

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 intrusions 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 in boats. Symington's steam tug, Charlotte Dundas, by its success in 1802 on the Forth and Clyde Canal, removed 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. 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. The fares were practically five times those prevailing to-day. 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. 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, 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 fifty 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 Hoy, 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 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' Works: the Waterloo, 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 engines each of 30 nominal horse-power, which 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. 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, 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-northwest wind and high sea for at least two-thirds of the way from Liverpool, her rate thither being nearly 9 knots."

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. 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 upper reaches of the Clyde, and passengers were brought from Glasgow to 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, and the engines ran at 56 revolutions. The fares¹ to Liverpool in those days were £2 15s. as compared with 11s. To-day; of course, very much better accommodation is now 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 Mclver, and inaugurated the competition with the Burns line, commenced in 1829.² The Mclver 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. The Ivanhoe, 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 26.5 hours.

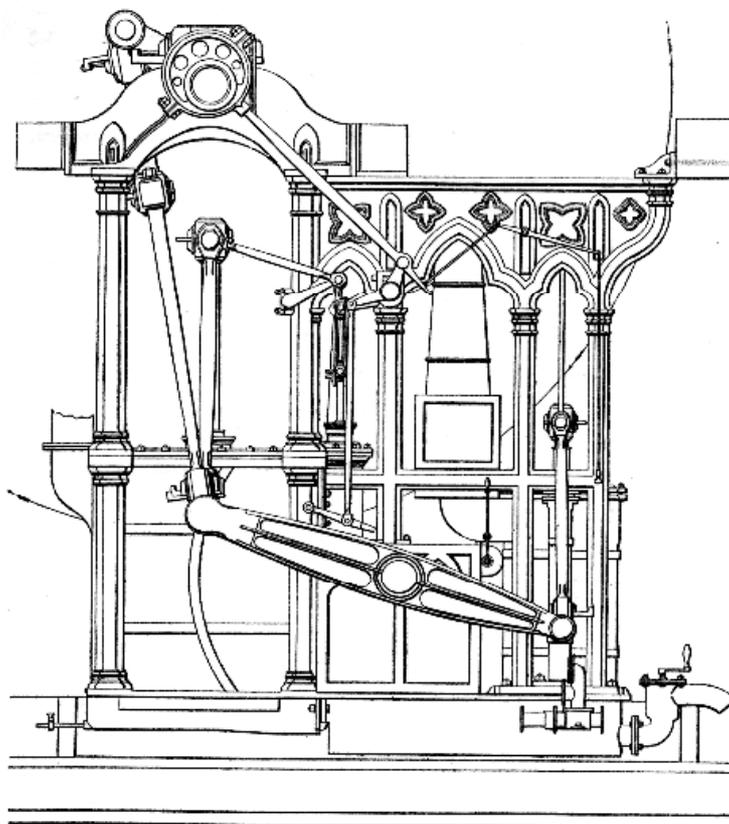
Thus the Scotts continued to improve on each successive ship, and to widen the area of their influence. The Clyde continued to largely monopolise the industry of steam shipbuilding, and it was not until the summer of 1822 that a steamer—not built in Scotland—appeared on the Clyde. This was the Saint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

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 over-all, 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 for £5000 the works which have since been developed into the well-known Greenock Foundry. This establishment was begun, although on a very small scale, about 1790, and in its equipment, which was considered thoroughly efficient, there was included a large cupola. Some idea is given of the extent of the establishment 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 amount to about two hundred and twenty, while the weekly distribution of wages is £180." As a contrast, it may be said here that there are now four thousand men in the works, earning per week over £5500 in wages, and that the Scotts are engaged on the largest set of engines yet constructed by them—for H.M.S. Defence. They are of 27,000 indicated horse-power, to give the immense armoured cruiser named, of 14,600 tons displacement, a speed of 23 knots.

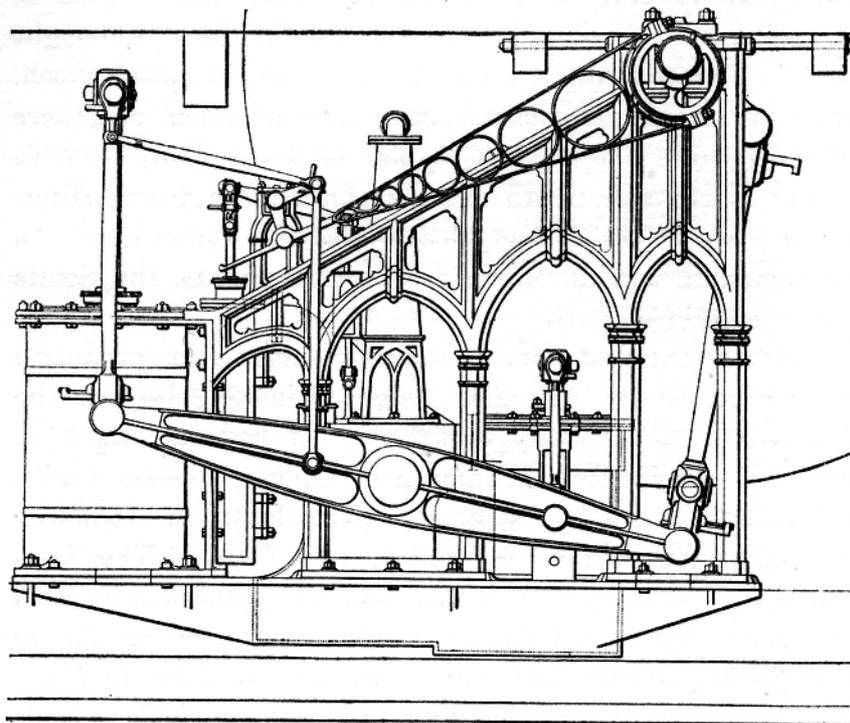
Since 1825, the Scotts have continued to do very satisfactory engine work, much of it of an original character, not only for vessels built for themselves, but for ships constructed on the Thames and other English rivers, and also for the series of warships built for the British Navy at their works, and for others constructed at the Royal Dockyards. This 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. 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 at Clyde works for the British Navy, H.M.S. Greenock, in 1839. 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.



A SIDE-LEVER ENGINE OF 1831.

We reproduce on the preceding page a drawing illustrating an early type of engine built by the firm. This is an engine constructed in 1831. The steam cylinder is 52.25 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.



AN ENGINE OF 1832.

A different type of engine, constructed in the following year (1832), is illustrated above. 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 187ft. 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.

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. 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*, 184 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 origin¹ 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.

The *Tagus*, which was thus amongst the first of the 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.

This vessel made the trip from London Bridge to the lightship off Spithead (246 miles) in thirty-one hours five minutes, on a consumption of 6 lb. of fuel per indicated horsepower 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 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. 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. 0.5in. 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 mechanical.

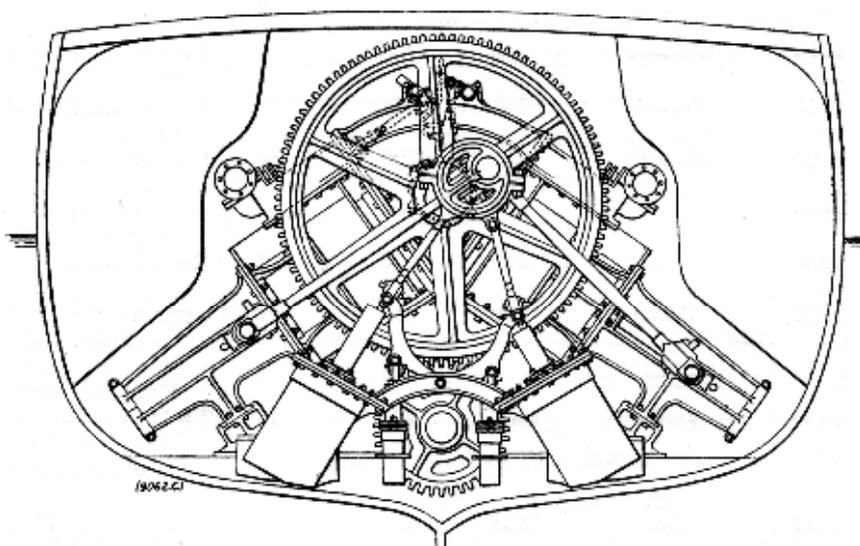
The Royal West India Mail Company's Service, still one of the best known of British lines, was commenced in 1841. Some of the steamers were purchased, but amongst those built originally for the service was the *Dee* by the Scotts. She was 213 ft. 9 in. long, 30 ft. 4 in. beam, and 30 ft. in depth, the burden tonnage being 1848 tons. On a draught of 17 ft. 6 in. 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 tons per day. The engines, which had cylinders 73 in. in diameter with a stroke of 7 ft., were of 450 horsepower, driving side paddle-wheels 28 ft. 6 in. in diameter.

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 started 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 thirty years.

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

Year.	Name.	Tonnage.	Horse-power	Speed m.p.h.	Remarks.
1819	Waterloo	200	60	9	Largest steamer of 1819
1820	Superb	240	72	9	Largest steamer of 1820
1821	Majestic	345	100	10	Largest steamer of 1821
1835	City of Aberdeen		200	12	Strongest steamer of 1835
1836	Jupiter	439	210	13	Record speed
1837	Tagus	709	286	10	Largest constructed on Clyde, 1837 for P&O
1839	India	1206	320	10	First steamer to India via Cape
1841	Dee	1848	450	10	First Royal West India Mail liner.

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. 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 this metal. 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.



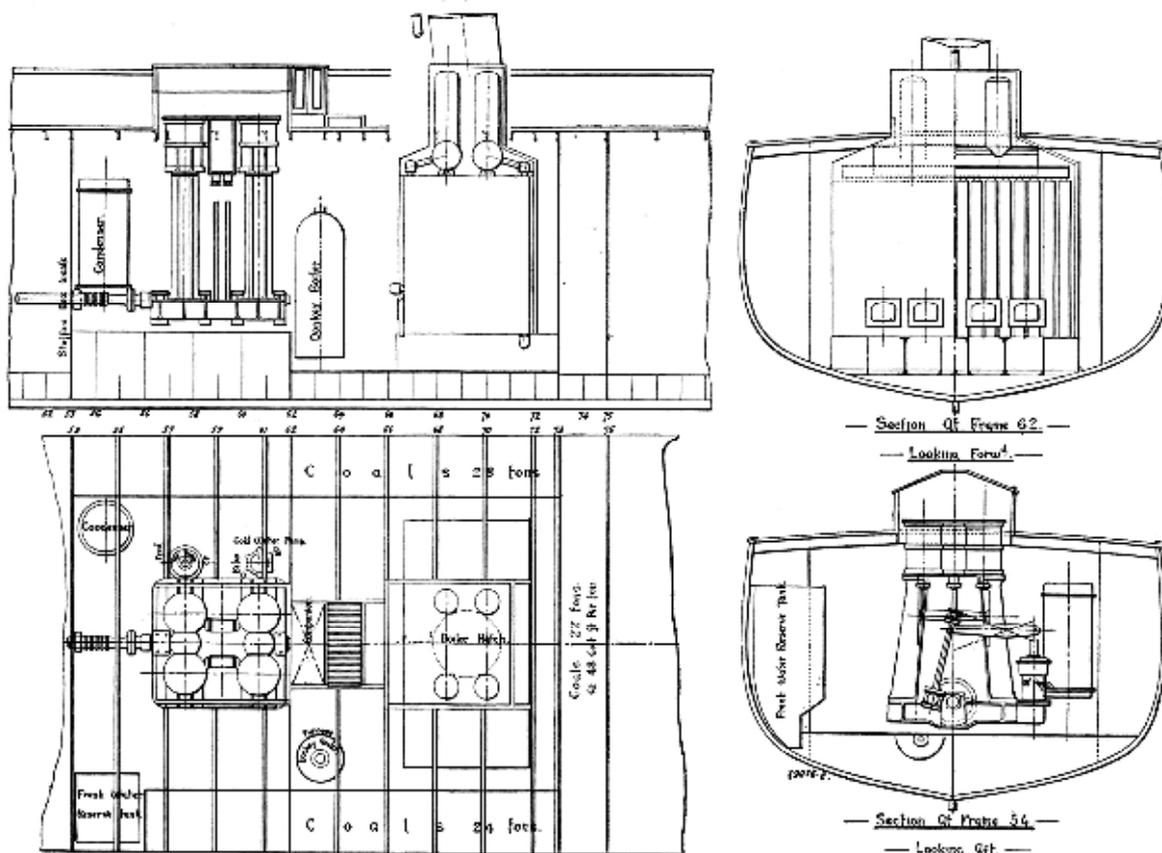
DOUBLE-GEARED ENGINE FOR EARLY ATLANTIC LINER.

The firm built several of the early Atlantic liners, and we reproduce above, as a further step in the development of the steam engine, a drawing showing the double-gear engines constructed early in the 'fifties for an iron screw steamer of 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," for although the power developed was 250 horsepower, 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. 5.5 in. in diameter, and the pinions on the screw-shaft 4 ft. 6 in.; so that the screw propeller made 2.5 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.

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. 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 developed 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.



HIGH-PRESSURE MACHINERY IN THE "THETIS."

For the first time, surface condensers were used in association with the compound marine engine. There were, as shown above, six cylinders, arranged in two groups, each with one high- and two low-pressure cylinders. The three pistons of each group worked one crosshead, connecting-rod, and crank. Each group had two slide-valves, one for the high-pressure group and one for the low-pressure cylinders, and both were attached to one valve spindle and one reversing link. The engines worked up to 51 revolutions per minute—equal to a piston speed of 255 ft. per minute—and the maximum indicated horse-power was 256. The engines were tried 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.

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 horsepower 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. 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 system 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.

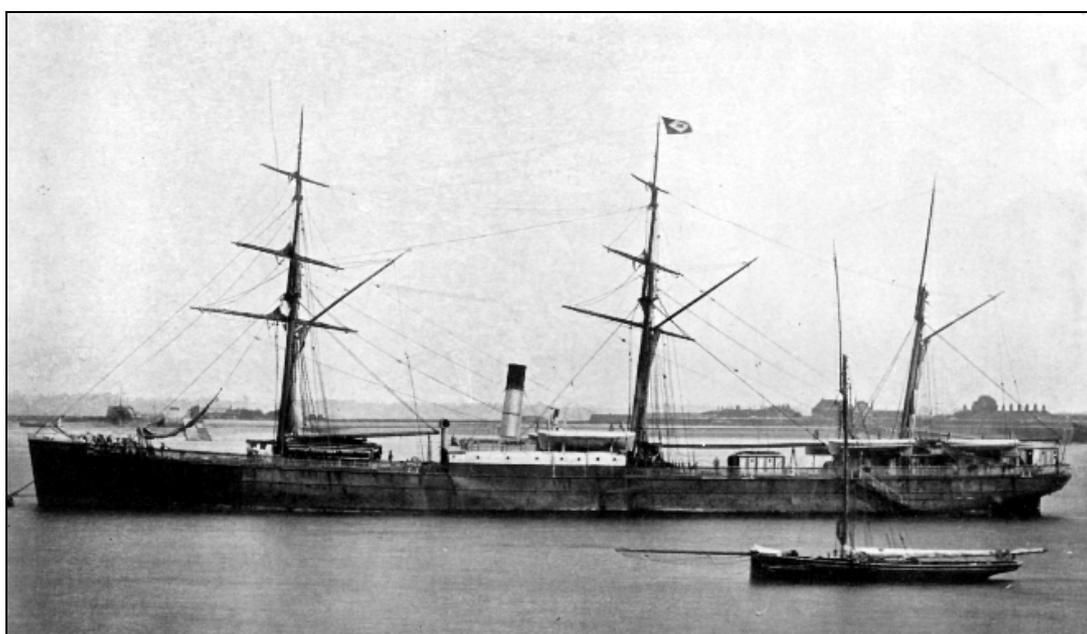
Another innovation which suggested future developments was the fitting at the base of the funnel in the *Thetis* of a series of water-tubes for the purpose of utilising the waste heat from the boilers to evaporate water for subsequent condensation to make up the boiler feed. The time was not ripe for such a utilisation of the waste gases—the heat was insufficient to generate the required steam—but now various schemes are applied for absorbing the waste heat in the uptake to heat air for furnace draught and to superheat steam.

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 Scott compound engine is found in the results of its application to the early Holt steamers. Alfred Holt commenced trading with the West Indies in 1855, while his brother, George Holt, became associated with Lamport in the River Plate trade in 1865. Both lines continue among the most successful in British shipping.

The Holt steam line to China was commenced in 1865, and was the only one via 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. Thence the vessels proceeded to Penang, Singapore, Hong Kong, and Shanghai. Unaided by any Government grants, they performed this long voyage with great regularity.

The three vessels which inaugurated the very successful 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 picture below.



The *Achilles* of 1865 off Gravesend

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 general drawings are reproduced on the next page and on Plate XII. 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 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 crankpin.

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, 17ft. in diameter, with 26ft. 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 1.5 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, 24in. in diameter; one circulating pump, 24in. in diameter; two feed pumps, 4.75½ in. in diameter; and one bilge pump 7in. in diameter: all the pumps were single-acting, with 17in. stroke. The diameters of the principal pipes were: main steam, 7.5 in.; to low-pressure cylinder, 12 in.; circulating inlet, 10 in.; discharge, 12 in.; air-pump discharge, 10 in.; main feed, 3.75 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. Each boiler had a long receiver passing through the uptake to dry the steam. On the receiver was a deadweight safety-valve 6.25 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 did not exceed 20 tons per day for all purposes, equal to 2.25 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, with a number of passengers and a fair cargo. The higher economy established for the compound engine on long voyages resulted in the ultimate supersession of the sailing ship. 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.

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 economy up to a certain stage, although with increased pressure the proportion of saving was not commensurate with the weight of the wheel, and the three-cylinder three-crank engine was ultimately adopted.

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 Company and for other lines, with services from Britain to the Far East, and carried out very extensive work in the building up of the coasting trade of Asia and Oceania. For the Holt line alone there have been constructed by the Scotts forty-eight steamers, aggregating 148,353 tons; while the propelling machinery of these represents 19,500 nominal horse-power. For the India and China services there have, in the past fifty years, been completed over one hundred and thirty 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 practically never 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 Vladivostok and the Amur river. They also have ships trading up the Yangtze Kiang to Ichang, 1000 miles from the sea, where the rapids prevent navigation farther into the interior. 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 Yangtze steamers were propelled by paddle-wheels driven by walking-beam engines. The first of the twin-screw steamers was built in 1878—a vessel of 3051 tons gross—and there has been constructed since then a long succession of very serviceable steamers. For

this line alone, sixty-four vessels have been constructed by the Scotts, the aggregate tonnage being 115,600 tons, while the nominal horse-power of the propelling machinery fitted to these vessels is 15,000 horse-power.

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 to offer rather an analysis of the progress made, deferring a description of typical modern steamers for a separate Chapter.

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 ; hut this latter has not been much adopted, only some 3 per cent, of the vessels registered at Lloyds being so fitted. This is in a large measure due to the satisfactory economy attained with triple-expansion engines. As to the progress made, Table II., giving average results at different periods, is instructive.

TABLE II.—PROGRESS IN THE ECONOMY OF THE MARINE ENGINE, 1872 TO 1901.

	1872	1881	1890	1901
Boiler pressure in pounds per square inch	52.4	77.4	158.5	197
Coal consumption in pounds per indicated horse-power per hour	2.11	1.83	1.52	1.48
Consumption on prolonged sea voyages in pounds per indicated horse-power per hour		2	1.75	1.55
Piston speed in feet per minute	376	467	529	654

The advance of the century may be popularly expressed by stating that, whereas in the first coasting steamships built by the Scotts the fuel consumed in carrying 1 ton of cargo for 100 miles was 224 lb., the expenditure to-day is from 4 lb. to 5 lb. The economy of the steam engine has accounted, as is shown in the Table, for a considerable part of this improvement. But, at the same time, the growth in the size of ships has enabled the normal speed of 10 knots to be realised, with an addition to engine power of much less ratio than the increase in the capacity of the steamer. As to speed, recent progress has been most marked in the Navy, and it is therefore fitting that here we should direct our attention to Naval work.

