390	32
1895	Wire-wound breech-loader	46 0	445·5	12	850	—	33,940	34·6
1900	Ditto ...	51 0	496·5	12	850	210	36, 290	35·4
1905	Ditto ...	58 0	558	12	850	—	47,700	46·2
1912	Ditto ...	76 0	626	13·5	1400	—	60,600	*50
1914 to 1918	Ditto ...	97 0	675	15	1900	—	82,300	*56

* At muzzle. Guns of 18-in. calibre were fitted to one cruiser during the war, but were subsequently removed and used in monitors.

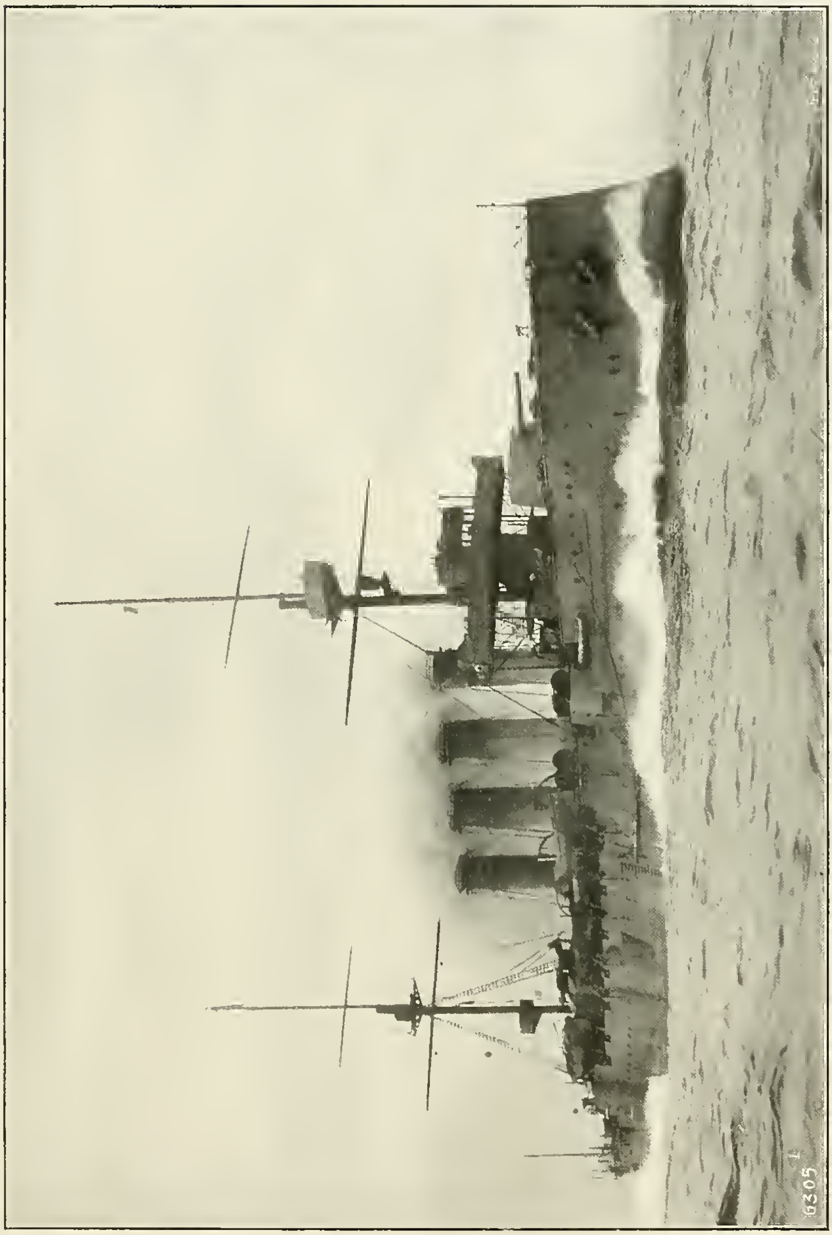
like 120 miles of wire, which itself has a breaking-strain of between 90 and 110 tons per square inch, and is put on under a tension of from 54 tons per square inch on the inner wires to 32 tons per square inch on the outer wires,[1] so that the ultimate resistance to strain consequent upon the firing of the gun is enormously increased. Velocities of 2600 ft. per second are thus realised, and even more is quite feasible, so that penetration of wrought iron at 1000 yards range has now been increased to 56 in.

If we compare the 15-in. gun to-day with the weapon of the same calibre of thirty years ago, when there was no widened chamber for the explosive, when prismatic powder of low expansive power was used, it is found, as shown in the table, that the penetration at 1000 yards has been nearly doubled, and the positive effective range multiplied five-fold. The tendency recently has been to reduce the muzzle velocity, especially in guns of large calibre, whereby erosion of the inner tube is minimised; the energy due to increased diameter of shell is sufficient to defeat armour of a thickness feasible of application in large ships, in view of the other claims on weight, while the larger bore also admits of a higher bursting charge within the projectile, and greater destruction when the hull of an enemy ship has been penetrated. There has also been an enormous gain in more rapid fire by improved breech mechanism and efficient hydraulic and electric mountings, by which the gun and all its loading, elevating and training machinery are manipulated. Advantage, too, has accrued, especially in respect of range by the elevating mechanism being designed to give the gun a higher elevation. In the latest ships the angle is 25° to 30° from the horizontal, which increased the range by 40 to 50 per cent. as compared with guns having a 15° to 20° elevation. This, however, involved problems in horizontal protection in ship design to which reference will be made in our chapter on Work for the Great War Fleet 1914–1918.

The metallurgist has also been successfully occupied in increasing the resisting power of armour. The earlier

[1] "Engineering," vol. lxxix., page 577, May 5th, 1905.

Plate XIX.



HIS MAJESTY'S ARMOURED CRUISER "ARGYLL," 1906.

wrought iron plates were increased from 4½-in. in thickness on the *Warrior* of 1861, to 24-in. on the *Inflexible* of 1881; the area protected being almost proportionately reduced. The artillerist with improved projectiles ultimately defeated this heavy cleading on the ships; but compound armour, first made in 1879, enabled the maximum thickness on the broadside to be reduced to 18-in., permitting a greater area to be covered for the same weight. It had a hard steel face and a soft iron back, the former to break up the projectile and the latter to prevent disintegration of the plate. At first the 80-ton gun failed in its attack, but heavier weapons with improved projectiles prevailed. The next step was the introduction of all-steel armour in 1890. Two years later there was introduced the super-carburising and subsequent chilling of the face of plates made of an alloy of nickel steel. In 1897 the process of hardening was still further developed, and now the 9-in. plate on the modern battleship is equal in resistance to a 26-in. wrought iron plate of the 'sixties, or a 20-in. compound plate of the 'eighties, or a 13-in. plate of the early-hardened type. It was thought by some that armour had gained the ascendency for ranges exceeding 8000 to 10,000 yards range; but during the war several ships had their armour penetrated at even greater ranges. Gunfire certainly accounted for many losses, although these were doubtless in part due, or accelerated by, explosions within the ship.

With the increased resistance of armour and the consequent reduction in its thickness, the naval designer can spread his protecting plates over a much wider area, so that the whole broadside of ships is clad with armour. At the same time the gun-power and speed of ships was greatly increased without making the displacement inordinately high. On page 65 a Table is given of the main features of representative ships at different epochs, which will show this at a glance.

The growth in the size of battleships has been steady, with the exception of the classes represented by the *Barfleur* and *Canopus,* both of which were engined by the Scotts. These vessels are embodiments of a desire to check the advance in the size and cost of the battleship. The deficiency in the number and calibre of their guns was partly compensated by the introduction, for the first time in battleships, of quick-firing weapons of large calibre. The *Barfleur* had four 12-in. breechloaders and ten 4.7-in. quick-firers ; while the *Canopus* had four 10-in. breechloaders and ten 6-in. quick-firers. But opinion had again strongly grown in favour of having in each British ship the best that can be achieved ; and thus the *Prince of Wales* has a displacement greater than any previous ship, while in the *King Edward* and the *Lord Nelson* classes there has been a further growth in every element of power. Then followed the "Dreadnought" battleship era beginning in 1905, but this will best be dealt with in our next chapter on Work for the Great War Fleet, 1914–1918.

As to the machinery made by the Scotts for the battleships of pre-Dreadnought era, the *Barfleur* had three-cylinder, triple-expansion twin-screw engines, to run at 108 revolutions, and to develop 13,000 indicated horse-power. On her trials the power was 13,163 indicated horse-power. There are eight single-ended, return-tube, cylindrical boilers, working at 155 lb. pressure.

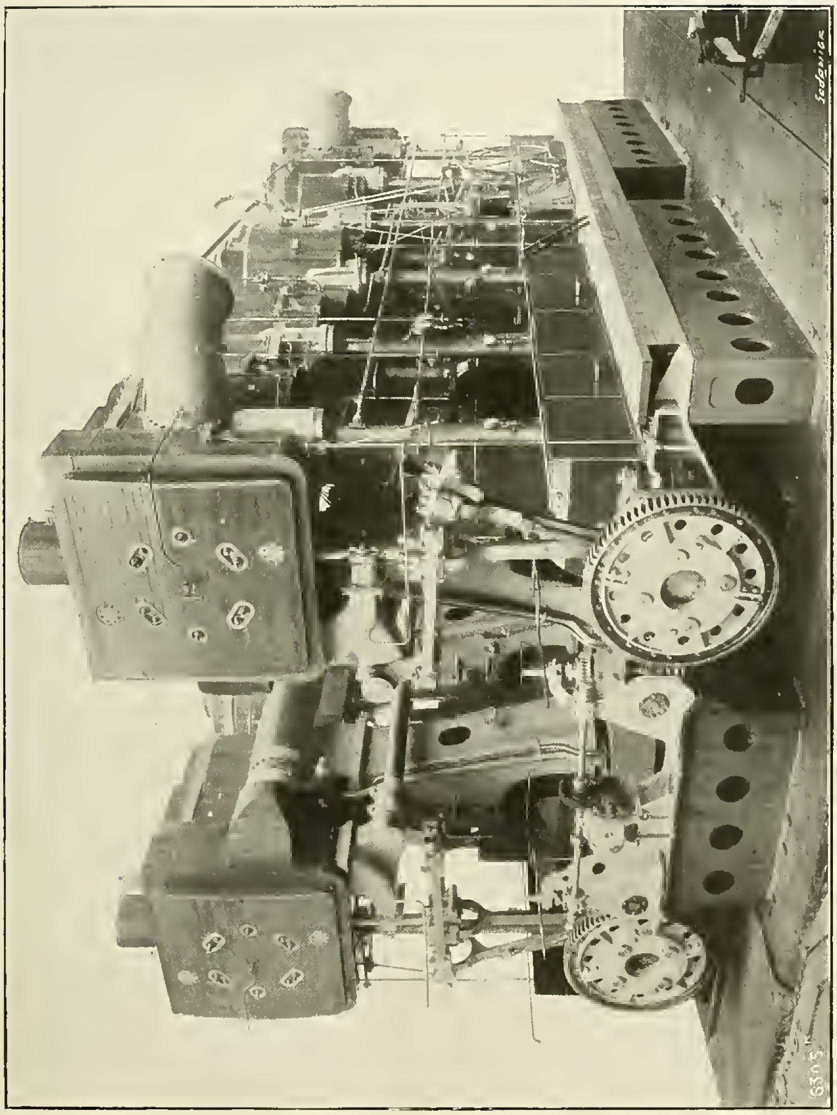
The engines of the *Canopus* are illustrated on page 51 by a drawing taken from a Paper read at the Institution of Civil Engineers, by the late Sir John Durston and Admiral H. J. Oram.[1] This was the first type of British battleship fitted with water-tube boilers. She was followed soon after by the *Prince of Wales.*[2]

The *Argyll,* which was built and engined by the Scotts in 1906, and the *Defence,* built in 1909, in one of the Royal Dockyards, and fitted with machinery constructed by the

[1] See "Proceedings of the Institution of Civil Engineers" (1899), vol. cxxxviii., part 3.

[2] "The Engineer," vol. xcviii., page 15.

Plate XX.



ENGINES OF H.M.S. "DEFENCE," 1909.

TABLE V.

SIZE AND FIGHTING QUALITIES OF BRITISH BATTLESHIPS OF DIFFERENT PERIODS.

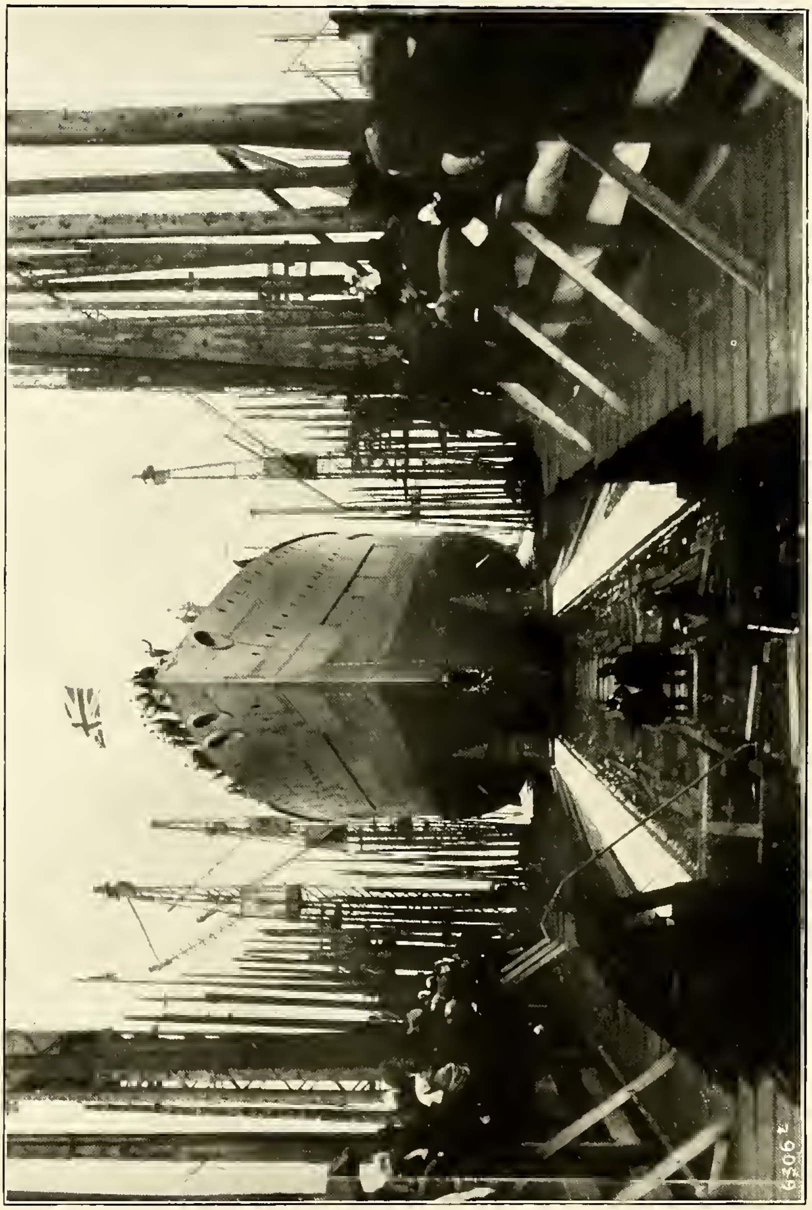
Name.	Date of Completion.	Displacement.	Side Armour.	Speed.	Total Weight of Shot in One Round.	Collective Energy at Muzzle of One Round.
		tons.	in.	knots.	lb.	foot-tons.
Warrior	1861	9,210	$4\frac{1}{2}$-in. wrought iron	$14\frac{1}{2}$	3800	61,476
**Hercules*	1868	8,680	9-in. to 6-in. wrought iron	14	5400	70,200
Alexandra	1877	9,490	12-in. to 6-in. wrought iron	15	5426	71,400
Inflexible	1881	11,880	24-in. to 16-in. wrought iron	13	6936	123,120
Benbow	1888	10,600	18-in. compound	16·75	4600	135,560
Royal Sovereign	1892	14,150	18-in. and 5-in. compound	17·5	5800	159,610
Barfleur	1894	10,500	12-in. compound	18·5	2450	67,670
Canopus	1900	12,950	6-in. hardened steel	18·25	4600	178,720
Prince of Wales	1902	15,000	9-in. super-hardened steel	18·25	4600	194,400
King Edward VII.	1905	16,350	9-in. hardened steel	19	6100	271,800
Dreadnought	1906	17,900	11-in. hardened steel	21	8800	487,100
Colossus	1911	20,600	12-in. hardened steel	21·5	8900	545,000
Ajax	1913	25,000	12-in. hardened steel	21·5	14,500	625,000
Queen Elizabeth	1914	27,500	13-in. hardened steel	25	(about) 16,400	710,000

* Re-engined by Scotts in 1892.

Scotts, signalised the beginning of that development in cruiser design, which culminated in the mighty battle cruisers which did such wonderful work in the Great War. The hardening of armour, increasing its resistance, permitted of a reduction in weight for a given measure of protection, so that it has been possible effectively to defend the modern cruiser, while at the same time giving an enormously increased gun-power. Moreover the introduction of express water-tube boilers, hitherto confined to destroyers, the use of oil fuel and the application of turbines, so increased power relative to weight that the speed realised was a speed far in excess of that possible a few years ago, either in the merchant or naval service, as will be shown in our next chapter.

The *Argyll* was the last of the British cruisers with cylindrical boilers, while the *Defence's* engines are in a way historical, as they were the last of the steam reciprocating propelling engines fitted in a British warship. The view of these engines on Plate XX is therefore interesting. They were of 27,000 indicated horse-power. The machinery, which was typical of that long adopted in warships, consisted of two sets of four-cylinder triple-expansion engines, arranged in separate watertight compartments. At full power of 27,000 indicated horse-power, developed with 125 revolutions, the piston speed was 1,000 ft. per minute. The cylinders were fitted with liners, and were steam jacketed. The *Argyll* had a combination of six cylindrical and sixteen water-tube boilers. In the later ships, including the *Defence*, the boilers were entirely of the water-tube type. From that time forward a new *régime* commenced, which is worthy of a separate chapter, especially as the ships of the old and the new *régime* were subjected to the crucial test of a long war with results eminently creditable to those responsible for British shipbuilding and marine engineering, as well as to the officers and men of the fleet, who again heroically maintained the most glorious traditions of the British Navy.

Plate XXI.



THE LAUNCH OF A BATTLESHIP FROM CARTSBURN DOCKYARD.

Work for the Great War Fleet, 1914-1918.

♣ ♣

ON August 4th, 1914, when Britain was forced to take her part in the great World War, to maintain the rights of the smaller nations against Teutonic aggression, the British Navy was ready. The time had come when "all the human patience, common sense, forethought, experimental philosophy, self-control, habits of order and obedience, thoroughly wrought hand-work, defiance of brute elements, careless courage, careful patriotism, and calm expectation of the judgment of God, as can well be put" into a warship was brought to the supreme test of battle. The surrender of the German High Sea Fleet on November 21st, 1918, was an all-convincing proof of the result of that test. We are not here concerned with the superiority in strategy and tactics shown by the British sailor in utilising the material supplied to him; nor do we propose to review the incidents of the great naval contest, whether as regards those glorious achievements off the Falkland Islands on December 8th, 1914, at the Dogger Bank on January 24th, 1915, or at Jutland, on the 31st May, 1916; or, indeed, at many other parts on the seven seas, less outstanding but equally effective, in establishing British naval supremacy, alike from the standpoints of tradition, *personnel* and material.

The complete record of the fighting demonstrates three great characteristics of the British race: the patient tenacity of the sailor, alike of the royal and merchant marine; the progressive spirit in the development of science and the determination to achieve efficiency in design; and the hereditary tendency towards sound construction. The time has not come to review in full detail the many innovations resulting from the ingenuity of the chemist and the engineer in devising new means effectually to combat new dangers, but here it is permissible to analyse the salient features which gave us the advantage in the material provided by shipbuilders and marine engineers. In this department of war activity the Scotts played a part not unworthy of their traditions.

In the preceding chapter we have attempted to bring into prominence the successive stages in the development of each of the principal elements in the design of the ship of the line—the hull, armoured protection, armament, propelling machinery, etc., up to the beginning of the new era inaugurated by the building of the *Dreadnought*. No one questions the view that in each of these successive stages, prior and subsequent to the *Dreadnought*, the German naval designer was several laps behind the British forerunner. Each was a well-ordered step towards the ideal laid down long years ago by Lord Fisher, to whom tribute must be paid for his genius shown in his conception of what a battleship should be, and in organisation. The dominant principle of the *Dreadnought* ideal was the carrying of the maximum number of guns of uniform large calibre, so disposed as to enable the greatest possible fire to be concentrated on the enemy ship, irrespective of the relative angle of the combatants, whether moving in line on the broadside or at any intermediate angle. The idea of the "all-big-gun" ship first occurred to Lord Fisher in the early days when he was captain of the *Inflexible*, at the time of the

H. M. S. Colossus.
Scotts Shipbuilding and Engineering Co. Ltd.

bombardment of Alexandria; but it was not until many years later, when Lord Fisher was in a position of influence at the Admiralty, that his first idea was carried into effect and gave us the *Dreadnought*, built in 1906. She was a great step in advance of her predecessors, and the rapidity in construction and secrecy maintained, enabled us to get two years' advantage over German battleship designers. Her length was 490 ft., her beam 82 ft., her displacement 17,900 tons, horse-power 23,000, and speed 21 knots. She had three pairs of 12-in. guns on the centre line of the ship, and two pairs mounted on the broadside opposite one another. Eight guns could be fired on either broadside, and four, or possibly six, guns could be fired simultaneously ahead or astern. She also carried twenty-four 12-pounder guns, and had five 21-in. submerged torpedo tubes. Her armour belt was 11 in. thick amidships; the redoubts and gunhouses were 11 in. to 8 in. thick, and the protecting deck varied from $1\frac{3}{4}$ in. to $2\frac{3}{4}$ in. Each year brought developments of this type, particularly in the increase of the light armament and in speed.

The *St. Vincent*, built in 1910, was engined by the Scotts, and marked an intermediate stage in the progress. She was 10 ft. longer than the *Dreadnought*, had 2 ft. more beam, and had a displacement of 19,250 tons. She had the same primary armament, but instead of twenty-four 12-pounder guns she carried eighteen 4-in. and four 3-pounder guns. The boilers were of the Babcock and Wilcox type, as in the *Dreadnought*, and the propelling machinery consisted of turbines developing 28,200 horse-power on trial, and gave a speed of 21·67 knots.

The next important stage in the development was in three vessels laid down in 1909, one of which, the *Colossus*, was built and engined by Scotts, and is illustrated on Plate XXII. In this vessel Scotts had the distinction of building the first of the *Dreadnought* type constructed on the River Clyde.

Again the dimensions were increased. The length became 510 ft., the beam 85 ft., and the displacement 20,000 tons. The armour was considerably increased, not only in thickness, but in the area of the broadside clad with it. The bunker capacity, and therefore the radius of action, was augmented. The power of the turbine machinery on trial was 29,300, and the speed realised by the ship 21·57 knots. The disposition of the big guns was still as in the *Dreadnought.*

It was not until 1910 that the higher conception of Lord Fisher was realised. In that year four vessels of the *Orion* class were laid down, and in the following year four more of the *King George V.* class, to which belonged the *Ajax,* built and engined by the Scotts, and launched in 1912. There was an advance in all the fighting elements of these ships. In the first place, the guns were of 13·5-in. instead of 12-in. calibre, representing an increase in the muzzle energy for each weapon from 47,000 to 60,600 ft.-tons, as shown on page 61, or an increase in the total weight of shot per round from 8800 lb. to 14,500 lb.; and in the collective energy at the muzzle, in a salvo from all guns, from 487,100 to 625,000 ft.-tons. In the second place, the disposition of the guns, as shown in the view of the *Ajax* on Plate XXIII, enabled a greater concentration of fire at any objective, but the turrets were all in the centre line of the ship, and, for the first time, Lord Fisher's idea of placing guns at different levels was introduced. Thus the guns in No. 2 turret from the bow were at a higher level than those in No. 1 turret, so that all four could fire on the same objective. Amidships there was a third turret, which could fire on either broadside, and had a large arc of training forward and abaft the beam. No. 4 and No. 5 turrets aft were arranged similarly to those forward, those in No. 4 turret being at a higher level than those in No. 5 turret. Thus all ten guns could fire on either broadside; four could fire right ahead, four right astern, while all ten had a great arc of training forward and abaft either the port or

H. M. Battleship "Ajax," 1912.

starboard beam. In the third place, the speed of the ship was increased to nearly 22 knots on trial, with the turbine machinery developing 32,900 shaft horse-power. The size of the ship had been greatly increased, the length being 555 ft. against the 490 ft. of the *Dreadnought*, the beam 89 ft. as compared with 82 ft., and the displacement tonnage 23,100 tons as against 17,900 tons.

The final stage in the development of the class prior to the war was in the *Queen Elizabeth*, laid down in 1913. In this class the size of the guns was further increased to 15-in. calibre, but only four turrets were fitted, each having two guns. Two of the turrets were forward and two aft in each case, two levels being provided as in the *Ajax*. The turret placed in the centre line amidships in the *Ajax* was omitted. The great feature of the ships of the *Queen Elizabeth* class, however, was the increase in the power of the propelling machinery, and consequently in the speed of the ships. The displacement tonnage went up to 27,500 tons, but, in consequence largely of the greater length of the ship (600 ft.) —an element conducive to higher propulsive efficiency— 25 knots were realised with the turbines developing 75,000 shaft horse-power.

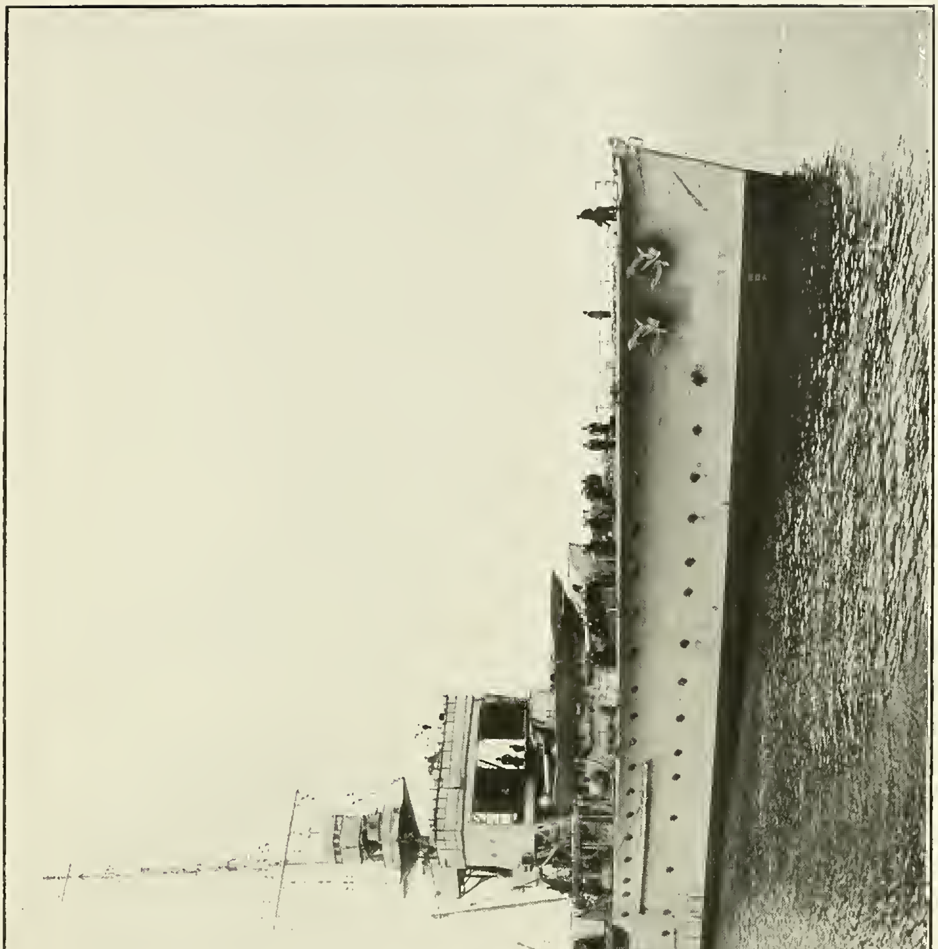
In the design of cruisers there has been a still more marked advance. This type of ship falls into two categories—the all-big-gun battle cruiser and the light scouting cruiser. Several of the latter have been built by Scotts. As regards the former, the year which saw the dawn of the *Dreadnought* battleship era was signalised by a correspondingly large step forward in cruiser design, the first three ordered, in 1906, being the *Invincible*, *Inflexible*, and *Indomitable*. These vessels, completed in 1909, were 530 ft. long, displacing 17,250 tons. Their turbine machinery developed 41,000 shaft horse-power, and gave a speed of 26 knots. They mounted four pairs of 12-in. guns.

Each successive battle cruiser from this date onwards marked a development, and in the *Tiger*, the latest ship laid down prior to the war, the length had become 660 ft., and the other elements were proportionately increased. During the war, however, still greater progress was made. Our greatest need was found to be for fast battle cruisers and scouts, and attention was concentrated upon such vessels. Of the battle cruisers it will suffice to mention the *Repulse* and *Renown*, completed in 1916. These vessels had an overall length of 794 ft., and measured 750 ft. between perpendiculars. Thus the advance in length upon the prototype, the *Invincible*, was nearly 50 per cent., and the displacement was increased to 26,500 tons. The ships mounted six 15-in. guns, and the hulls were fitted with modified bulge protection. The greatest advance, however, was made in speed, which reached 32 knots, with turbine machinery developing 112,000 shaft horse-power. This great speed was decided upon because of the German cruisers' "tip-and-run" tactics, namely, rushing across the North Sea to bombard undefended coast towns for twenty minutes, and then returning to their base as fast as they could steam. This game terminated when the Germans heard of the building of our big fast cruisers.

A further notable development of cruiser design was seen in the very large light cruisers *Courageous*, *Glorious*, and *Furious*, which were completed in 1916–17. The vessels were 735 ft. in length between perpendiculars, and their outstanding feature, apart from the thin protection of the hulls, was the great speed for their size, namely, 32 knots on relatively light draught. The two first vessels carried four 15-in. guns. The *Furious* was subsequently altered to a seaplane-carrying ship, and was further notable as she was the first vessel of great power—about 90,000 shaft horse-power—to be fitted with geared turbines. These ships were also designed with a modified form of bulge under-water protection.

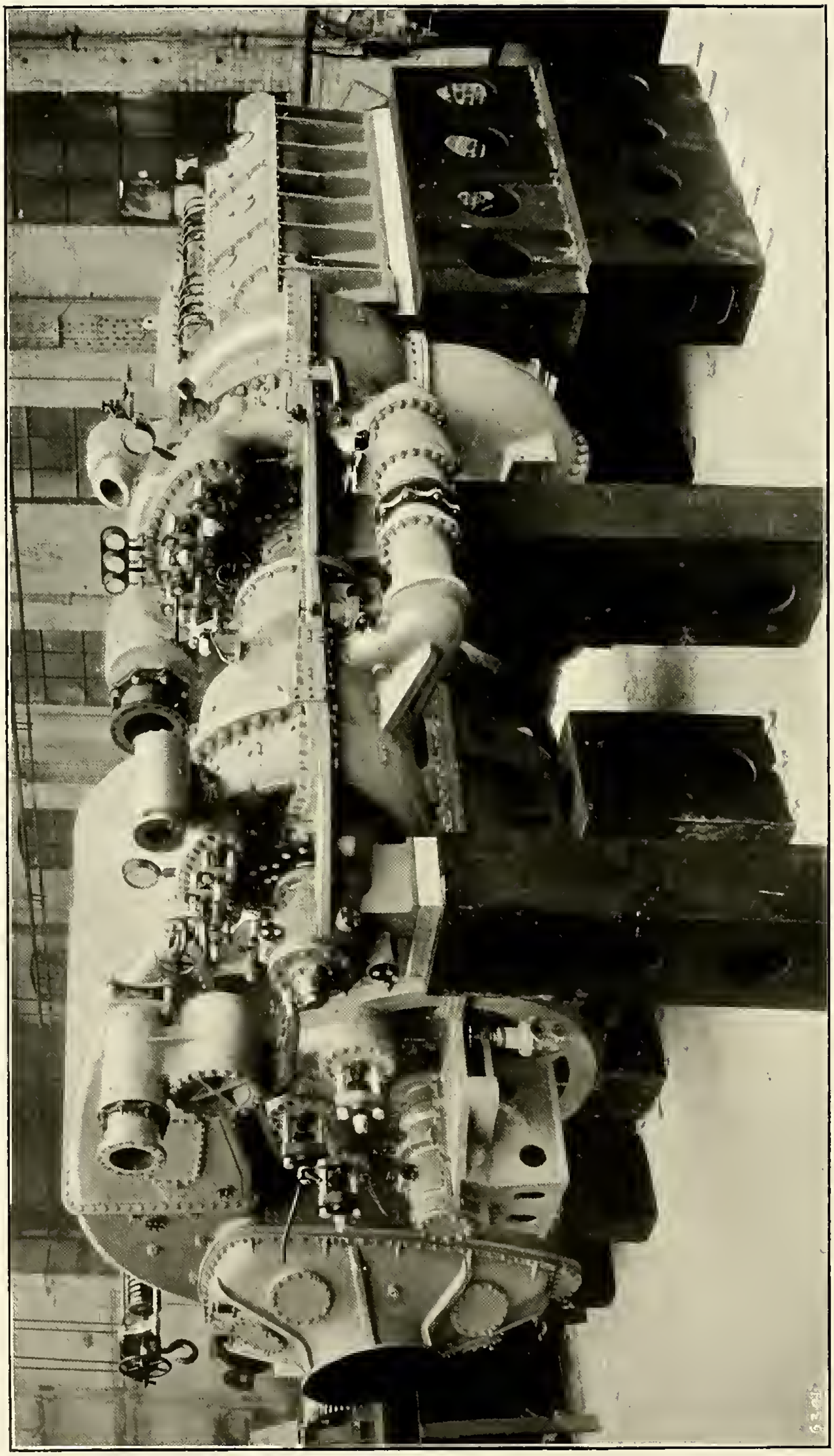
Here it may not be uninteresting to refer to some of the influences of naval tactics, disclosed by the early period of the war, upon the design of the lighter cruisers, and, indeed,

Plate XXIV.



THE LIGHT CRUISER "DRAGON."

Plate XXV.

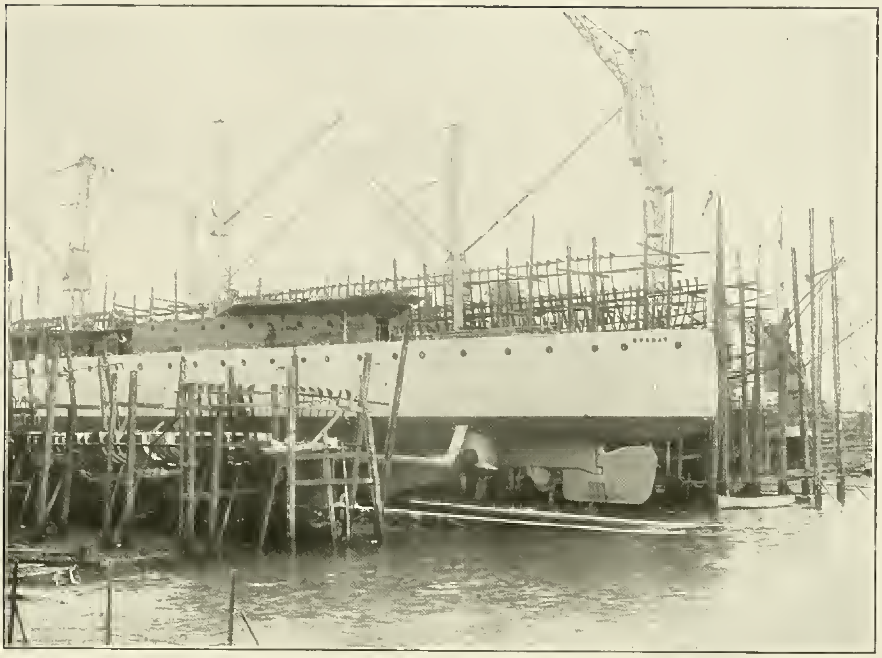


THE TURBINES OF H.M.S. "DRAGON."

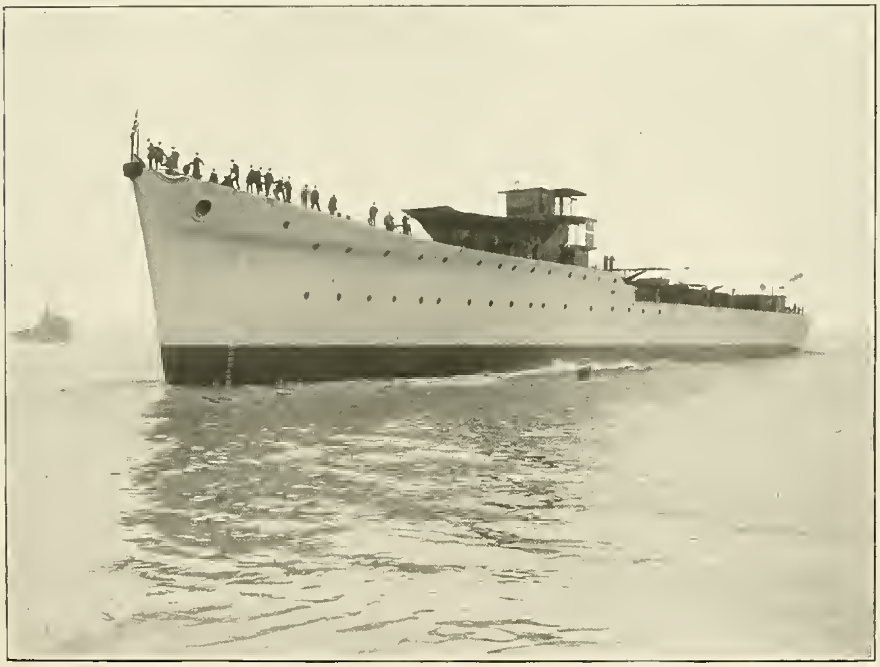
practically upon all types of warships. Briefly expressed, these influences were, first, the increased range and general efficiency of gun fire ; second, the increased efficiency of the torpedo ; and, third, the advent of the submarine as a fighting weapon. These three influences, in association with increased power of aircraft, have greatly affected warship design. The first is the direct result of the improvements that have been made in range finding and in fire control, which enabled accurate practice to be made at much greater ranges than was previously thought possible. This seems to have been first realised by the Germans, who, with their more efficient instruments, and with the use, in the early days of the war, of aircraft for range spotting, were able to open fire at a much greater angle from the horizontal than had ever been done before and than had been adopted in the British service. Practically all the German naval guns, great and small, were ranged for elevation up to 30 degrees, whereas the British guns in most cases only elevated to 15 degrees, or at the outside to 20 degrees. The greater elevation, of course, gave a greatly increased range, roughly about 40 per cent., so that early in the war our guns were, in most cases, outranged by those of the German ships. Arrangements, however, were made to alter this, so far as our naval ordnance was concerned. After the Battle of Jutland it was recognised that the danger of plunging shell penetrating the vitals of a ship demanded increased protection on deck and over the magazines. Consequently this was arranged for in the new ships, and as far as possible in the old ships. These provisions incidentally afforded the necessary protection from air attack.

The improvement in the efficiency of the torpedo, and its greatly augmented range, tended also to increase the distance at which naval actions were engaged in, as the opposing ships were naturally anxious to keep beyond the danger zone of the torpedoes of their rivals. From this point of view also it became necessary to increase the range of guns, as well as to improve the horizontal protection, so that the torpedo helped to produce those changes which at the same time demanded superior under-water protection. Very early in the war the activity of the submarine, as well as the improvement in torpedo range, pointed to the necessity of rendering still more effective the under-water protection. Before the war a series of experiments had been conducted, and great improvements made in this direction. The efficiency of these improvements was shown when His Majesty's battleship *Marlborough* was torpedoed at the Battle of Jutland, yet still remained a considerable time in the line, continuing the action, and finally returning to port in safety. The damage sustained, however, was somewhat serious, and would probably have sunk a ship with anything less in the way of protection.

Immediately after the outbreak of war, Sir Eustace T. d'Eyncourt, Director of Naval Construction at the Admiralty, put forward proposals for what is now termed " bulge " protection for ships. Experiments were made, and his ideas proved to be correct. Bulges were then fitted to some of the old cruisers of the *Endymion* class and to the new large monitors mounting heavy guns. The monitor *Sir John Moore,* built by the Scotts and described on page 98, was fitted with this form of protection, which consisted of a water-tight outer compartment full of air, and an inner compartment open to the sea and therefore full of water. It was a long time before any vessel fitted with this arrangement was actually torpedoed, but in the end several vessels fitted with bulges were torpedoed, and they all survived. This, therefore, may be accepted in principle as a satisfactory form of under-water protection, and a measure of protection along these lines is likely to be adopted in future in all large naval vessels. The actual results show that this form of protection is as effective against torpedo attack under water as modern armour is against gun attack above water. It is certainly a great achievement, though the arrangement adds considerably to



THE LIGHT CRUISER "DURBAN" ON THE STOCKS.



H.M.S. "DURBAN" AFTER LAUNCH.

the weight of the structure of the ship, and therefore to the displacement. If, however, the form of the ship is carefully designed, the loss of speed is small with ships of ordinary proportions, and is, indeed, not much greater than that entailed by the increased displacement consequent on the weight of the bulge. An important benefit of the bulge is that the gases generated by the explosion of a torpedo vent themselves in the air, to a large extent, immediately above the bulge, instead of venting themselves inside the ship.

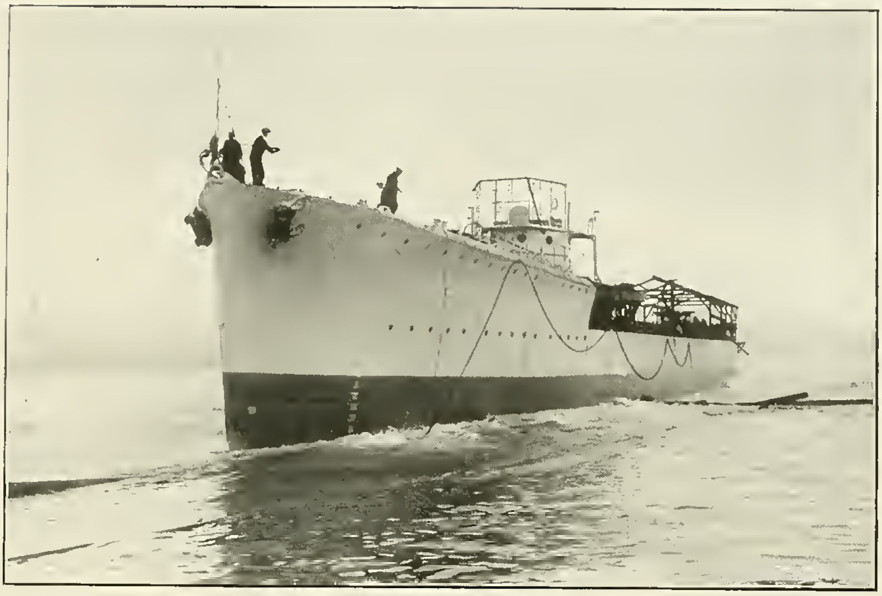
Both these considerations—the increase in the horizontal deck protection against plunging gunfire and the under-water protection—add very considerably to the total weight of protection which it is necessary to carry when making a modern capital ship in any way secure against attack, so that the tendency towards larger ships will be accelerated. The trend is towards increased length. Taking the *Renown* and *Repulse,* and comparing them with a destroyer, it may be pointed out that, with not more than four times the horse-power, about twenty-four times the displacement could be driven at the same speed as that of the destroyer. These results apply to smooth water ; in anything of a head sea, the destroyers are left behind by the big ships. This interesting conclusion gives considerable food for thought.

Two of the notable light cruisers built during the war were constructed by the Scotts—the *Caradoc* and the *Dragon*—while a third, the *Conquest,* built at Chatham, was supplied with her machinery by the Scotts. There had been great advance in this type of warship prior to the war consequent upon the adoption of turbines. The most important step, however, was taken in the 1912–13 programme, when the *Arethusa* class was designed by Sir Philip Watts. The greatest importance was attached to speed, and this was obtained on a minimum machinery weight by utilising for the first time a type of engines and boilers closely approximating in scantlings and design to that hitherto used for destroyers. The vessels of the *Arethusa* class were 410 ft. in length between perpendiculars, and had a displacement of 3500 tons, yet the turbine machinery of 40,000 shaft horse-power gave a speed of 29 knots. Two 6-in. and seven 4-in. guns were carried, and the ship's sides were protected up to the level of the upper deck by specially high tensile plating, varying from 2 in. to $1\frac{1}{2}$ in., and 1 in. throughout the machinery spaces, in addition to the usual 1-in. shell plating.

The *Caradoc* marked an advance in size by 15 ft. in length and 390 tons in displacement, the increase being largely to give additional fuel capacity in order to augment the radius of action. In the case of the *Dragon*, the length was further increased to 445 ft., and the displacement to 4723 tons, so that six 6-in. guns could be carried in addition to two 3-in. high-angle guns to combat seaplane and airship attack. The oil fuel capacity was also augmented, being brought up to 1050 tons, against 810 tons in the *Arethusa.*

A fleet of torpedo boat destroyers was built during the war by the Scotts, six being completed in 1916—the *Obedient, Obdurate, Paladin, Plucky, Portia,* and *Parthian;* two in the following year—the *Tirade* and *Ursula;* and four in 1918—the *Westminster, Windsor, Swallow,* and *Strenuous.* It is interesting to observe the development in machinery which took place in this short period. Particulars will be found in Table VIII, page 96. It will be noted that from direct-driving reaction turbines on three shafts, a change was made to nclude geared cruising turbines on the outer shafts, and that finally twin screws were introduced, driven by geared turbines.

It is not here intended to attempt any detailed description of these various vessels. As in the case of other ships, there has been a steady increase in size and power, to enable vessels to carry a heavier armament of guns, torpedoes and depth charges, and, above all, to augment the oil fuel supply, in order to increase the radius



THE TORPEDO BOAT DESTROYER "STURDY" AFTER LAUNCH.

H.M.S. "STURDY" ON TRIAL.

of action. Thus the destroyers built immediately before the war were 260 ft. in length, had 965 tons displacement, and with turbines of 24,500 shaft horse-power attained a speed of 29 knots. They carried three 4-in. guns, two torpedo tubes, and 135 tons of oil fuel. The later ships by Scotts ranged in size up to 300 ft. in length, had 1425 tons displacement, and with turbines of 27,000 shaft horse-power steamed at 33 to 34 knots. They carried four 4-in. guns and a high-angle firing gun, six torpedo tubes, in addition to other weapons evolved during the war. The length of the later torpedo boat destroyer flotilla leaders went up to 320 ft., and they had turbines of 44,000 shaft horse-power, giving a speed of 36 to 38 knots. They mounted five 4·7-in. guns.

It will be recognised that one of the outstanding characteristics of all these vessels, from battleships to torpedo boat destroyers, was the great advance in speed, notwithstanding the additional load due to increased weapons of warfare. In the twenty years preceding the war, the engine power of battleships increased from 12,000 indicated horse-power to 30,000 shaft horse-power, while the speed of the ship advanced from 17 knots to 22 knots. At one step we advanced to the 75,000 horse-power of the *Queen Elizabeth* class, while the speed reached 25 knots, notwithstanding that the displacement tonnage had advanced to 27,500 tons. Still more remarkable was the development in cruisers. In the twenty years before the war the engine power of what were then designated "first-class cruisers" advanced from 25,000 indicated horse-power in the *Powerful* to 85,000 shaft horse-power in the *Tiger*, while the speed of the ship increased from 23 knots to 28 knots, with a doubling of the displacement tonnage to 28,000 tons. The advances made in the years of the war have been referred to already; there are now several cruisers with almost the offensive and defensive power of battleships, having a speed of 32 to 33 knots.

As regards the reduction in weight of machinery, Table VI is very striking and needs no comment.

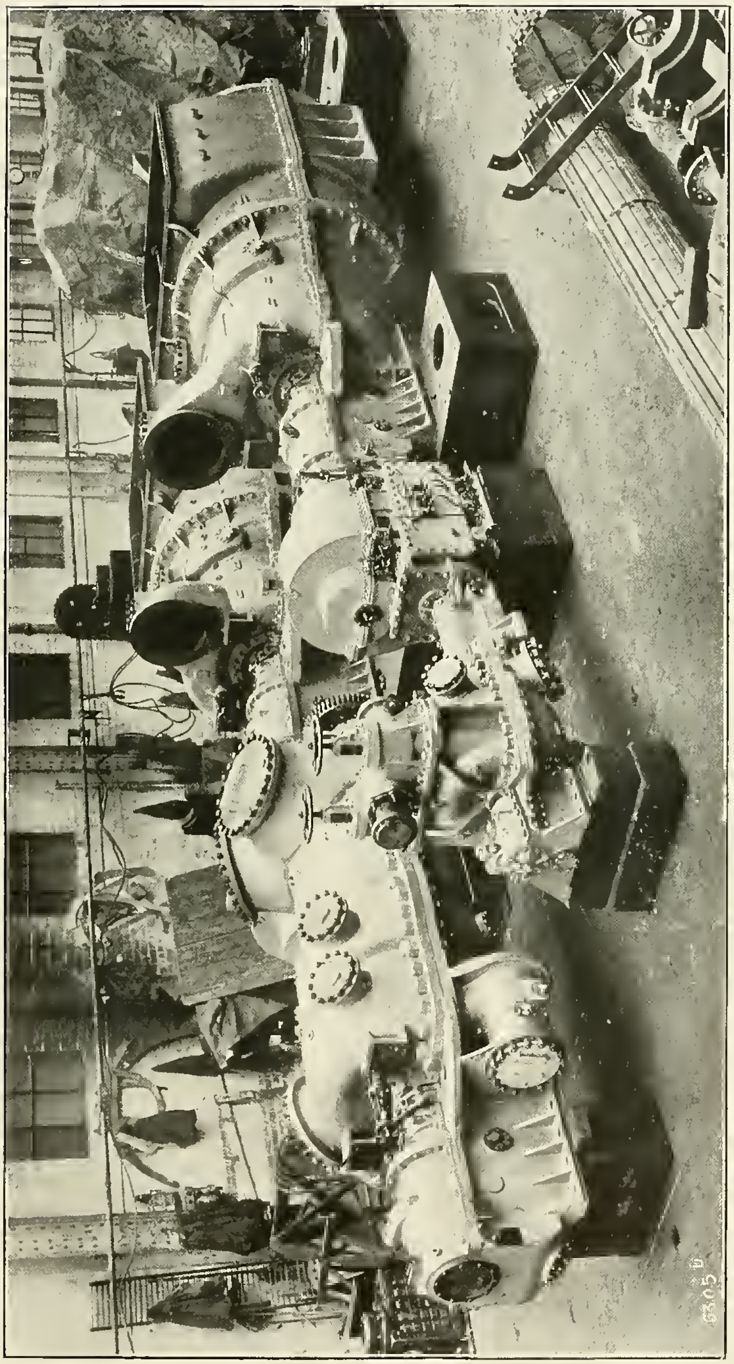
TABLE VI.
WEIGHT OF MACHINERY.
(Lbs. per Horse-power.)

—	1894.	1914.	1919.
	lb.	lb.	lb.
Battleships	242	174	110*
Battle Cruisers	194	113	75*
Destroyers	50	35*	30*

* Burning oil.

This reduction in the weight of machinery is in large part due to the use of oil fuel for all ships. Briefly expressed, the advantages of oil over coal are that the radius of action is increased by 50 per cent. for a given weight of fuel or 70 per cent. for a given capacity for fuel. The thermal efficiency in the boiler is increased from 65 per cent. in the case of coal to about 75 per cent. in the case of oil; the boilers can also be forced to well over their normal steam-raising capacity, and this is the more important with turbine machinery, which also is capable of being greatly overloaded. Thus destroyers having turbine machinery of a normal shaft horse-power of 30,000 have, during the war, been on occasions forced up to 40,000 shaft horse-power, greatly increasing their speed. This facility for overloading the machinery proved invaluable to our destroyers and cruisers when they had to chase the retreating enemy. There are other incidental yet important advantages due to oil fuel. The smoke question was one which in the initial stages proved difficult of solution, but success was achieved before the war, and thus there was no pillar of cloud by day to disclose the movements of a squadron. On the other hand, when a smoke screen was required it was easily produced in great density from the funnels of warships.

Plate XXVIII.



TURBINES OF A TORPEDO BOAT DESTROYER.

Stokehold labour was reduced by about 70 per cent. in the case of oil fuel ships and they could readily have their oil bunkers filled while at sea.

Another influence tending to reduction of weight per unit of power developed was the adoption of speed-reduction gear between the turbine and the propeller, so that the turbine could be run at the high rate of revolution which was conducive to thermal efficiency, while the speed of the propeller was reduced to meet the conditions necessary for propeller efficiency. The reduction gear was of considerable weight, but this was nearly compensated by the reduction in the weight of the turbines, while the higher thermal efficiency of the turbines became appreciable at reduced powers. As a consequence, the radius of action could be considerably increased for a given amount of fuel carried. In battle cruisers the single-reduction geared turbines were designed for a consumption of steam of about 9·9 lb. per shaft horse-power at full power, excluding the auxiliary machinery, but including this the consumption was only about 11·15 lb. in the case where the exhaust steam from the auxiliaries passed into the turbines, as was the case in most ships. In light cruisers of the new twin-screw type, each driven by an independent set of compound turbines and gearing, the steam consumption was 10·75 lb. per shaft horse-power, or, including auxiliaries, 12 lb. Even at one-fifth of the full power, the consumption for the turbine was only 13·25 lb. per shaft horse-power.

At the outbreak of the war, as already stated, the destroyers being built were generally propelled by three screws, each shaft being driven by turbines, while geared cruising turbines in some instances were fitted on two shafts. The steam consumption with such an arrangement was, for the turbines only, about 12 lb. per shaft horse-power at full power, 15 lb. at one-fifth of the power, and 16 lb. at one-tenth of the full power. In the latest twin-screw destroyers, where each shaft was driven by an independent set of compound turbines operating through single-reduction gearing, the steam consumption was brought down to 11·5 lb. per shaft horse-power at full power, 12·4 lb. at one-fifth of the power, and 15 lb. at one-tenth of the power. These consumptions were based on a vacuum of 27 in. The change over from the directly-driving turbines to the two-shaft all-geared turbines permitted not only an increase of from 8 to 10 per cent. in propeller efficiency, but an improvement in the steam consumption of the turbines of about 5 per cent. at full power.

An interesting departure in connection with naval auxiliary machinery was the Weir closed circuit feed-water system, which combined reduction in weight with increase of economy in the vessels in which it was fitted. Consideration of this idea was taken up by the Scotts in the beginning of 1916, to test the feasibility of its application to a destroyer under construction at the time. By this system the feed water was to be maintained in a closed circuit with the object of preventing boiler corrosion by keeping air from entering the boilers, and, at the same time, to improve the fuel economy by considerably increasing the temperature of the feed water returned to the boilers. After a careful consideration of the subject, discussions were entered into with Messrs. Weir and the Admiralty.

In the following year, after experiments by Messrs. Weir to make the system effective against breakdown, and investigations as to the expected weight, economy, and working of the installation, the Admiralty ordered the system to be applied to the torpedo boat destroyer *Strenuous*, built by the Scotts. It was also decided that guidance drawings of the arrangements in this vessel should be circulated to other firms, who were to fit out vessels with the system. In December, 1918, the *Strenuous* went on trial, and passed the tests successfully, although, as might be expected, maximum results were not at once obtained. On the full power trial the vacuum measured at the top of the condenser was equal to that obtained in similar destroyers, in spite of the fact that air

Plate XXIX.

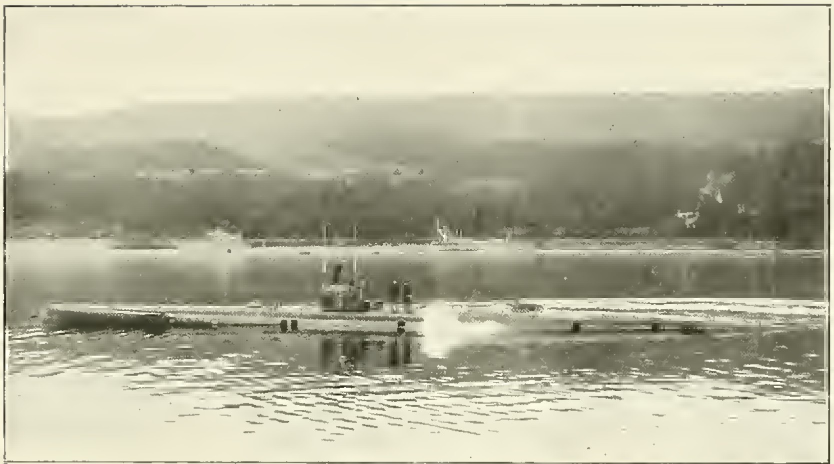
H.M.S. "STRENUOUS" ON TRIAL.

leaks were discovered later on. When these leaks were stopped, a vacuum of 29 in. on a 30-in. barometer could be maintained. It was noteworthy that the oil consumption was about three tons less over the four-hours' full-power trial than was usual for ships fitted with dual air pumps and contact heater. While it will take a considerable period of service to prove definitely that the main object of the system has been achieved, the results of the period of probation are awaited with confidence.

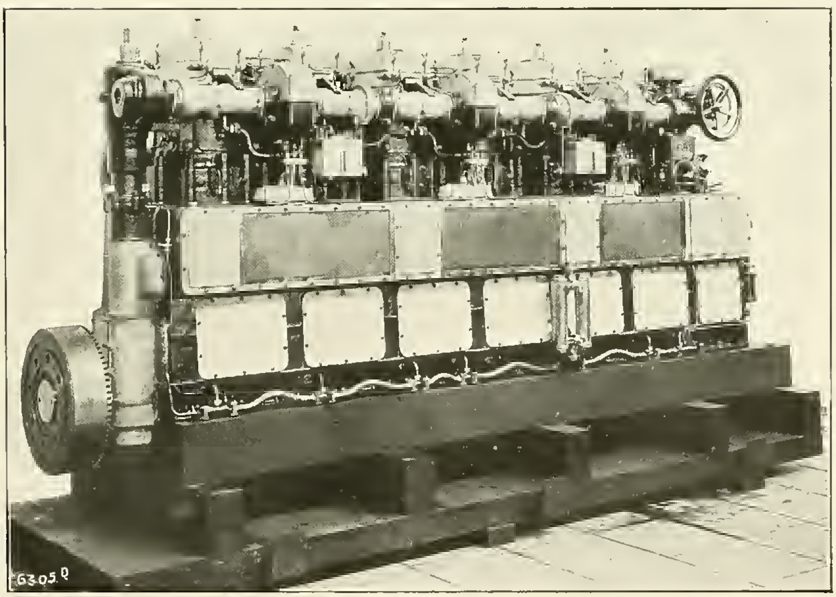
In connection with the development of water-tube boilers for naval purposes a series of investigations were made by the Scotts with the object of producing a boiler giving greater evaporation per unit of space occupied and higher efficiency. It was necessary to obtain information upon the limits of space required for the combustion of oil, and an experimental furnace was constructed and fitted up for this purpose. Numerous tests were made, and analyses of the gases taken, and, while the whole matter is receiving further consideration, it was demonstrated by the experiments that higher rates of combustion were possible in a furnace, under certain conditions, than were indicated by current naval practice.

Towards the end of 1917 attention was directed by the Admiralty to the necessity for silencing the noises made by high-speed ships when under way, and proposals were invited for doing this. A preliminary consideration of a variety of suggested methods of quietening the sound emitted from the propellers and shafting of ships, pointed to the sound-screening effect of air bubbles as offering the most likely field for investigation. In pursuance of this line of thought, numerous experiments were carried out by Scotts with model propellers, and later with apparatus for producing air bubbles under water. Eventually a practical method was arrived at for applying the results of the experiments to a vessel in motion, and through the interest of the Admiralty, a ship, *P.C.* 43, was fitted up with the apparatus. The trials were of short duration, as the vessel was required for other purposes. From an acoustic point of view, the results were unsatisfactory, but there were certain features in connection with the trials which encourage the view that a solution of the problem may be arrived at ultimately along the lines of the experiments.

The Scotts also made a valuable contribution to the war fleet by the building of a number of submarine boats, and, more important still, by many improvements in design and equipment, ensuring higher efficiency and speed in these absorbingly interesting craft. The firm first turned serious attention to the subject of under-water craft in 1908, and in the following year took out a licence, applicable to all countries under the British flag, for the building of the well-known Laurenti design, so highly developed by the Fiat San Giorgio Society, of Spezia, Italy. As a result of this enterprise, Scotts received, in 1912, an order for a boat of this type for the British Navy. This boat, *S.* 1, the first submarine boat built in Scotland, was designed and fitted out in all respects for service, delivery being given at the end of July, 1914, immediately before the outbreak of war. The Laurenti submersible boats possess distinct advantages over other types, and the fact that certain of the outstanding features have been adopted with highly satisfactory results by some of the leading navies of the world proves the soundness of the principles laid down by the Italian constructor, Cesare Laurenti. Broadly, these principles ensured great strength of hull and a large reserve of buoyancy, rendering the boats particularly seaworthy and easy to handle on the surface in all weathers. The outer hull is of ship-shape form, a departure from the circular form commonly adopted up to this time, which enables the boats to obtain a higher speed for a given power than other types, while giving a corresponding augmentation of the radius of action. The great reserve of buoyancy in surface trim is achieved by the arrangement of water-tight superstructure, which, besides forming a roomy deck with a relatively high freeboard, stiffens the upper parts of the hull, to which it



H.M. SUBMARINE "S.1."



ONE SET OF SCOTT-FIAT OIL ENGINES FOR "S.1."

is attached by strong beams, so as to withstand the heavy pressures experienced when submerged. The vessels are constructed with an outer hull, as already mentioned, and an inner hull; the latter having the effect of minimising the internal cubic capacity, and ensuring satisfactory conditions when submerged. The double skin, which is a special feature of the type, is braced with stays to ensure the maximum of structural strength, the space between the hulls being utilised to form water ballast tanks for submergence. Kingston valves are fitted on the bottom beyond the turn of the bilge on each side for the flooding of the compartments. The construction is made sufficiently strong to enable the water to be pumped out without danger of collapse due to the pressure of the sea water on the outer skin, though compressed air is normally used for expelling the water when the boat has to return to the surface.

Following upon the order for the first submarine, *S.* 1, the Admiralty placed orders for two others, namely, *S.* 2 and *S.* 3, the prefix " S " being adopted to indicate that they were Scotts' submarines. All three vessels are alike. Their length overall is 148 ft. 1½ in., the beam 14 ft. 5 in., and the draught, fully loaded, 10 ft. 4½ in., at which the displacement is 265 tons; and in submerged condition with the superstructure empty, 390 tons. The engines, to which reference will be made presently, give a maximum surface speed of 13·25 knots when developing 650 brake horse-power. The radius of action at a surface speed of 8·5 knots is 1,600 nautical miles. The submerged speed when the propellers are driven by electric motors developing 400 brake horse-power is 8·5 knots, and the radius of action when submerged is 75 nautical miles at a speed of 5 knots. The vessels are fitted with two torpedo tubes, and carry two spare torpedoes, in addition to a torpedo in each tube.

An interesting feature was the adoption of the Scott-Fiat Diesel engine, which differed from that in use in previously built British submarines, being of the reversible two-cycle type capable of using any kind of fuel oil. The specification required that the specific gravity of the fuel oil should not be less than 0·9, and that the engine should be able to start when using fuel of not less than 0·82 specific gravity and 150 degrees F. flashpoint without utilising compressed air, except for a few revolutions to attain compression. In view of the novelty, we may give a complete description.

The engines are of the six-cylinder Diesel marine type, each set capable of developing 325 brake horse-power at under 460 revolutions per minute, and on a weight of approximately seven tons without oil or circulating water. The engine is reversible, the operation of going from "full ahead" to "full astern" occupying less than ten seconds. It is of the two-cycle type, the scavenging air being provided by using the lower part of the stepped piston as an air pump. The air is drawn in and delivered through a piston valve operated by gearing from the vertical shaft which drives the cam-shaft. On the suction stroke the pump is in communication with the atmosphere; and on the delivery stroke with a chamber in the crank casing, where air is stored at a pressure slightly in excess of the engine exhaust. This scavenging air is admitted to the cylinder at the correct moment by mechanically operated scavenging valves in the cylinder head. The exhaust is by means of ports in the walls of the cylinder uncovered by the piston at the bottom of its stroke. The engine is started by compressed air, which may be admitted to three or six cylinders as required. The fuel is sprayed into the cylinder by compressed air, and is delivered to the six fuel-injection valves by a single pump. The regulation of the fuel supply is obtained by a mechanism which keeps the fuel pump suction valves open for a longer or shorter period according to the amount of fuel required. The compressed air for spraying the fuel is supplied by an air compressor of the three-stage type, worked by a crank on the main engine crank-shaft. The cooling water is delivered by a horizontal reciprocating pump driven by a single crank, which in turn is actuated by toothed gearing from the main engine crank-shaft. The lubricating oil is supplied by a wheel pump geared to the crank-shaft. All lubrication is forced, and the cooling of the piston heads is provided for by the circulation of lubricating oil through a chamber in the piston heads. The cylinders are 9⅝ in. in diameter and 10½-in. stroke; and the crank-shaft 5⅝ in. diameter. The propellers are of manganese bronze, three bladed, the diameter being 3 ft. 8 in., and the expanded area 5·06 square feet.

In addition to these boats of the "S" class, the Scotts built several other British submarines which were driven by oil

Plate XXXI.

THE SCOTT-FIAT OIL ENGINES FOR H.M. SUBMARINE "G.14."

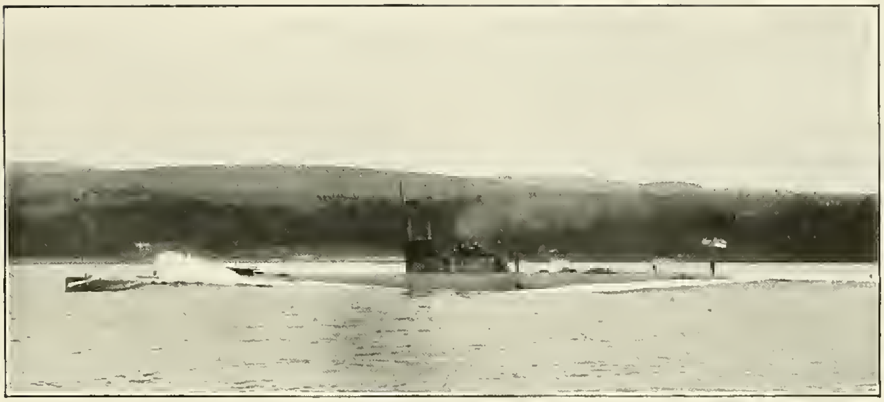
engines. Two of these were of the well-known " E " class, the overall length of which was 181 ft., the beam 22 ft. 8 in. over the side tanks, and the displacement when submerged 839 tons. One of these boats, *E.* 31, was fitted with five 18-in. torpedo tubes, two in the bow, two in the broadside, and one in the stern. Each tube was provided with one spare torpedo, the total carried being therefore ten. The radius of action at the cruising speed of 10 knots was 3225 nautical miles, with a total oil fuel capacity of 42 tons. A surface speed of 15 knots was obtained by twin screws, driven by 8-cylinder heavy oil engines of the four-cycle, vertical single-acting type, each developing 800 brake horse-power. The electro-motors for use with the vessel submerged developed 420 brake horse-power, giving a speed of 10 knots. The other " E " boat referred to was *E.* 51, which was of special type, being designed and fitted out for mine-laying. Another notable boat built by Scotts was of the " G " class, which, it is important to observe, had a double hull, arranged as in the " S " boats. This vessel, *G.* 14, was 187 ft. long, 22 ft. 8 in. beam, with a submerged displacement of 1026 tons, which was greater than in the " E " class, owing to the adoption of the double hull. Her twin-screw engines were constructed by Scotts, and were of the two-cycle reversible Scott-Fiat type. The armament comprised two 18-in. bow torpedo tubes, two 18-in. broadside tubes, and one 21-in. stern tube ; and, in addition, two guns were carried, one being of the disappearing type, with a calibre of 3 in., and the other, a 2-pounder high-angle-fire gun, for attacking aircraft.

Perhaps the most important development in connection with submarine work by the Scotts was the design of the first steam-driven submarine built for the British Navy. The lack of reliable and safe oil engines in the 'eighties and early 'nineties had induced the French naval authorities of that period to consider the question of reviving steam machinery for submarine craft. In 1896 Labœuf, the well-known French naval architect, had designed the *Narval* with steam engines for surface propulsion, and with electric motors for submerged running. Following this, several steam-driven submarine boats were built in France. But the heavy oil engine, largely owing to the introduction of the Diesel system, proved ultimately more acceptable, and it was adopted for all submarine craft by the British Government. There came a time, however, when the demand for extended spheres of activity called for higher speeds, and necessitated a reconsideration of the whole subject of prime movers for the surface propulsion of this type of craft. Scotts took up the question, and, prior to the war, laid down the vessel which was subsequently known as the *Swordfish*, the hull being built on the Laurenti principle, while the surface propelling engines were of the impulse reaction turbine type, driving twin propellers through reduction gear. Steam was supplied by a Yarrow boiler giving rapid steam generation, so arranged that it could be closed down quickly before the submergence of the vessel. The boiler had a large heating surface, and it is interesting to note that it contained a superheater element. The propelling machinery was designed to give more than double the power of the oil engines fitted in submarine vessels of that date.

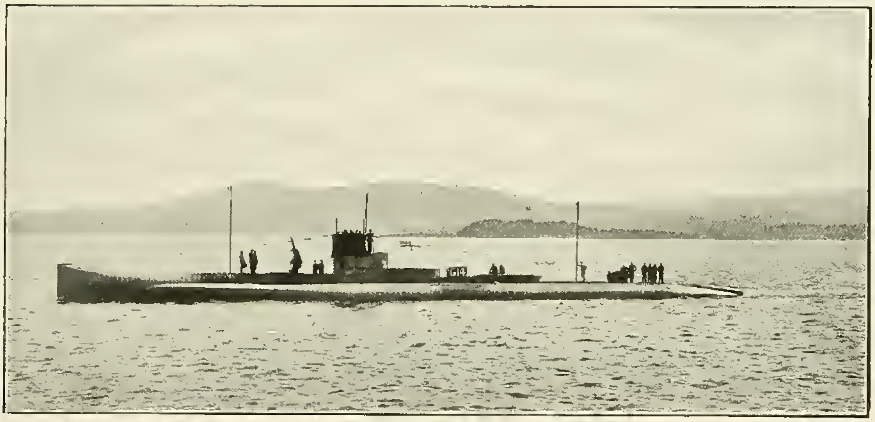
Many new problems, some of most difficult and intricate character, had to be solved by the Scotts in perfecting the design of the hull and machinery. A review of the improvements effected as a result of research and experiment may be deferred until we have given some details of the *Swordfish* as completed, and of the further development of steam propulsion of submarines, as embodied in the British vessels of the "K" class, of which she was the pioneer.

The *Swordfish* had a length overall of 231 ft. 3½ in., a beam of 22 ft. 11 in., and the total height from the bottom of the hull to the top of the periscopes when fully raised was 39 ft. 6 in. Her draught when loaded was 14 ft. 11 in. from the base line, the displacement then being 932 tons; the

Plate XXXII.



H.M. SUBMARINE "SWORDFISH" AT FULL SPEED.



H.M. SUBMARINE "G.14."

H.M. SUBMARINE "L.71."

maximum displacement when submerged was 1475 tons. The boiler and turbine machinery were designed to give a maximum speed of 18 knots, the radius of action at the cruising speed of 8·5 knots being 3000 nautical miles. The speed, when submerged, resulting from the working of the electric motors, was 10 knots. The *Swordfish* was fitted with two bow torpedo tubes and four amidships; and in all twelve torpedoes were carried. The vessel mounted two 3-in. 12-pounder guns in water-tight casings, and the ammunition carried was sufficient for 150 rounds. The hull was of the Laurenti type, already described, and the inner hull had no flat surfaces on any part subject to pressure due to submergence. Another feature was its subdivision into a number of comparatively small compartments isolated from one another by double doors in the bulkhead, so arranged that in the event of one compartment being flooded the pressure acted on the back of the doors only. Other features will follow to be dealt with in our analysis of the experimental work done and the improvements effected in design. The following is a brief description of the machinery when completed :—

Engines.—The boat is propelled by twin screws each driven by one set of geared turbines of the Parsons type. Each set of turbines comprises one high-pressure and one low-pressure turbine, arranged to work in series, and connected by flexible expansion couplings to toothed pinions actuating the main gear wheel on the propeller shafting at a speed of 530 revolutions per minute; the speed of the turbines is 3500 revolutions per minute, and the combined power of the two sets is 4000 shaft horse-power. An astern turbine is incorporated with each of the low-pressure turbine casings. The turbines exhaust to a Weir Uniflux condenser placed above them.

Boiler.—Steam is generated by one Yarrow-type boiler of 4551 square feet heating surface, including the superheater element, and is designed for a working pressure of 250 lb. per square inch. The steam is supplied to the engines through the superheater, which raises the temperature by 100° F.

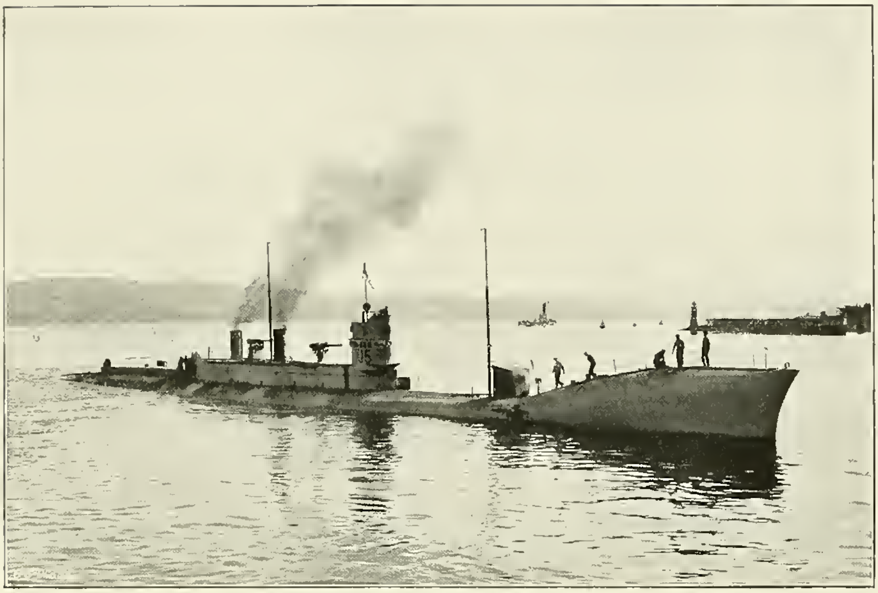
Boiler Room Ventilation and Funnel Operating Gear.—The forced-draught fans in the boiler room draw their air supply from the conning tower fairing, a proportion of the air being drawn also from the engine room through a door in the forward bulkhead, thus preventing an excessive temperature arising in that compartment. An auxiliary fan is mounted on the main fan spindle. This fan draws air from the boiler room and discharges it underneath the boiler, thus ventilating that space, the air being kept in circulation underneath the boiler, and back over the top into the stokehold.

In the funnel scheme a motor-driven sluice valve is provided at the underside of the main deck, the valve being placed with its face downwards. The motor is placed in the control room. Between the main-deck and the bridge level there is a water-tight casing which is capable of taking the submerged pressure. Within this casing the actual funnel casing is placed; this also extends to the bridge level. In the annular space between these two casings cooling water is constantly circulated. The funnel is hinged at the fore side, and swings through 180 degrees into the conning tower fairing. This operation is operated by the same motor as operates the sluice valve. In the case of breakdown the motor can be turned by hand. For closing the funnel aperture a water-tight cover is provided. This cover swings on a vertical shaft placed abaft the funnel casing. When in the closed position it joints on a rest bar which is bolted to the top of the external casing.

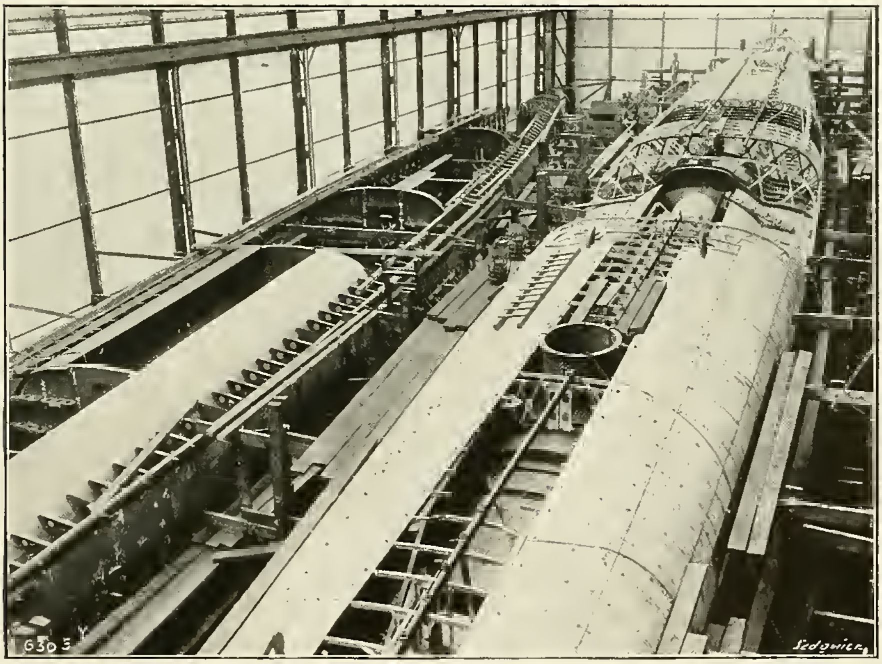
The cover is swung and clipped by means of two handwheels placed in the control room. It is raised and lowered by a hydraulic motor, and its weight whilst being swung is taken on spring rollers which run on rails on the bridge.

Auxiliaries.—The steam-driven auxiliaries are as follows:—Air pump, circulating pump, and forced lubrication pump in the engine room; turbo fan for forced draught, two feed pumps and two oil-fuel pumps in the boiler room. The following are also fitted:—Chain-driven oil and water pumps, an oil cooler and an evaporator, in the engine room; and an oil-fuel heater and a feed-water heater in the boiler room.

As already stated, the *Swordfish* was the typeship and basis for the class which embraced the largest submarines built for the British Navy; of this class the Scotts supplied and fitted on board the main propelling machinery for *K.* 5 built at Portsmouth, and constructed and completed in all respects *K.* 15, a later vessel of the class. The "K" boats had a displacement when submerged of 2815 tons, being 339 ft. long overall, with a beam of 26 ft. 6 in. They were of the double hull construction, as in the *Swordfish.* The speed was 25 knots on the surface, power being obtained from twin sets of geared steam turbines, which together developed a shaft horse-power of 10,500. Steam was generated in two Yarrow-type boilers working at a pressure of 235 lb. per square inch. The turbine



H.M. SUBMARINE "K.15."



SUBMARINES UNDER CONSTRUCTION IN SHED.

machinery was supplemented by an 800 brake horse-power heavy oil engine coupled to a dynamo, an arrangement which enabled the turbines to be reserved for higher speeds only. The dynamo, in addition to charging the batteries, supplied the main motors with power for running at cruising speed. In this case the propeller shaft was driven by electric motors through helical gearing, the ratio of reduction being 5 : 1. The armament included four bow and four broadside tubes of 18-in. diameter, and the vessel carried a spare torpedo for each tube. The guns were carried on a superstructure above the deck, and included one 4-in. gun and one 3-in. gun for high-angle fire.

The evolution of the design of the steam-driven turbine for the *Swordfish* involved extensive research and experiment. A review of this is not only interesting from the historical standpoint, but discloses the originality of invention of the design department of Scotts. It indicates also that experiments were carried out on an extensive scale, and that tests were made at each stage to ensure satisfactory results.

When the gear for operating the vertical and horizontal rudders for the *Swordfish* came up for consideration, it was felt that something better might be fitted than the usual electric drive, which had the objectionable feature that it involved a motor running intermittently. After a considerable amount of original designing work on various alternative arrangements, the Williams-Janney hydraulic power unit was adapted by Scotts, and proved to fulfil the requirements admirably. Subsequently the "E," "G," and "K" classes of submarines were similarly fitted, and later on this became the universal practice in submarines.

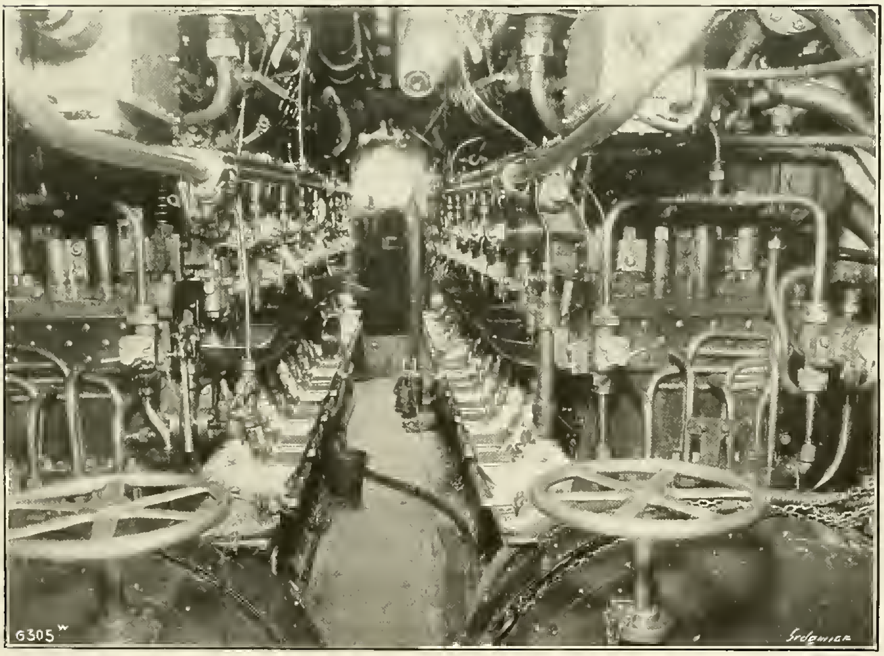
As the *Swordfish* was the first British submarine to be steam-propelled, many new problems had on this account to be faced in connection with the machinery.

For the housing of the funnel and the closing up of the ship for diving numerous designs were made embodying ingenious ideas, and from these an arrangement was ultimately adopted for employing electric gear for hinging down the funnels, and hydraulic gear for operating the water-tight cover which closed the funnel aperture. The whole operation of closing down took just over a minute, which was considered good at that time. The earlier "K" vessels were fitted with electric funnel-operating gear, but for *K.* 15, which they built, funnel gear of the hydraulic type was designed by Scotts. When this gear was installed in the vessel, it was found to be simpler, more reliable, and quicker in operation than the electric gear; the funnels and water-tight covers, which were connected by gearing, being closed in ten seconds. Hydraulic funnel gear was fitted in all subsequent vessels of the "K" class.

A new and far-reaching departure from established practice was made when Scotts designed a telemotor system, whereby valves at a distance could be operated by the pressure of oil led in pipes from a central position. In the *Swordfish* this system was applied successfully to the numerous valves required for flooding and venting the water-tight superstructure. The telemotor system is peculiarly suited to the conditions obtaining in submarines, and may be applied in various directions. The idea has been utilised in boats following the *Swordfish,* comprising the British "G," "J," "K," and "L" classes.

A compensated oil-fuel system was fitted in connection with *S.* 1, by means of which sea water was automatically admitted to the fuel tanks to take the place of the oil fuel consumed in the internal-combustion engines. By this expedient the trim of the vessel was preserved, a most important consideration in submarines. A similar arrangement was fitted to the *Swordfish,* and later to the "G," "K" and "L" classes. With the compensated oil-fuel system, a slight pressure was maintained in the oil-fuel tanks, so that it was not practicable to use ordinary sounding rods for oil measuring purposes. To overcome this difficulty, an apparatus was designed and patented by Scotts which embodied a new principle, and was

SUBMARINE INTERIOR, VIEW IN MOTOR CONTROL ROOM.



SUBMARINE INTERIOR, VIEW IN ENGINE ROOM.

found to be extremely satisfactory in practice. The " K " and subsequent classes were fitted with the arrangement.

In the " K " class submarines an emergency arrangement was found to be necessary to cut out the main electric motors automatically, in the event of their having been inadvertently left in gear when the revolutions of the turbines reached a predetermined maximum, beyond which it was not advisable to run the motors. An arrangement was devised by the Scotts which met the peculiar conditions and proved so reliable in operation that it was fitted in nearly all the vessels of the " K " class.

The torpedo tubes of the submarines *S.* 1, *S.* 2, and *S.* 3, and the *Swordfish*, included some novel features. In the three first vessels the rear doors of the tubes were of special quick-opening and closing form. The *Swordfish* was fitted with 21-in. bow torpedo tubes, and, on account of the size, it was decided that the bow caps should be operated by power. This was a departure from previous practice, and the electrical arrangement devised for the purpose gave entire satisfaction, being adopted in some of the later boats.

The advantage of central control in connection with submarines was appreciated from the outset, and in the *Swordfish* much time and attention was devoted to this matter, involving painstaking pioneer work in the designing departments. All the valves and fittings necessary for submerging and controlling the vessel when submerged were fitted in the control room, and were thereby under the immediate charge of the captain. In subsequent submarines built for the British Navy the tendency has been in the direction of central control along these lines.

When the *Swordfish* was under construction there were no available data for guidance as to the temperatures that would be experienced due to the closing down of the machinery spaces of such a vessel. Arrangements were made, therefore, for taking very complete records of the temperatures under these conditions. Temperatures were taken at half-hour intervals

TABLE VII.

WORK FOR THE GREAT WAR FLEET, 1914–1918.

Particulars of Vessels.

(For particulars of machinery, see Table VIII.)

Type and Name of Vessel.	Date of Launch.	Dimensions in Feet. Length × Breadth × Draught.	Displacement. (Tons.)	Horse-power.	Speed. (Knots.)	Armour.		Guns.	Torpedo Tubes.
						Belt.	Deck.		
Battleships—									
**St. Vincent*	1908	500×84×27	19,250	28,200	21·67	10″	¾″–1¾″	Ten 12-in., eighteen 4-in., four 3-pdr., five maxim	3
Colossus	1910	510×85×27	20,000	29,300	21·57	11″–3″	2½″	Ten 12-in., sixteen 4-in., four 3-pdr., five maxim	3
Ajax	1912	555×89×27·5	23,100	32,900	21·85	12″–6″	—	Ten 13·5-in., sixteen 4-in., four 3-pdr.	3
Armoured Monitor—									
Sir John Moore	1915	320×90×10	5,906	2,600	7·75	6″	2″	Two 12-in., two 6-in., two 3-in. A.A., two maxim	—
Light Cruisers—									
**Conquest*	1915	420×41 ×13·5	3,750	40,000	29	3″	—	Two 6-in., eight 4-in.	4
Caradoc	1916	425×42·75×13·5	3,890	40,000	29	3″	—	Five 6-in., two 3-in. A.A.	8
Dragon	1917	445×46·0 ×14·25	4,723	40,000	29	3″	—	Six 6-in., two 3-in. A.A.	12
Destroyers—									
Obedient	1915	265×26·8×8·8	1,123	25,000	34	—	—	Three 4-in. Q.F., one 2-pdr. A.A.	4
Obdurate	1916	265×26·8×8·8	1,123	25,000	34	—	—	,, ,, ,,	4
Paladin	1916	265×26·8×8·8	1,123	25,000	34	—	—	,, ,, ,,	4
Plucky	1916	265×26·8×8·8	1,123	25,000	34	—	—	,, ,, ,,	4
Parthian	1916	265×26·8×8·8	1,123	25,000	34	—	—	,, ,, ,,	4
Portia	1916	265×26·8×8·8	1,123	25,000	34	—	—	,, ,, ,,	4

* Machinery only by Scotts; ships built at Royal Dockyards.

TABLE VII—*continued.*

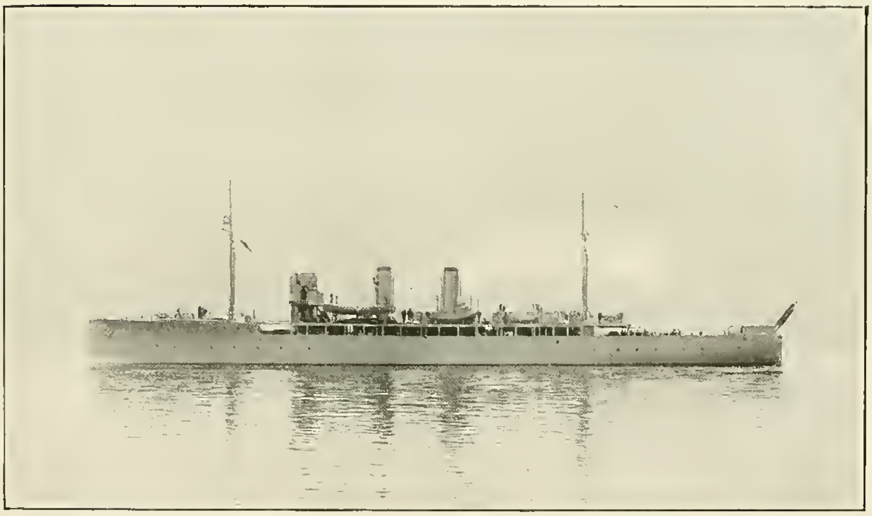
Type and Name of Vessel.	Date of Launch.	Dimensions in Feet. Length × Breadth × Draught.	Displacement. (Tons.)	Horse-power.	Speed. (Knots.)	Armour.		Guns.	Torpedo Tubes.
						Belt.	Deck.		
DESTROYERS—*cont.*—									
Tirade	1917	265×26·8×9·0	1,123	27,000	34	—	—	Three 4-in. Q.F., one 2-pdr.	4
Ursula	1917	265×26·8×9·0	1,123	27,000	34	—	—	" " "	4
Westminster	1918	300×29·6×8·1	1,425	27,000	33	—	—	Four 4-in. Q.F., one 3-in. A.A.	6
Windsor	1918	300×29·6×8·1	1,425	27,000	33	—	—	" " "	6
Swallow	1918	265×26·8×9	1,123	27,000	34	—	—	Three 4-in. Q.F., one 2-pdr.	6
Strenuous	1918	265×26·8×9	1,123	27,000	34	—	—	" " "	6
SUBMARINES—									
S. 1	1914	148·1×14·4×10·3	390	650	13·25 surface	—	—	—	2
S. 2	1915	148·1×14·4×10·3	390	650	13·25 "	—	—	—	2
S. 3	1915	148·1×14·4×10·3	390	650	13·25 "	—	—	—	2
E. 31	1915	181 ×22·6×12·6	839	1,500	15 "	—	—	Two 3-in.	5
E. 51	1916	181 ×22·6×12·6	839	1,600	15 "	—	—	Two 3-in., twenty mine tubes	3
G. 14	1917	187 ×22·6×13·5	1,026	1,600	14·5 "	—	—	One 3-in., one A.A.	5
Swordfish	1916	231·3×22·9×14·9	1,475	4,000	18 "	—	—	Two 3-in.	6
**K.* 5	1916	339 ×26·5×15·9	2,815	10,500	25	—	—	Two 5·5-in., one 3-in. A.A.	10
K. 15	1917	339 ×26·5×15·9	2,815	10,500	25	—	—	" " "	10
MINESWEEPERS—									
Bluebell	1915	255·25×33·5×11·0	1,207	2,200	17	—	—	Two 4-in., two 3-pdr.	—
Daffodil	1915	255·25×33·5×11·0	1,207	2,200	17	—	—	" "	—
Magnolia	1915	255·25×33·5×11·0	1,207	2,200	17	—	—	" "	—
DEPOT SHIP—									
Maidstone	1912	320×45×15·9	3,563	2,800	14·25	—	—	—	—
FLEET AUXILIARY—									
**Servitor*	1914	200×34×12·6	1,800	450	8	—	—	—	—

* Machinery only by Scotts; ships built at Royal Dockyards.

in all the required positions, and the data collected proved that the temperatures did not rise very much after closing down—that they were indeed not higher than existed in parts of the boiler rooms of torpedo boat destroyers and light cruisers. It had been anticipated that there would be considerable rise in temperatures in proportion to the time the vessel was closed down, but the records, taken subsequently on sea trials submerged, did not bear this out; and, while the temperatures increased up to a point, they were always within reasonable limits.

In addition to the question of temperatures, another important problem which came up for consideration referred to the quality of air in the boiler room, due to closing down with steam up, and advantage was taken of the temperature trials to investigate the matter. It was necessary to know if it would be safe for a man to enter the boiler room at any time after closing down, as it was feared that there was a possibility of harmful vapours arising from drops of oil fuel reaching the hot plates. To determine the point, samples of air were drawn at intervals throughout the trials from the boiler room by means of specially designed connections. The samples were chemically analysed, and the analyses recorded. Special tests were also made for light hydrocarbon vapour and explosive vapour, but no trace of these vapours could be detected. It was found that even under the worst conditions that could exist, that is, with the boiler room closed down and steam up, without the vessel being submerged, the air in the boiler room remained safe for breathing purposes, and that no liability of explosion existed when relighting the burners. The information obtained by these trials, both as regards temperature and quality of air when closed down after running, was invaluable in the light of the developments which were projected at that time, and subsequently carried out by the naval authorities in connection with the "K" class of steam-propelled submarines.

H.M. ARMOURED MONITOR "SIR JOHN MOORE."



H.M. MINESWEEPER "MAGNOLIA."

In the Laurenti type submarines various safety appliances were introduced which had not hitherto been fitted in British submarines. It will be of interest to enumerate some of these devices. Each boat was fitted with safety buoys which were capable of being released from the interior of the boat, and, by means of attached lines, arrangements could then be made for raising the vessel. A telephone buoy was also provided. This buoy was arranged to be released from the control room, and carried, in addition to the telephone transmitter and receiver, a food pipe, through which liquid food could be passed from the surface. In the case of the *Swordfish*, the telephone buoy was further improved by the fitting of an electric lamp to indicate its position in the dark. Another safety arrangement provided an emergency fresh-air pipe extending through all the habitable spaces. This pipe was always charged with high-pressure air which could be released at will into any compartment, thus helping to freshen the air.

We may now pass on to the consideration of a few ships of different types built by the Scotts for the auxiliary services of the war fleet.

A ship which performed much useful work during the war was H.M.S. *Maidstone*, built in 1910, to serve as a depot ship for submarines; she was the first of her type. This vessel was completely equipped with workshops, including an engineer's machine shop, smithy and foundry, and had all the accessories required by a mother ship for supplying the needs of submarines. Amongst these auxiliaries were included five electric generators, three high-pressure air compressors, and one set of ice-making machinery. She was able to deal with all repairs to submarines except those of a very serious nature, and large store rooms were provided for stocking spare parts of machinery and consumable stores, while oil fuel bunkers were arranged for the fuelling of submarines alongside. In addition to the accommodation for her crew, the *Maidstone* was provided with cabins, berthing spaces and hospitals, for

TABLE VIII.

WORK FOR THE GREAT WAR FLEET, 1914–1918.

PARTICULARS OF MACHINERY.

(For particulars of vessels, see Table VII.)

Type and Name of Vessel.	Horse-power.	Propeller Revolutions.	Number of Shafts.	Boilers.		Particulars of Machinery.
				Number.	Type.	
BATTLESHIPS—						
**St. Vincent*	28,200	330	4	18	B. and W.	Direct-driving Parsons reaction turbines.
Colossus	29,300	337	4	18	,,	,, ,, ,, ,,
Ajax	32,900	347	4	18	,,	,, ,, ,, ,,
MONITOR—						
Sir John Moore	2,600	189	2	2	B. and W.	Reciprocating triple-expansion engines.
LIGHT CRUISERS—						
**Conquest*	40,000	580	4	8	Yarrow	Direct-driving Parsons turbines with geared cruising turbines.
Caradoc	40,000	335	2	6	,,	Geared Parsons turbines with geared cruising turbines.
Dragon	40,000	270	2	6	,,	Geared Brown-Curtis turbines with cruising turbines.
DESTROYERS—						
Obedient	25,000	750	3	3	Yarrow	Direct-driving Parsons reaction turbines.
Obdurate	25,000	750	3	3	,,	,, ,, ,, ,,
Paladin	25,000	750	3	3	,,	Direct-driving Parsons turbines with geared cruising turbines.
Plucky	25,000	750	3	3	,,	,, ,, ,, ,,
Parthian	25,000	750	3	3	,,	,, ,, ,, ,,
Portia	25,000	750	3	3	,,	,, ,, ,, ,,
Tirade	27,000	340	2	3	,,	Geared Brown-Curtis turbines.
Ursula	27,000	340	2	3	,,	,, ,, ,,
Westminster	27,000	340	2	3	,,	,, ,, ,,

* Machinery only by Scotts; ships built at Royal Dockyards.

TABLE VIII—*continued.*

Type and Name of Vessel.	Horse-power.	Propeller Revolutions.	Number of Shafts.	Boilers.		Particulars of Machinery.
				Number.	Type.	
DESTROYERS—*cont.*						
Windsor	27,000	340	2	3	Yarrow	Geared Brown-Curtis turbines.
Swallow	27,000	340	2	3	"	" " "
Strenuous	27,000	340	2	3	"	" " "
SUBMARINES—						
S. 1	650	430	2	—	—	Scott-Fiat two-cycle reversible oil engines.
S. 2	650	430	2	—	—	" " " "
S. 3	650	430	2	—	—	" " " "
E. 31	1,600	380	2	—	—	Four-cycle oil engines (supplied by Admiralty).
E. 51	1,600	380	2	—	—	" " " " "
G. 14	1,600	430	2	—	—	Scott-Fiat two-cycle reversible oil engines.
Swordfish	4,000	530	2	1	Yarrow	Geared Parsons impulse reaction turbines.
**K.* 5	10,500	380	2	2	"	Geared Brown-Curtis turbines.
K. 15	10,500	380	2	2	"	" " "
MINESWEEPERS (SLOOPS)—						
Bluebell	2,200	170	1	2	Cylindrical	Reciprocating triple-expansion engines.
Daffodil	2,200	170	1	2	"	" " "
Magnolia	2,200	170	1	2	"	" " "
DEPOT SHIP—						
Maidstone	2,800	180	2	4	Cylindrical	Reciprocating triple-expansion engines.
ROYAL FLEET AUXILIARY—						
**Servitor* (oil tank)	450	200	2	—	—	Scott-Fiat two-cycle reversible slow-running oil engine.

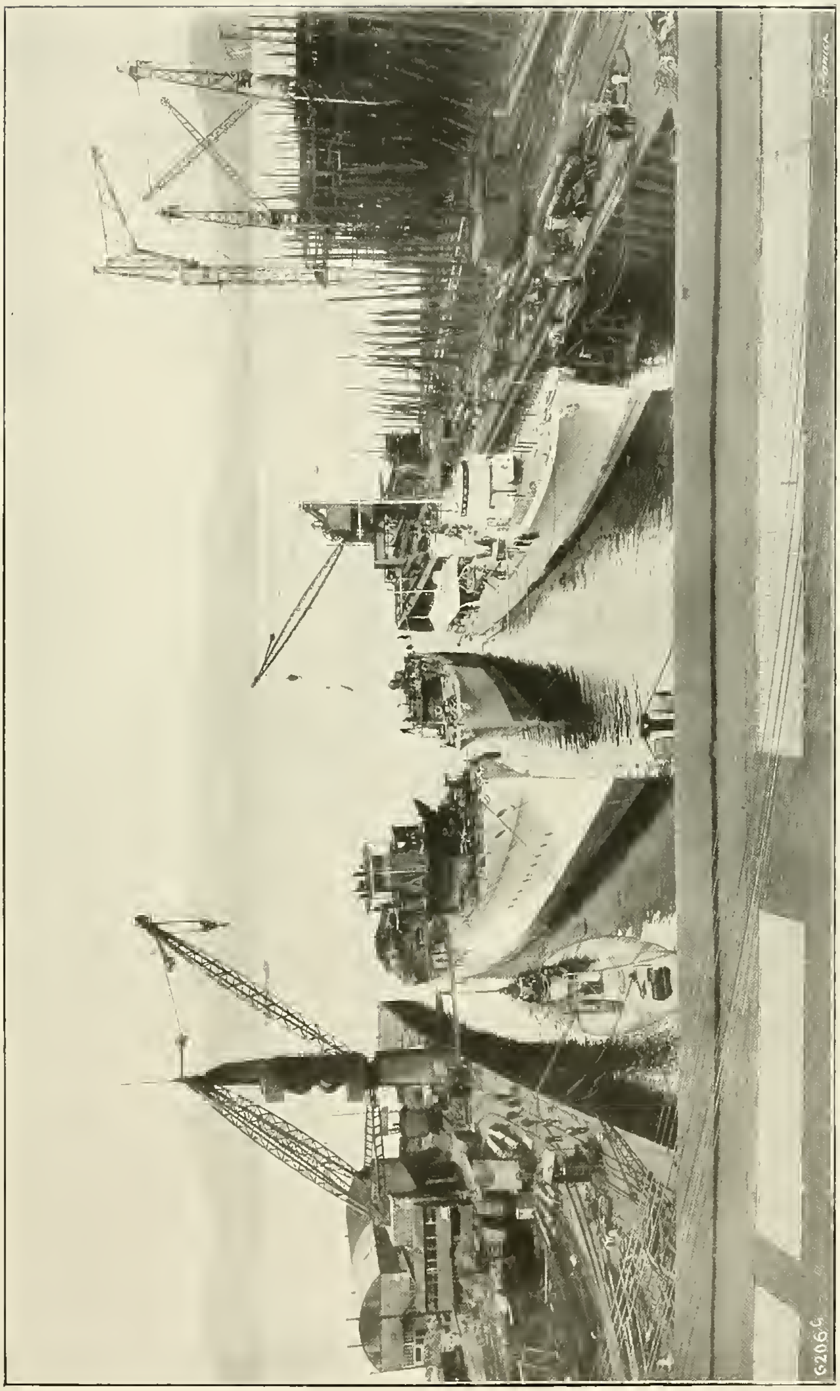
* Machinery only by Scotts; ships built at Royal Dockyards.

the use of the officers and men in training and "standing by" to act as crews for submarines. The main propelling machinery consisted of two sets of triple-expansion engines, developing a total horse-power of 2800 when running at about 180 revolutions per minute. The four boilers fitted were of the cylindrical type, working under forced draught on the closed stokehold principle.

One of the monitors—the *Sir John Moore*—which did such splendid work on the Belgian coast and elsewhere during the war, was launched in May, 1915, and completed in the same year within twenty-four weeks of the laying down of the keel. Reference is made on page 163 to this ship as an outstanding example of rapid construction. It is interesting to note that on account of the great beam the unusual expedient was adopted of launching from three lines of sliding ways. The *Sir John Moore* was 320 ft. in length overall, of 90 ft. beam, and displaced 5906 tons. She was designed for shallow draught, and had bulge protection for the greater proportion of her length. Her armament included two 12-in. guns mounted in one barbette, two 6-in. guns, two 12-pounder guns, one 2-pounder pom-pom in high-angle pedestal, two 3-in. high-angle guns and two Maxim guns. The propelling machinery consisted of two sets of triple-expansion engines driving twin screws and developing 2600 horse-power, the boilers being of the Babcock and Wilcox type. This machinery gave the monitor a speed of $7\frac{3}{4}$ knots, but speed was not a material factor in the war work of this type of vessel. The important features were rather the large gun power and the light draught, combined with the bulge protection of the hull, which gave the ship great striking power and little liability to serious disablement from torpedo attack.

Amongst the other vessels built for the war fleet were three of the special sloops required for mine-sweeping. These were named the *Bluebell*, the *Daffodil* and the *Magnolia*, and belonged to the boats known as the "Flower" class. The sloops had a length between perpendiculars of 255 ft. 3 in., and over-

Plate XXXVI.



VARIOUS TYPES OF WARSHIPS IN THE FITTING-OUT BASIN.

TABLE IX.
WORK FOR THE GREAT WAR FLEET.

PARTICULARS OF WORK IN HAND AT THE BEGINNING OF 1919.

Note.—A considerable amount of work was done on these vessels during the War period.

Type and Name of Vessel.	Keel Laid.	Dimensions in Feet. Length × Breadth × Draught.	Displacement Tonnage.	Horse-power (Shaft or Indicated).	Number of Shafts.	Particulars of Machinery.
LIGHT CRUISER—						
Durban	January, 1918	445·0×46·0×14·25	4,723	40,000	2	Geared Brown Curtis turbines, with cruising turbines.
DESTROYERS—						
Stronghold	March, 1918	265×26·8×9·0	1,123	27,000	2	Geared Brown Curtis turbines.
Sturdy	March, 1918	265×26·8×9·0	1,123	27,000	2	,, ,, ,,
**Wheler*	July, 1918	300×29·6×8·1	1,425	27,000	2	,, ,, ,,
**Whelp*	—	300×29·6×8·1	—	27,000	2	,, ,, ,,
SUBMARINES—						
L. 71	September, 1917	235·4×24·4×13·75	1,307	2,400	2	Four-cycle oil engines (supplied by Admiralty).
**L.* 72	December, 1917	235·4×24·4×13·75	1,307	2,400	2	,, ,, ,,

* These vessels were subsequently cancelled.

all of 267 ft. 9 in., the beam being 33 ft. 6 in. The load draught was 11 ft., and the displacement tonnage about 1207 tons. They were fitted with triple-expansion engines driving a single screw of sufficient power to give a speed of 17 knots. Their armament consisted of two 4-in. guns and two 3-pounders. The machinery for a number of the sloops subsequently built by other firms was made from the specifications and drawings prepared at this time by Scotts under Admiralty approval.

In addition to the new ships built a valuable contribution to the war effort was made in the docking and repairing of ships during the period of the war. In all, 190 vessels were overhauled, some of them very extensively, and the list included practically all types—one battleship, six cruisers, fifty torpedo boat destroyers, twenty-one mine-sweepers, four gun-boats, thirteen submarines, four armed merchant cruisers, eleven tugs, two battle targets, fourteen R.F.A. oil ships, forty-three patrol yachts, fourteen trawlers and a number of M.L. boats.

At the beginning of 1919 the firm had in hand a number of vessels for the Navy, as shown on Table IX, on which a considerable amount of work was done during the period of hostilities. Of these the following were delivered during the year: the light cruiser *Durban*, the torpedo-boat destroyers *Stronghold* and *Sturdy*, and the submarine L. 71.

Looking back over the whole period of war work activity of the Scotts, it is pleasing to record that the work was carried out in a fine spirit, which permeated all classes from the management to the lowest rank. The extent and originality of the work done is certainly highly creditable to the staff and workers.

The record of Scotts' work for the war would be incomplete without a reference to the large number of men who, in the early stages, at once joined up in each of the sections of our fighting forces. Many of these have made the supreme sacrifice, and it is appropriate that this record should be supplemented by a list of "our glorious dead." This will be found on pages 178 to 181.

Plate XXXVII.

THE HOLT LINER "ACHILLES," OF 1900.

The Merchant Ships of the Twentieth Century.

PROPHECY has its allurements, even in the domain of applied mechanics, and having reviewed progress during the past two centuries in naval architecture as embodied in sailing ships, merchant steamers, warships, submarines and other craft, there is a temptation to speculate on the prospects of the future. The possibilities of electric propulsion and water jet propulsion, and the problems which stand in the way of the application of the universally desired internal-combustion turbine, are topics which would prove interesting, even although no conclusion could be arrived at.

The historian, however, is not concerned with the future, and the justification for the title given above is the intention here briefly to review the state of marine construction, as represented by typical vessels recently built or being built by Scotts. It is difficult where so many ships of distinctive design and equipment have been constructed to select a few representative types. Amongst the countries which have had new ships in more recent years are France, Russia, Italy, Denmark, Holland, Portugal, Greece, India, the Straits Settlements, China, Australia, New Zealand, Brazil and other South American Republics, and the United States of America.

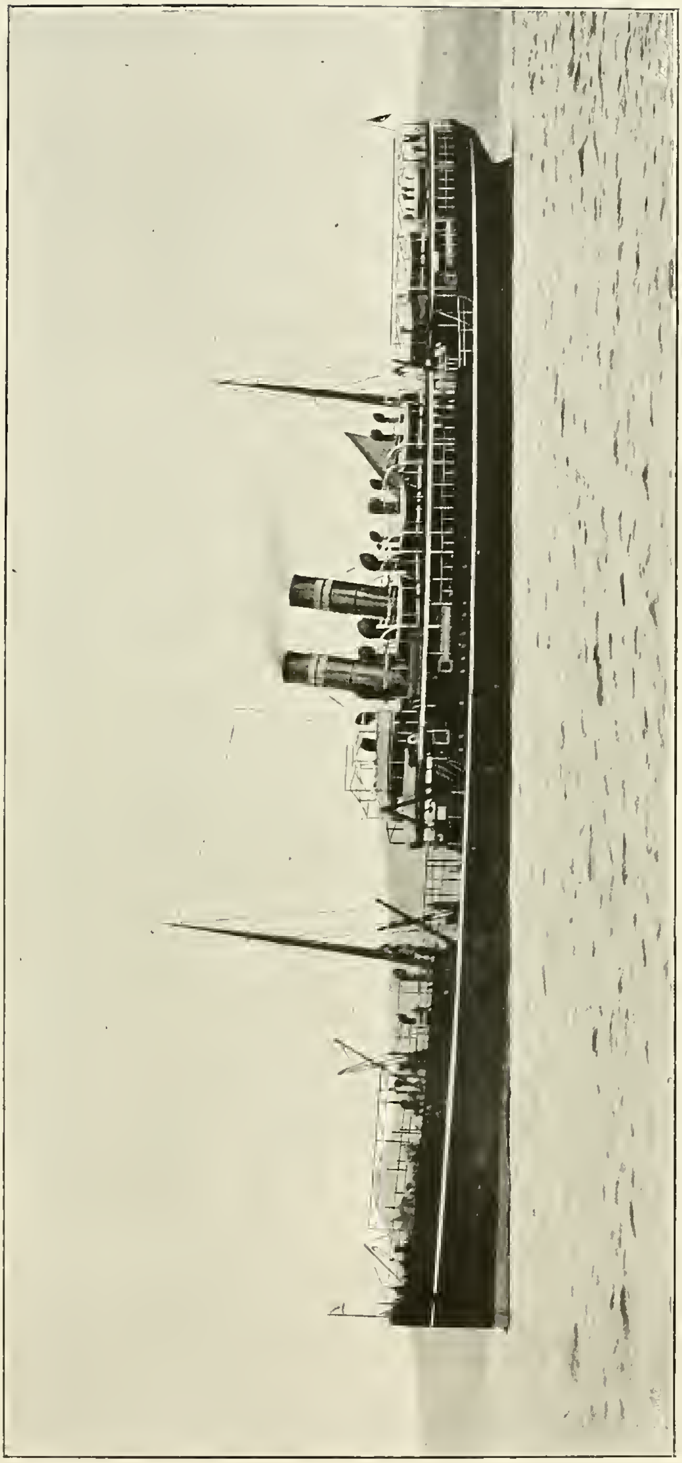
This list of foreign *clientèle*, however, is being diminished, owing to the influence of the subsidies paid by foreign Governments to shipowners and shipbuilders.

Taking account only of the large vessels built by the Scotts during the past sixty years, there were four for the North Atlantic trade ; one hundred and twenty-four for the China Seas ; twenty-six for the Indian Ocean ; nine for the South African Seas ; thirty-four for South American waters ; eighteen for the Colonial Services ; and one hundred and eighty-four for the European Coast, while for home waters there were many more.

One of the gratifying features in connection with the commercial relationships of the Scotts is the continuance of confidence, over a long period of years, of several large steamship companies ; this is perhaps the best indication of the satisfactory character of the work done. The Holt Lines have had built for them by the Scotts, within fifty years, sixty-three vessels of an aggregate of 248,032 tons. The China Navigation Company, for whom the Scotts started building in 1875, have had sixty-seven vessels, aggregating 122,633 tons. The vessels of this latter company have been an important factor in the development of trade in China, and, together with the Holt liners, have done much for the advancement of British interests in the Far East. An important continental firm has had twenty-one vessels, while for a Portuguese company five large vessels were built, and for the French Transatlantic Company eleven fast liners.

As regards fast steamers, the recent warships, ranging in speed up to 35 knots, and described in preceding chapters, may be accepted as indicative of the ability of the Scotts to solve the problems of marine propulsion. But it must be remembered that the maritime predominance of Britain is due more to that enormous fleet of moderate-sized, intermediate and cargo ships, which maintain exceptionally long voyages with regularity and economy than to the fast ships on comparatively

Plate XXXVIII.



THE BRITISH INDIA COMPANY'S S.S. "BHARATA," 16 KNOTS, BUILT IN 1902.

short routes. Taking the period before which the comparison is influenced by war losses, we find that of the total number of ships, British and foreign, included in *Lloyd's Register*, 1915–1916 (24,500), less than two and a-half per cent. had a speed of over 16 knots, which in itself proves that economy rather than speed is the controlling consideration.

TABLE X.—NUMBERS OF BRITISH AND FOREIGN SHIPS, CLASSIFIED ACCORDING TO THEIR SPEED, FROM "LLOYD'S REGISTER," 1915-1916.

Speed.	Number of Vessels Registered.		
	British.	Foreign.	Total.
25 knots and over	2	—	2
22 knots to 25 knots	21	20	41
20 knots to 22 knots	40	39	79
19 knots to 20 knots	26	10	36
18 knots to 19 knots	64	39	103
17 knots to 18 knots	68	65	133
16 knots to 17 knots	108	92	200
Total number of ships of 16 knots speed and over	329	265	594
Total number under 16 knots speed	9889	14,025	23,914
Total number of ships—100 tons gross and over	10,218	14,290	24,508
Percentage number of ships over 16 knots speed	3·22	1·89	2·49

Several notable liners have been built by the Scotts in recent years for the Cunard, Booth, Donaldson and Leyland Companies, and these may be accepted as representative of the most useful types of steamer in the British merchant fleets. First, reference may be made to the *Transylvania*, ordered by the Cunard Company in 1913. She was notable as being the largest merchant ship built on the lower reaches of the Clyde at the time of her launch, and still more as she was the first Atlantic liner fitted with geared turbines. She had a length of 548 ft., a beam of 66 ft. 3 in., and a depth of 45 ft. Her gross tonnage was 14,500 tons, and she carried 2380 passengers, in addition to about 8400 tons deadweight. The large passenger accommodation and cargo capacity in conjunction with the economy of the engines in fuel and stores, rendered the *Transylvania* a most valuable revenue earner for her size. The special feature of the vessel was the propelling machinery.

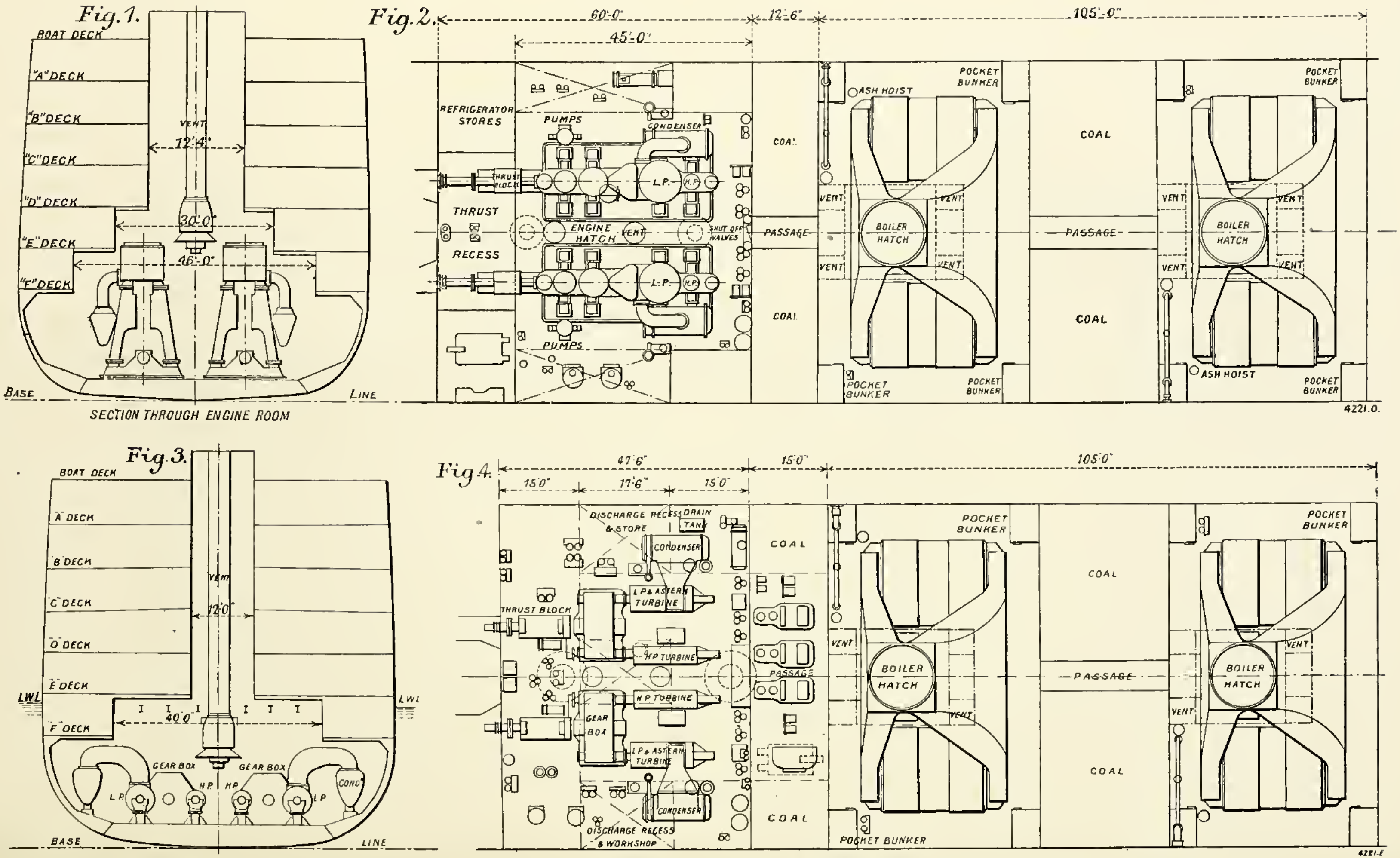
The original design was prepared for reciprocating engines of the quadruple-expansion type of 9500 indicated horse-power driving twin screws. The economy claimed for geared turbines induced the Cunard Company, when the vessel was in the earlier stages of construction, to substitute this type of machinery for the quadruple-expansion engines, and it is therefore possible to make a direct comparison between the two types of machinery as designed. On Plate XL there is given a plan and cross-section of the installation as originally decided upon and underneath there are corresponding drawings, to the same scale, of the geared turbines as finally fitted. When it was decided to fit geared turbines it was too late to modify the stokehold arrangements, although less steam and fuel were required for the geared turbines, owing to their higher economy.

To take advantage of the relatively greater boiler power available under the new conditions, the turbines and gearing were designed for 11,000 horse-power, which resulted in a higher speed, namely, 16·75 knots against 15·5 knots. In the turbine arrangement the electric generators and refrigerating plant were placed between the engine-room and the aft boiler room, in a space which, in the quadruple-expansion engine design was given up entirely to coal, so that the space elsewhere in the ship, required for the electric and refrigerating machinery, was saved and rendered utilisable for cargo. It will also be noted that there was a considerable saving in the fore and aft length of the turbine room—amounting to 12 ft. 6 in.—as compared with the reciprocating engine room, notwithstanding the increased power of the turbines. The

Plate XXXIX.

T.S.S. "TRANSYLVANIA" FOR THE CUNARD COMPANY.

Plate XL.



ALTERNATIVE RECIPROCATING AND GEARED TURBINE MACHINERY FOR THE "TRANSYLVANIA."

cubic capacity of the machinery spaces was reduced by 10 per cent., and about one-third of this was available for increasing the first-class, second-class, and more particularly the third-class accommodation, so that the gain on this account was an important item. As regards the weight of machinery, the geared turbines enabled a reduction of 12 per cent. to be effected, which, in view of the increased power developed, was very satisfactory.

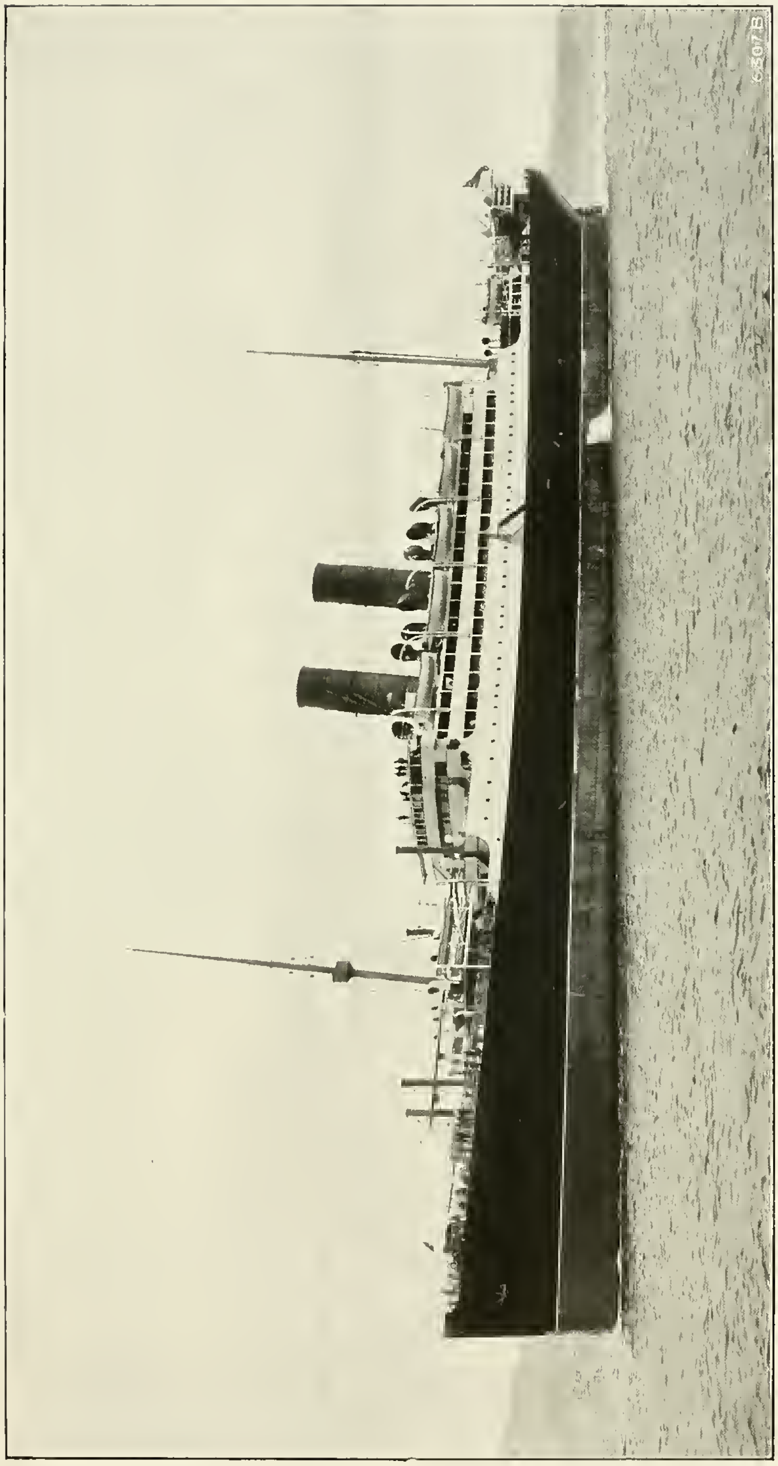
The turbines of the *Transylvania* ran at 1500 revolutions per minute, which gave a high thermal efficiency, while, by means of the gearing, the speed of the propeller was brought down to 120 revolutions, giving good propeller efficiency. Each propeller was driven by an independent set of compound turbines, the pinion on the inner side of the main gear wheel being driven by a high-pressure turbine, while the outer pinion was driven by a low-pressure turbine. The trials demonstrated that the vessel possessed admirable manœuvring qualities, the starting, stopping and reversing of the turbines being accomplished with great ease. The most distinctive feature was the absence of vibration.

The performance of the *Transylvania* on the Atlantic was a surer test than trial trip results, and an analysis made by the owners of the year's work as recorded in the logs of the vessel, showed that, at the service speed of 15·5 knots, the geared turbines gave an economy of about 15 per cent. in coal, oil and stores over quadruple engines of corresponding power. Naturally, therefore, the *Transylvania* marked an important stage in the development of turbine machinery, and since her date there has been a great increase in vessels propelled by geared turbines. In May, 1915, the vessel was converted into a troop transport, and was employed principally in the conveyance of soldiers to Egypt and Gallipoli. On this service she was unfortunately struck successively by two torpedoes. The first blow was in the vicinity of the engine room, but had little effect. The enemy, however, realising that the vessel would probably be towed into port, fired a second torpedo, which proved effective, the vessel going down with the loss of 413 lives.

When the Cunard Company re-entered the Canadian trade in 1911, after an interval of over forty years, they decided to build two specially designed vessels to popularise the St. Lawrence route, and placed the contract with the Scotts. The first of the vessels, the *Andania*, was completed about the middle of 1913, and her sister ship, the *Alaunia*, a few months later. Both ships had a length of 520 ft., a beam of 64 ft., and a depth moulded of 46 ft., having accommodation for 2078 passengers, with a crew of 289. The deadweight carrying capacity was 9450 tons on a draught of 28 ft. 2 in. Among notable features of the arrangements may be mentioned the placing of the main dining saloon on a deck below that used in most steamships, with the result that the space occupied was in the vicinity of the ship's vertical centre of gravity, an important factor in reducing the effect of rolling. The dining saloon extended the whole width of the ship, and permitted of nearly all the cabin passengers dining at one sitting. Another feature was the finely equipped gymnasium on the promenade deck. Special consideration was given to the accommodation for the third-class passengers, all being berthed in cabins, of which a considerable number were arranged for two persons ; comfortable dining and recreation rooms were also provided, while the deck space reserved was roomy and well placed, with both open and closed promenades.

The machinery was of the quadruple-expansion type, driving twin screws. Steam was generated in five double-ended boilers, and the power of 7500 horse-power gave the vessels a service speed of 14 knots, with a coal consumption of only 128 tons per twenty-four hours. Both vessels played a large part in the war. In 1915 the *Andania* housed, on an average, 1800 German prisoners, and subsequently became a transport on the Indian-Mediterranean service. Later she was used for

Plate XLI.



THE CUNARD LINER " ANDANIA "

similar service in the North Atlantic, and was torpedoed and sunk on January 27th, 1918. The *Alaunia* served from September, 1914, to October, 1916, as a troopship carrying Canadians to the scene of war. She struck a mine in the English Channel on October 19th, 1916, sinking subsequently, in spite of efforts made to beach her.

Early in 1916 the Cunard Company entrusted the Scotts with the construction of a large twin-screw passenger and cargo liner named the *Albania*, with propelling machinery, which in some respects formed a notable advance on anything hitherto attempted. Originally it was intended by the owners that the vessel should have single reduction geared turbines, supplied with saturated steam from cylindrical boilers burning coal under natural draught. The machinery, however, which was eventually decided upon for the vessel, as the result of a conference between the owners and builders, formed a complete departure from existing practice, which was quite in keeping with the progressive traditions of the Cunard Company. It was arranged that the engines should comprise two sets of Brown-Curtis turbines, driving twin screws through double-reduction gearing, steam being supplied from an oil-fired superheater, working in conjunction with water-tube boilers of the Yarrow type, which were arranged to burn oil fuel under forced draught on the Wallsend-Howden system. The three boilers, of large-tube type arranged abreast in the ship, and specified to work at 250 lb. per sq. in., were specially designed to meet the conditions prevailing in the merchant service. After the drawings had been completed and some of the material for the boilers delivered, it was decided by the owners to revert to coal-fired cylindrical boilers, fitted with smoke-tube superheating apparatus, owing to the anticipation of difficulty in procuring oil-fuel supplies, in view of the unsettled state of the markets at the time.

The decision to adopt water-tube boilers for this vessel, though not adhered to for the reason stated, is important, as it suggests that developments along these lines may be looked for. The claims of water-tube boilers have not been properly recognised in the past by owners of merchant shipping in this country, but the advantages, more especially for the larger powers and when burning oil fuel are so outstanding, that general recognition is bound to come in certain services.

Of the "standard" emergency cargo vessels built during the war, a considerable number were fitted with water-tube boilers of various types, and this will no doubt have an effect in familiarising owners with the subject and result in directing attention to the possibilities of these boilers for merchant work.

The dimensions of the *Albania* are 522 ft. in length by 63 ft. 9 in. beam, by 46 ft. 9 in. in depth. She is capable of carrying 500 passengers, and was at the time of ordering one of the greatest cargo carriers, her deadweight capacity being about 15,500 tons. The passengers are carried throughout on one 'tween deck only, so that this ship will be very popular in the second-class passenger trade on account of the relatively large amount of promenade and airing space allotted per passenger. The general equipment for dealing with the cargo is particularly complete and effective.

When the managers of the Booth Steamship Company saw some possibility of a tourist service to Spain, Portugal and Madeira, which might be conducted concurrently with, and without detriment to, the passenger service between hcme ports and South America, they decided to build a special vessel to encourage this trade. The contract was placed with Scotts, and the vessel, which was named the *Hildebrand*, was completed in April, 1911, and formed a notable addition to the Booth Line fleet. She was their largest vessel, and had all the appointments of an Atlantic liner, having accommodation for two hundred and twelve first-class passengers, four hundred and sixty-two third-class passengers, and a crew of one hundred and seventy-six. The dining saloon, which was finished in white and gold, was capable of seating two hundred and three

Plate XLII.

T.S.S. "HILDEBRAND," FOR THE BOOTH STEAMSHIP COMPANY.

persons at thirty small tables. On the promenade deck was a verandah *café*, smoking room, children's room and a music room ; the latter with walls of pale green, having dove coloured panels and a ceiling of finely modelled plaster work.

She was provided with a wireless telegraphic installation and with submarine signalling apparatus, which in those days was not so common as now ; she carried a motor launch of large size, for use as a passenger and mail tender.

The *Hildebrand* had a length of 440 ft., a beam of 54 ft., and a depth moulded of 38 ft., the gross tonnage being 6991 tons and the deadweight carrying capacity 6180 tons. The machinery was of the twin-screw quadruple type, balanced on the Yarrow Schlick and Tweedy system in order to reduce vibration, the further provision being made that the port propeller should run a few revolutions faster than the starboard, in order to avoid that synchronism which involved the vibration of the whole ship. The result of these arrangements was observed in the smooth running of the engines. This vessel during the war was converted into an auxiliary armed cruiser, acting efficiently and without mishap practically throughout the whole course of the war.

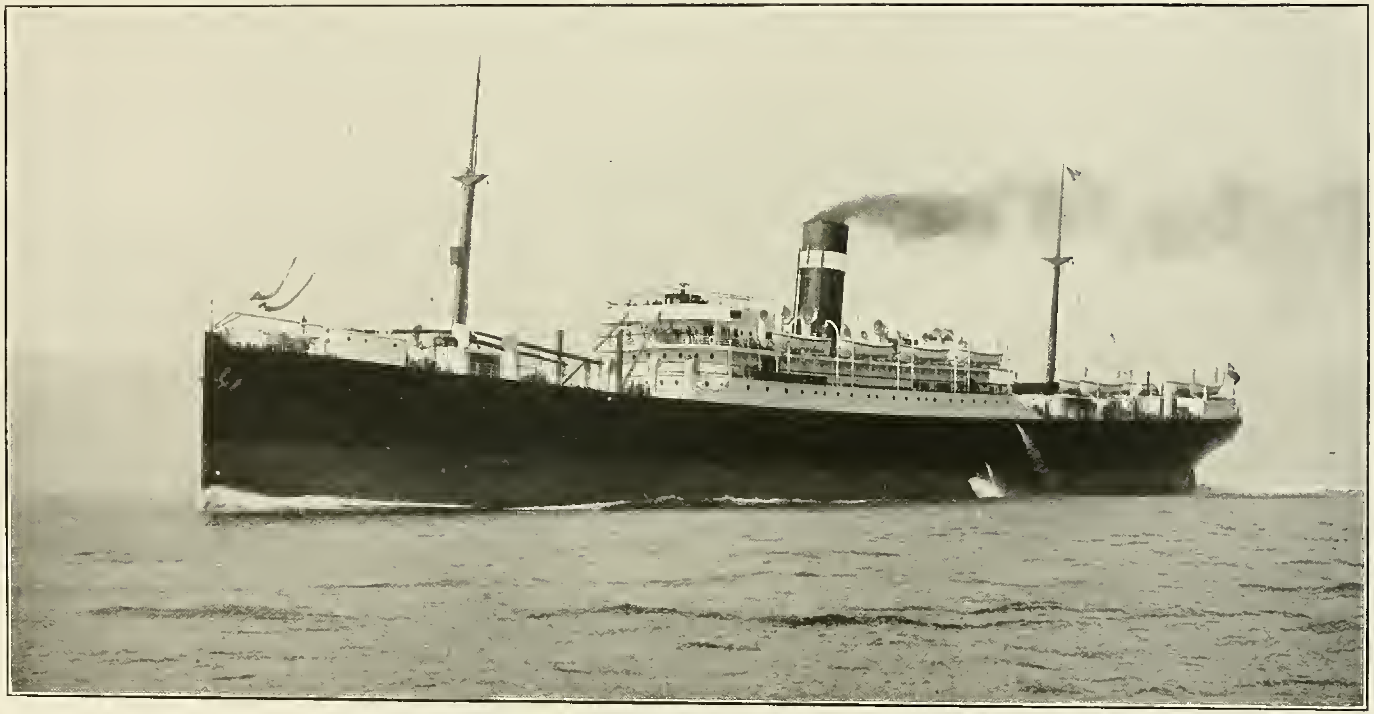
An earlier vessel built by the Scotts for the Booth line was the *Manco*, which was completed about the beginning of 1908. She was built for the Iquitos trade, which involved not only service in the Atlantic, but a voyage of some 2000 miles up the River Amazon. This necessitated special construction of details. For instance, the decks were of teak, and the construction of the deckhouses received special consideration. Complete awnings, too, were fitted fore and aft to suit the tropical conditions.

Owing to the absence of harbour equipment on the River Amazon, it was necessary to fit ten derricks, worked by powerful steam winches, with a special derrick capable of lifting 45 tons. The length of the vessel was 300 ft., the breadth 45 ft., and the depth 23 ft. 6 in. moulded. In addition to having accommodation, suitable for a tropical country, for sixty-two first-class passengers and a large number of third-class passengers, the vessel carried 3140 tons deadweight on the small draught of 20 ft. 10 in. The engines were of the triple-expansion type, with two cylindrical boilers worked under forced draught, and the service speed was about 12 knots. The *Manco* did service as an Admiralty store ship from December, 1914, to October, 1915, and later as a Government transport until August, 1916, returning then to her former service.

The Donaldson line had built for them in 1906 a ship named the *Cassandra*, which proved to be one of the most popular vessels in their fleet. An illustration of this vessel is given on Plate XLIII. facing this page. While primarily intended for the Atlantic passenger trade, she was of such moderate dimensions as to suit almost any service, having a length of 455 ft., between perpendiculars, a beam of 53 ft., and a depth of 32 ft. moulded. The displacement was 13,500 tons on a draught of 26 ft. While designed to carry 8000 tons deadweight, she had accommodation for a large number of passengers, who were afforded more room than on the larger and faster liners, with the same luxury and comfort. This latter fact accounts in a large measure for the growing preference of a great proportion of the travelling public for the intermediate ship. The vessel was propelled by triple-expansion engines driving twin screws and supplied with steam from two double-ended and two single-ended boilers.

The success of this vessel resulted in the owners placing an order with the Scotts for a larger vessel of similar design named the *Letitia*, which was completed in 1912. This vessel is illustrated on Plate XLIV. She had a length of 470 ft., a beam of 57 ft., and a depth of 39 ft. 6 in., and was designed for a speed of 13½ knots. She, like the *Cassandra*, had a great revenue-earning capacity, for she carried 1408 passengers, in addition to a crew of one hundred and fifty-four, and 8400 tons of

Plate XLIII.



THE ANCHOR-DONALDSON LINER "CASSANDRA."

deadweight on a draught of 27 ft. 1 in. The engines were similar to those of the *Cassandra*, but of greater power, and provided with steam from six boilers. The power developed was about 5500 indicated horse-power, and the coal consumption about 90 tons per twenty-four hours. Proof of the satisfactory character of the living quarters, alike as regards comfort and ventilation, is found in the fact that the vessel was engaged as a hospital ship from the beginning of the war. She was, unfortunately, wrecked in August, 1917, near Halifax.

For the Leyland Line there was built in 1912 the *Nessian*, and in 1914 the *Orubian*. These two vessels combined satisfactory passenger arrangements with large cargo capacity, and in service proved very successful. The *Nessian* during the war was utilised for the transport of troops, being fitted up for five hundred horses and two thousand troops. She served for fifteen months, and returned ultimately to her usual trade with the West Indies and the Gulf of Mexico. The *Orubian*, while running on the West Indian service, was sunk by enemy action on July 31st, 1917.

In dealing with the development of the steamship in a previous chapter, we had occasion to refer to the Holt liners, which inaugurated the first regular steamship service to the Far East, *viâ* the Cape of Good Hope. That was in 1865, and since then a long series of most successful steamships has been constructed by Scotts for the China trade of the Ocean Steamship Company. As representative of the modern single-screw ship for this service, we take three vessels recently completed—the *Helenus*, the *Agapenor*, and the *Mentor*—which were of the three-island type, while, as examples of the larger vessels built by the Scotts for the Holt Company, reference will be made to the *Talthybius*, the *Ixion*, and the *Tyndareus*, which, owing to their great size, were fitted with twin screws, further to ensure against breakdown. The three latter vessels were of different construction from the single-screw steamers, being designed with flush decks and forecastles which better suited them to the heavy weather so often encountered in the Pacific.

The deep-water conditions associated with the trade routes which the Holt steamers traverse between this country and the Far East, have permitted designs allowing relatively great deadweights to be carried in proportion to the dimensions of the vessels; while these deep draughts associated with the fairly fine models, enabled the large deadweights to be transported at a speed of 13½ to 14 knots on a very favourable coal consumption. The single-screw ships which followed the Suez Canal route were limited to a draught of 28 ft., but the larger ships of the *Tyndareus* type, which crossed the Pacific, were designed for a draught of 32 ft.

The Holt liners have been improved in course of time until they now represent the best economical balance for the various factors mentioned, and also for the carriage of a large number of passengers and special cargoes. Thus we find that the *Helenus* class had a length of 452 ft., a breadth of 56 ft., and a depth of 35 ft. 3 in., with a gross registered tonnage of 7555 tons. The deadweight carrying capacity was 9800 tons on a draught of 28 ft. A service speed to and from China of 13½ to 14 knots was realised, with the single-screw engines developing 4500 indicated horse-power.

The vessels of the *Tyndareus* class had a length of 503 ft., a beam of 63 ft., and a depth of 44 ft. 6 in., with a gross registered tonnage of 11,347 tons. The deadweight carrying capacity was 14,000 tons, and there was very extensive accommodation for emigrants. In this case the triple-expansion engines, driving twin-screw propellers, developed 5200 indicated horse-power on service, and gave a speed on the voyage of about 14 knots.

The ships of the *Helenus* class had two double-ended boilers 17 ft. 1½ in. in diameter, by 21 ft. long, while the *Tyndareus* class were fitted with three double-ended boilers 15 ft. 9 in. in

T.S.S. "LETITIA."

diameter by 21 ft. long; the boilers in all cases worked at a pressure of 200 lb. per square inch, under Howden's system of forced draught.

The latest vessel of the *Helenus* class was named the *Troilus*, and was fitted with Brown-Curtis double-reduction geared turbines; while a fourth vessel of the *Tyndareus* class named the *Achilles* had twin-screw machinery of the same type as the *Troilus*, and boilers of the same size as the *Tyndareus*.

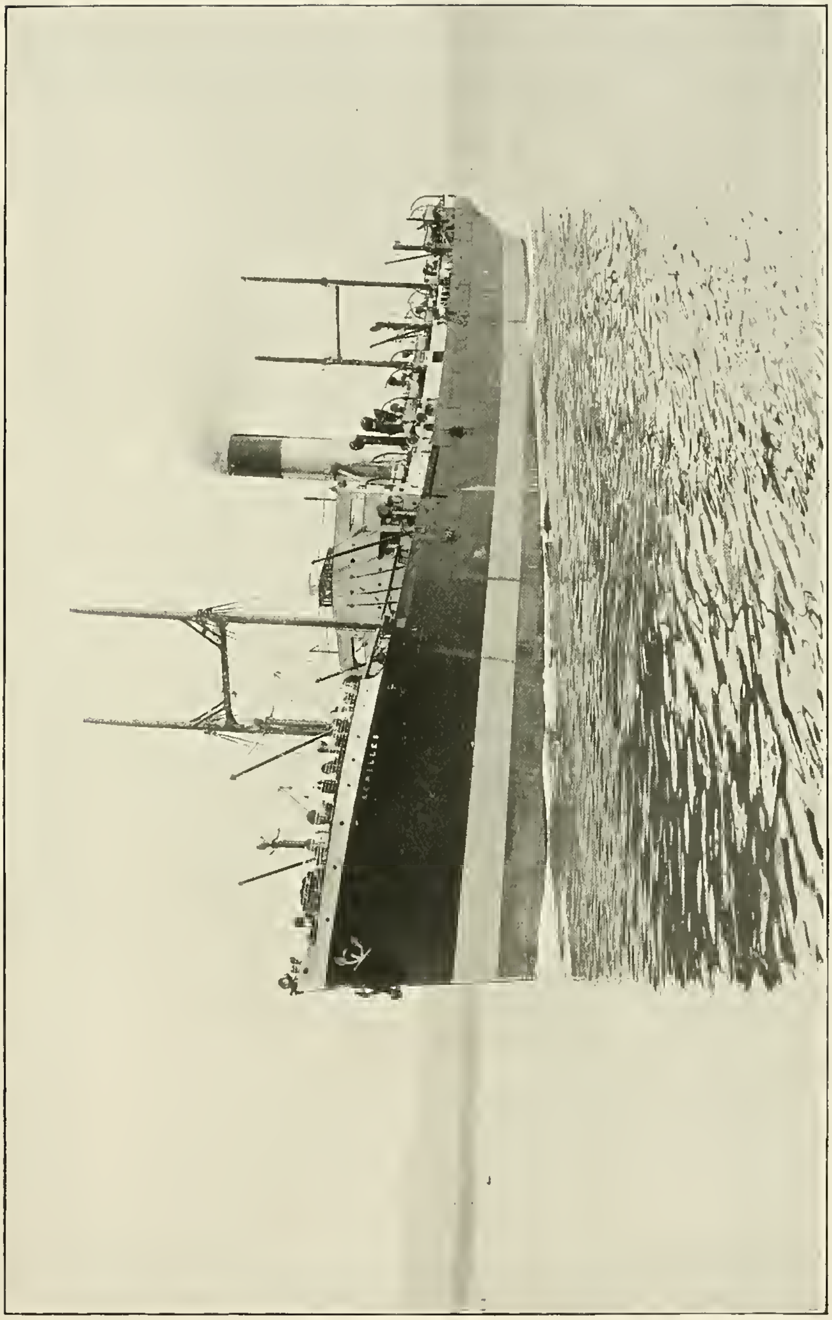
An opportunity is thus afforded of comparing the designed particulars of the two systems of propulsion in first-class cargo ships. These particulars have been tabulated, and will be found in Table XI. on the next page. It is not necessary to describe the machinery in detail, as it follows standard lines. The size and, to some extent, the forms of the two classes of ship differ, and the twin-screw ship has the advantage of length, which is very desirable under heavy weather conditions. In the case of the smaller ships the coefficient of fineness was 0·737, and in the case of the larger ships 0·746. Notwithstanding this, the comparison should bear an approximation to accuracy when stated in terms of work done.

Referring to the table there are some points to be noted. To assist the comparison, the horse-powers have been reduced to the same basis, 1·0 indicated horse-power being taken as equivalent to 0·9 shaft horse-power. The relatively high propeller revolutions with single-screw turbine machinery is due to the necessity for limiting the sizes of the gear wheels which, owing to the considerable power passing through one shaft, tend to become large. The reduction in weight of turbine machinery is not in proportion to the reduction in power per unit, and thus the twin-screw turbines are heavier relatively than the single screw. With regard to the water consumption per horse-power, it is observed that the single-screw turbines are slightly more economical than the twin-screw, on account of the larger size of the turbine units, making for better efficiency. It is right to mention that the geared turbines of both the single and twin-screw vessels have the advantage of superheated steam.

Table XI.—Comparison of Performance in Service of Single and Twin-Screw Steamers with Different Types of Machinery.

Particulars.	Single-screw Vessels.		Twin-screw Vessels.	
Type of machinery	Triple-expansion reciprocating	Double-reduction geared turbines	Triple-expansion reciprocating	Double-reduction geared turbines
Saturated or superheated steam	Saturated	Super-heated	Saturated	Super-heated
Relative horse-power (on same basis)	4500	6200	5200	6800
Revolutions of turbines (service)...	—	3000 and 1800	—	3500 and 2650
Revolutions of propellers (service)	75	90	85	80
Weight per horse-power (lb.)	510	367	545	402
Area of machinery space per horse-power (sq. ft.) ...	0·63	0·495	0·8	0·6
Cubic capacity of space per horse-power (cubic foot) ...	22·2	16·2	24·0	18·7
Water consumption; lb. per horse-power hour	17·25	11·2	17·25	11·3
Coal consumption; lb. per horse-power hour	1·8	1·29	1·8	1·3
Coal per 1000 ton-miles of voyage (lb.)	60·5	54·5	47·5	42·5
Per cent. saving in coal per 1000 ton-miles	Basis	9·75	Basis	10·5
Per cent. saving in cubic space	Basis	23·0	Basis	22·0
Per cent. saving in weight per horse-power	Basis	28·0	Basis	26·0
Speed in knots	13·8	14·75	13·9	14·6

Comparing now the single-screw vessels only, the figures in the table which will appeal to the shipowner and general reader, namely, the coal consumption per 1000 ton-miles, indicate that the double-reduction geared turbine is 9·75



THE HOLT LINER "ACHILLES" OF 1920.

per cent. more economical than the reciprocating engine in coal, notwithstanding the fact that the cargo is transported in the former case at a much faster rate ; the increase in speed amounts to nearly one nautical mile per hour. This is on account of the greater horse-power obtained with the same size of boilers due to the more efficient engines. Moreover, there is a saving in weight due to the turbine machinery of 28 per cent. as compared with the reciprocating engines. In the case of the cubic space occupied by the machinery the difference is 23 per cent. in favour of the geared turbines. There is a further gain in reduction of lubricating oil and stores required for the upkeep of the turbines, and in the less attention required.

Turning to the results of the twin-screw vessels included in the table, we find the figures again in favour of the geared turbine machinery, and in about the same degree ; though it has to be noted that owing to the twin-screw vessels being so much larger, the double-reduction geared turbines appear to better advantage in comparison with the reciprocating engines in the matter of coal consumption per 1000 ton-miles, the figures being in this case 10·5 per cent. in favour of the turbines. These economies directly affect the possible revenue from cargo carrying and amply justified the advice of the Scotts, as well as the foresight of the Holt Company, in thus extending the principle of gearing between the turbines and propellers.

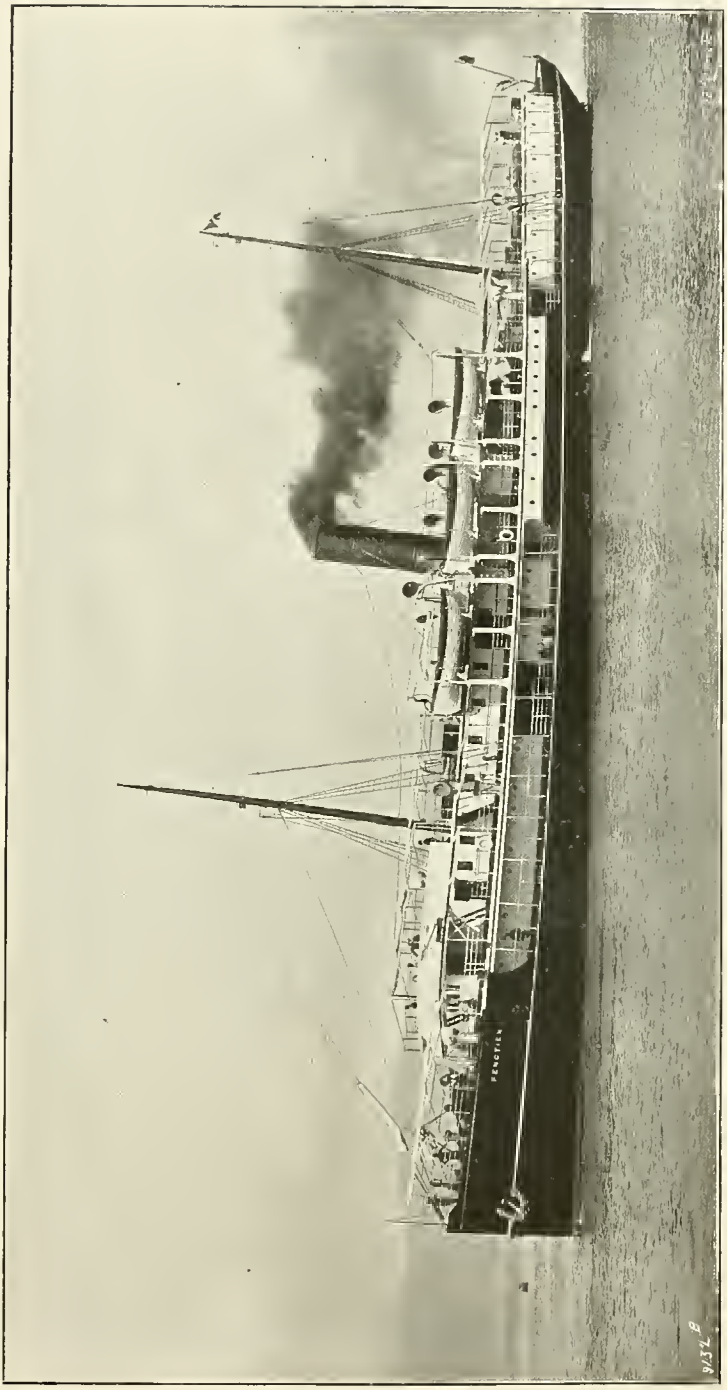
Previous to the *Troilus*, a vessel of the *Helenus* class, completed in 1917, and named the *Diomed*, was fitted with Parsons turbines, driving the propeller through single-reduction gearing. It was the satisfactory performance of the machinery of this vessel under service conditions that confirmed the owners in their opinion as to the advantages of geared turbines. The turbines ran at 1350 revolutions per minute, and the propeller at 100 revolutions, the reduction ratio being 13·5 to 1.

Here again the geared turbines showed a considerable economy over reciprocating machinery, but not in so marked a degree as with the double-reduction gearing of the later vessels. With double-reduction gearing the turbines run at a higher speed of revolution, and the propeller at a relatively lower speed as compared with single-reduction gearing, and both these factors make for greater efficiency. There is in the former case a slight relative loss in mechanical efficiency owing to the extra gear wheels, but this is negligible in comparison with the other advantages.

Many cargo vessels do not carry as much cargo gear as could be fitted to give maximum discharging speed, for the reason that generally the port facilities at one end or the other are not capable of handling more than a certain amount of cargo per day. The Holt liners trading to the Far East do not suffer from such penalties owing to the far-sighted policy of the owners in the early days, under which was inaugurated a scheme of building wharfs, and providing go-downs and lighters which enabled the cargo to be worked as quickly as the vessels could deal with it. The Scotts were closely associated with the owners from the first in the design of the ships, which was advanced concurrently with the port improvements, and it may be said that the cargo-handling equipment of the Holt fleet at the present time marks the high-water mark of practice in the merchant service.

The fifty years' work done by the Scotts for the Holt Line show the advances in naval architecture and marine engineering as applied to the moderate-sized intermediate liners. We find an increase of 63 per cent. in the linear dimensions of the ship, the later Scotts' vessels being 503 ft. between perpendiculars. In respect of deadweight capacity, however, the change has been more noteworthy, due to the adoption of mild steel, and structures based on scientific principles, permitting a reduction in the scantlings of the hull, and in the weight of the machinery. The new vessels, with a draught of 32 ft., carry 14,150 tons deadweight—four times the weight carried by the earliest Holt liners.

Plate XLVI.



THE CHINA NAVIGATION COMPANY'S S.S. "FENGTIEN."

In fifty years the boiler pressure of the Holt liners has increased from 60 lb. to 220 lb., and in the case of reciprocating engines the piston speed had advanced from 400 ft. to 800 ft. per minute. The heating surface in the boilers has decreased from 6 square feet to 2·5 square feet per unit of power, and the condenser surface from 1·83 square feet to 1·0 square feet per unit of power. On the other hand, each square foot of grate gives now 18 horse-power, as compared with 6·6 horse-power formerly.

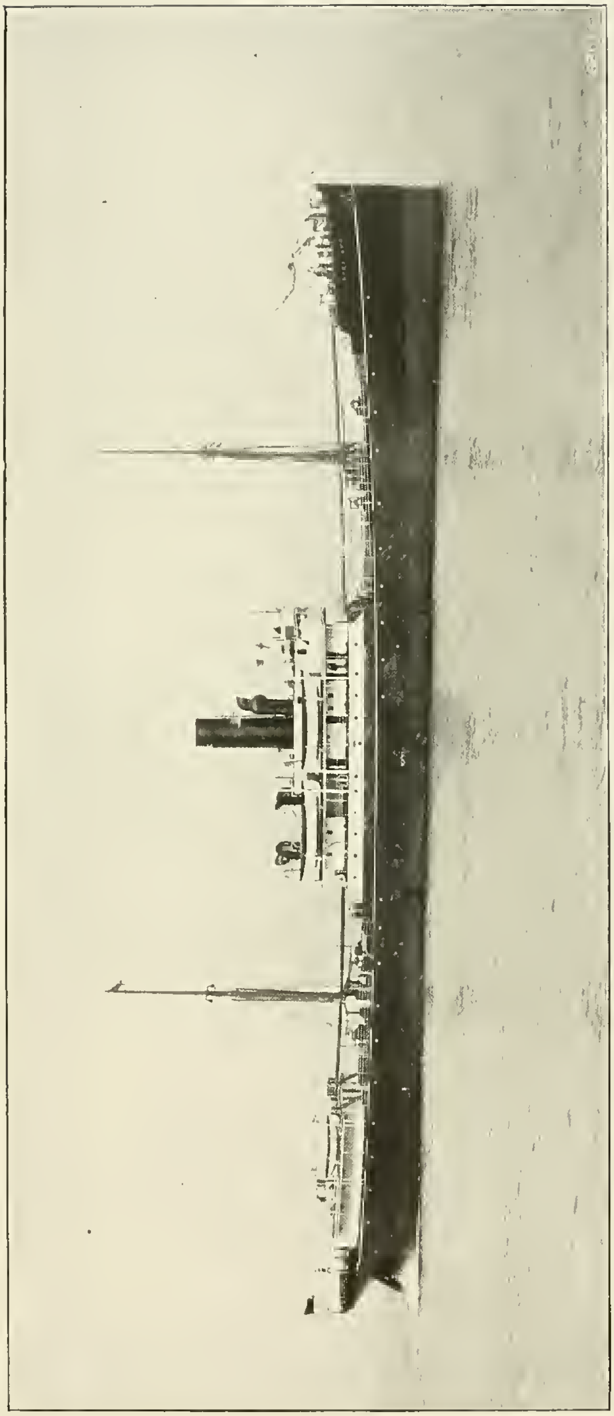
As a result of increased steam pressures and greater efficiency of propulsion, it may be taken that, notwithstanding the increase in the dimensions and capacity of the ship, and the consequent advance in engine power, the coal required for a voyage half-way round the world has been reduced to less than half that of 1865 when measured in terms of horse-power.

The Holt liners have done very creditable work during the war, and it is not surprising that several of them have been sunk. The *Diomed*, built in 1895, was sunk by gunfire from a submarine, when outward bound to China, after two hours' chase. The second *Diomed*, the first of the Holt liners to be fitted with geared turbines, met the same fate on a voyage from Liverpool to New York in ballast, her mission being to bring back American troops. The *Achilles*, built in 1900, and illustrated on Plate XXXVII., was torpedoed when homeward bound from Australia, being then 90 miles west of Ushant. The *Calchas*, built in 1899, was sunk by torpedo when homeward bound from New York to Liverpool. The *Machaon* was also sunk by torpedo off Cape Bon when sailing in a convoy from Liverpool to the Straits Settlements. The *Glaucus*, built in 1896, was sunk by torpedo, also on a voyage to the Straits and China.

As an offset to the loss of these six vessels was the triumph of four other Holt liners built by the Scotts, which after attack succeeded in making port. The *Tyndareus* struck a mine off Cape Agulhas on her maiden voyage to the Far East. The explosion was terrific. Nos. 2 and 3 holds were filled, while in No. 1 hold there was 4 ft. of water, and in No. 4 hold 6 ft. Other ships in the vicinity came to her rescue. The *Tyndareus* proceeded under her own steam, stern first, to Simonstown, where she was docked. Viscount Buxton, Governor-General of South Africa, wrote to Mr. Richard D. Holt, of Messrs. Alfred Holt and Co., as follows :—" I went a day or two ago to see the *Tyndareus* in dry dock, and to examine her wounds. The hole is a terrible one. The bottom, plates, and bulkhead twisted and torn. It is a wonderful thing that she was able to float at all, and did not sink within a few minutes. You and your firm, the designer and the builders, are greatly to be congratulated on the result of the great improvements in regard to double bottom, bulkheads, etc., designed for the *Tyndareus*. These were, I presume, consequent on the loss of the *Titanic*. There is no doubt whatever, so I understand (and it would certainly so appear after seeing the effect of the explosion), that without these well-designed and costly improvements the ship would have gone to the bottom. I thought that it might be a source of satisfaction to you to have this tribute paid to your firm by an old colleague, and one who, as you know, was much interested when at the Board of Trade in all things shipping."

The *Idomeneus*, built in 1899, was torpedoed on a voyage from New York to Liverpool. She had a general cargo, and was the commodore ship of a convoy of eleven vessels when she was struck. The engine room, bunkers and stokehold filled at once, and later the water percolated into holds Nos. 4, 5, and 6. Notwithstanding this, she was towed for about fifty hours, and beached in Vatersay Sound, the captain and crew remaining by the ship, greatly to their credit. The *Helenus*, already referred to, and launched in 1913, had a similar fate also in the Atlantic. The torpedo struck her in No. 5 hold, the hatches of which were thrown up with a column of water some 50 ft. high. The vessel listed to starboard about

Plate XLVII.



S.S. "SINKIANG."

10 degrees, but soon righted herself. No. 6 hold made a little water, but No. 4 hold remained dry. After examination of the damage the engines were put full speed ahead and a course shaped for the Lizard, a distance of about 49 miles. A destroyer remained in the company of the *Helenus.* On reaching the Lizard she was taken into the cross roads, where she was moored.

The *Alcinous,* built in 1900, was torpedoed on a voyage from London to Boston with only 1000 tons of cargo on board. The vessel was struck on the starboard side in No. 6 (aftermost) hold, a little abaft the bulkhead, which was damaged by the explosion so that two holds were flooded. After examination the vessel proceeded, and for part of the way was convoyed by a destroyer. The Commander of the destroyer advised beaching the vessel to the west of Dungeness, but the master decided that she would be able to reach the Thames. At Dover the salvage pump appliances were taken on board, and ultimately the vessel succeeded in reaching Tilbury Dock. The only other war service of Holt liners to which reference need be made is the *Menelaus,* which was converted into a balloon ship, having the whole of the forward end made into one big hold for the carriage of a balloon.

The Holt liners have done much to develop the trade with China, while at the same time the China Navigation Company, of London, for whom the Scotts began building ships in 1875, have had a large fleet of vessels for the coasting and river trade of China. One of the later ships, the *Fengtien,* built in 1905 in an exceptionally short period of time, is illustrated on Plate XLVI. facing page 116. The contract was made late in 1904, the first keel plate laid on January 15th, 1905, and the vessel launched on April 20th of that year. She arrived at Shanghai on July 14th, less than twenty-six weeks from the date when building was commenced. She had a length, between perpendiculars, of 267 ft., a beam of 40 ft., and a depth moulded of 18 ft., with a deckhouse having accommodation for thirty-three European first-class passengers; while on the top of this house there was, as shown in the engraving, a promenade for the passengers. Fifty-six first-class Chinese passengers were also carried, as well as seventy steerage native passengers. In addition to this considerable source of revenue, the ship carried 1720 tons of deadweight cargo on a draught of 14 ft. The *Fengtien* was fitted with triple-expansion engines, which developed 2146 horse-power on trial at service draught, giving a speed of $13\frac{1}{4}$ knots, which was considered highly satisfactory, in view of the unusual dimensions.

In 1911 two further ships were built, of increased dimensions, the length being 285 ft. and the beam 44 ft., with a depth of 20 ft. These vessels had a block coefficient of 0·76, and although the total displacement was 4050 tons, including a deadweight of 2960 tons, at a draught of 16 ft. 9 in., the triple-expansion engines, with which they were fitted, gave them a speed of 9·5 knots for a power of 850 indicated horse-power. A notable feature was the attention devoted to the adequate ventilation of the machinery spaces, in view of the hot climate for which they were built, and in this respect the vessels marked a considerable advance on previous ships.

For the same company there was built, in 1916, the *Sinkiang*, which marked a further advance, the length being 310 ft. In this case a higher freeboard was adopted, in order to make the vessel suitable for passenger trade under heavy weather conditions, particularly during the monsoon period. The owners reported most favourably upon the general design of the *Sinkiang*, making special reference to her ability to make headway against monsoons. As to the machinery, it may be noted that steam superheating apparatus was fitted of the smoke-tube type, and the logs of the vessel showed a considerable reduction in coal consumption on this account. It is a tribute to the work of Scotts that no trouble was

Plate XLVIII.

THE LARGEST OIL-CARRIER OF HER DAY, THE S.S. "NARRAGANSETT"

experienced with the details of the reciprocating machinery on service due to the high temperatures involved.

In 1903 the *Narragansett*, which was the largest oil-carrying ship of her day, was built by the Scotts for the Anglo-American Oil Company. She carried in her sixteen separate compartments 10,500 tons of oil. She was 531 ft. long overall, with a total deadweight carrying capacity of 12,000 tons on a draught of 27 ft. and a speed of 11 knots on service. Her coal consumption of 49 lb. per 1000 ton-miles deadweight was considered a very satisfactory performance. While primarily for the Atlantic trade, the vessel was designed to undertake, if required, the much longer voyages of the Eastern service. She was sunk by an enemy submarine off the Scilly Islands, on March 16th, 1917, and no trace was found of the officers or crew.

The latest oil-carrier built by Scotts was named the *Tatarrax*. She was built in 1912, and was constructed on the Isherwood system of longitudinal framing, the suitability of which the firm was quick to recognise. This vessel had a length of 420 ft., a beam of 55 ft., and a depth of 32 ft. 10 in., the total deadweight capacity being 9614 tons, on a draught of 26 ft. The vessel had nine main cargo oil tanks below the main deck, each being divided into two compartments by a longitudinal bulkhead. The propelling machinery was of the quadruple-expansion reciprocating type, fitted, as in most oil tankers, at the after end of the ship. There were three boilers, and these were adapted for burning coal or oil alternatively, the oil-burning apparatus being of the Wallsend-Howden type.

This alternative system promises to be very extensively adopted, as either kind of fuel can be used according to the price obtaining on the route along which the ship is travelling. In cargo ships the coal consumed in carrying 1000 tons deadweight one nautical mile at the present time is from 40 lb. to 60 lb., whereas the corresponding figures for oil fuel are about 27 lb. to 40 lb. On service the machinery of the *Tatarrax* proved most economical. Taking as an example one voyage from Japan to America, the average oil fuel consumed, according to the log, worked out at 1·04 lb. per indicated horse-power per hour for all purposes, while the main engines took only 0·9 lb. per indicated horse-power per hour—a very good performance. The speed for the whole voyage averaged about 12 knots, with the engines running at about 75 revolutions per minute.

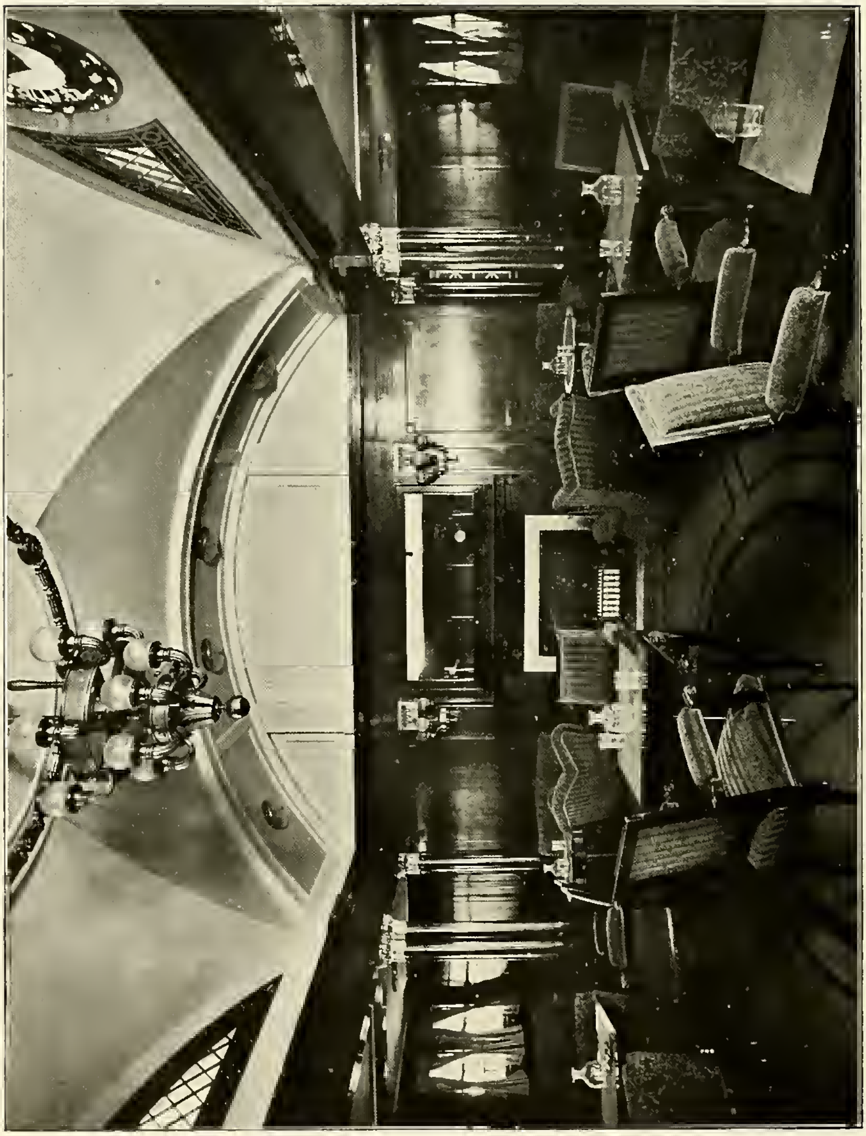
In our historical review of the development of the steamship it was clearly shown that Scotts took a prominent part in the evolution of channel steamers, and passing reference may be made to a few of the vessels of this class built in the last few years at the Company's works. For the Glasgow and Manchester trade two very serviceable ships, the *Lurcher* and *Setter*, were built for Messrs. G. and J. Burns ; for the Clyde Shipping Company's trade, the *Pladda* ; and for the Grangemouth and London service of the Carron Company, the *Carron*. These vessels are notable for the cargo carried and for their speed, notwithstanding limitations in length and draught. The *Carron* was representative of the type. She had a length of 295 ft., a beam of 40 ft. 6 in., and a depth of 27 ft. 6 in., the gross registered tonnage being 2351 tons. The displacement was 3870 tons on a draught of 18 ft. 8 in., and under those conditions she carried a cargo of 570 tons, in addition to having accommodation for one hundred and twenty-two first-class and seventy-eight third-class passengers. The triple-expansion engines with which she was fitted developed 3000 indicated horse-power, giving the vessel a service speed of 15 knots. A vessel of somewhat similar design was built for the Singapore trade of the Straits Steamship Company in 1911. This vessel had a length of 210 ft., and was designed to carry 760 tons of cargo on a draught of 11 ft.

It may be said regarding these Channel steamers that many of them were requisitioned for war service. The *Pladda* was

THE FIRST CLASS DINING SALOON IN A CUNARD LINER.

THE WRITING ROOM IN A CUNARD LINER.

Plate L.



THE FIRST CLASS SMOKING ROOM IN THE "TRANSYLVANIA."

converted into a "Q," or mystery ship, by the Admiralty, and in this way carried out some remarkable surprise attacks on enemy ships. The *Carron* served as a transport for troops. The *Setter* was sunk by enemy action ten miles off Corsewall, on September 12th, 1918, on a voyage from Manchester to Glasgow. It was dark, and a gale of wind was blowing, but nineteen members of the crew managed to land in two of the ship's boats, the master and eight others of the crew being lost. The ship's boy, aged fifteen, was picked up by a torpedo boat destroyer next day when clinging to a raft with only a shirt on. Subsequently he was landed at Belfast. With this pathetic record we will conclude our reference to the Scotts-built ships lost during the war by directing the reader to the complete tabulated statement given on page 177.

We have referred generally to the passenger accommodation in the ships built by Scotts, and it will be of interest to refer here to the character of the work in a typical example of an ocean liner. The views of the public rooms and state rooms of the *Transylvania* illustrate the best modern practice, the main endeavour being to provide the maximum of comfort for the passengers, and at the same time the greatest simplicity in design, so that the minimum of dust may collect. In this vessel the general decorative scheme was in white, and this was particularly effective, as shown by the illustrations of the dining saloon and writing room on Plate XLIX.; as a relief, the first-class smoking room, shown on Plate L., was panelled in dark walnut, while the lounge, Plate LI., was a tasteful combination of sycamore panelling and olive wood.

The verandah *café*, illustrated on Plate LII., was situated at the after end of the promenade deck, and very effectively finished in flat white and dark green pilasters. In the first and second-class cabins two berths were fitted, but, in addition, the settees were so arranged that they could be converted into two additional berths. There were in each cabin two wardrobes, a dressing table, two porcelain wash basins, and a hot water heater which could be regulated by the occupants; minor fittings of a handy nature were also provided, such as watch and toothbrush holders.

Many of the cabins had inter-communicating doors, so that a suite of rooms could easily be arranged when so desired. The surrounding bulkheads of the staterooms were so arranged that electric wires, pipes, etc., were obscured from view, but access could readily be obtained to these, as required, by unscrewing the mouldings by which they were covered.

The equipment included a complete arrangement for emergency lighting, power-controlled water-tight doors which could be operated from the bridge, submarine signalling, ventilation and heating by thermotanks, apparatus for indicating on the bridge the presence of fire in any compartment, boat turning-out gear and transporters, large refrigerating chambers, and, in fact, everything found to be of practical use on board a passenger vessel of the highest class.

Provision for the carriage of refrigerated cargoes has entered largely into the design of recent steamers built by the Scotts. The *Andania* and *Alaunia*, to which reference has been made already, each had a portion of her holds—amounting to 51,300 cubic feet—insulated for the carriage of fruit, dairy produce, etc., the temperature of the spaces being maintained by a cold-air system. The *Diomed*, already referred to, had an insulated capacity of 109,800 cubic feet suitable for the carriage of frozen meat and also for fruit, the temperatures in this case being maintained by brine piping and cold-air systems respectively. The firm are at present engaged upon the construction of a vessel for the Donaldson line which has been specially designed for the carriage of chilled and frozen meat, with insulated holds having a capacity of 380,000 cubic feet. When completed, this vessel will have equipment of the most modern type, both in regard to the insulated spaces and refrigerating machinery and the cargo-handling gear.

Scotts' practice with respect to paddle-wheel engines

Plate LI.

THE LOUNGE IN THE "TRANSYLVANIA."

Plate LII.

THE VERANDAH CAFE IN A PASSENGER LINER.

THE SECOND CLASS DINING SALOON IN A PASSENGER LINER.

has been no less varied than in the case of screw-propeller machinery ranging from the side lever engine of past years to the stern-wheel machinery of the shallow-draught steamers of later date. Oscillating and diagonal engines, both compound and triple-expansion, are also within the experience of the Company. Paddle wheels as a mode of propulsion, however, have given place in recent years to screw propellers, except for certain limited services, and, as a result, few orders for paddle steamers are now placed. The last contract undertaken by the Scotts for paddle engines, it may be said, was in 1905, when they designed and constructed the machinery for twenty of the shallow-draught steamers built for the London County Council's passenger service on the River Thames.

Towards the end of 1919, the Scotts laid down two vessels for the service of the Lloyd Royal Belge between Europe and South America, and early in 1920 two for the Compania Sud Americana de Vapores for service between Valparaiso and New York. The Belgian vessels are 445 ft. in length, will steam 15 knots on service and will accommodate 150 first-class passengers and about 1100 emigrants. They will each have a deadweight carrying capacity of 8200 tons on a draught of 26 ft. 6 in. The Chilian vessels are 420 ft. in length, and will steam 17 knots loaded. Accommodation will be provided for 120 first-class passengers in 1 and 2-berth rooms, also for 90 third-class passengers in rooms. The deadweight carrying capacity of these ships will be 5800 tons on 26-ft. draught. On account of their high freeboards, the ships should prove very popular. The propelling machinery in each ship will consist of twin-screw double-reduction geared turbines supplied with superheated steam, and the boilers will use alternatively oil fuel or coal under forced draught.

Many more examples of the modern intermediate and cargo ship might be given, but we will conclude with a reference to the *Munwood*, because of the data yielded by the progressive speed trials on the measured mile, and for the remarkable efficiency disclosed by these. The vessel, which was built for the Crossburn Steamship Company, Limited, under the superintendence of Messrs. Clarke and Service, had a length of 345 ft., a beam of 47 ft. 9½ in., and a depth of 26 ft. 6 in., the coefficient being 0·73. She had a deadweight carrying capacity of 5280 tons, on a draught of 22 ft. 4 in. The engines were of the triple-expansion type, driving a single propeller, and were supplied with steam from three cylindrical boilers placed abreast in the ship, and working under Howden's forced draught. The power required for the service speed of 12 knots was found to be just under 2000 shaft horse-power, and on the progressive loaded trials the Admiralty coefficient proved that particularly good propulsive efficiency was realised. The figures were as follows :—

Speed.		Revs.	Admiralty Coefficient.
9·41	... Mean of two runs	57·1	... 382
10·74	... ,, ,, ...	65·5	... 369
12·18	... ,, ,, ...	75·5	... 332
12·89	... ,, ,, ...	82·0	... 310

Expressed popularly, the results showed that in this medium-sized vessel, the coal consumption for carrying 1000 tons deadweight for a mile, or 1 ton of deadweight per 1000 miles, was 57·5 lb.

The cost of ocean transport has been much reduced in recent years by economy in fuel and stores associated with other improvements tending to the same result. It has already been noted that great advances have been made in connection with the machinery and methods adopted for rapidly loading and discharging ships, so that they are required to spend only the minimum of time in the ports. In this way the shipbuilder and engineer are ever contributing towards reducing the cost of transport of all goods which require to be brought over the seas, and the Scotts have played an important part in achieving this end.

Marine Engineering Progress.

♣ ♣

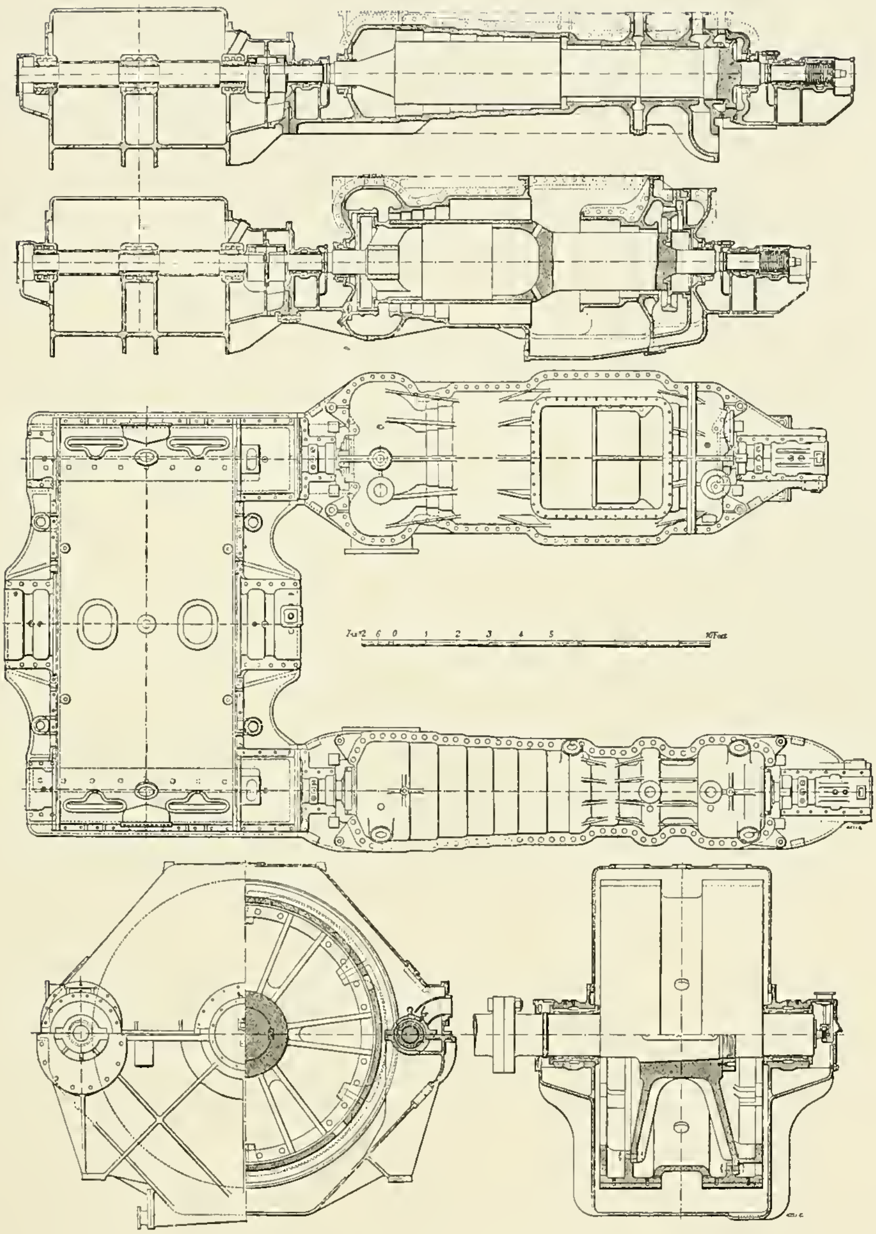
TAKING the period up to the declaration of war, the quadruple-expansion engine had to a considerable extent superseded the triple-expansion engine for ships intended to make long voyages, and more especially for passenger liners in which a four-crank engine had to be fitted on account of the higher powers and greater smoothness of running demanded. For cargo steamers, even of large size, the majority of owners still preferred the three-cylinder engine, as it was considered that any gain in fuel economy, due to the quadruple principle, was neutralised by the loss in cargo space, because of the greater length needed for the latter engine, and its increased first cost, weight and expense in maintenance.

Turning to the faster vessels associated with the passenger service, the reciprocating engine appears in a new light. It was in the cross-channel passenger service that the inherent limitations of the reciprocating engines became first apparent. In these vessels, it is, on the one hand, of the highest importance to reduce weight wherever possible, so as to minimise tonnage, and save harbour dues ; while, on the other hand, it is necessary to obtain very high speeds to suit the public convenience, and this on a ship restricted in size by available harbour accommodation. To meet these conditions, and to provide the required powers by reciprocating engines, increase of piston speed and rate of revolution had to be achieved. Remarkable success was attained through most careful design and the adoption of the highest quality of materials and workmanship. In the later 'nineties, however, still higher powers being demanded in association with lighter weights per horse-power, a point was reached beyond which further progress along prevailing lines could not be hoped for.

In the meantime significant developments were taking place in another direction. After a long period of research, Sir Charles A. Parsons, K.C.B., having achieved commercial success in driving electric generators by steam turbines, directed his attention to the application of the turbine to marine propulsion. The *Turbinia* (1894) was the first vessel to be fitted with turbines, but, owing to difficulties in connection with the high speed propellers due to cavitation, it was not till 1897 by the application of multiple shaft propellers that the expected results were achieved. Two destroyers were fitted with this type of machinery in 1899, one the *Viper* and the other the *Cobra*, and it was then that the complete success of the system was finally established, particularly for small craft. The performances of these pioneers led in 1901 to the building of the turbine passenger steamer, *King Edward*, so well-known on the River Clyde, which was followed by the cross-channel steamer *Queen* in 1902, and the *Brighton* in 1903. The success of those vessels led to the general adoption of the steam turbine for cross-channel service. Thus the introduction of the steam turbine proved opportune by opening up a way to further progress in economy, combined with lightness, far beyond the possibilities of the reciprocating engine.

The turbine was now fairly established in the cross-channel service, but the field of the larger vessel remained yet untouched. Here the reciprocating engine was supreme. The first moderate-sized ship fitted with turbines was H.M. Cruiser *Amethyst* in 1905, and in the same year the

Plate LIII.



THE SINGLE-REDUCTION GEARED TURBINES OF THE "TRANSYLVANIA."

Admiralty ordered the system to be installed in the battleship *Dreadnought*. At this time also, the turbine entered the lists in the trans-Atlantic service, when the *Victorian* and *Virginian* of the Allan Line took up their stations, to be followed later in the same year by the Cunard Liner *Carmania*. In order to test the relative economy of the new machinery, the Cunard Company, with characteristic enterprise, ordered to be built at the same time the *Caronia*, a twin-screw vessel of similar dimensions and form, but driven by quadruple expansion engines. The results on service, however, did not warrant the adoption of direct-acting turbines to drive a ship of this type at a speed of 18 knots, for it was found that the coal consumption of the *Carmania* was considerably greater than that of the *Caronia*. The performances of the *Carmania* did not, however, interfere with the employment of turbines for liners of relatively higher speeds, and when the Cunard Company laid down the *Lusitania* and the *Mauretania*, there were data enough to justify a commission of experts in recommending the adoption of the turbine in these leviathan ships, completed in 1907. Direct acting turbines were fitted from this time onwards to many first-class liners, including the *Aquitania*, *Imperator*, *Alsatian* and *Calgarian*. Scotts were among the earliest of the engineering firms in the country to adopt the system in high speed vessels, alike for the Navy and the merchant fleet, as has been shown in the preceding chapters.

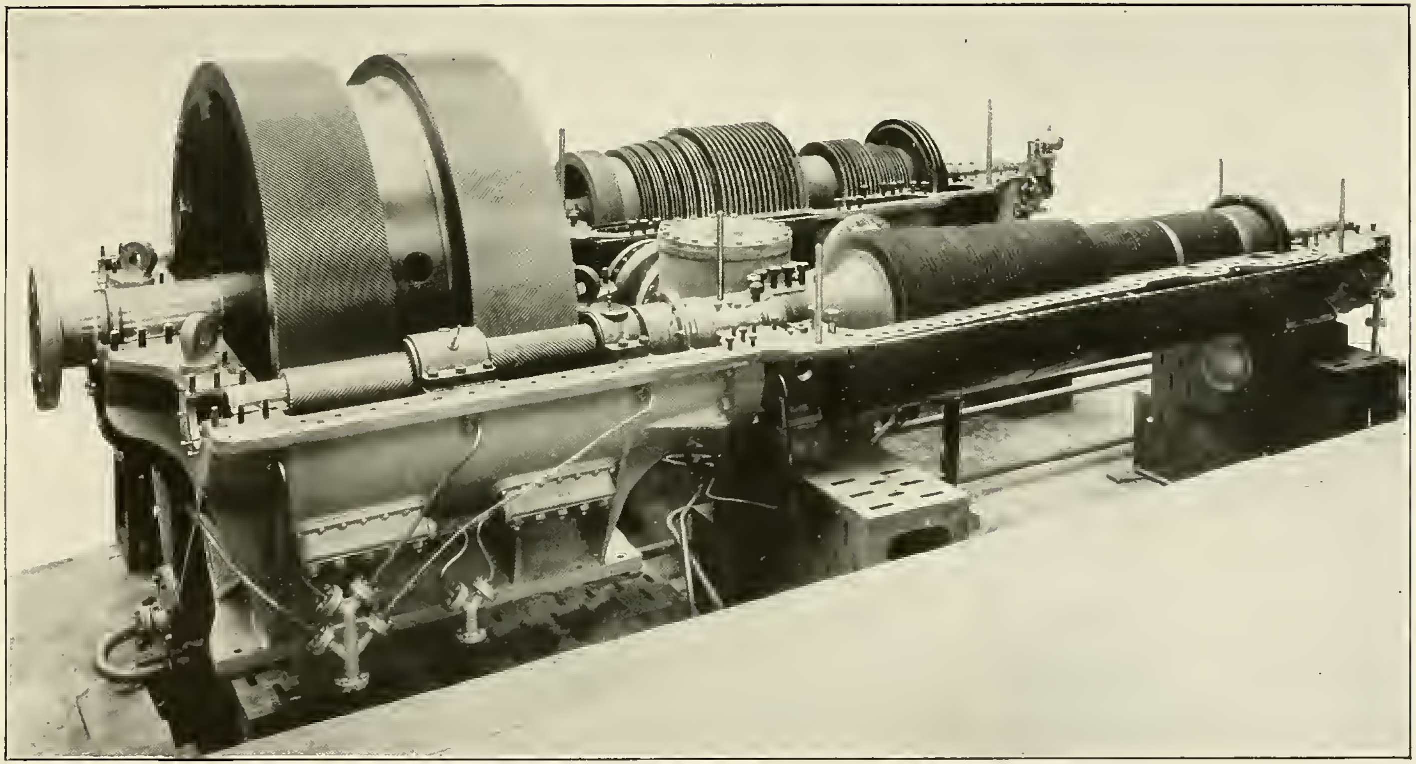
The results in service in the case of the *Carmania* as compared with those of her sister ship, tended to interfere with the natural development of the system in intermediate liners, for which greater powers were being demanded day by day. To trace the means adopted to overcome, at least temporarily, the difficulty here presented, reference must be made to the records of the Navy. In 1901 an interesting experiment was tried in the destroyer *Velox*, which was fitted for cruising speeds with a combination system of machinery in which the steam after it had done duty in the reciprocating engines, was made, before passing to the condenser, to perform work in Parsons' low pressure turbines. By this means a notable reduction in steam consumption was obtained. This improvement was due to the special feature of the turbine which enables it to utilise economically steam of a very low absolute pressure.

It was not, however, till 1908 that the "Combination System," as this arrangement came to be known, was tried in an ocean liner—the New Zealand steamer *Otaki*. In comparison with her sister ships, having triple expansion engines, the *Otaki* gave an economy in steam consumption of about 20 per cent. It was anticipated that the Combination System would find a field for application in slow-speed vessels, but this was not borne out in practice. For comparatively small powers, the machinery was too complicated, but for large ships of moderate speed the economy proved attractive.

Thus the reciprocating engine, in association with the turbine, entered upon a new lease of life for large powers. The comparative popularity of the Combination System may be gathered from the statement that, taking ocean liners of over 3000 tons register, there were in 1916, twenty-eight driven by direct turbines, and twenty-four by combination machinery. Notable among the latter were the *Laurentic, Olympic, Titanic* and *Britannic*, this last vessel having a horse-power of 50,000. The Combination System proved, however, to be but one phase in the development of marine propelling machinery. Even at the time when the arrangement seemed firmly established, ingenious minds were at work with the object of eliminating the weak partner—the reciprocating element.

Investigation proved that the turbines of the *Carmania* ran too slowly, and that the propellers revolved at too great a speed to give a maximum overall propulsive efficiency. Various expedients were proposed to overcome the difficulty, of which mechanical gearing is the simplest and most widely

Plate LIV.



PERSPECTIVE VIEW OF TURBINES OF "TRANSYLVANIA," WITH TOP PARTS OF CASINGS REMOVED.

adopted. Reference has been made to the early days of gearing in marine propulsion, and it is recorded on page 32, that gear wheels were fitted on vessels built by Scotts to increase the revolutions of the propeller as necessitated by the slow-running engines of those days. With the new application of gearing the converse takes place, the gearing being employed to reduce the revolutions of the propeller.

Parsons' turbines and mechanical gearing were fitted in the single-screw steamer *Vespasian* in 1910, having previously been tried successfully in a small launch. The installation included two turbines, each with a toothed pinion on its spindle, which engaged with a common main gear wheel on the propeller shaft, the difference in diameter between the small pinions and the large wheel resulting in the decrease in revolutions of the propeller. In 1911 two partly-geared destroyers were built, and in the same year the cross-channel steamers *Normannia* and *Hantonia* were fitted with mechanical gearing, to be followed in 1913 by the *Paris* and *King Orry*.

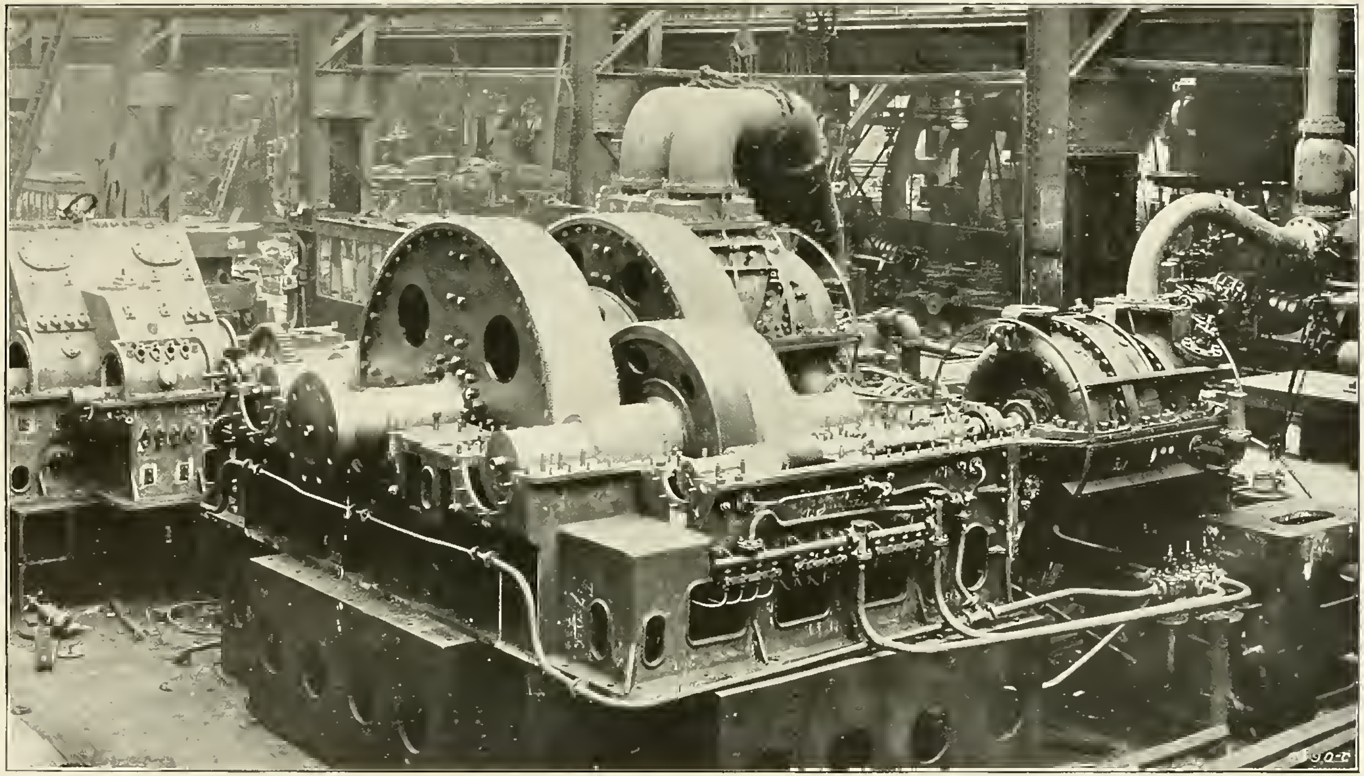
The most outstanding development, however, was the fitting of gearing in 1913 to the *Transylvania*, built for the Cunard Company by the Scotts for the Atlantic service, this being the first ocean liner so fitted. This departure on the part of the Cunard Company once more established the great enterprise of one of our leading ocean steamship lines, and was in keeping with the innovation of the direct-driven turbine drive in the *Carmania*, *Lusitania*, and *Mauretania*. The details of the work on the *Transylvania* are dealt with in a preceding chapter on "The Merchant Ships of the Twentieth Century." The ratio of reduction in revolutions in some of the earlier vessels was 20 : 1, but higher ratios are now realised by the adoption of double-reduction gearing, which has been applied by the Scotts in their later steamers as already described.

By this system a better efficiency is obtained in the turbine and also in the propeller. The turbines may be run at very much higher rotating speeds, resulting in reduction in diameter, simplification in construction, and less chance of breakdown in service. The gear wheels, in the double reduction gear, are smaller, so that the helical teeth are more easily cut. The wheels are more easily handled and replaced, while the pinions, relatively to the wheel, are greater in diameter, giving a much better contact between the teeth and a reduction in the wear and tear of the gear. There is certainly a disadvantage in the duplication of the number of bearings for the gearing, which necessitates the most careful design, associated with good workmanship to ensure a proper alignment and uniform wear, and an efficient arrangement of forced lubrication. Where these essentials are attended to there is no doubt that double reduction gearing presents favourable features in comparison with single reduction. The loss in transmission is slightly increased, but not to any greater extent than 2 per cent., and a definite increase in economy is obtained by adopting the system, subject to the reservation that where the proportions of the vessel and the speed and power are such as to justify a propeller running at over 150 revolutions per minute on service, the single-reduction gearing may be fitted in many instances with advantage.

Single-reduction gears are adopted for high-speed naval ships, where immense developments have taken place during the past two or three years, the power developed reaching, in some cases, to between 120,000 and 150,000 horse-power transmitted through four sets of gearing. These have been fully dealt with in the chapter on "Work for the Great War Fleet, 1914–1918."

It would appear that from the highest powers down to 3500 horse-power per shaft, the steam turbine, geared or otherwise to suit the conditions, will be generally adopted in the merchant service, though for powers below 5000 per shaft the reciprocating steam engine will contest the position

Plate LV.



DOUBLE-REDUCTION GEARED TURBINES OF 4500 S.H.P. FOR THE "CLAN MACTAGGART," ERECTED IN POSITION FOR SHOP TRIALS

for a time. For powers under 3500 the latter engine continues to have the confidence of the shipowner.

The internal combustion engine, however, is making its presence felt and with good reason. As time passes there is increasing proof that the oil engine in one form or another will eventually displace the reciprocating steam engine for many services. In the contest between the two types of reciprocating engine there are elements tending to the advantage of the steam engine which are likely to prolong the issue; these are (1) the use of superheated steam, and (2) the burning of oil fuel in the furnaces of steam boilers. Both of these elements contribute, of course, to the economy of steam engines of all powers and both have been greatly extended in application during the last few years. With cylindrical boilers the superheaters in common use are of the well-known smoke tube type. While superheat is being usefully employed for reciprocating engines, the construction of the turbine lends itself more favourably to the use of superheated steam, which is being largely adopted in new ships.

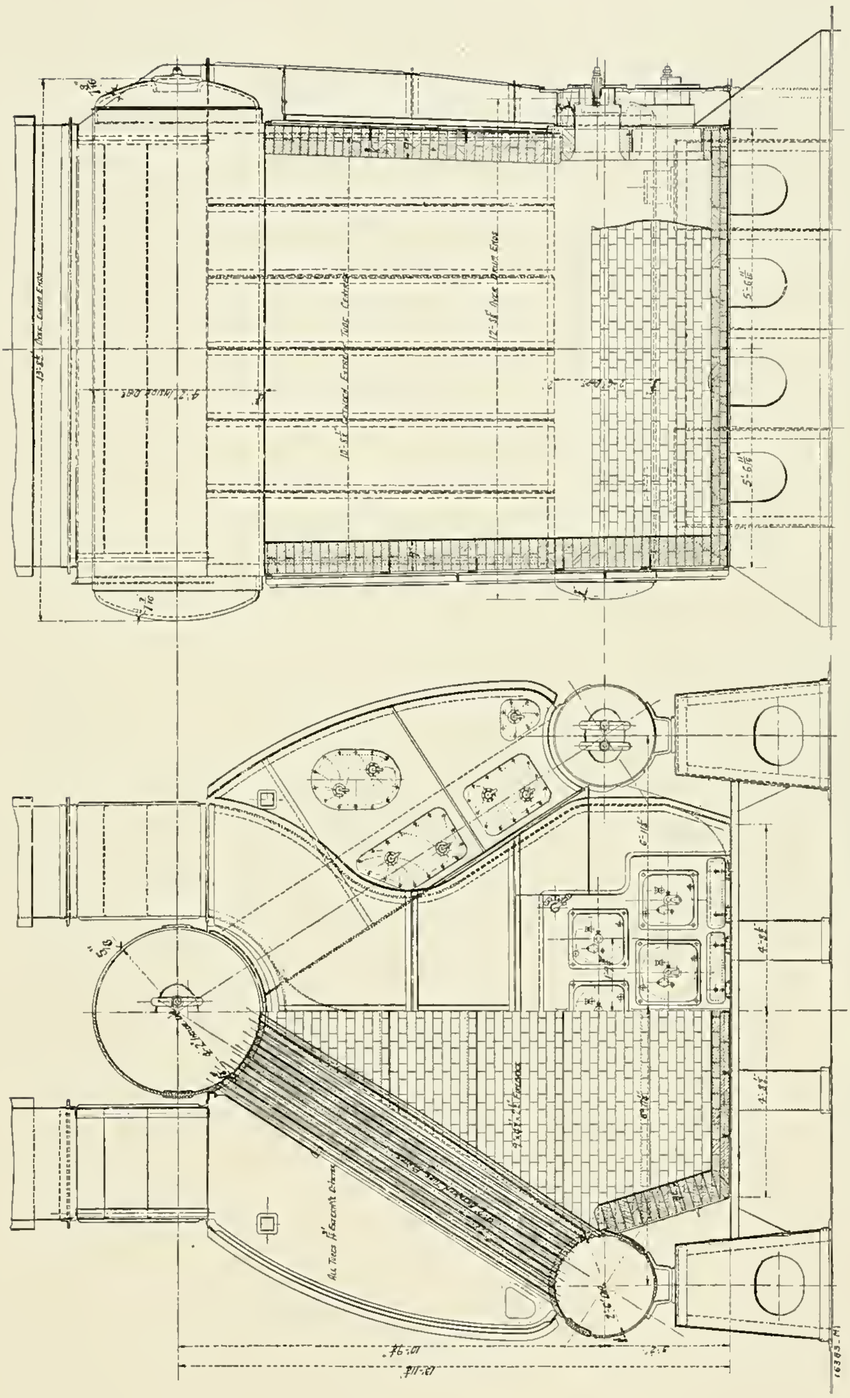
Superheat has not so far made much headway with the naval authorities, probably on account of more or less unfavourable experiences in the past, due to complications introduced into the boiler design and pipe arrangement, and to the extra wear and tear of the turbine blading. No doubt a further reason for the policy pursued by the Admiralty in regard to superheat is to be found in the fact that naval vessels are rarely working at full power, and even when so running it is usually for a short period and under conditions which make the question of fuel economy relatively of minor importance. Again, at cruising speeds the arrangements for working boilers in the Navy are such that steam is being supplied by boilers working at much less than full capacity, under which conditions the degree of superheat obtained is so small that its effect on economy has been considered in the past hardly worth the extra complication required to produce it. However, with improvements in the design of superheaters and turbines, and the use of suitable materials, it is not too much to expect that the principle of superheat will be recognised once more in certain naval services.

The general question of the design of blading for turbines is receiving special attention among engineering experts at present, and it is possible that improvements may be made which will give an increased economy from this source alone, apart from the additional advantage due to the adoption of superheat.

The burning of oil fuel in the furnaces of marine boilers is no new development for it dates back to about 1870, when it was employed in Russia in vessels serving on rivers in the neighbourhood of the oil fields. The means adopted in those days were crude, and it was not till twenty years later that considerable improvements were made in the apparatus for oil burning. The system was utilised in the Navy for destroyers some years ago, and within the last five or six years for battleships and high speed battle cruisers where the demand for speed, in association with great fighting power, made every possible reduction in the weights on board of the utmost importance. Significant figures showing the advantage in weight obtained in such vessels by this and other means are given in Table VI, on page 78.

In the merchant service when oil fuel is consumed alone the advantages from the shipowner's point of view are greater speed, reduced number of stokers, increased capacity for cargo due to smaller bunkers, less wear and tear on the boilers, bunkers and floorplates, the elimination of ashes, and the facilitating of the re-fuelling of the ship. In connection with the augmentation of the cargo space, it may be said that 39 cubic feet of oil have the equivalent heating value of 65 cubic feet of coal, and further, that oil fuel can be carried in spaces where it is impossible to load or trim the coal. From the point of view of the engineer in charge the advantages are

Plate LVI.



OIL-BURNING WATER-TUBE BOILER FOR A MERCHANT LINER.

facility of obtaining and maintaining steam, less tendency to priming in the boilers, no losses due to the opening of fire doors, and the ability to shut down fires instantly thus obviating standby losses.

The provision that is being made on the various trade routes and outlying stations for the supply of oil fuel to steamers appears to be at first sight equally to the advantage of the internal combustion engine. On the other hand, it is becoming a common practice in the merchant service for boilers to be arranged so as to be capable of burning either coal or oil as may be found most expedient; and while certain of the advantages accruing to the use of oil fuel exclusively are sacrificed, the steamers fitted with the alternative arrangements are more favourably placed for general trading and are able to take advantage of the fluctuations in the market.

Here it may be noted that the merchant vessels at present under construction at Scotts (1920) are all fitted with steam turbines which are arranged to drive the propellers through double reduction gearing. The steam boilers in every ship are fitted with superheaters of the smoke tube type. In most of the vessels oil fuel burning apparatus is fitted. In some cases arrangements are made to burn oil fuel exclusively, and in others, to burn either coal or oil as may be found most suitable.

Reference has been made in a previous chapter, page 107, to the advantages which would follow the adoption of water-tube boilers in the merchant service. Boilers of this type are invariably fitted now for cross-channel steamers. Certain steamship companies have adopted the system for liners, and further developments in this direction may be anticipated. For cross-channel steamers coal is the fuel employed, but in the case of ocean-going vessels the water-tube boilers should always be associated with the burning of oil fuel and the popular movement in the latter direction is to the advantage of the newer type of boiler. The question is of great importance to the naval architect, on account of the reduction in weight and space occupied by these steam generators for a given power despite the fact that, according to published results, the oil consumption of cylindrical boilers is 5 per cent. less than that obtained with water-tube boilers of equal power.

TABLE XII.—TO SHOW THE EFFECT OF DIFFERENT TYPES OF MACHINERY ON BLOCK COEFFICIENT AND SPEED OF CROSS-CHANNEL STEAMERS.

Basis of Figures :—

(1) Hull dimensions, 310 ft. × 40 ft. × 11 ft. 6 in.
(2) Boilers to provide same amount of steam.
(3) Total coal consumption to be the same.
(4) Total deadweight to be the same.

	Basis Vessel.	First Alternative.	Second Alternative.	Third Alternative.
Type of Machinery.	Reciprocating Engines and Cylindrical Boilers.	Direct Turbines and Cylindrical Boilers.	Direct Turbines and Water-tube Boilers.	Geared Turbines and Water-tube Boilers.
Hull, percentage of displacement ...	51·0	51·0	50·08	51·0
Machinery, "steam up," percentage of displacement ...	33·7	31·7	27·12	28·7
Passengers, fuel, cargo, etc., percentage of displacement ...	15·3	15·3	15·3	15·3
Displacement ...	100·0	98·0	92·5	95·0
Block coefficient ...	0·515	0·505	0·479	0·488
Horse-power ...	6000 I.H.P.	7300 S.H.P.	7300 S.H.P.	8250 S.H.P.
Speed in knots ...	21·0	22·1	22·8	23·4

Reverting to the subject of cross-channel steamers it is of interest to note the effect of different types of machinery on the hull elements of such vessels. Some particulars have been put into tabular form, and the tables are self-explanatory. Table XII shows the effect of different types of machinery on block coefficient and speed; and Table XIII the effect on hull dimensions of different types of machinery. The effects

Table XIII.—To Show the Effect on Hull Dimensions of Different Types of Machinery of Cross-Channel Steamers.

Basis of Figures :—

(1) Speed to remain constant at 21 knots.

(2) Total deadweight the same in each case.

(3) Hull dimensions to be varied accordingly.

	Basis Vessel.	First Alternative.	Second Alternative.	Third Alternative.
Type of Machinery.	Reciprocating Engines and Cylindrical Boilers.	Direct Turbines and Cylindrical Boilers.	Direct Turbines and Water-tube Boilers.	Geared Turbines and Water-tube Boilers.
Dimensions of hull	310 ft. × 40 ft. × 11 ft. 6 in.	302 ft. × 40 ft. × 11 ft. 6 in.	295 ft. × 40 ft. × 11 ft. 6 in.	288 ft. × 37 ft. 6 in. × 11 ft. 6 in.
Hull, percentage of displacement ...	51·0	49·5	48·6	45·6
Machinery, "steam up," percentage of displacement ...	33·7	26·8	23·7	20·3
Passengers, cargo, etc., percentage of displacement ...	11·8	11·8	11·8	11·8
Fuel, percentage of displacement ...	3·5	2·9	2·9	2·4
Displacement ...	100·0	91·0	87·0	80·1
Block coefficient ...	0·515	0·48	0·47	0·475

noted in connection with cross-channel steamers are to be observed in varying degrees in other types of vessels so that the tables given are of considerable general significance.

Electrical propulsion for ships has not yet found favour in this country. In the United States, however, the naval authorities take the view that the system possesses features which justify its trial in the heavier classes of warships.

TABLE XIV.—IMPORTANT DATES IN THE DEVELOPMENT OF MARINE PROPELLING MACHINERY.

—	Approximate Date of Introduction in the United Kingdom.			
	Merchant.		Naval.	
Compound engines...	—	1860	—	1865
Triple-expansion engines	—	1880	—	1885
Quadruple - expansion engines ...	—	1890	Not fitted ...	—
Cylindrical boilers ...	—	1862	—	1869
Water-tube boilers...	Cross-channel ...	1911	Destroyers ...	1893
	Ocean liners ...	1914	Battleships ...	1897
Direct turbines ...	Cross-channel ...	1901	Destroyers ...	1898
	Ocean liners ...	1905	Light cruisers ...	1904
			Battleships ...	1906
Combination engines and turbines	Intermediate liner	1908	(For cruising only)	1902
Geared turbines ...	Single-reduction ...	1911	Single-reduction ...	1913
	Double-reduction...	1916	Not fitted ...	—
Electric propulsion	First attempts ...	1904	Not fitted ...	—
	Modern plant ...	1912	—	—
Oil fuel burning ...	First attempts ...	1870	Coal and oil—	
			Destroyers ...	1902
			Battleships ...	1904
	Modern plant ...	1892	Oil alone—	
			Destroyers ...	1910
			Battleships ...	1913
Heavy oil engines ...	First attempts ...	1904	Tender	1914
	Modern plant ...	1910	Submarines ...	1908

The advantages claimed are extreme flexibility, high economy at cruising speeds and comparative immunity from total disablement of the machinery. Favourable reports of trials

TABLE X V.

PROGRESS IN MARINE MACHINERY—INTERMEDIATE OCEAN LINERS.

Year	1880.	1892.	1911.	1914.	1920.
Ship dimensions—					
Length	400 ft.	470 ft.	520 ft.	550 ft.	550 ft.
Beam	45 ft.	53 ft.	64 ft.	66 ft. 6 in.	66 ft.
Performance—					
Speed in knots	12·5	12·5	14·5	16·5	17
Horse-power	3,000 I.H.P.	3,500 I.H.P.	7,500 I.H.P.	11,000 S.H.P.	11,000 S.H.P.
Engines—					
No. of propellers	One	Two	Two	Two	Two
Type of machinery	Vertical compound	Vertical triple-expansion	Vertical quadruple expansion	Geared steam turbines	Geared steam turbines
Dimensions of cylinders	52-in., 96-in. by 66-in.	$22\frac{1}{2}$-in., $36\frac{1}{2}$-in., 60-in. by 48-in.	26-in., 37-in., 53-in., 76-in. by 54-in.	Two H.P. and two L.P. turbines with single-reduction gearing	Two H.P. and two L.P. turbines with double-reduction gearing
Propeller (revs. per min.)	61	80	82	133	85
Piston speed (feet per min.)	671	640	738	Turbine revs. 1,650	H.P. turbine, revs. 3,200; L.P. turbine, revs. 2,000
Referred mean pressure	20·5	32·0	37	—	—
Condenser surface per H.P.	1·85	1·6	0·84	0·80	0·62
Boilers—					
No. and type	Two cylindrical	Two D.E. and one S.E. cylindrical	Five double-ended cylindrical boilers	Five double-ended cylindrical boilers	Five water-tube boilers, burning oil fuel (superbeated steam)
Working pressure (lb. per sq. in.)	90	170	210	210	250
System of draught	Natural	Natural	Natural	Howden's forced draught	Oil-burning with forced draught
Heating surface per H.P.	3·1 sq. ft.	3·3 sq. ft.	3·25 sq. ft.	2·5 sq. ft.	2·25 sq. ft.
H.P. per sq. ft. of grate	7·6	10·0	11·75	17·5	—
Total weight of machinery, "Steam up"	685 tons	795 tons	1,750 tons	1,800 tons	1,210 tons
H.P. per ton of machinery	4·35	4·4	4·25	6·1	9·1
Coal consumption per H.P.	2·375 lbs.	1·875 lb.	1·55 lb.	1·4 lb.	* 0·875 lb.

* Oil Fuel.

TABLE XVI.

PROGRESS IN MARINE MACHINERY—CARGO STEAMERS.

Year	1877.	1885.	1911.	1914.	1920.
Ship dimensions—					
Length	314 ft.	320 ft.	440 ft.	450 ft.	503 ft.
Beam	35 ft.	38 ft.	52 ft. 6 in.	56 ft.	63 ft.
Performance—					
Speed in knots	11·25	12·25	13·25	14·25	14·25
Horse-power	775 I.H.P.	1,650 I.H.P.	4,200 I.H.P.	4,000–5,000 S.H.P.	7,000 S.H.P.
Engines—					
No. of propellers	One	One	One	One	Two
Type of machinery	Tandem compound with flywheel	Triple-expansion	Triple-expansion	Steam turbines and single-reduction gearing ; one H.P. and one L.P. turbine	Steam turbines and double-reduction gearing ; two H.P. and two L.P. turbines
Propeller (revs. per min.)	52	70	73	102	80
Piston speed (feet per min.)	450	560	750	1,350 revs. of turbines	H.P. turbines, 3,500 revs. ; L.P. turbines, 2,500 revs.
Referred mean pressure	23	31·5	35	—	—
Condenser surface per H.P.	2·17	1·83	1·5	1·18	1·12
Boilers—					
No. and type	One–Oval ends and round middle portion	Two cylindrical	Two main cylindrical	Two cylindrical	Three cylindrical oil-fired boilers with superheaters
Working pressure (lb. per sq. in.)	70	150	190	195	200
System of draught	Natural	Natural	Forced draught	Howden's forced draught	Oil-burning with forced draught
Heating surface per H.P. sq. ft.	4·46	2·82	2·8	2·30	2·25
H.P. per sq. ft. of grate	7·6	10·4	16·25	20·0	—
Weights—					
Weight of machinery	200	340	900	930	1,100
H.P. per ton of machinery	3·87	4·85	4·67	6·45	6·35
Coal consumption per H.P.	About 2·5 lbs.	1·95 lb.	1·65 lb.	1·45 lb.	* 0·85 lb.

* Oil Fuel.

TABLE XVII.

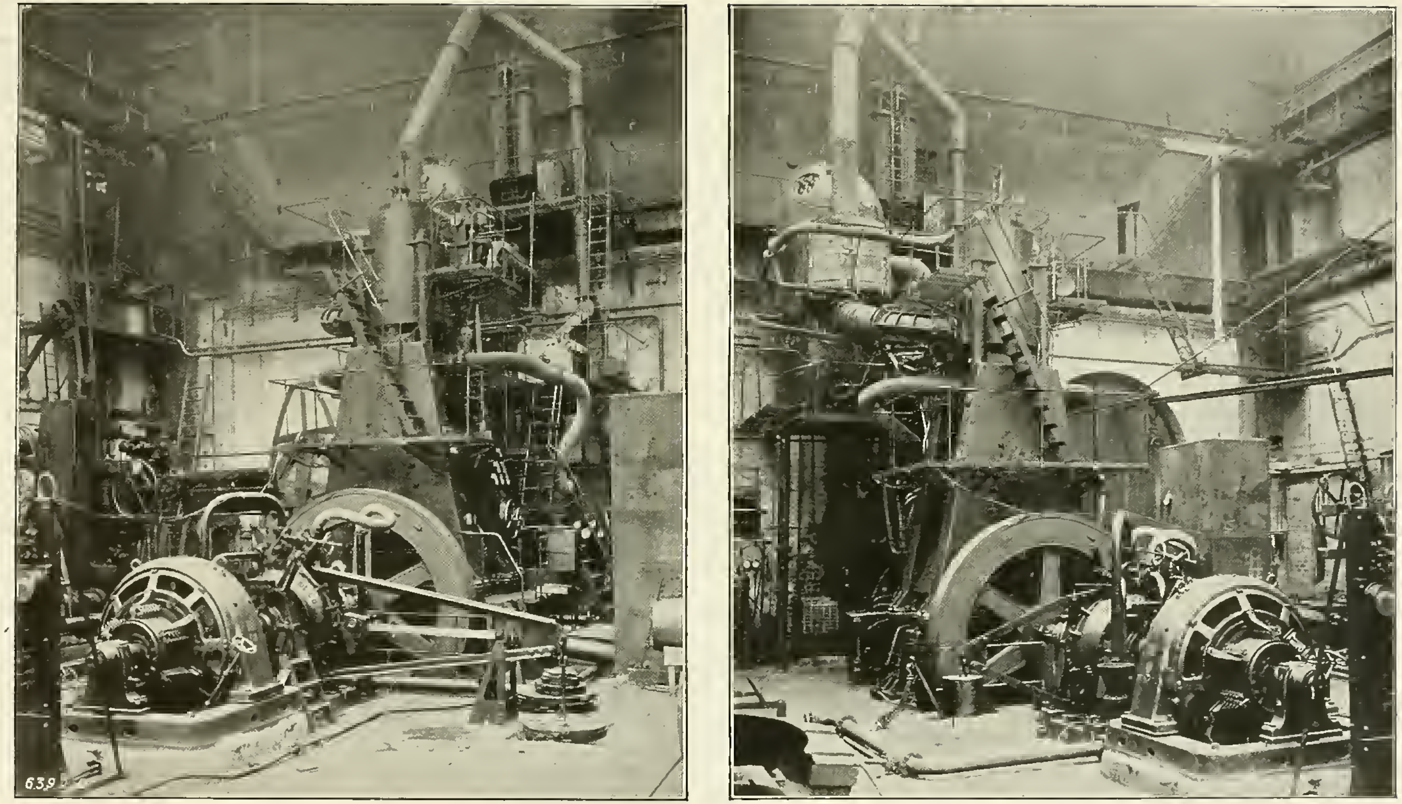
PROGRESS IN MARINE MACHINERY—CROSS-CHANNEL STEAMERS.

Year	1890.	1898.	1904.	1910.	1920.
Ship dimensions—					
Length	300 ft.	315 ft.	330 ft.	316 ft.	302 ft.
Beam	34 ft. 6 in.	37 ft.	42 ft.	41 ft.	35 ft. 6 in.
Performance—					
Speed in knots	18	19·75	19·5	21·5	23·5
Horse-power	4,400 I.H.P.	5,520 I.H.P.	5,500 S.H.P.	8,500 S.H.P.	12,300 S.H.P
Engines—					
No. of propellers	Two	Two	Three	Three	Two
Type of machinery	Three-cylinder triple-expansion	Four-cylinder triple-expansion	Parsons direct turbine, one H.P. and two L.P.	Direct steam turbines, one H.P. and two L.P.	Geared steam turbines, two H.P. and two L.P. turbines
Propeller (revs.)	130	165	550	625	435
Piston speed (feet per min.)	780	910	Turbines, 550 revs.	Turbines, 625 revs.	H.P. turbine, 2,600 revs.; L.P. turbine, 1,800 revs.
Referred mean pressure	30·75	43·0	—	—	—
Condenser surface per H.P.	1·42	1·4	1·35	0·75	0·6
Boilers—					
No. and type	Five S.E. cylinder boilers	Four S.E. cylinder boilers	Two D.E. and one S.E.	Seven water-tube	Eight water-tube
Working pressure (lb. per sq. in.)	160	180	150	190	195
System of draught	Natural	Forced	Forced	Forced	Forced
Heating surface per H.P.	2·6	1·95	1·9	1·95	2
H.P. per sq. ft. of grate	12·25	17·5	16·5	15·0	22·0
Total weight of machinery—					
Steam up	590 tons	610 tons	590 tons	735 tons	1,055 tons
H.P. per ton of machinery	7·45	9·62	9·3	11·6	11·65
Coal consumption per H.P.	2·25 lbs.	2·1 lb.	1·8 lb.	1·7 lb.	1·50 lb.

where the system has been employed have been published in this country and the further developments are being watched with interest. It may be that there is a field for electrical propulsion for large naval vessels, and the extending use of electrically-driven auxiliary machinery of all kinds may have an influence on the decision. Electrical propulsion means a power station afloat, and, while the conditions obtaining on land can be reproduced to a certain degree on a large warship, it is another matter when merchant vessels are under consideration. For such vessels there do not appear to be any advantages to place alongside the obvious drawbacks, and there is no doubt that many of the materials employed in electrical work are of a nature which is unsuitable for the conditions to be found in the engine rooms of the majority of merchant vessels on service. With regard to the application of the system one method is to couple direct the steam turbine to a high-speed alternator which is electrically connected to a motor mounted on the propeller shafting. By this means the required reduction in the speed of the screw is obtained, the shaft being driven at revolutions which correspond to a good propeller efficiency. The advocates of the system maintain that this method of speed reduction is preferable to mechanical gearing. But electrical propulsion is in a more or less experimental state, whereas mechanical gearing has been tested during the war on naval vessels under the most trying service conditions, and can be said generally to have come through the ordeal successfully.

The internal combustion engine is, as already stated, a serious rival of the steam engine for certain powers and services, and in its development the Scotts were early interested, so that it is appropriate that their work in this connection should be referred to here. The internal combustion engine owes much to the experimental work done by them in conjunction with other firms, particularly in connection with the building of such machinery for submarines. There can be no doubt

Plate LVII.



THE "STILL" EXPERIMENTAL ENGINE, SHOWING THE TESTING APPARATUS.

that the reliability and economy achieved in such craft have done much to commend the application of the internal combustion engine to merchant shipowners. There has been in the last few years a great accession to the number of vessels fitted with such engines. While most of these ships are under 300 ft. in length there were in 1919 about sixty vessels between 300 ft. and 500 ft. in length so fitted, and at least one over 500 ft.

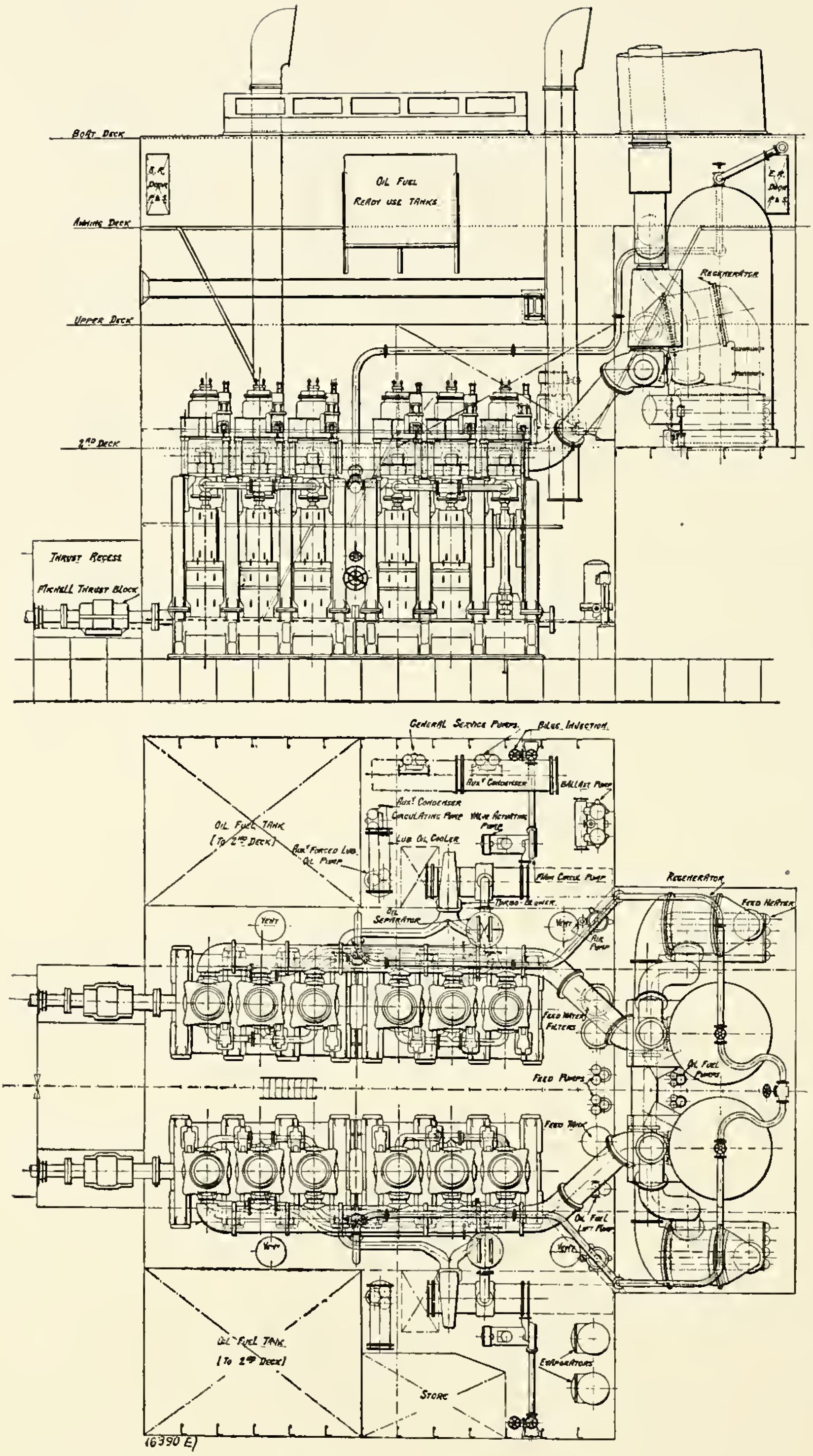
Very satisfactory results are attained in respect of fuel consumption, which is about 0·4 lb. of heavy oil per brake horse-power for all purposes, or less than a third of the weight of coal consumed by vessels with steam machinery. Thus on long voyages there is a great saving in the total fuel carried, which is utilised for augmenting the cargo space, and has a great effect on the balance-sheet of the oil-propelled ship for the year's operations.

The Scotts became associated with the well-known Fiat engineering firm in Italy, and, adopting the Fiat principle, fitted Scott-Fiat two-cycle engines to several naval vessels. The first machinery of this type which they fitted was for the submarine *S.* 1, which was delivered in 1914 before the outbreak of war. As her engines have been described in the chapter dealing with the "Work for the Great War Fleet," page 84, no more need be said about them here. The predominant feature of the Scott-Fiat engine apart from the question of reversibility, is the ease of control both in connection with starting and speed of revolution; while a further important consideration is the fact that the engine can utilise any normal kind of mineral oil.

A set of machinery of the Scott-Fiat two-cycle slow-speed type, suitable for merchant work, was fitted in the *Servitor*, an oil-tanker attached to the Royal Fleet Auxiliary Service. This vessel was built in 1914 at Chatham Royal Dockyard, and engined by the Scotts, who also supplied the oil cargo pumping arrangements. The vessel was propelled by two sets of oil engines developing a total brake horse-power of 450, the revolutions being 200 per minute. The engines were reversible, and the operation of going "full ahead" to "full astern" occupied less than eight seconds. A considerable time was spent in experimental work when running these engines on the test bed in the works before sending them to the ship at Chatham. The starboard engine had a dynamo with water resistance to dissipate the current generated. The dynamo was also able to run as a motor. For the port engine a different testing arrangement was adopted, the power being absorbed by a Heenan and Froude water brake, which confirmed the results obtained by the dynamo. The official test was of ninety-six hours' duration. Highly successful manœuvring tests were carried out on each engine, the engines being put from "full ahead" and "full astern" continuously until the air storage was exhausted.

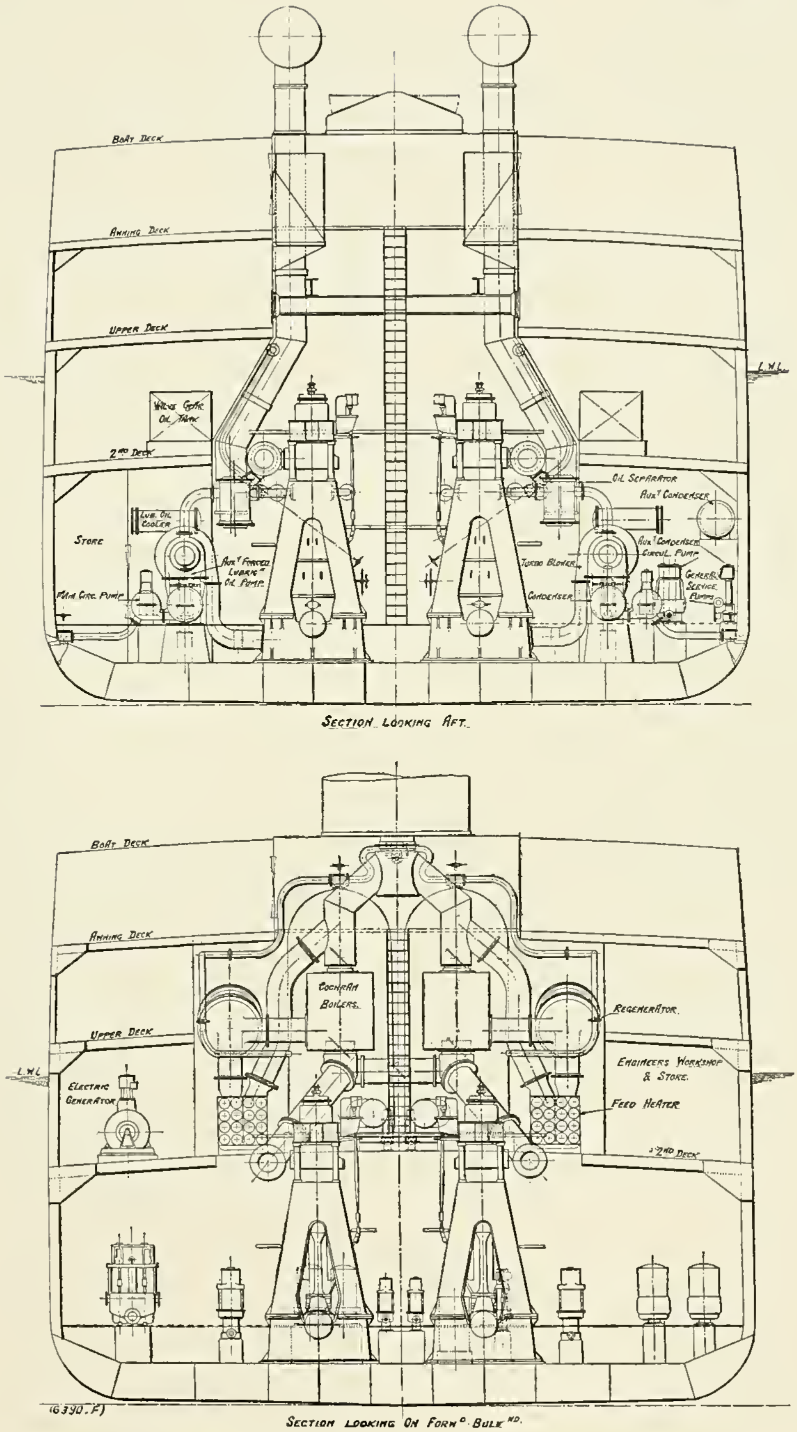
The work done by Scotts in connection with internal combustion engines put them in a very favourable position to take advantage of a development in marine propulsion embodying a new principle, and consisting of an ingenious combination of an oil engine and a steam engine, which appeared to offer great possibilities. In 1916 negotiations were entered into with the Engine Development Company, London (now The Still Engine Company, Limited), who held the patent rights. The main source of power of the marine "Still" engine, as the new engine was termed, is oil consumed within a cylinder for the down-stroke, operating on the two-cycle principle, while steam forms a supplementary source of power, being used for the up-stroke. The war prevented rapid progress, but designs were proceeded with, and, in the latter part of 1919, constructional work was commenced upon an experimental engine having one cylinder of about 350 brake horse-power. This experimental engine, which is illustrated on Plate LVII, is now undergoing (June, 1920) exhaustive running and fuel consumption tests. The cylinder, which is 22 in. diameter

Plate LVIII.



GENERAL ARRANGEMENT OF "STILL" ENGINES FOR TWIN-SCREW VESSEL.

Plate LIX.



ARRANGEMENT OF "STILL" ENGINES, SECTIONS.

with a stroke of 36 in., is intended to form a standard, and a range of powers up to 4200 brake horse-power will be obtained by varying the number of cylinders in line up to six and employing single or twin screws. Greater horse-powers will be met by increasing the size of the cylinders.

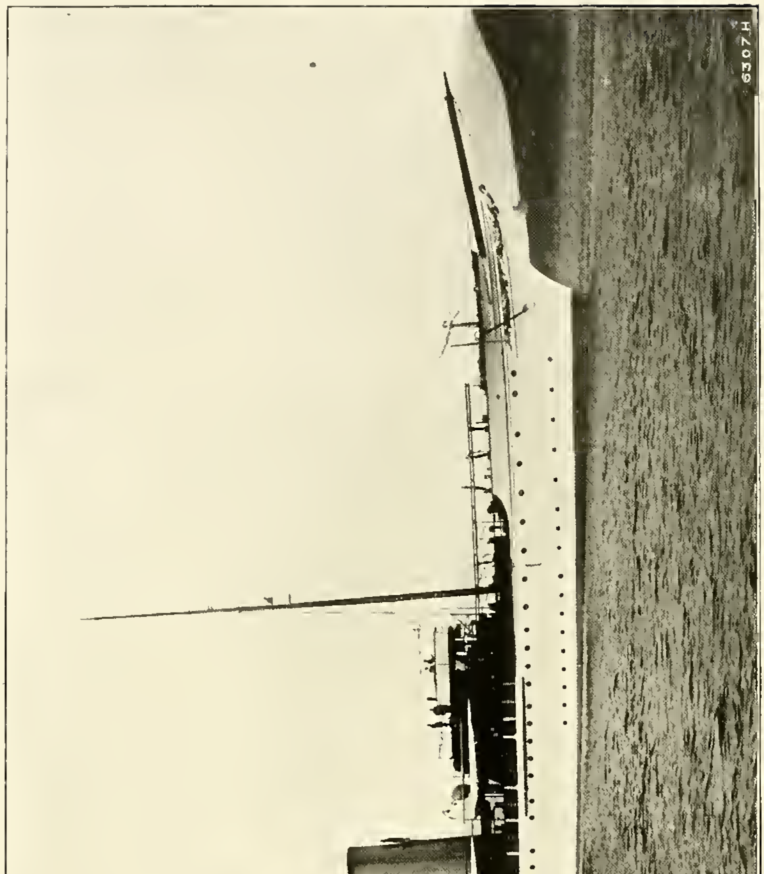
The " Still " engine is designed to reduce heat losses to a practical minimum, the primary consideration being to accomplish this in such a manner as to improve the thermal conditions of the working cylinders and so ensure the maximum efficiency from the fuel burnt therein. The engine is practically free from the array of rods, valves and cams associated with oil engines. There are no exhaust valves on the oil side to give trouble, and the fuel inlet valves are automatic in action. The valves on the steam side of the cylinders are operated by oil under pressure, thus dispensing with the usual valve gear, and simplifying and facilitating the control of the engine. In comparison with ordinary oil engines, it is believed that the wear and tear and upkeep expenses will be small. The manœuvring of the " Still " engine is greatly facilitated by the existence of the steam side with the result that the engine is very easily handled. It is capable of relatively low speeds of revolution and is notable for quiet running and absence of vibration.

On Plates LVIII and LIX are illustrated the machinery arrangements for a typical installation of " Still " engines of 4200 brake horse-power, suitable for a ship of about 450 ft. in length. It will be observed that two vertical steam boilers are fitted. These supply steam for starting the main engines, oil fuel being burnt in the furnaces for this purpose in the usual manner. When the main engines are started the oil burners on the boilers are shut off and the boilers then serve the purpose merely of steam and water reservoirs. The combustion cylinder jackets and the jackets of the exhaust pipes and the regenerators are in circuit with these boilers. The cooling water therefore enters and leaves the cylinder jackets at a constant temperature, regulated by the pressure of the steam. During compression, owing to the cylinder walls being at steam temperature, the entering charge picks up heat instead of losing it during the greater portion of the stroke, an advantage of the greatest value to the " Still " engine. During combustion and expansion heat is taken up by the water circulating in the cylinder jacket, all of which goes to form steam, and steam is also produced by heat recovered from the exhaust gases through the medium of the regenerators. The steam regenerated from these sources, when the ship is under way, performs useful work on the steam side of the main engine pistons and is also employed for auxiliary purposes. The steam boilers are of course available for port use.

As already stated, the " Still " engine is relatively more economical than the best heavy oil engine; but even more important is the fact that the space occupied by a "Still" engine installation and the weight of machinery under working conditions, are considerably less than for an oil-engine installation of the same power. In view of these considerations, which are so vital from the shipowner's point of view, it is anticipated that the " Still " engine will be adopted for many vessels in preference to the ordinary heavy oil engine. There is no doubt that the new prime mover marks an important development in the progress of marine propulsion.

In the course of our narrative we have given tables for the purpose of comparison : in Table XIV on page 138, dates are given of important successive developments of marine propelling machinery. Records of the progress of marine machinery for cargo steamers are given in Table XV, page 139, for intermediate liners, in Table XVI, page 140, for cargo steamers, and in Table XVII for cross-channel steamers. In Table XV, there is included an intermediate liner with water-tube boilers and double-reduction geared turbines for comparison with cylindrical boilers and single-reduction geared turbines.

Plate LX.



THE STEAM YACHT "MARGARITA," 17·1 KNOTS.

Yachting and Yachts.

♣ ♣

YACHT designers and builders, when votaries of the sport, produce much better results, and in this truism we have some explanation of the success of the Scotts in the long series of yachts built during the past century. There are a few misty memories and time-worn traditions to the effect that yachting of a kind was indulged in on the Clyde in the closing years of the eighteenth century; but there are no authentic records antecedent to the nineteenth century. From 1803 onwards the Scotts have been closely identified with the pastime, and with the production in the early years of sailing yachts; and, later, of steam craft.

The first notable Clyde racing yacht, of which there is any record, was launched by the Scotts in 1803, as already referred to on page 11 *ante.* She was a 45½-ton cutter for Colonel Campbell, an Argyllshire soldier, and the launching ceremony, the honours of which were done by Lady Charlotte Campbell, was attended with military honours. For the twenty years immediately following the launch of this cutter, yachting made good progress, and in 1824 the Royal Northern Yacht Club was formed for the better organisation and encouragement of the pastime. The club had its origin in the North of Ireland, and had jurisdiction over that district, as well as over the West of Scotland up till 1838, when the Irish section was disbanded. The Royal Northern gave regattas throughout the season, at almost every suitable port, from Helensburgh on the Clyde to Oban. Amongst the leaders of the Clyde Division was John Scott, the second of the name, and a large number of the racing craft owned by the members were built by him. Indeed, one of the most experienced writers on Yachting in Scotland, Mr. J. D. Bell, says that "among the old yachting families of the West of Scotland, the Scotts and the Steeles filled the foremost place."

Among the best remembered of the yachts built by John Scott were the cutters *Hawk* and *Hope*, constructed for himself, and the *Clarence*, built for his son-in-law, the late Robert Sinclair. The *Hawk* was a boat of about 30 tons, the *Hope* was rather smaller, and was used for cruising rather than for racing; the *Clarence* was about 18 tons.

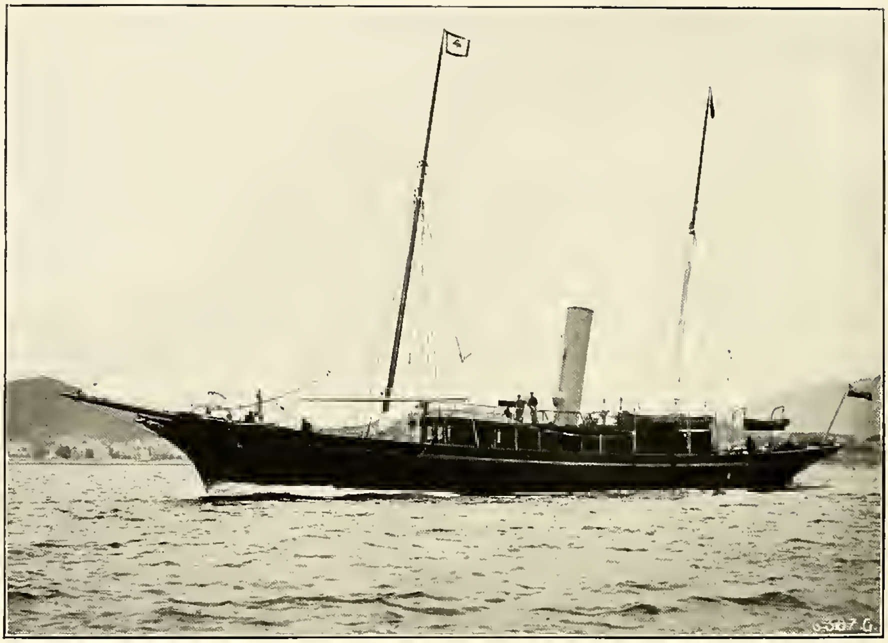
The *Hawk* was a successful racer, and secured many cherished prizes, but the *Clarence* was her superior, and was the first of a long line of prize-winners which have brought renown to the Clyde. In all she won over thirty challenge trophies, and in her best season never suffered defeat. Robert Sinclair, the owner, was himself a keen and accomplished yachtsman.

In the races held in 1833–34—most prominent years —John Scott, with the *Hawk*, won the Anglesey Cup at Dublin, and the Oban and Helensburgh Cups; while Robert Sinclair, with the *Clarence*, won the Ladies' Cup at Oban, the Kintyre Cup at Campbeltown, the Dublin, Adelaide, and Booth Cups at Dublin, the Stewart Cup at Greenock, the Largs Cup and the Dunoon Cup. These two yachts were indeed close rivals, although the principal honours rested

THE "GRETA," OF 1876.

THE "GRETA," OF 1895.

Plate LXII.



THE "GRETA," OF 1898.

THE "TUSCARORA."

with the *Clarence*. On one occasion, however, the *Hawk* unexpectedly defeated the *Clarence* in an important race at Dublin, and the owners were anxious to have the cup in Greenock as soon as possible for a special reason. Recognising that the *Clarence* was really the faster boat, they handed over the trophy to her crew to take to the Clyde port; but the luck which enabled the *Hawk* to win the cup stood by her on the passage home, and she made the port a considerable time before her rival.

The *Clarence* became a pilot boat, and was unfortunately run down off Garroch Head, while the *Hawk* was transferred to the fishing trade. In later years John Scott, C.B., had the laudable desire to secure as a relic the vessel his grandfather had owned, but the negotiations failed; and the boat may still be at work among the islands of Scotland.

The Royal Northern Club's fleet in the 'thirties numbered about fifty, but there were no steam vessels on the list until 1855. Among the principal boats in the club were the Duke of Portland's ketch, the *Clown*, of 156 tons; the Duke of Buccleuch's cutter, the *Flower of Yarrow*, of 145 tons; Mr. John Scott's cutter, the *Lufra*, of 81 tons; Mr. Robert Meiklem's schooner, *Crusader*, of 126 tons; and Mr. Lewis Upton's cutter, *Briton*, of 91 tons. The membership was about one hundred and fifty, the aggregate tonnage of the fleet about 2000 tons, and its cost, at a fairly generous estimate, about £20,000.

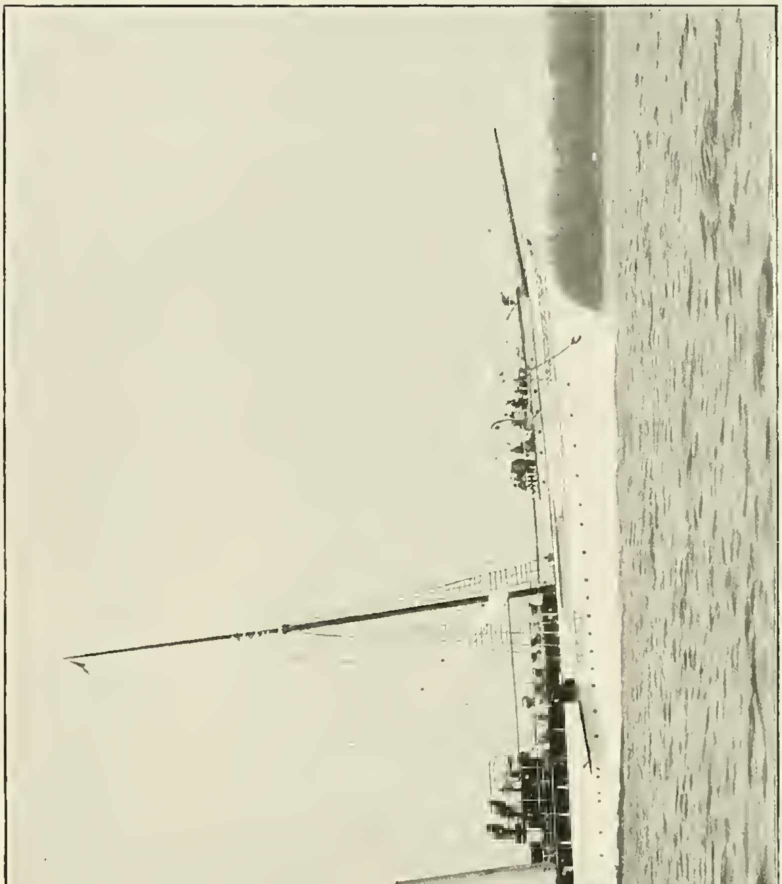
What a contrast is suggested by a review of the fleet of yachts owned on the outbreak of war by Clyde yachtsmen! There are now eight clubs in the Firth recognised by the Yacht Racing Association, and one of the largest of these—the Royal Clyde—alone had over a thousand members, with a fleet of over three hundred and seventy yachts, a collective tonnage of 26,000 tons, with a first cost of a million sterling. The club-house at Hunter's Quay, which cost about £20,000, is representative of the best of its kind. Many of the yachts—sailing and steam—are of considerable size, and have international repute for their excellence, either as racers, or as comfortable seaworthy cruisers.

The origin of the Royal Clyde Club in itself affords interesting suggestion of the development of the pastime on the Clyde. Owing to a rule enforced by the Royal Northern Club during the earlier period of its existence, boats smaller than 8 tons could not be enrolled; many enthusiastic owners of small craft were thus debarred from membership, and in 1856 they decided to form a new club. This, first named the Clyde Model Yacht Club, became, a year later, the Clyde Yacht Club; and, having grown immensely in influence, obtained, in 1872, Queen Victoria's sanction to the appellation of "Royal." To-day the Royal Clyde Yacht Club is one of the most important in the Kingdom.

John Scott (1752–1837) was long a prominent member of the Royal Northern Club. His son, Charles Cuningham Scott, was an original member, but did not take the same active part in the pastime, the claims of a quickly-developing industry being probably the reason. But the records of the family were again revived by his sons—John Scott, C.B., Robert Sinclair Scott, and Colin William Scott. They displayed a preference for steam craft, although the first-named owned several cutters, beginning with the *Zingara;* later several beautiful steam yachts, each successive ship being named the *Greta*, were built for him. Three of these, of 1876, 1895 and 1898, are illustrated on Plates LXI and LXII. He was elected Commodore of the Royal Clyde Club in 1895 in acknowledgment of his services to the club and to yachting generally, and occupied the post until his death in 1903.

These were exciting times in Clyde yachting. It was then that Lord Dunraven and Sir Thomas Lipton made their gallant but unsuccessful efforts to recover the America cup with Clyde-

Plate LXIII.



THE "ERIN," OWNED BY SIR THOMAS LIPTON, BART.

built boats; while the performances of the *Britannia*, owned by the then Prince of Wales, later King Edward VII., and of the *Meteor*, belonging to the ex-German Emperor, gave a distinction to the sport which it had never enjoyed before.

The Mudhook Yacht Club was formed in 1873 by a few skilled yacht designers and yachtsmen, and included Robert Sinclair Scott, Colin William Scott, and James Reid. The membership was limited to forty, and the aim of the founders was to " encourage amateur yacht sailing." There were many inspirations connected with the founding of the club; there is a tradition that when a "Mudhooker" was being initiated, he was usually confronted with a coil of rope, a small marlin-spike, a chart and dividers, a forecastle bucket and other implements; and, before the hand of fellowship was extended to him, he was exercised, with more or less of solemnity, as to their uses.

Robert Sinclair Scott was Admiral of the Club from the foundation of the Club until his death in 1905. For twenty-nine years from the same period his brother, Colin William Scott, acted as Honorary Secretary, and his great services were recognised on the club attaining its majority in 1894, by the presentation by the members of a set of old candelabra and fruit dishes. The present chairman of the firm, R. L. Scott, son of John Scott, C.B., was Honorary Secretary for 10 years.

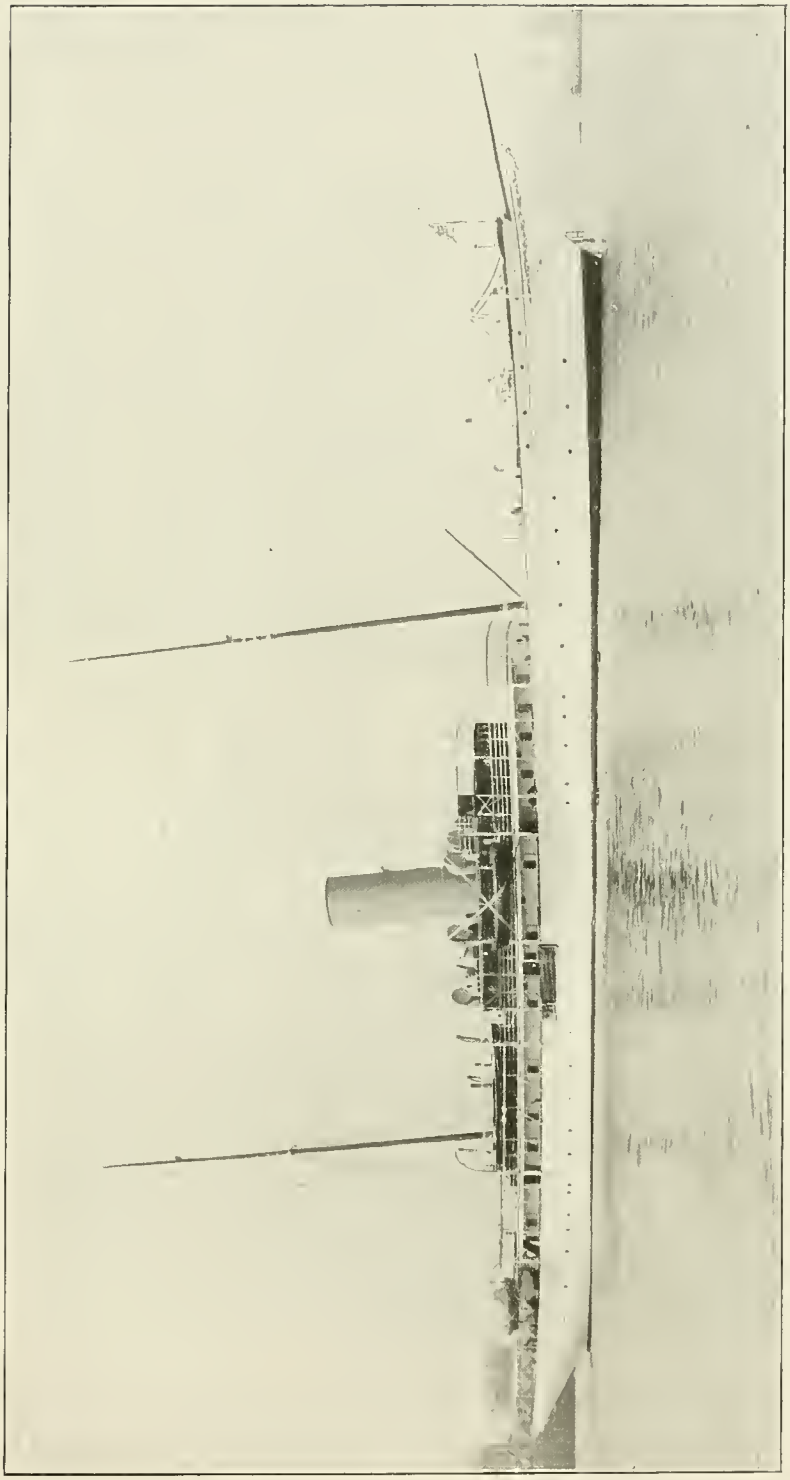
Although, as we have said, the Scotts never owned racing yachts, they have built for themselves and for others a long succession of beautiful steam yachts, as recorded in the table on page 153. In all, seven yachts have been built in succession for the Scotts themselves. Each was named the *Greta*, after a small stream which runs through the Halkshill Estate, excepting the last, which was called the *Grianaig*, the Gaelic for Greenock.

The last *Greta* was exactly double the length of the first, while the yacht tonnage was practically eightfold. The successive steps may bc noted. The *Greta* of 1876 was 76 ft. long, and of 53 tons, and she was purchased by a Kilmarnock lady, Miss Finnie. The vessel built for John Scott, C.B., in the following year was slightly larger, and she also was coveted and secured. In 1878 a still larger ship was built, and for many years this craft continued in the possession of its original owner, but in 1892 was displaced by a vessel of greater size of 135 ft. 6 in. in length, and of 230 tons yacht displacement. Other vessels followed at periods of three years, and the *Greta* of 1898 was 154 ft. long, and of 393 tons.

Many other notable vessels were constructed in the same period for other owners ; and while it is not possible to refer to all of them, mention may be made of the *Tuscarora*, built in 1897, for Mr. William Clark, of Paisley. This vessel, which is illustrated on Plate LXII, is 170 ft. long, and of 775 tons. She had a bridge and promenade deck 104 ft. long ; and there were ten state-rooms and large saloons for the owner and his guests. Built for oversea cruising, she had a very complete installation of refrigerating machinery. The triple expansion engines with which she was fitted developed 1030 horse-power when running at 150 revolutions, equal to a piston speed of 675 ft. per minute. Steam was supplied by a single-ended boiler working under forced draught.

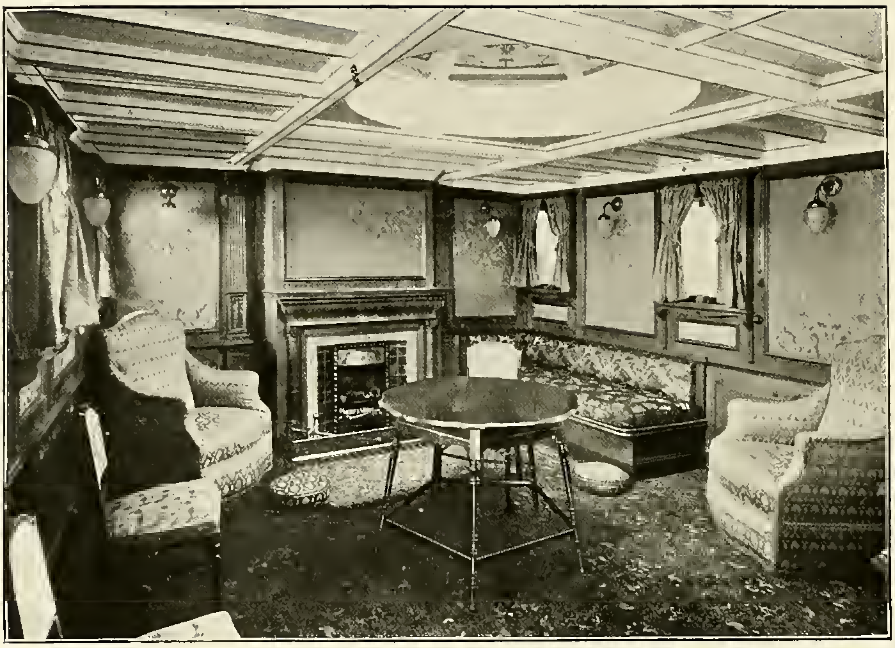
A much larger vessel—indeed, the largest pleasure yacht constructed by the firm—was the *Margarita* (Plate LX), constructed for Mr. A. J. Drexel, Philadelphia, to the designs of the late Mr. G. L. Watson, who did so much for the advance of the science of naval architecture as applied to sailing and steam yachts. This vessel was 272 ft. in length, with a displacement of 2522 tons. For the owner and his guests there were thirteen large state-rooms, and the general saloons included dining, drawing, and smoking rooms, a boudoir, and a children's nursery. The yacht was equipped with all the accessories of the modern liner, including refrigerating appliances. It was propelled at a

Plate LXIV.



THE TWIN-SCREW YACHT "CASSANDRA," 15·6 KNOTS.

Plate LXV.



THE DRAWING-ROOM IN THE STEAM YACHT "BERYL."

ONE OF THE STATEROOMS IN THE "CASSANDRA."

TABLE XVIII.

GENERAL PARTICULARS OF PRINCIPAL STEAM YACHTS BUILT BY SCOTTS.

Name.	Date of Construction.	Length.	Breadth.	Depth.	Displacement in Tons.	Speed.	Type of Engines.	Indicated Horse-Power.	Boiler Pressure.	Owner.
		ft. in.	ft. in.	ft. in.		knots.			lb.	
Greta	1876	76 0	12 0	9 3	53	7·5	Compound	58	74	John Scott, Esq., C.B.
Greta	1877	84 0	12 6	9 6	73	8·25	,, ...	76	78	John Scott, Esq., C.B.
Greta	1878	90 0	14 0	9 6	86	9·33	Compound tandem	105	78	John Scott, Esq., C.B.
Ulva	1879	162 0	21 0	15 6	350	11·08	,, ,, ...	277	70	F. A. Hankey, Esq.
Griffin	1879	120 0	16 6	11 0	152	9·8	,, ,, ...	130	78	C. E. Dashwood, Esq.
Eagle	1879	84 0	12 6	9 6	77	7·7	Compound	74	75	Count Stackleberg, St. Petersburg.
Retriever	1884	123 0	17 0	12 0	144	11	,, ...	215	90	O. Randall, Esq.
Alca	1887	80 6	14 0	10 0	93	10	Triple-expansion	110	160	Colonel Malcolm, Poltalloch.
Santanna	1887	180 0	24 0	15 6	495	13·6	,, ,, ...	780	150	M. Louis Prat, Marseilles.
Foros	1891	236 0	30 6	20 6	1170	12·5	,, ,, ...	960	160	M. Kousenzoff, Moscow.
Greta	1892	135 6	18 6	12 0	230	11	,, ,, ...	280	160	John Scott, Esq., C.B.
Kittiwake	1893	113 0	21 0	13 6	210	9·55	,, ,, ...	185	160	Lord Carnegie.
Lutra	1894	117 0	18 0	12 0	200	10·75	,, ,, ...	250	160	Colonel Malcolm.
Greta	1895	145 0	22 0	13 5	338	11	,, ,, ...	340	170	John Scott, Esq., C.B.
Erin	1896	252 0	31 6	20 6	1330	15·6	Triple-expansion, 4-cyl.	2500	180	Sir Thomas Lipton, Bart.
Tuscarora	1897	170 0	26 6	15 7	775	12·5	,, ,, ,,	1030	170	Wm. Clark, Esq., Paisley.
Greta	1898	154 0	22 9	13 6	393	12·25	,, ,, ,,	480	170	John Scott, Esq., C.B.
Lutra	1899	140 0	21 0	13 0	348	11·65	,, ,, ,,	480	170	Lord Malcolm of Poltalloch.
Margarita	1900	272 0	36 6	28 0	2522	17·1	Twin-screw, triple-expansion, four cylinders in each engine	5200	200	A. J. Drexel, Esq., Philadelphia, U.S.A.
Waihi	1900	82 0	14 6	10 0	102	10·3	Triple-expansion	130	170	J. Bulloch, Esq.
Saevuna	1901	76 4	14 6	9 3	95	8·4	Compound	75	130	Maurice Bernard Byles, Esq.
Grianaig	1904	160 0	23 9	14 0	435	12·6	Triple-expansion	740	190	R. Sinclair Scott, Esq.
Beryl	1904	160 0	25 0	14 6	500	13·3	,, ,, ...	910	200	Lord Inverclyde.
Cassandra	1908	238 0	32 10	20 0	1390	15·63	Twin-screw, triple expansion	2530	200	Roy A. Rainey, Esq., New York.

speed of over 17 knots by twin-screws, operated by two independent sets of triple-expansion four-cylinder engines, balanced to obviate vibration.

The *Aegusa* was designed and built in 1896 for a Sicilian nobleman, and was purchased later by Sir Thomas Lipton, who re-christened her the *Erin*. One of the largest yachts of her time, she was 250 ft. long, and of 1330 tons displacement. The four-cylinder balanced engines of 2500 indicated horse-power gave a sea speed of 15·6 knots. This yacht had an interesting history. Shortly after the outbreak of war Sir Thomas fitted her out as a hospital ship, and proceeded to the Near East on a mission to the Serbians. Later there was a reversion to the original name of *Aegusa* when the Admiralty took her over as an armed patrol steamer, there being already an *Erin* in the Navy. She did good work on our coasts until her career was ended by an enemy torpedo.

The *Beryl* included in the table on page 153, was a vessel of 160 ft. in length, with a displacement of 500 tons on a draught of slightly less than 12 ft. She steamed 13.3 knots on trial, with the engines indicating 910 horse-power, steam being supplied from a large single-ended boiler with three furnaces working under forced draught.

The *Grianaig*, the last of the series of yachts built for the Scotts themselves, was completed in the same year as the *Beryl*. Her machinery was noteworthy, as a system of forced lubrication was applied to the principal bearings, with highly satisfactory results. The dimensions of the yacht are given in the table. The engines developed on trial 740 indicated horse-power, when running at 148 revolutions per minute, the boiler pressure being 190 lb. per sq. in., and the condenser vacuum 26·5 in.

The *Cassandra*, the latest of the yachts, illustrated on Plate LXIV, was completed about the middle of 1908, for the well-known American sportsman, Mr. Roy A. Rainy, of New York. She was a vessel of considerable size, having a length of 238 ft., a displacement of 1417 tons, and a draught of 12 ft. 6 in. The vessel was conspicuously graceful, and one of the best "appointed" yachts afloat. The public rooms, including dining, drawing and smoke rooms, were arranged upon the promenade deck, upon which also was located an observation room, which formed a special feature. The owner's quarters included sitting, dressing and business rooms, all artistically furnished. In addition, nine state rooms were provided for the accommodation of guests, and a considerable space was allotted to the crew and attendants.

The machinery consisted of two sets of balanced triple-expansion engines with cylinders of 16-in., 26-in., and 42-in. diameter respectively, having a 27-in. stroke. Steam was supplied at a pressure of 200 lb. to the square inch by two single-ended cylindrical boilers, 16 ft. in diameter and 11 ft. long, working under natural draught or alternatively under forced draught on the closed stokehold system. Exhaustive trials were carried out, and the vessel attained a speed of about 15·63 knots with an indicated horse-power of 2350, when the engines were running at 145 revolutions per minute.

This performance may be taken as an indication of the progress in the forty years that had elapsed from the date of the building of the first *Greta:* the ratio of horse-power to tonnage was increased from 1 : 1 to 2 : 1; the steam pressure from 74 lb. to 200 lb.; and the piston speed from 300 ft. to 675 ft. per minute. The aim of the Scotts in the design of yacht machinery has always been to ensure reliability by the production of steady and easy-running engines having extra large bearing surfaces. Appearance has always been studied, and the result has invariably been a highly finished engine. The general practice of the firm has been to balance the engines, whether so specified or not, and the gain in comfort to all on board, owing to the absence of vibration, more than compensates for the extra cost involved.

As to the future, it is probable that in large pleasure yachts of relatively high power the geared turbine will find an important place. There are indications that in small vessels some form of internal combustion engine will be popular. In the intermediate sizes it is likely that the balanced reciprocating steam engine will hold its own for some time.

Plate LXVI.

ONE OF THE DRAWING OFFICES.

Experiment, Design, Administration.

♣ ♣

HAVING reviewed the history of the firm, and dealt briefly with the results obtained by some of the modern steamers constructed by them, we propose now to describe the works in order to indicate the measures adopted to secure efficiency in design and construction of all types of ships and machinery. Experiment, design and administration are as important factors towards this end as the mechanical methods and appliances adopted, and it may be well, therefore, to deal first with these.

As regards experimental work, many indications have already been given of the Scotts' appreciation of the aid of the scientist in solving many problems arising in the industrial world, and reference may be made first to their well-equipped laboratories, which are capable not only of carrying out all [the routine testing work necessary to determine the quality of, and best method of utilising, the materials employed, but also of conducting prolonged researches into the causes of failures, and fully to investigate almost any of the problems in connection with the work. These laboratories comprise three rooms.

In the mechanical testing department there is a 50-ton testing machine, which is illustrated in Plate LXVII. This machine is of the screw type, and is driven by a separate electric motor.

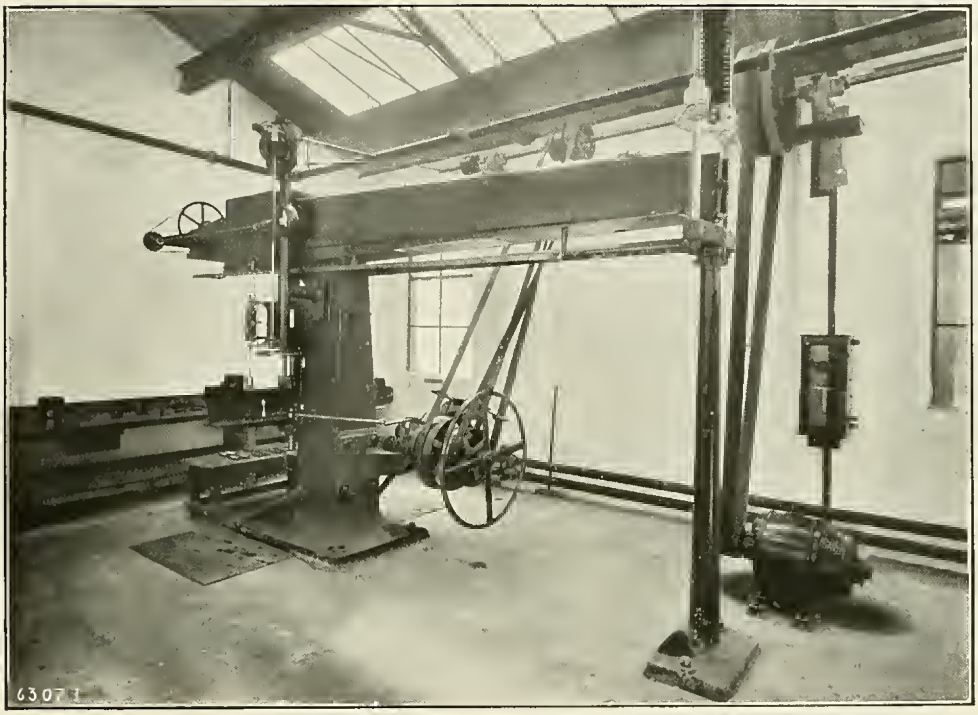
The chemical laboratory, which adjoins the mechanical testing room, is illustrated in Plate LXVIII. It is mainly employed in general routine work, and particularly on analysis. Opening off the chemical laboratory are an office and library, and a balance room.

In the physical laboratory, which is also connected with the chemical laboratory, and is illustrated on Plate LXVII, there is a horizontal metallurgical microscope, which can be used for visual or photographic work. A portion of this laboratory is partitioned off for use as a photographic dark room.

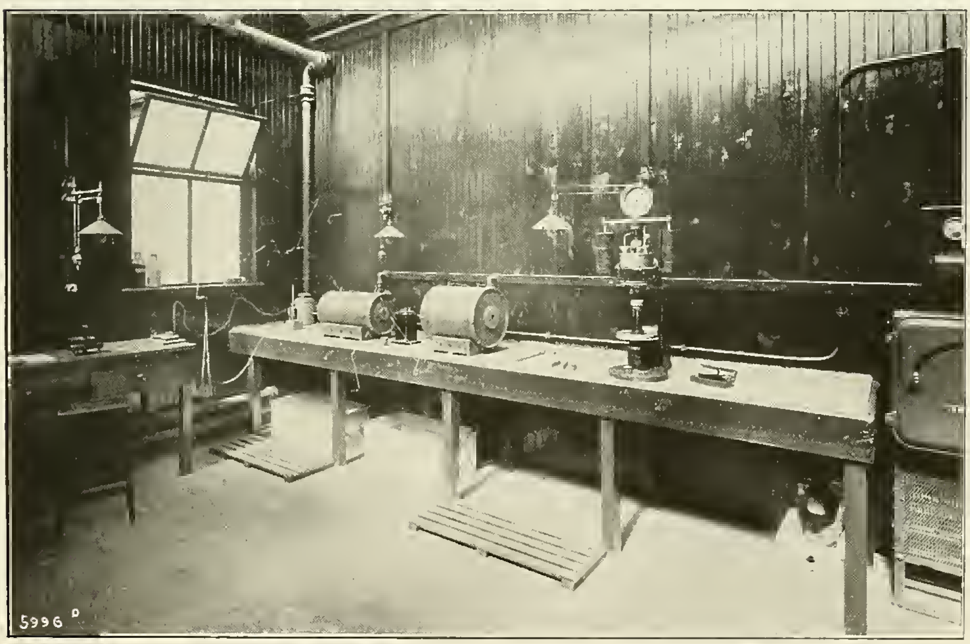
The work carried on in these laboratories is of the varied character associated with a large shipbuilding and engineering establishment. To ensure the continuous production of sound and reliable castings in the brass foundry a system of temperature control is maintained. Experiments are conducted to ascertain the best method of heat treatment for each grade of tool steel. Case hardening is another matter which is scientifically dealt with. The work from the shipyards includes the investigation of the failures of plates and welds, the testing of the strength of welds, and the determination of the composition and purity of paints, oils, greases, rubber, insulation, and other non-metallurgical materials used in shipbuilding.

The firm have been responsible for the design of most of the merchant ships constructed by them. Success has been rendered more certain by the possession of carefully collated

Plate LXVII.

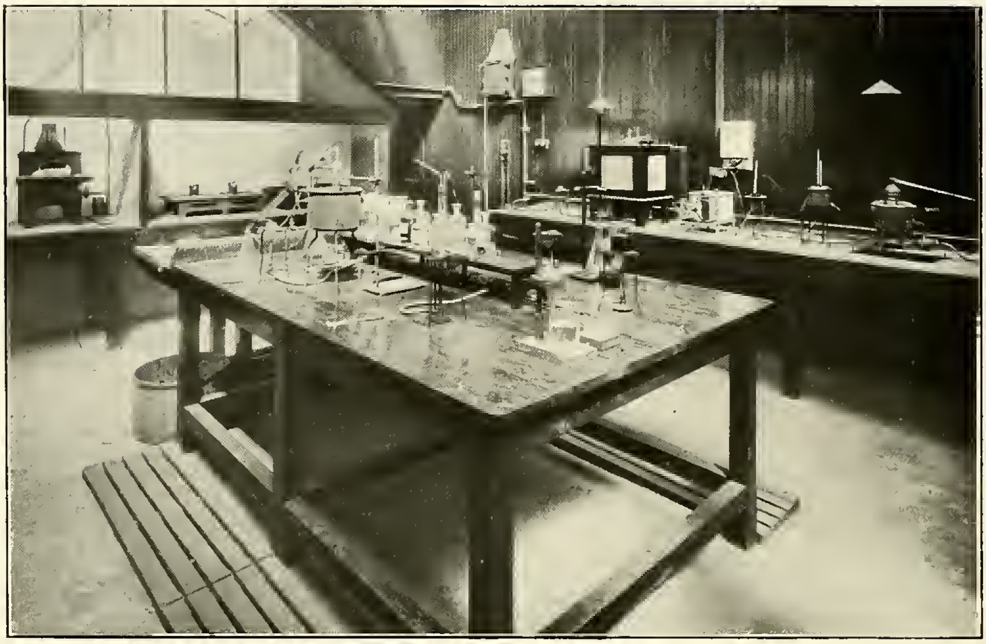


THE TESTING HOUSE.



THE PHYSICAL LABORATORY.

Plate LXVIII.



THE CHEMICAL LABORATORY.

ANOTHER VIEW OF THE CHEMICAL LABORATORY.

records, the product of an organised system of working up all data, of tackling new problems, of making calculations regarding any scientific question, and of studying contemporaneous work as described in the technical press and in papers read at the technical institutions. This continuous investigation produces a wealth of suggestion, which enables the chiefs of the respective departments to determine how far practice may be improved; and thus there is steady progress not only in design but in constructional methods. A well-selected technical library, from which the staff can borrow books, also contributes to the same end.

The drawing and designing departments, in which the work is initiated, have been considerably extended in recent years. The broad principle adopted is that all details must be shown on the drawings, and that no work is to be done in the shops or yards without drawing office instructions. Encouragement is given to draughtsmen of outstanding ability for special work.

There is a large estimating department, where records of costs, rates, wages, etc., are of the most complete description. The card system adopted is admirably suited for enabling references to be made at any time as to the cost of units in any contract. Here also it is possible, by the simple process of comparison, effectually to check the economy of design and manufacture, without which there is a great handicap on efficiency.

The staff in these departments is largely recruited from the shops, and thus there is an incentive to the willing apprentice and worker to excel. Competitions are instituted at intervals to encourage expertness in some branch of work—for instance, in the use of the slide rule, etc.

The same broad policy is pursued in the shops. Payment by merit to the tradesman is adopted as far as possible. In the engine works the premium bonus system—first adopted in 1902—is extensively applied. The arrangement is satisfactory from the point of view of tradesman, employer and client.

Contract or piecework is the rule in the shipyards, and it is also employed in the boilershops and in connection with fitting machinery on board ships at the fitting-out basin. The effect of the encouragement given the men to greater effort by these means is reflected in the great output of the works during the war period.

Considerable attention is directed to work planning, and the progress departments assist in work being turned out in correct sequence. It is found that by adopting central control, where possible, much overlapping is avoided in connection with management, and labour is reduced.

With a view to improving the *personnel*, the Scotts have always carried out a broad, enlightened policy in their treatment of apprentices and young tradesmen. Alive to the importance of the matter, the firm have appointed a supervisor of the general and moral well-being of the youth of the establishment, whose aim is to keep in touch with the boys personally, and gain their respect and confidence, so as to be in a position to act as an intermediary with the firm on all questions affecting the efficiency and welfare of the boys.

To further this object there is a Boys' Club, of which illustrations are given on Plates LXIX and LXX. The Club has a Gymnasium, Workshop, Baths, Lecture Hall, Recreation Rooms and Study Rooms; while outdoor recreation and sports and a summer camp are also organised. It is anticipated that the system of training and communal intercourse at the Club will improve the standard of physical fitness of the younger employees, broaden their sympathies, and gradually create an *esprit de corps*, the effect of which will be experienced in improved co-operative effort in the workshops and more rational and pleasure-yielding recreation in leisure time.

BOYS' CLUB, RECREATION ROOM.

BOYS' CLUB, READING ROOM.

Plate LXX.

BOYS' CLUB, GYMNASIUM.

BOYS' HOLIDAY CAMP, NEAR CAMPBELTOWN, 1919.

The necessity for improvements in the methods of education and technical training of apprentices has been long appreciated, but the progress that can be made by an individual firm in this direction is limited. It has taken the upheaval of a war to overcome the existing inertia, and bring together the elements necessary to promote the success of such a movement.

The firm are in close touch with the latest developments affecting the question of apprentice training, and are co-operating in the most whole-hearted manner with the education authorities. The general subject is still in the transition stage, and the course eventually followed will depend to a certain extent on the methods which are adopted in the district for the administration of the Education (Scotland) Act, 1918.

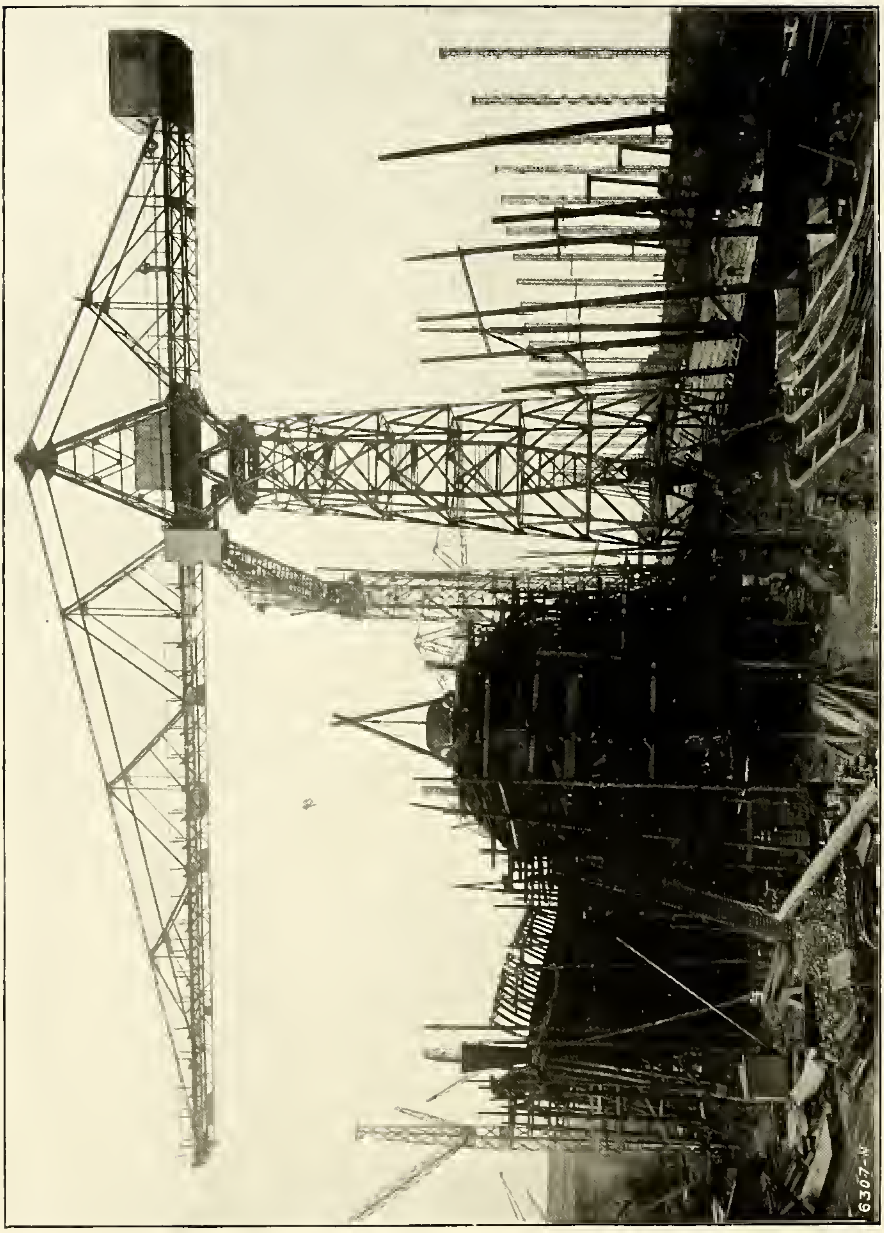
In connection with the training of apprentices a departure has been made in some of the workshops, where the apprentices have been put in charge of apprentice masters for trade instruction with encouraging results, and the principle is being extended in application. For the older apprentices special trade classes are provided in the evenings, combined, so far as is possible, with practical demonstrations in the works. Apprentices are encouraged to greater diligence by the payment of graduated bonuses to those who attain a specified standard of efficiency in the successive years of this educational course. In the case of the better educated and more promising youths special facilities are granted for the continuation of technical education on the "sandwich" system at a technical college or university.

With a view to extending the area from which apprentices may be drawn, the firm have had in successful operation for some years a scheme for the attraction of new blood from out-of-the-way parts of the Highlands and Islands of Scotland. Under this scheme the firm assist likely lads by paying travelling expenses and granting a weekly gratuity to each in order to bring up the minimum pay to a figure at which it is possible to make ends meet. Taking advantage of these arrangements are youths hailing from so far north as the Hebrides, Sutherland, Ross-shire and Inverness. The lads have proved healthy and well conditioned, and it is believed that the enlightened policy of the Scotts in this matter will tend in the course of time to raise the standard of mental and physical well-being of the men in the works.

Plate LXXI.

THE FITTING-OUT BASIN, CARTSBURN YARD, 1919, SHOWING THE BOOTH LINER "HILDEBRAND" BEING RE-CONDITIONED.

Plate LXXII.



A VIEW OF THE CARTSDYKE YARD.

The Shipbuilding Yards.

♣ ♣

COVERING an area of forty-five acres, the works are capable of dealing with the construction of an aggregate gross tonnage of 70,000 to 80,000 tons at one time; and with a corresponding horse-power, for which the figure can hardly be stated, as so much depends upon the class of construction on hand at a given time. It may be said, however, that when naval work is well represented the corresponding horse-power might be over 200,000. With departments for producing also all the accessories of ships and their machinery—engine and boiler works, foundries, sheet iron shops and plumber shops, saw mill and extensive wood-working departments—the establishment gives employment to 6,000 workmen.

The building of a Monitor for the British Navy, the *Sir John Moore,* described on page 98, is but one of many instances of rapid construction which might be enumerated. Work was commenced on January 13th, 1915; the launch took place on May 31st, 1915, and the propelling machinery was fitted on board and the vessel completed ready for trials on June 30th, 1915; that is within twenty-four weeks from the laying down of the keel, an achievement which was highly creditable in view of the size and weight of the vessel. The launching weight was 4416 tons.

As previously stated, the building of ships is carried on at two yards, the Cartsburn Dockyard and the Cartsdyke yard. It will be sufficient, for our purpose, to describe briefly some of the leading features of both yards.

The plans of ships are prepared in the designing department and drawing offices, to which reference has already been made. The moulding loft, where the work of construction is commenced, is situated in a substantial four-storey building, accommodating practically all the wood-finishing departments. Each floor has an area of 12,500 square feet; the ground and first floors are given up to the joiners and cabinet-makers with their numerous machine tools, while the top floor is utilised for drawing offices and polishing shop. The moulding loft monopolises the third floor, and as the length is 240 ft. and the width 52 ft. there is ample space, as is shown on the engraving on Plate LXXIII facing this page, for dealing with the extensive template making so necessary for rapid construction; and for the various moulds and mockings required in the building of warships and special vessels.

The ironworkers' departments are extensive and important. When the material is delivered into the yard, it is discharged from the railway wagons by 5-ton electric overhead travelling high-speed cranes, which stack the plates and bars in such a manner that any piece can be readily removed by the same cranes for conveyance to the furnaces.

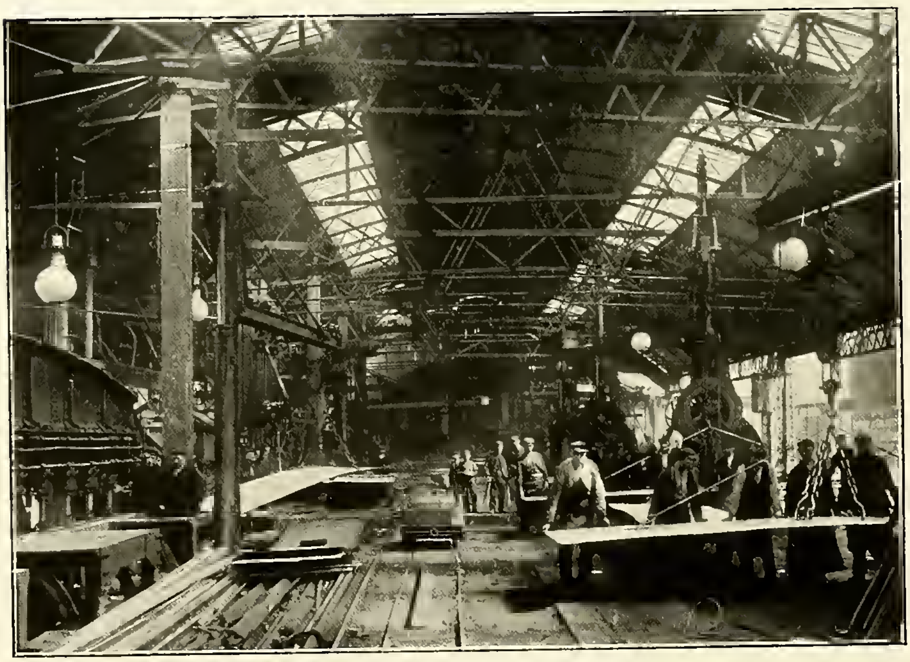
There are two plate furnaces suitable for heating shell plates of the largest size, and two double-ended frame furnaces capable of dealing with frames up to 60 ft. in length. Adjacent to the furnaces are the scrieve boards and the frame bending blocks. The channel, bulb angle or Z bars, used so extensively now for framing in large ships, are bevelled in special machines placed on rails at the front of the frame furnaces. The bars are passed through these machines on their way from the furnace to the bending blocks, and receive the necessary bevel, varying at different points of their length as required, and

THE MOULDING LOFT.

SHIPYARD PLATE RACKS, CARTSBURN YARD.

Plate LXXIV.

ONE OF THE FRAME SHEDS.



VIEW IN ONE OF THE PLATERS' SHEDS.

arrive at the blocks ready for bending. In this way only one heat is required for bending and bevelling. The manipulation of the plates and bars from the furnaces is done by means of electric winches. Portable hydraulic rams, capable of dealing with the heaviest scantlings, are used for frame bending. The frames are cut to the required length by hydraulic guillotines or by a special shearing and notching machine, while more particular or angled cuts are made at the high-speed saws. The hammering of the furnace plates to shape is done by means of pneumatic hammers supported by, and travelling on, hydraulic cranes. A set of these tools is installed at each plate furnace.

A view in one of the platers' sheds, where the plates, angles, bulbs, bars, etc., are machined, is given on Plate LXXIV, facing this page. It may be said generally that the machines are designed to deal with plates up to 36 ft. in length, and with angles up to 60 ft. in length and of corresponding sections. It follows that the straightening and bending rolls, edge planers, and punching and shearing machines, are of great power. It is scarcely necessary to make detailed references to all the tools for these and other purposes.

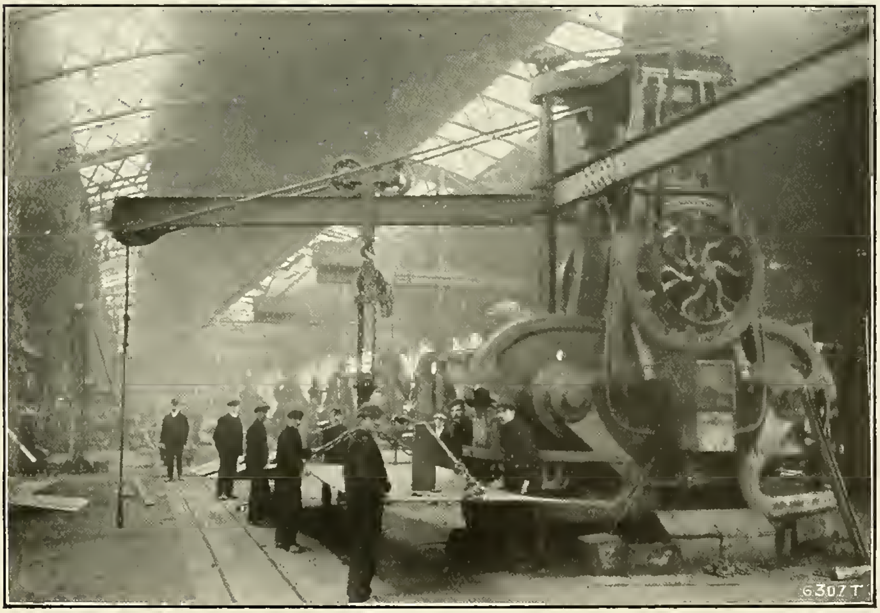
All the tools are driven electrically or by hydraulic power. A liberal installation of hydraulic cranes is provided throughout the yards, lifting up to 5 tons. There are plate bending rolls capable of rolling mild steel plates 36 ft. in length, with rollers 36 ft. 4 in. between housings, operated by a direct-geared main motor of 100 brake horse-power and two small motors of 15 brake horse-power for elevating and lowering ; in addition, there are plate rolls capable of dealing with $1\frac{1}{2}$-in. thick nickel steel plates cold ; 8-ft. mangles ; plate edge planers with hydraulic rams ; plate scarphing machines ; joggling machines ; flanging machines and manhole punching and flanging machines, capable of punching 42-in. by 16-in. manholes and dishing keel plates. There are many heavy punching and shearing machines, with gaps up to 48 in. ; some of these are arranged to punch $1\frac{1}{2}$-in. holes through $1\frac{1}{2}$-in. nickel steel plates at the rate of 30 holes per minute. A large number of high-speed radial drills are installed, each having its own electric motor. There is also an hydraulic flanging press for bending angles and tees to form knee bars and other stiffening pieces. The angle bar planing machine deals with bars up to 12 in. by 12 in. by 1 in., and planes both flanges simultaneously.

A specially powerful tool is provided for bending channel irons and beams and for drilling horizontal holes in them. The hydraulic joggling machines, already referred to, are used for joggling frames and beams cold, and so dispensing with the use of slips in way of the outside strakes of plating. The only slips required are at the ends of the vessel, where the bevel of the frames precludes the use of joggling. There are three pneumatic hammers employed for forming tapered slips, each actuated by an independent electric motor.

The angles, etc., to form the frames are assembled at the head of the building berths, and when lying on skids are riveted by hydraulic machines. The frames thus riveted are conveyed down the berths by a simple and ingenious cableway, known in the works as the "switchback," from its resemblance to the well-known amusement railway. A derrick post stands at the head of the berths adjacent to the skids on which the frames are riveted. The cable stretches from a derrick at the foot of the shipbuilding berths over a pulley at the top of the large derrick post, and thence through a lead block to an electric winch. The frame or unit of the ship's structure is suspended on a running block on the cable, which is then made taut, by the working of the winch. The running block with its load travels down the taut cable by gravity, under the guidance of the workmen. The gradient of the cableway is only sufficient to enable the load to move at a slow speed to its position at the shipbuilding berths.

Hydraulic riveting machines are extensively employed throughout the yards, some twenty of these machines being in use, with gaps ranging up to 72-in. Electric blower forges

PUNCHING AND SHEARING.



A LARGE PUNCHING MACHINE.

Plate LXXVI.

THE SAW MILL

THE JOINERS' SHOP.

are generally used in heating the rivets for this work. Pneumatic tools are employed for drilling, tapping, riveting, caulking, also for buffing rivet points where it is necessary to have a flush surface. There are over 250 of these tools constantly in operation, in addition to electric drills for lighter drilling, and electric magnet machines for heavy work. In connection with the riveting of the keel, centre girder and garboard strakes of vessels, pneumatic hammers are now being used. In the iron departments there are also installed several portable oxy-acetylene plants for cutting and welding.

The building berths range in length up to 700 ft.; but slight alterations would enable the firm to build vessels of still greater size. Several of these are shown on the engraving on Plate LXXII, facing page 163. The berths are well equipped with the most modern appliances, and special mention may be made of the electrically-operated hammer-head cranes, dealing with 5-ton loads at a radius of 100 ft., the steel uprights, and the concrete keel blocks which form part of the installation. There are also a number of special derricks having separate motors for slewing, traversing and lifting, and capable of dealing with 5-ton lifts. Eight locomotive steam cranes are provided for transporting material throughout the yards. One of these deals with ten tons, six with five tons, and the other crane with four tons.

Temporary electric lighting is installed in each vessel in the building berth at an early stage in its construction, and contributes to general efficiency and rapidity of construction, while portable electric fans are used for ventilation of the spaces on board ship where necessary. The launching ground is probably the finest on the river, the channel being here of great depth and very wide. Indeed, ordinary merchant vessels with full lines are launched without any check chains; the fine-ended ships—mail steamers and cruisers—are, as a precautionary measure, checked by drags in the usual way.

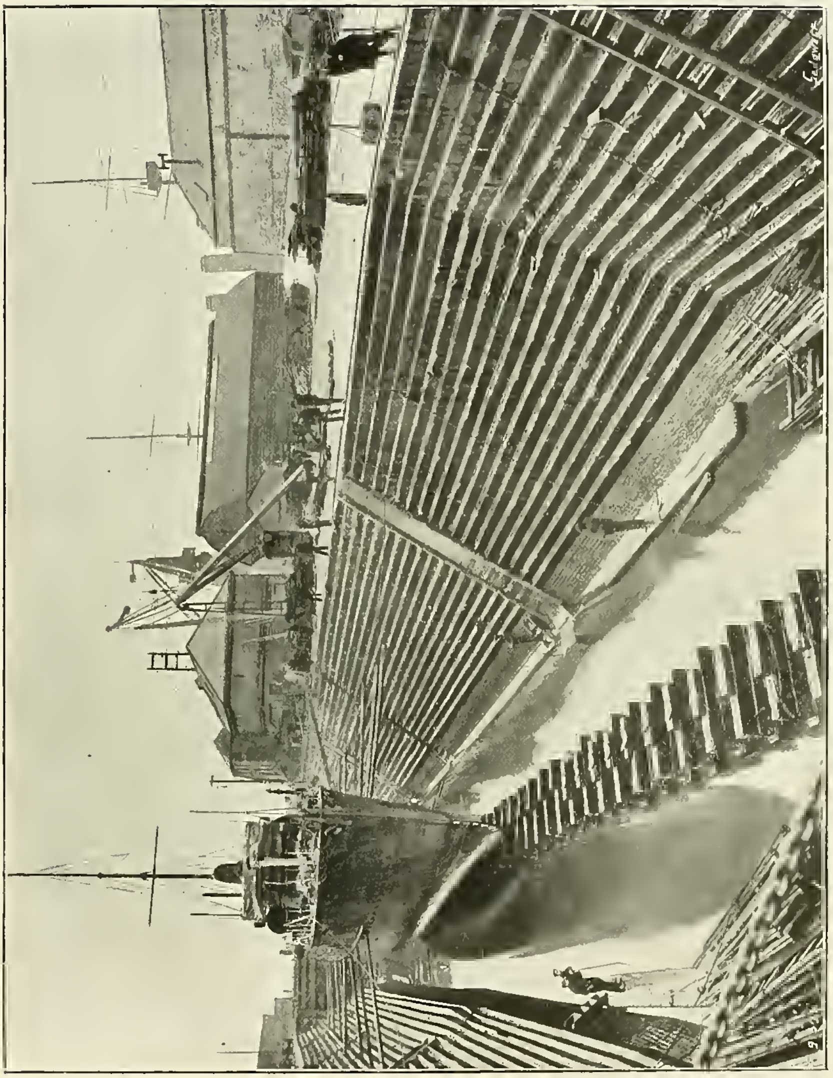
After being launched the ships are engined and completed in all respects in the fitting out wet basin illustrated on Plate LXXI. This dock has a length of 690 ft. and a width of 172 ft. and opens directly into the channel of the River Clyde. There is sufficient depth of water to keep the largest of ships afloat at all states of the tide. On one side of the basin there is a 120-ton electric crane, which lifts the maximum load at a radius of 70 ft. The maximum radius of the crane is 90 ft., and a load of 60 tons can be dealt with at this outreach. The crane has also a light purchase, which can take care of loads up to 10 tons at a radius of 98 ft.

On the opposite wharf of the dock there is a 20-ton travelling electric crane. There are also electric winches and capstans to facilitate the handling of vessels in the dock. Adjoining the fitting out basin is the Company's graving dock, which has a length of 360 ft. and is kept fully occupied by ships for repair or bottom cleaning preparatory to trials.

The saw mill is well equipped, having four vertical saw frames, in addition to circular and cross cut saws, and planing, moulding and turning machines. The saw shop is complete with up-to-date tools for saw sharpening and repairs. The overhead travelling cranes range up to 5 tons capacity. The yards provided for the drying of timber have an area of upwards of three acres. (See Plate LXXVI.)

The joiners' shops are well supplied with electrically-driven wood working machines, arranged in convenient groups. Portable circular saws are used on board vessels building on the stocks. Portable deck planers of electric and pneumatic lawn-mower type are also provided, and have proved very serviceable for planing decks and scrieve boards.

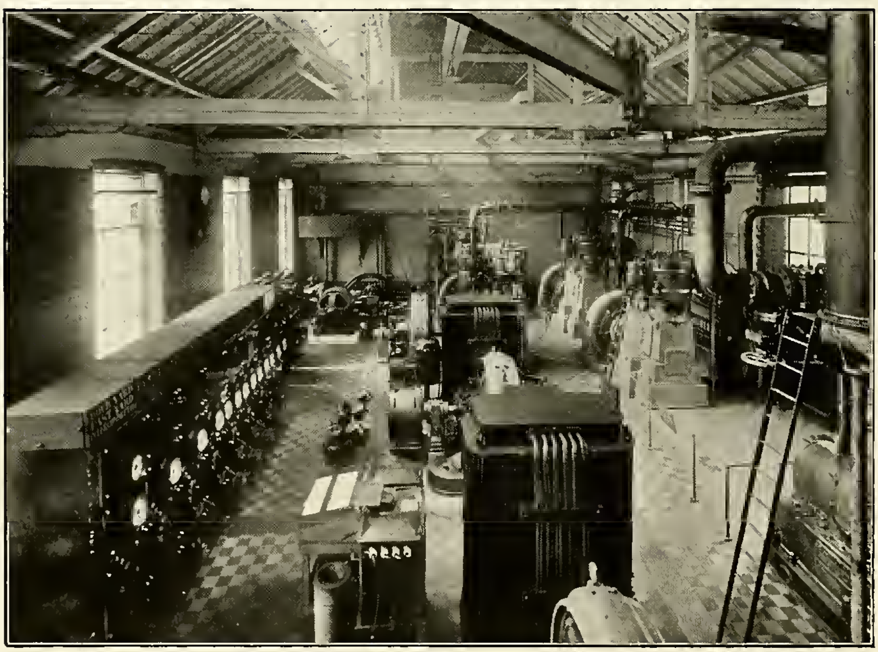
The smithy (Plate LXXVIII) is convenient to the building berths and fitting out basin, while the finishing shop adjoins the smithy. There are some sixty fires and ten compressed air hammers ranging up to 15 cwt. capacity. The fires are operated by mechanical blowers, and the smoke and waste



THE GRAVING DOCK.

Plate LXXVIII.

THE SHIPYARD SMITHY.



VIEW OF POWER STATION, CARTSBURN YARD.

gases are carried off by overhead ventilating pipes. Extensive work is carried out in this department. Die stamping is largely adopted in connection with the making of eye-plates, cleats, stanchions, clips, etc. The finishing shop is well equipped with band saws, drills and other machines, and the smiths' stores are arranged on the flat above this shop. A proving machine is installed adjacent to the smithy for testing shackles, eye-plates, etc., to the satisfaction of the Admiralty or Board of Trade surveyors.

The plumbers' shop is fitted with a special machine for bending pipes when cold, also screwing and tapping machines, drills, saws, grinders and fires. The welding of pipes by the oxy-acetylene process has been extensively adopted in the plumbing department, a separate shop being fitted out for the welding and cutting of pipes. In each case a large acetylene generator is used, which supplies gas to a number of blow-pipes.

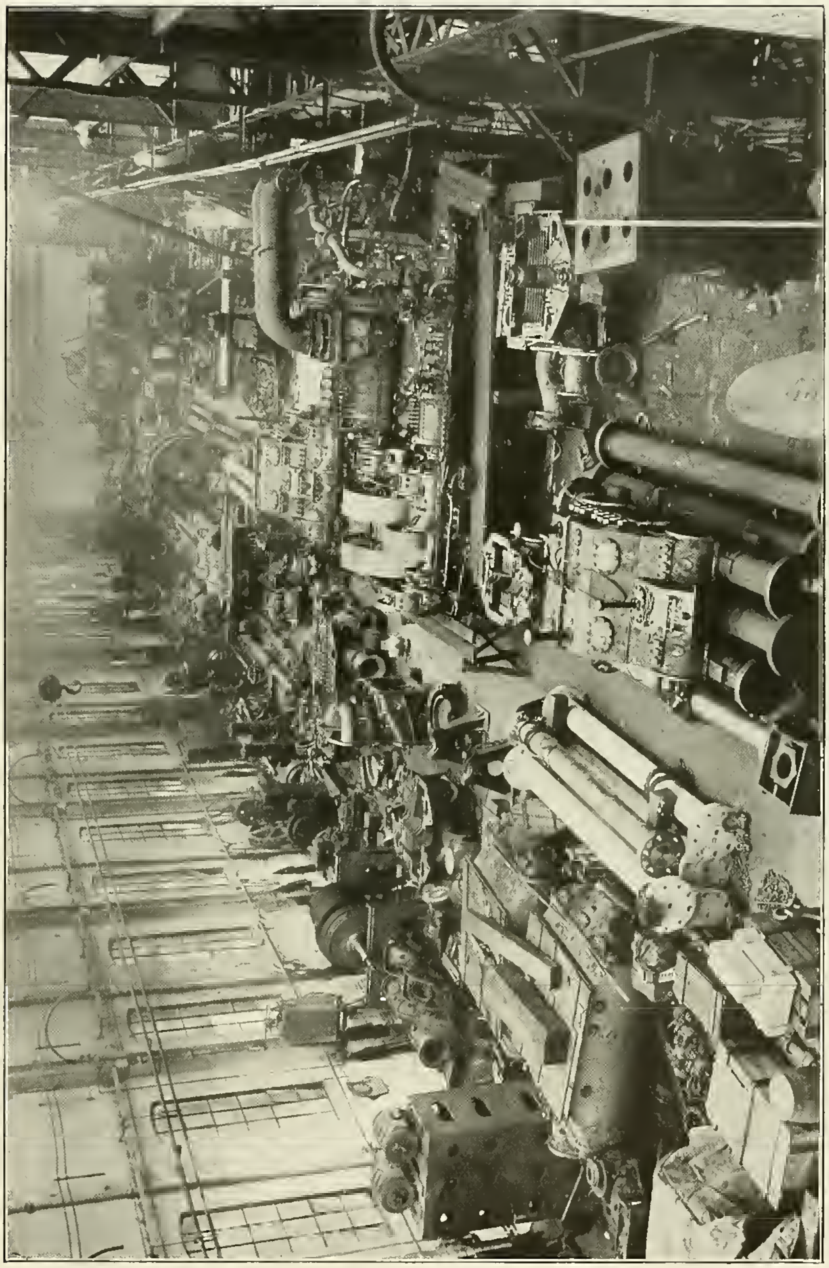
All lamps and motors in both the shipyards and engine works are arranged to suit 250 volts continuous current. There are three electric substations, one in each shipyard and one in the engine works, which are fitted up with electric transformers and rotary converters. High tension alternating current at 3300 volts is supplied from the main power station of the Greenock Corporation electricity department to the transformers, which provide 400-volt. alternating current, and by means of the rotary converters this is converted to 250 volts direct current for use throughout the establishment.

One set of hydraulic power plant is installed in each shipyard, and one set in the engine works. Each plant consists of three-throw horizontal pumps, driven through double helical gearing by an electric motor of 100 brake horse-power, and controlled by combined electric and hydraulic gear. The pumps are capable of delivering 100 gallons of water per minute at a pressure of 1000 lb. per square inch, and the pressure pipes are led underground to the various hydraulic tools.

Throughout the establishment there are nine independent sets of air-compressing plant, seven of these being in the shipyards and two in the engine works. The air compressors are of the two-stage type, delivering free air at a pressure of 100 lb. per square inch. One of the compressors has a capacity of 3000 cubic feet per minute, while the remaining machines each deal with 1000 cubic feet of free air.

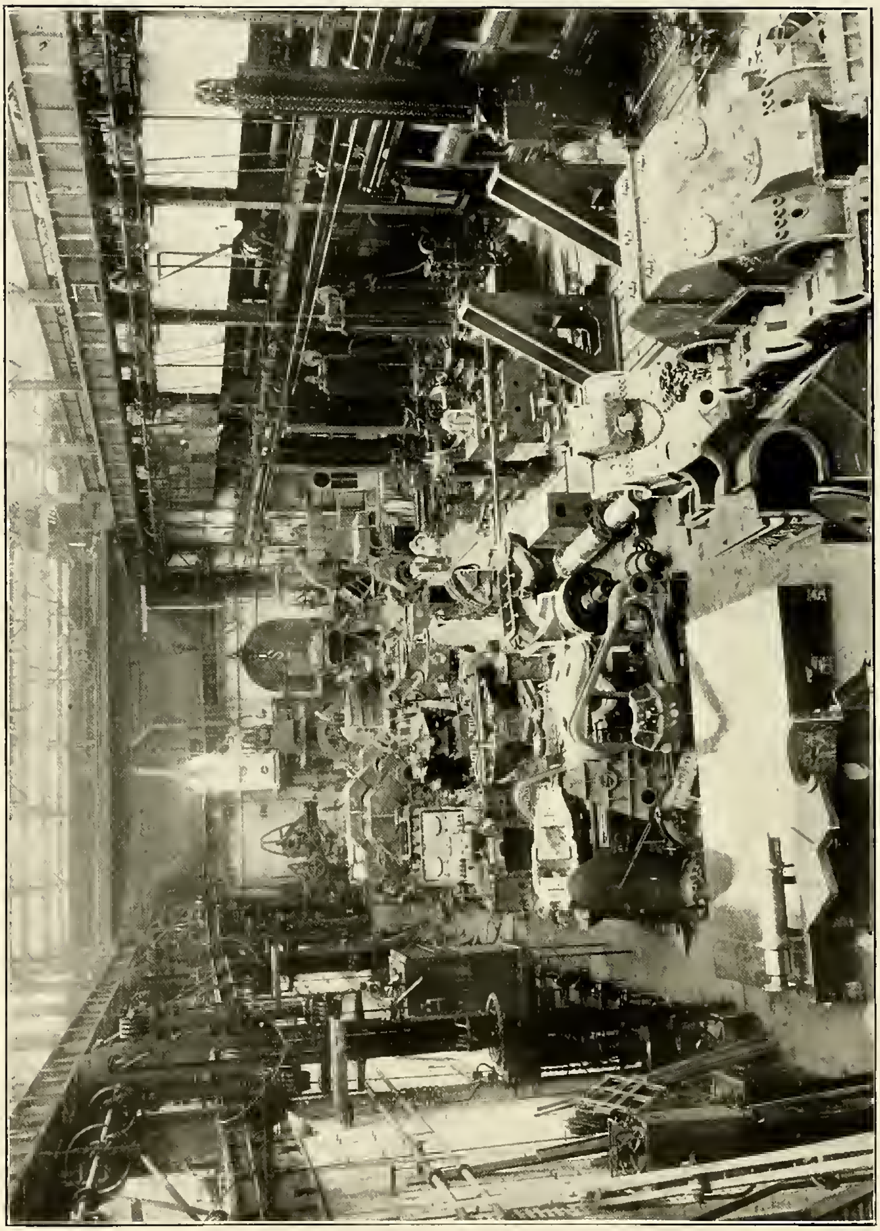
Alongside the wet basin there is a large engineer's store to facilitate the fitting out of vessels. This store is really an adjunct of the progress department at the engine works; the main portion of the building being employed as a store for receiving, checking and storing, with due regard to proper sequence, the numerous valves and fittings associated with the propelling machinery. This is an appropriate place at which to leave the shipyards, and turn our attention to the Engine Works.

Plate LXXIX.



VIEW OF THE TURBINE SHOP.

Plate LXXX.



THE FITTING SHOP, WITH EXPERIMENTAL "STILL" ENGINE IN BACKGROUND.

The Engine and Boiler Works.

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RAPIDITY of construction has been characteristic of the engine and boiler works of Scotts to at least as great an extent as in the shipbuilding yards ; it is unnecessary to give special examples where the engines and hulls are constructed by the same firm. In addition to supplying propelling machinery for all the vessels launched by the firm, sub-contracts are undertaken for the machinery of naval ships being built at Government Dockyards, and also of merchant ships being constructed by other shipbuilders. Scotts have always made a special feature of this class of work, and the engineering establishment has been specially laid out to deal with the extra output of horse-power required. Without going into considerable detail, it will be interesting to note some of the outstanding features of the various workshops.

The pattern shop is fitted with the usual wood-working machinery, including a special pattern making machine, which is largely used for the making of core boxes.

The brass foundry is an equally important department, in which first-class work is done. The principle of crucible pot holes has been departed from for the smaller heats in favour of rapid melting air furnaces, giving much increased output. In these furnaces coal is burnt under forced draught, and each furnace can deal with twenty heats per day. Forced combustion hot-air furnaces are used as core drying stoves, and a brass recovery mill is installed for recovering brass from the foundry sweepings. For heavy castings an air blast furnace of large capacity is fitted. The foundry is served by an electrically-operated crane.

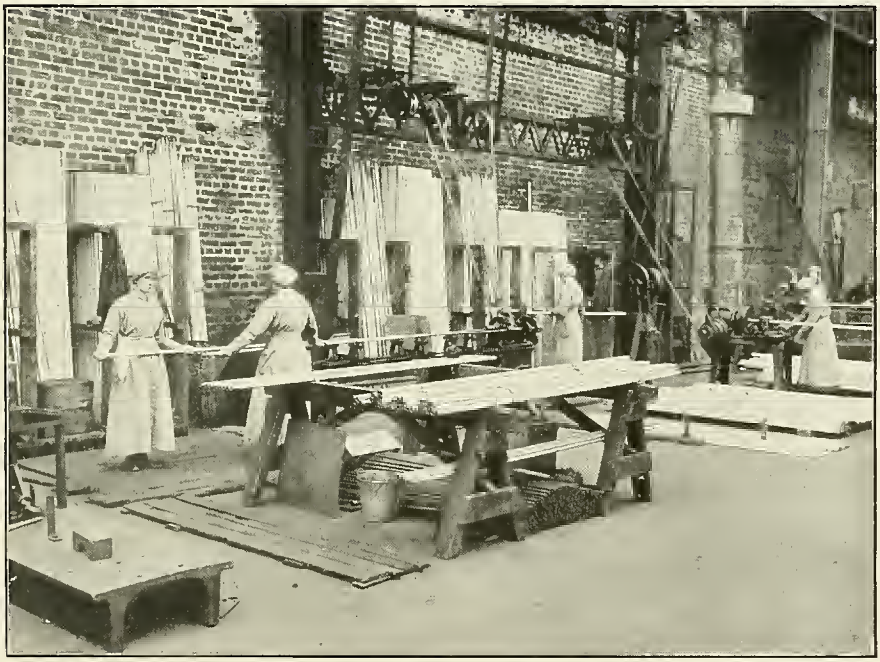
In the forge and smiths' shop a large amount of detail work is done in units ranging up to three tons in weight. The forge hammers are worked by compressed air at a pressure of 100 lb. per square inch, supplied by a motor-driven air compressor. The bolt and nut-making hammers are of the twin compound pneumatic type. In this department a considerable amount of die stamping is done.

The iron finishing shop, which was one of the first in the country to be constructed with a completely glazed roof, is 400 ft. in length by 45-ft. span from centre to centre of crane rails. This shop contains a large number of up-to-date machines, prominent among which are turret lathes and milling, shaping and drilling machines. A large tool store is arranged in the centre of the shop, and a considerable space is allotted to bench work and hand finishing and fitting. The whole area is controlled by two motor-driven travelling cranes, one of which is capable of lifting 10 tons.

The main machine shop has a width of 60 ft., and with the adjoining bay accommodates some of the finest engineering tools. The larger machines have independent electric motors, and some are fitted with electrical reversing gear and push button control. The smaller machines are grouped for driving from line shafting driven by motors. The shop is traversed by five overhead electric cranes, ranging up to 40 tons lifting capacity.

The turbine shop, illustrated on Plate LXXIX, is completely fitted out for the construction of turbines of the largest size. The tools in this shop include, amongst others, a planing machine to plane 20 ft. horizontal and

THE TURBINE BLADING SHOP.



THE GALVANIZING SHOP, SHOWING DILUTION OF LABOUR, 1915-18.

Plate LXXXII.

THE BRASS FINISHING SHOP.

16 ft. vertical; a turbine lathe to swing 14 ft. in diameter, and admit 50 ft. between centres; a horizontal boring and milling machine having a $4\frac{3}{4}$-in. diameter spindle, with a range of 20 ft. horizontal and 13 ft. vertical; and a horizontal boring machine to bore up to 14 ft. diameter. This shop is served by four overhead electric cranes, respectively of 110 tons, 100 tons, 70 tons and 25 tons lifting power. A complete installation of gas shrinking plant is provided and supplied with air from a positive blower. Adjoining the turbine shop there is a special department fitted with all the latest machines and tools for dealing with the preparation and assembling of blading for turbines.

The brass finishing shop, shown on Plate LXXXII, serves both for ship and engine work. The machines, according to the latest practice, are arranged down each side of the shop, and the benches occupy the centre. There are representative types of the best makes of automatic tools, turret lathes, brass finishers' lathes, and grinding machines with specially large discs.

There is a well-equipped tool-making shop, 400 ft. in length by 25-ft. span, with the most up-to-date machinery, including universal grinding and universal milling machines, a special tool workers' relieving lathe, and a Whitworth measuring machine. One end of the shop is reserved for the toolsmiths, and is fitted up with smiths' fires, pneumatic hammer, tool hardening, case hardening and annealing furnaces. Optical and electrical pyrometers are employed, by means of which the temperatures required for annealing and hardening are readily controlled—a point of great importance with the special steels now in use.

The light boiler shop, coppersmiths' shop, galvanising shop and sheet iron shop are all under one roof, covering a total area of about 6000 square yards, the shops being separated by expanded metal divisions. The total height from the floor level to the ridge of the building is 50 ft., while the height of the crane rail is 30 ft. The light boiler shop is equipped for dealing with light plate work, such as funnels, uptakes and ventilators, etc., and is served by a three-motor crane with a span of 50 ft. and a lifting capacity of 15 tons.

The coppersmiths' shop is laid out to deal with all types of piping of copper, iron and steel. The pipe-bending machines are operated by hydraulic power supplied by pumps driven by independent electric motors and worked in conjunction with an intensifier. The crane in this shop also is of 15 tons capacity. The galvanising shop is well equipped for dealing with tubes of every description. The electricity for the bath is supplied by a 12-kw. motor-driven dynamo. In this shop upwards of 200 boiler tubes can be dealt with per day. There are numerous jib cranes fitted with hand chain blocks throughout the shop.

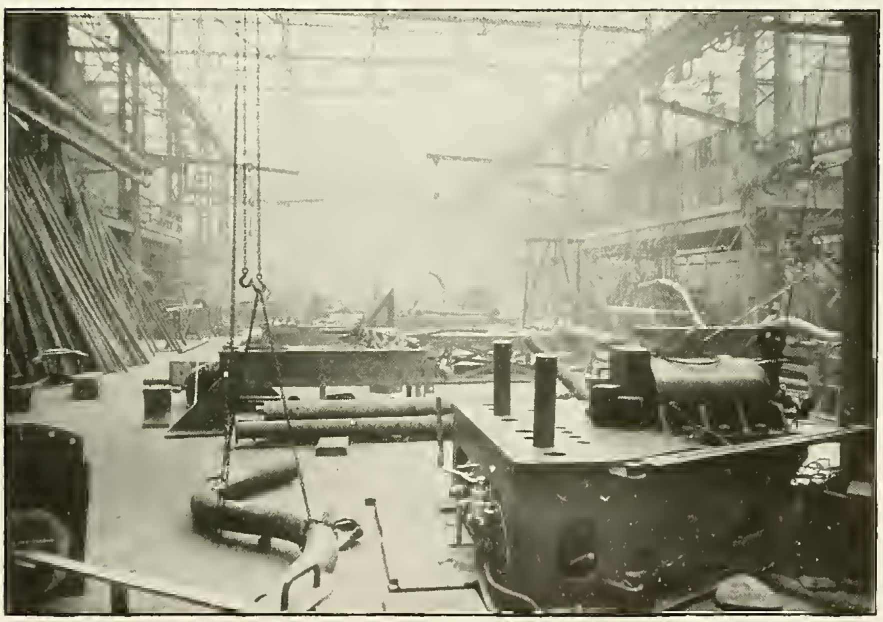
The sheet iron shop is fitted out with modern tools for dealing with the large amount of sheet metal work required nowadays for naval vessels of all descriptions and for passenger liners. A sub-division of this shop is set apart for welding work by the oxy-acetylene process. A three-motor overhead travelling crane with a span of 50 ft., and capable of lifting 7 tons, runs the whole length of the shop.

The scarcity of gas under war conditions for the oxy-acetylene process led to the early consideration of an alternative method of welding, with the result that electric welding plant was laid down in various departments of the works, and found of much service, particularly in connection with the tacking of plates together for erection purposes in the sheet iron department.

A check system is used in connection with the distribution of templates, tools, drawings, etc., and a separate store in the centre of the works is arranged for this purpose.

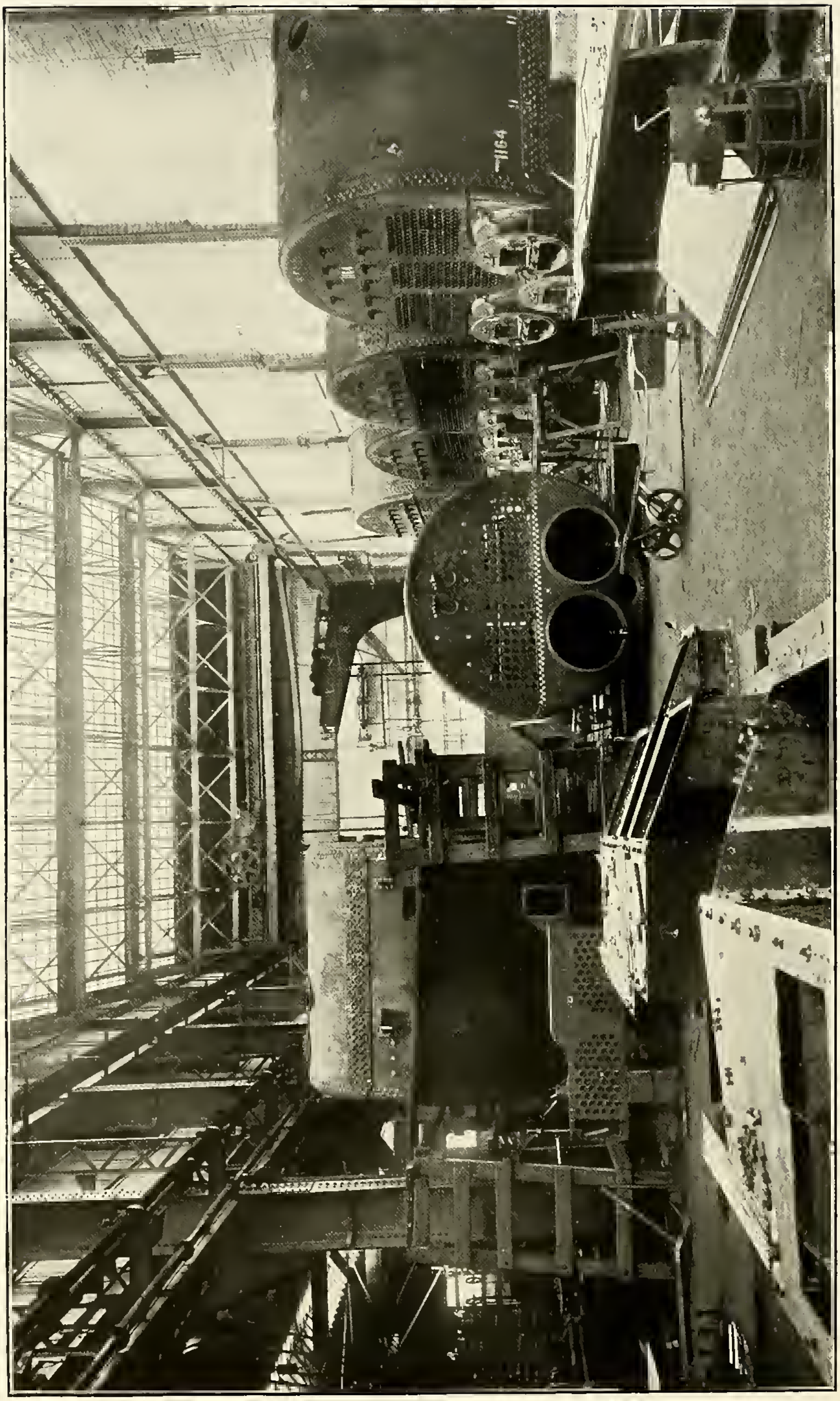
The main boiler shop, together with its yard, has an area of 7000 square yards, and a height of 45 ft. to the crane rail; it is served by five overhead electric cranes, ranging in lifting power from 25 to 110 tons, with numerous jib and other cranes associated with the various machine tools.

THE SHEET-IRON SHOP.

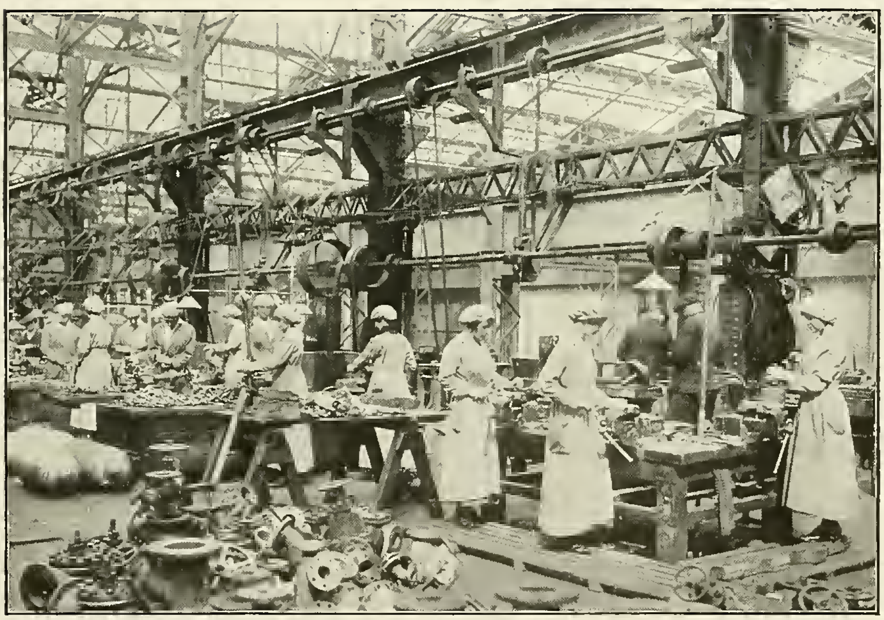


THE COPPERSMITHS' SHOP.

Plate LXXXIV.



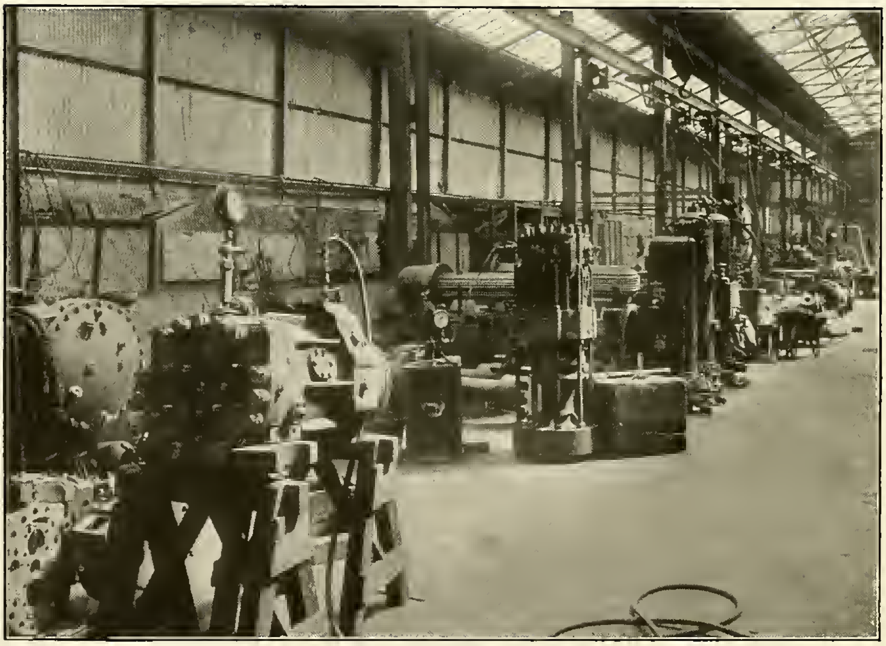
ONE BOILER SHOP BAY, SHOWING CYLINDRICAL BOILER CONSTRUCTION.



DILUTION OF LABOUR, 1915–1918.

Plate LXXXVI.

MACHINE SHOP FOR OIL ENGINE WORK.



TESTING OIL ENGINE CYLINDERS.

The machine tools fitted in the boiler works are all of a very powerful character ; but only a few of these need here be referred to. There is a 13-ft. gap hydraulic plate-bending machine, to bend plates up to 2-in. thick when cold. The flanging is done in an hydraulic machine, exerting a pressure of over 160 tons, which is served by a special hydraulic jib crane, capable of lifting the heaviest plates. There are also plate-edge planers and triple-boring mills of corresponding power, while for the riveting of the boilers there is a 13-ft. gap hydraulic riveting machine, capable of exerting a load on each rivet of 200 tons, and served by an independent hydraulic jib crane. There is also a large installation of pneumatic tools of all kinds and special plant for the manufacture of water-tube boilers, but it is scarcely necessary to go into more detail.

A well-equipped shop recently completed is devoted to the later stages of oil engine construction. Here the various castings and forgings of oil engine parts are assembled for machining and finishing, while a portion of the shop is set apart for erection purposes. The machine tools, which are the best obtainable for this class of work, are laid out on the grouping system for driving from line shafting, and adequate bench accommodation is provided for the lighter handwork operations. The shop is 200 ft. in length by 45-ft. span, and the area is served by a 3-ton overhead travelling crane which is controlled from the floor level. Though built primarily for the construction of oil engines, this shop proved of considerable service during the war period in relieving the other machine shops of much of the lighter work. The testing of oil engines is carried out in a separate department.

In a central position in the engine works there is installed a progress department where a staff of technical and clerical workers is employed. This department keeps in constant touch with the drawing office and works staff, and a system of priority marks and work planning is adopted, in order that work may be undertaken in the shops and eventually reach the fitting out basin in correct sequence.

When describing the shipyards reference was made to the very complete electric installation for lighting and power purposes throughout the establishment as a whole; also to the outfit of hydraulic plant and air-compressing machinery, and nothing further need be added here.

The far-reaching importance of the work of the engineering chemist is recognised by the Scotts, as already mentioned, and the Works Laboratories are excellent examples of their kind. It would be possible to give other indications of the admirable equipment of the works, but enough has been said to show that there is directed towards the realisation of the best work in all departments—firstly, the advantage of accumulated experience; secondly, the benefits which the psychologists claim for hereditary influence—applicable here, not only through the proprietors, but also through many of the workmen; and, thirdly, a sound progressive spirit, which recognises the necessity for continual improvement in administration and design, and in machine tools and methods of manufacture.

Appendix.

VESSELS BUILT BY SCOTTS' SHIPBUILDING AND ENGINEERING CO., WITH SPECIAL WAR RECORDS.

Original Name of Vessel.	Original Owner.	Year Built.	Remarks.
T.S. Transylvania (Geared Turbines)	Cunard Steam Ship Co.	1914	Operated by Anchor Line. Torpedoed, 413 lives lost.
T.S. Andania	Ditto	1913	Torpedoed.
T.S. Alaunia	Ditto	1913	Sunk by mine.
Narragansett	Anglo-American Oil Company	1903	Sunk without trace by enemy action, 47 lives lost.
Falls of Nith	Wright, Graham and Company	1907	Bought by Imperial Direct Line. Torpedoed.
Kish	Clyde Shipping Co.	1902	Sunk by enemy action, 6 lives lost.
Nore	Ditto	1902	Name changed to *Kalibia*. Sunk by enemy action, 26 lives lost.
Beachy	Ditto	1909	Sunk by enemy action.
Hurst	Ditto	1909	Ditto.
Pladda	Ditto	1906	Converted into "Q" ship by the Admiralty.
Glenlee	Gardner (James) and Co.	1904	Torpedoed.
Tatarrax	Tank Storage and Carriage Company	1913	Burnt at sea and lost with all hands.
Nessian	F. Leyland and Co.	1912	Government Transport.
Orubian	Ditto ...	1914	Sunk by enemy action.
Carron	Carron Line	1909	Transport for troops.
Kalgan	China Navigation Co.	1895	Torpedoed.
Szechuen	Ditto	1895	Ditto.
Yochow	Ditto	1901	Ditto.
T.S. Anhui	Ditto	1903	Ditto.
Diomed (1)	A. Holt and Co.	1895	Sunk by gun fire, 10 lives lost.
Achilles	Ditto	1900	Torpedoed, 5 lives lost.
Calchas	Ditto	1899	Torpedoed.
Machaon	Ditto	1899	Ditto.
Glaucus	Ditto	1896	Torpedoed, 2 lives lost.
Diomed (2) .... (Geared Turbines)	Ditto	1915	Sunk by gun fire, 2 lives lost.
T.S. Tyndareus	Ditto	1914	Mined but made port.
Idomeneus....	Ditto	1899	Torpedoed but made port, 4 lives lost.
Helenus	Ditto	1913	Torpedoed but made port.
Alcinous	Ditto	1900	Ditto.
Menelaus	Ditto	1895	Bought by Admiralty and converted into an Admiralty Balloon Ship.
T.S. Letitia	Donaldson Bros.	1912	Lost by marine risk.
Setter	G. and J.Burns, Ltd.	1906	Sunk by enemy action, 9 lives lost.
Benmohr	Ben Line	1912	Sunk by *Emden*.
Munwood	Munson Steamship Line	1914	U.S. Transport.
T.S. Hildebrand	Booth Steam Ship Co.	1911	Converted into Auxiliary Armed Cruiser.
Manco	Ditto	1907	Government Store Ship and later a Transport.
Dalhanna	John M. Campbell and Son	1905	New name *Snowdon Range*; new owners Furness, Withy and Company. Torpedoed, 4 lives lost.
Dalmore	Ditto	1907	New name *Waitotara*; new owners Union Steamship Company of New Zealand. Lost by fire at sea.
Daldorch	Ditto	1907	New name *Spital*; new owners Japp Hatch and Company. Lost by enemy action.
Gulistan	F. C. Strick and Co.	1905	New name *Tritonia*; new owners the Donaldson Line. Torpedoed.
S.Y. Aegusa	Count Ignazio Florio	1896	Owned later by Sir Thomas Lipton and named *Erin*. Resumed the name *Aegusa* and sunk by mine.

ROLL OF HONOUR

1914. 1918.

Name.	Rank.	Regiment.	Occupation.
Robert Aitken	Private	Gordon Highlanders	Carpenter.
Donald Badden	Sergeant	Seaforth Highlanders	,,
Alexander Bain	Private	,, ,, ...	,,
Stewart Bates	L.-Corpl.	5th A. & S. H.	App. Boilermaker.
John Black	Private	Seaforth Highlanders	App. Caulker.
Robert Blanche	,, ...	,, ,, ...	Caulker.
George Bonnar	,, ...	5th A. & S. H.	Driller.
S. Bonnar	,, ...	,, ...	Plater.
C. Boyle	,, ...	,, ...	Rivet Heater.
Jaime C. Brown	2nd Lieut.....	8th A. & S. H.	App. Engineer.
W. Fraser Brown	Lieutenant	R.N.V.R.	Ship Draughtsman.
William Brown	Private	R.N. Division	Joiner.
Fyfe Bryson	Trooper	5th Dragoon Guards	App. Engineer.
Alexander Cameron	Private	5th A. & S. H.	Carpenter.
Colin Cameron	Sergeant	A. & S. H.	Riveter.
James Canning	Private	Cameron Highlanders	Caulker.
Charles Coghill....	,, ...	Gordon Highlanders	Blacksmith.
Samuel Coyle	,, ...	5th A. & S. H.	Plater.
Francis Cunningham	,, ...	,, ...	Driller.
James Deatcher	Sergeant	K.O.S.B.	,,
Duncan Denny	Corporal	5th A. & S. H.	Engineers' Craneman.
John Docherty....	Private	Gordon Highlanders	Carpenter.
Michael Docherty	,, ...	5th A. & S. H.	Rivet Heater.
Robert Docherty	,, ...	,, ...	,,
Alfred Douglas	,, ...	1st Gordon Highlanders	Plumber.
George Dunlop	,, ...	Royal Scots Fusiliers	Blacksmith.
William Dunlop	,, ...	5th A. & S. H.	App. Sheet Iron Worker.
Thomas Finlayson	Private	Royal Field Artillery	Carpenter.
John Forrest	Corporal	Royal Scots	S.Y. Gateman.
Patrick Forrester	2nd Lieut.....	Black Watch	App. Engineer.
Charles Friel	Private	Royal Dublin Fusiliers	Caulker.

ROLL OF HONOUR

1914. 1918.

Name.	Rank.	Regiment.	Occupation.
Michael Gallacher	Private	Gordon Highlanders	Holder-on.
T. J. Gould	Sergeant	9th Scottish Rifles.....	E. W. Commissionaire.
James Gray	Private	3rd H.L.I.	Riveter.
R. Griffen	Seaman	Royal Navy....	App. Sheet Iron Worker.
William Haggerty	Corporal	2nd Leinster Regt.	Carpenter
William Halden	Private	5th A. & S. H.	Welder.
James Hall	Rifleman	King's Royal Rifles	Ship Draughtsman.
James Hamilton	Sapper	Royal Engineers	Joiner.
James Hannah	Private	Inniskilling Fusiliers	Electrician.
T. Hastings	L.-Corpl.	A. & S. H.	App. Patternmaker.
John Henderson	Private	A. & S. H.	App. Sheet Iron Worker.
Robert Henderson	,, ...	5th A. & S. H.	App. Patternmaker.
William Hill	,, ...	A. & S. H.	Carpenter.
Robert Hopkins	Seaman	R.N.V.R.	App. Turner.
James Hunter	Private	Seaforth Highlanders	App. Engineer.
Thomas Hutchison	Lieutenant	R.N.V.R.	Ship Draughtsman.
Thomas Johnstone	Private ...	3rd A. & S. H.	Holder-on.
Joseph Kemp	,, ...	5th A. & S. H.	Electrician.
Hugh Kennedy	,, ...	,, ...	Carpenter.
William Kerr	,, ...	A. & S. H.	Riveter.
William Kerr	,, ...	5th A. & S. H.	App. Riveter.
John King	,, ...	Soaforth Highlanders ...	Driller.
James Kinniburgh	,, ...	Cameron Highlanders ...	Caulker.
John D. Kinniburgh	2nd Lieut.	5th A. & S. H.	Engine Fitter.
George Logan	Private	Gordon Highlanders	Engine Fitter's Helper.
W. K. Lyle	,, ...	A. & S. H.	App. Patternmaker.
James McAulay	,, ...	3rd Highland Howitzer B'de.	Boilermaker.
Donald McCallum	,, ...	5th A. & S. H.	Carpenter.
Andrew McConnachie....	,, ...	7th Royal Inniskilling Fus.	Rigger.
William McCulloch	,, ...	A. & S. H.	Carpenter's Helper.
Duncan McDonald	,, ...	5th A. & S. H.	Joiner.

ROLL OF HONOUR

1914. 1918.

Name.	Rank.	Regiment.	Occupation.
John McDougall	Private	Seaforth Highlanders	Carpenter.
Thomas McDougall	,,	H.L.I.	Riveter.
— McDougall	,,	Gordon Highlanders	Sparmaker.
Archibald McEwan	Corporal	5th A. & S. H.	App. Engineer.
Samuel McEwan	Private	,,	Plater's Helper.
William McFie	,,	Seaforth Highlanders	App. Engineer.
James MoGlashan	,,	5th A. & S. H.	Coppersmith's Helper.
Neil McGonnigle	,,	,,	Riveter.
John McGowan	,,	,,	Driller.
John McGregor	,,	Gordon Highlanders	App. Boilermaker.
E. McGregor	,,	A. & S. H.	Boilermaker's Helper.
Thomas McGroarty	,,	15th A. & S. H.	Driller.
John McGuinness	,,	1st Royal Inniskilling Fus.	Coppersmith's Helper.
Charles McIntyre	,,	A. & S. H.	Carpenter.
William McKay	Seaman	Royal Navy	Rivet Heater.
Donald McKillop	2nd Lieut.	3rd Scottish Rifles	Engine Draughtsman.
Samuel McKillop	Private	Royal Highlanders	Riveter.
William McKinnon	,,	2nd Cameron Highlanders	Sheet Iron Worker.
Malcolm McLean	,,	Seaforth Highlanders	Carpenter.
William McLean	,,	5th A. & S. H.	App. Riveter.
John McLeod	,,	Seaforth Highlanders	App. Turner.
James McMillan	,,	A. & S. H.	App. Patternmaker.
George McMichael	,,	1st Royal Inniskilling Fus.	Coppersmith's Helper.
Hugh McNair	,,	Seaforth Highlanders	E. W. Timekeeper.
John McNaught	,,	A. & S. H.	S. Y. Clerk.
Daniel McNellis	,,	10th A. & S. H.	Plumber.
Thomas McPherson	,,	K.O.S.B.	E. W. Machineman.
Henry McWhinnie	,,	11th A. & S. H.	App. Brassfinisher.
Hubert Malcolmson	Lieut. & Adj.	Royal Irish Regt.	Engine Fitter.
Bertram Mares	Private	Scots Guards	App. Engineer.
Henry Millen	Sergeant	H.L.I.	Driller.
Alexander Milloy	Private	3rd H.L.I.	Holder-on.
W. Morton	,,	5th A. & S. H.	App. Sheet Iron Worker.
John Muir	,,	,,	App. Engineer.
John Mullan	,,	A. & S. H.	Riveter.

ROLL OF HONOUR

1914. 1918.

Name.	Rank.	Regiment.	Occupation.
Alexander Mullen ...	Private ...	3rd A. & S. H.	Holder-on.
Charles Munro ...	,, ...	4th South Lancs. Regt. ..	Joiner.
James Murray ...	,, ...	A. & S. H.	Carpenter.
William Noone ...	,, ...	Seaforth Highlanders	Driller.
H. E. O'Hara	2nd Lieut.	R.A.F.	App. Engineer.
James Piggott ..	Private ...	Inniskilling Fusiliers ...	Driller.
Richard Porter	,, ...	A. & S. H.	App. Sheet Iron Worker.
Robert Punton	,, ...	5th A. & S. H.	Boilermaker.
Alfred Reffel	,, ...	,, ...	App. Patternmaker.
Stephen Regan	,, ...	3rd A. & S. H.	Holder-on.
John Scott, M.M. ..	Sergeant	5th A. & S. H.	Plater.
William Scott, D.C.M.	L.-Corpl.	,, ...	Joiner.
Richard Simpson	Private ...	1st Cameron Highlanders	Boilermaker.
Richard Simpson ..	,, ...	North Staffs Regt.	App. Engineer.
William Simpson ...	,, ...	Seaforth Highlanders ...	App. Coppersmith.
Andrew Smillie ...	,, ...	6th Cameron Highlanders ...	Carpenter.
Neil Smith	,, ...	Seaforth Highlanders	,,
Archibald Spence ...	,, ...	—	Stower.
Andrew Stormonth ...	,, ...	A. & S. H.	Riveter.
John Strachan....	Leading Seaman	Howe Batt., R.N.D.	App. Engineer.
Dugald Taylor ..	Sergeant	5th A. & S. H.	Turner.
D. Torbit	A.B. D.N.T.	Hood Batt., R.N.D.	Plater.
Wallace Tosh	Private	1st A. & S. H.	Plumber.
John Trainer	Seaman	R.N.V.R.	E. W. Sawyer.
John Tweedie	Private	1st Gordon Highlanders	Electrician.
James Walmsley	2nd Lieut.....	K.O.S.B.	Engine Fitter.
Lionel Wilson	Private ...	5th A. & S. H.	Electrician.
Claude N. Young ..	2nd Lieut.....	14th Royal Scots.	Engine Draughtsman.

GOD SPEED GREENOCK

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