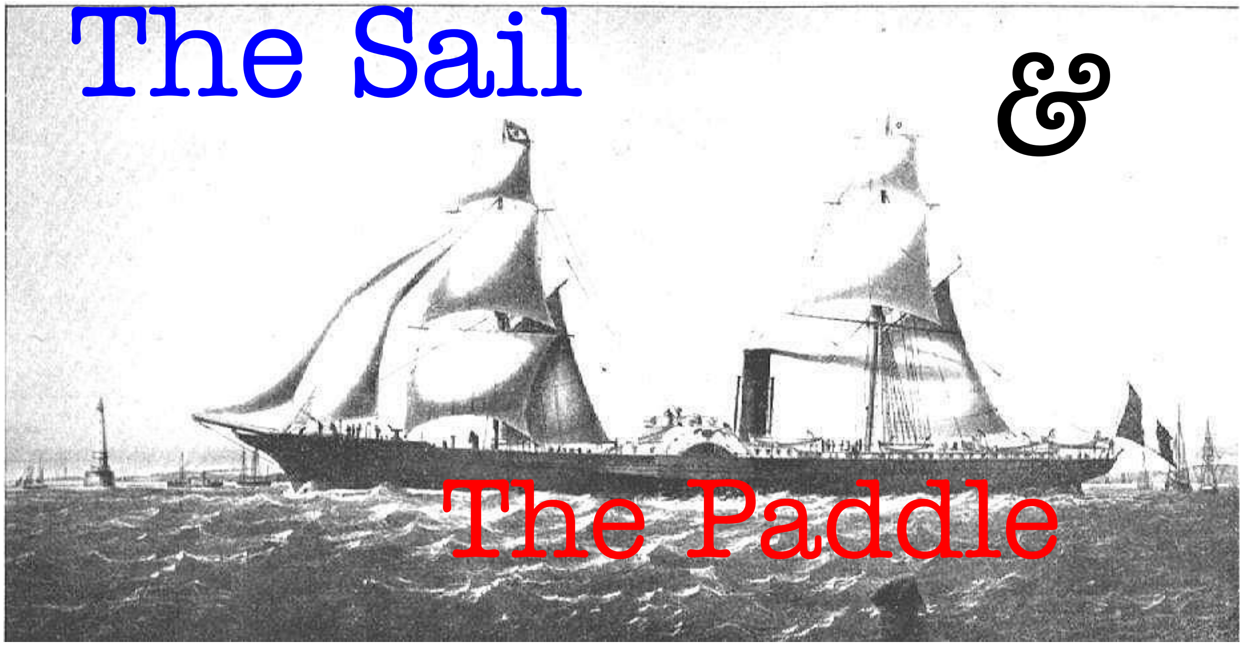


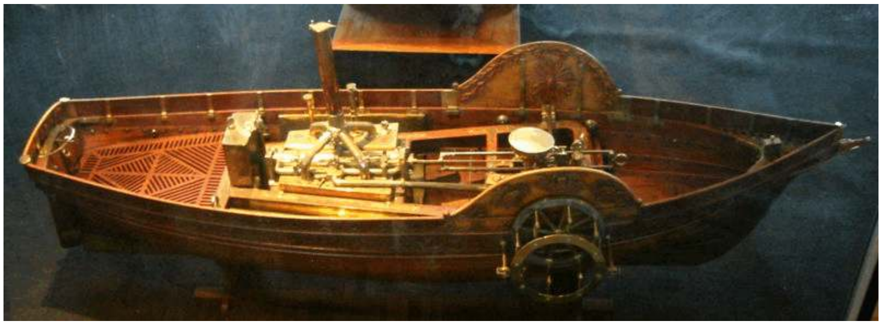
The Sail & The Paddle

THE MECHANICAL REVOLUTION

The desire for some means of mechanical propulsion for ships is nearly as old as the use of sails for propulsion. The sail, particularly in the days before man had learned to brace the yards to the wind when it was ahead, always placed a limitation on the course that a vessel could steer. She could only sail a course which the wind direction allowed, which was not necessarily the most direct, and to reach her destination if the wind headed her might mean sailing three, or even four, times as far as the straight course. And if her course took her across the equator she might lie motionless for days in the doldrums, without a breath of wind to fill her sails.

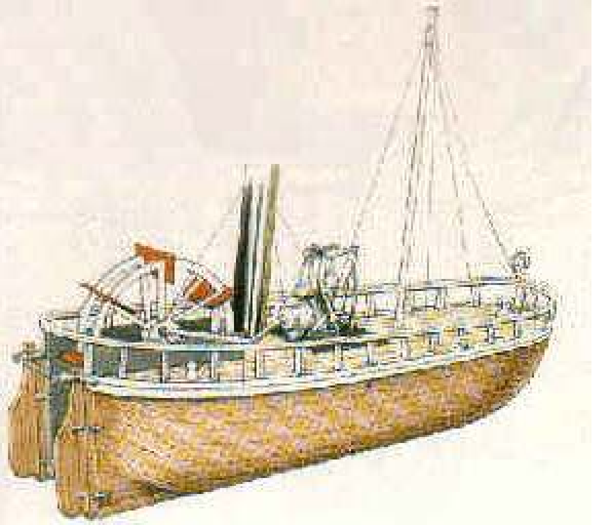
The Romans are said to have invented a form of paddlewheel, operated manually by means of a crank, but they discovered, not surprisingly, that rowers with oars were more efficient. During the Middle Ages the Chinese are supposed to have built a junk with paddlewheels attached to the keel and driven by slaves on a treadmill, but this, too, appears to have been a failure, since the invention was not followed up. What was needed - and the innovators soon recognised it - was some means of turning the paddlewheel other than by manpower. In 1685 a French inventor put forward the theory that air pressure would force a piston down a cylinder if a vacuum could be created below it, and that the resultant power could be used to turn a paddlewheel. The vacuum was to be formed by condensing steam injected beneath the piston. Twenty-seven years later, in 1712, this idea was, in fact, to be the basis of the first working steam engine, built by Thomas Newcomen, but even this had no application to ships because it proved impossible to generate enough power to drive a paddlewheel.

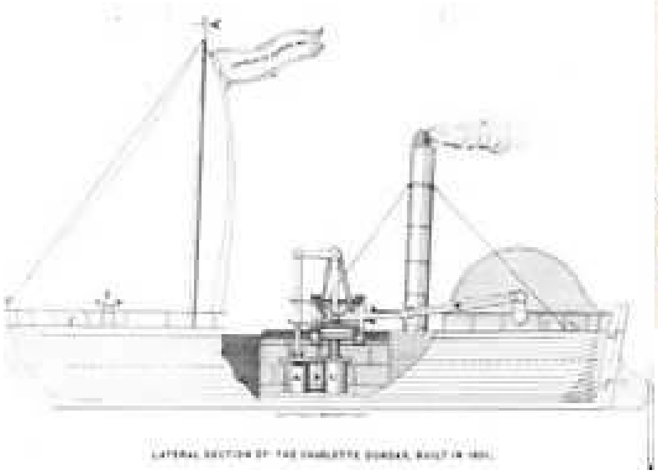
The first breakthrough came in 1765 when James Watt, in an attempt to eradicate the chronic inefficiencies of Newcomen's engine, invented the condenser and made the cylinder double-acting, by admitting steam both above and below the cylinder. Here, at last, was a steam engine which developed reasonable power and , with the further invention of a centrifugal governor, power at a constant speed. This was what was needed if mechanical power was to replace the sail. In 1768 Watt went into partnership with Matthew Boulton, who had an engineering workshop in Birmingham, and it was Boulton and Watt engines which powered most of the world's first steamships.


Pyroscaphe

Strictly speaking, the worlds first steam vessel was the *Pyroscaphe*, a large clinker-built boat with an engine which turned a pair of small paddlewheels. It was invented by the Marquis Claude de Jouffroy d'Addans, and in 1783 was tried out on the River Saone in France. The engine worked for 15 minutes before breaking down, and during that time the *Pyroscaphe* moved forward through the water under power.   It would be equally correct to say that the second steam vessel in the world was the John Fitch, a small barge-like hull with an engine which operated, through linking beams, six vertical oars on each side. This vessel, named after its inventor, made a short trip on the River Delaware in the United States in 1786. However, since neither of these two was reliable enough to prove that steam was a viable method of propulsion for ships, it was left to a later vessel to demonstrate the steamship's potential.

The vessel which really inaugurated the era of the steamship was the *Charlotte Dundas*, which made her first voyage in March 1802. She was built on the River Clyde in Scotland to the order of Lord Dundas, a governor of the Forth and Clyde Canal, and he named her after his daughter.





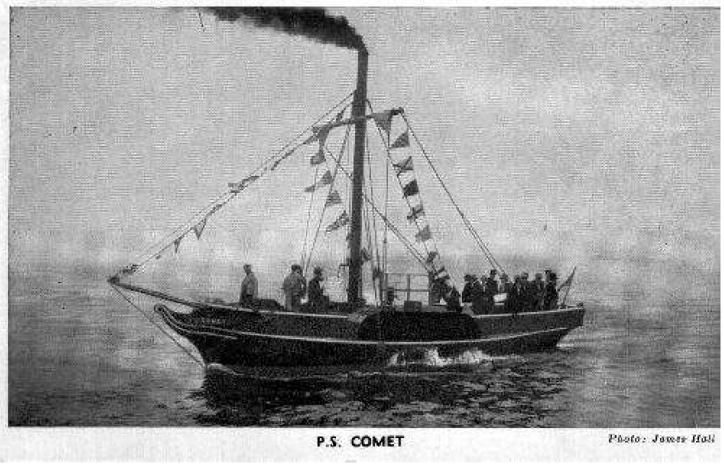
She was a wooden vessel 58 ft. long, with a beam of 18 ft. and a draught of 8 ft., with a single tall funnel amidships. Lord Dundas wanted her to replace the horses which towed the barges un and down the canal, and he gave the order for her to William Symington, an engineer with a workshop on the Clyde. She had a single paddlewheel at the stern, driven by a single-cylinder steam engine which developed about 12 horsepower. On her first voyage she towed two 70-ton barges up the canal for a distance of 20 miles at a speed of over 3 knots, which would have been higher but for a strong headwind. She ran steadily up and down the canal towing barges for three or four weeks, but was then taken out of service as it was feared that the wash from her paddlewheel would cause the banks to fall in.

With the *Charlotte Dundas* proving that a steam-driven ship was a commercial proposition, the race for steam propulsion was on. Robert Fulton, an American inventor who had lived in Paris, and who was involved in the birth of the submarines, was the next on board the *Charlotte Dundas* during one of her canal trips, and decided to attempt a similar feat on the River Seine in Paris. His first attempts were a failure, as the wooden hull which he constructed was not strong enough to take the weight of the engine and boiler. It broke in two and sank. Undeterred, Fulton built a stronger hull, recovered his engine from the bottom of the Seine, and in August 1803 gave a demonstration by towing two boats upriver for an hour and a half.

Convinced that the steamship had a commercial future, Fulton returned to the United States and , in co-operation with a financier named Robert Livingston, who lived at Clermont, built a wooden hull, with a length of 133 ft. and a displacement of 100 tons, on the East Hudson River. As there were no engineers in the United States with sufficient experience of building steam engines he sent over to Britain, to Boulton and Watt, for an engine to be shipped across the Atlantic. The engine had a single vertical cylinder, 24 in. in diameter, with a stroke of 48 in. and, through bell cranks and spur gearing, drove two 15-ft. paddlewheels, one on each side of the hull. She was named *Clermont*, after Livingston's home town, and on her maiden voyage in 1807 she covered approximately 240 miles by steaming to Albany and back in 62 hours, as an average speed over the whole distance of 3.9 knots, though her best speed was 4.7 knots. She continued in commercial service on the East Hudson River for two seasons, eventually proving too small for the crowds that thronged the landing stages to take a passage in her. She was so successful commercially that Fulton built a second steam vessel, which he named the *Phoenix* to operated similarly on the Delaware River. Since she was built at Hoboken and had to steam down the coast of New Jersey to reach the Delaware, she can claim to be the first steamship to make a voyage in the open sea, though she hugged the coastline the whole way.

The "Clermont" New York Sept. 25, 1909

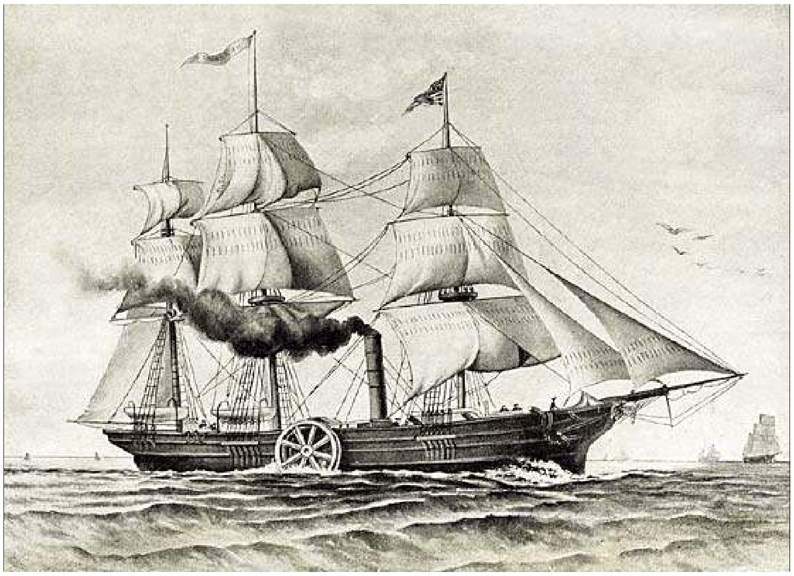
The financial success of the river steamers in the United States inspired a Scottish engineer, Henry Bell, to enter the steamship business. He built the *Comet* at Glasgow in 1812 for a ferry service on the Clyde between Glasgow, Greenock, and Helensburgh, which proved so successful that he extended it up the west coast of Scotland to Oban and Fort William, 200 miles away. The *Comet* was smaller than Fulton's *Clermont*, but her engine produced a better average speed of 6.7 knots. Two years later Henry Bell had five similar ferries running services on the River Thames from London as far down as Margate. The biggest ferry of this early steamship period was the *James Watt*, operating a coastal service between London and Leth. She had an overall length of 141 ft. 10 in. and a maximum beam over her paddle-boxes of 47 ft. Each paddlewheel was 18 ft. in diameter.



Henry Bell's 'Comet'

By 1816 a steamship passenger service was in operation across the English Channel between Brighton and Le Havre, and in 1820 a service between London and Paris was opened with the *Aaron Manby*. She had an engine designed by Henry Bell which gave her an average speed of between eight and nine knots. After a few regular passenger trips she was purchased by a syndicate of French shipowners and used for pleasure trips up and down the River Seine.

All these vessels were, of course, relatively small; all had paddlewheels driven by single cylinder engines (occasionally, as in the *James Watt*, with one cylinder to each paddlewheel); and all were used only for river or coastal passages. But they opened the way to more ambitious steamship operations, across the oceans, with bigger ships and greater horsepower. In fact, by the year in which the *Aaron Manby* made her passage from London to Paris, the Atlantic had already been crossed by a ship with a steam engine, though she did not really rank as a steamship. This was the American *Savannah*, a full-rigged ship with an auxiliary engine and detachable paddlewheels. She crossed the Atlantic in 1819 from Savannah to Liverpool in 21 days, but used her engine for only 8 hours during the passage. A similar voyage, and much more noteworthy because steam propulsion was used to a significant extent, was made in 1825 by the Enterprise, a ship of 470 tons, which made a passage of 11, 450 miles in 103 days from London to Calcutta. She was still primarily a sailing ship, but used her engine on sixty-four days of the 103.


The "Savannah" first steamship to cross the Atlantic.

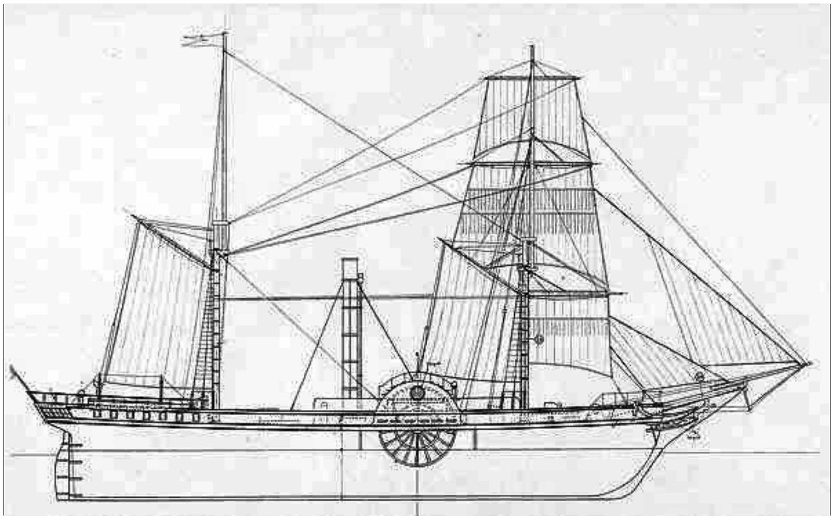
The great problem still facing marine engineers and designers was the accommodation of sufficient coal on board to feed the boiler throughout a long ocean passage. By the 1830's the steam engine itself, still a single-cylinder reciprocation engine, was reliable enough to be used for ocean passages, but in general, the ships themselves were still too small to accommodate the amount of coal required and still to provide sufficient space for passengers or cargo to make the ship commercially viable.

The answer to this particular problem was, of course, one of ship design, and it was finally solved in a somewhat dramatic fashion. The directors of the Great Western Railway Company in Britain decided in 1837 to extend their railway line to Bristol and called in for consultation their company engineer, Isambard Kingdom Brunel. At the meeting one of the directors complained that the line, when extended to Bristol, would be too long, whereupon Brunel said he thought it would be far too short and ought to be extended to New York by building a passenger steamship. The idea was discussed, approved, and as a result Brunel was told to go ahead and build an Atlantic liner, to be named the *Great Western*.

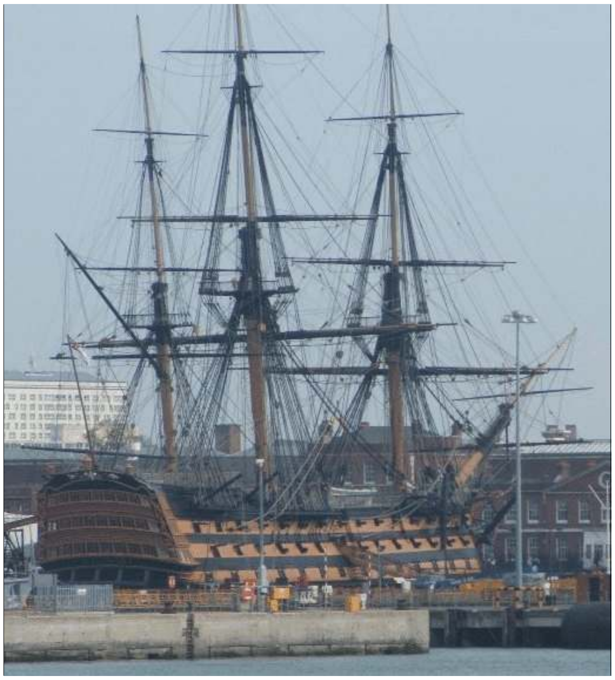
There was at the time a steamship company in existence called the British and American Steam Navigation Company, and as soon as it was learned that the Great Western Railway were building a steamship specially for an Atlantic crossing, they decided that they would beat them to it. It was known that the *Great Western* was to be a ship of 1,340 tons with an engine developing 750 horsepower, and the British and American company placed an order for a larger ship, to be called the *British Queen*.

The “Great Western”

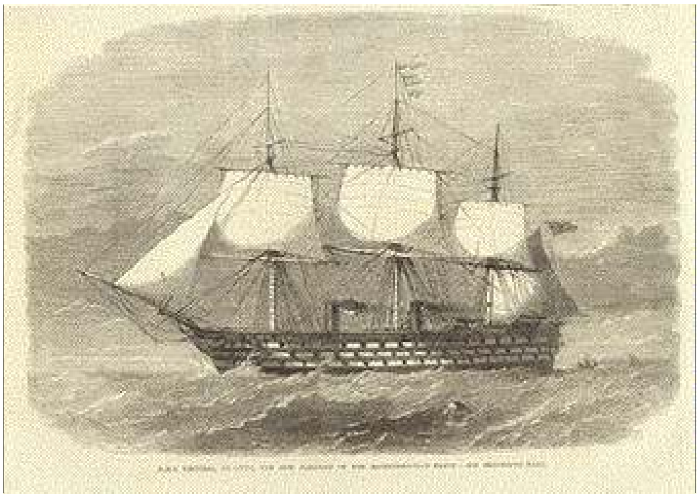
There were many delays in her building, and before long it became apparent that the *British Queen* would not be ready before the *Great Western*. British and American, therefore, looked round for a ship to charter, and chose the *Sirius*, built for passenger and cargo service between London and Cork. She was a ship of 700 tons with an engine developing 320 horsepower, and in the race across the Atlantic she was the first away, leaving Cork on 4 April 1838 with 40 passengers on board. Every available space below decks was packed with coal, and she carried two large heaps of it on the upper deck as well. Out in the Atlantic she ran into a severe storm which slowed her up and entailed the use of more coal than had been planned. As a result she ran out of coal before she could complete her crossing, but, by feeding the furnace with all the cabin furniture, the wooden doors throughout the ship, all her spare yards and one of her masts, she reached New York. She was greeted by an immense throng of cheering people eager to greet the first ship in the world to make an ocean crossing entirely under steam power. She had taken 18 days, 10 hours and her average speed for the whole voyage was 6.7 knots.


The “Sirius”

She was followed into New York a few hours later by the *Great Western*. The latter had left Bristol four days later than the *Sirius*, carrying only seven passengers, and her time across the Atlantic was 15 days, 5 hours, giving her an average speed of 8.8 knots. What was far more important, however, was the fact that when she arrived in New York she still had 200 tons of coal in her bunkers - proof that, with a proper allowance of bunker space in their design, trans-ocean passages were will within the capability of the new steamships.


HMS Victory

By the middle of the nineteenth century the wooden ship had reached her maximum size, with tonnage approaching 7,000 on waterline lengths of about 340 ft. these huge wooden ships, built only as warships, drew so much water that they could not be used inshore for the classic naval operations of close blockage and bombardment, required immense crews to man them, and were popular only with commanders-in-chief afloat, who found superb personal accommodation in the immense cabins aft. One such ship was the last three-decker of the British navy, H.M.S. *Victory*, launched in 1859. In her, the wooden hull had been taken to the limit, and there was not enough strength in wood to extend any further, or to support the huge array of masts and yards required to drive so large an object through the water.


HMS Victory with 102 guns.

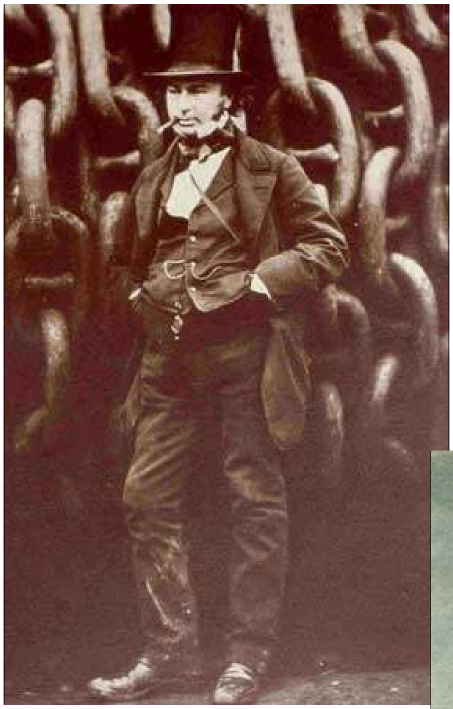
Some other shipbuilding material was obviously necessary, if ships were to develop beyond the limitations imposed by wood, and the only obvious alternative was iron. In the late eighteenth century an iron lighter had been constructed on the Thames, and confounded the sceptics when she did not sink. Nonetheless, there were far more doubters than believers, and resistance to the new material was considerable, even in the face of demonstrable success.

The first true ship to be built with an iron hull was the *Aaron Manby*, the first steamship to operate a service between London and Paris. She was relatively small vessel of 116 tons, and in spite of many gloomy prognostications, she lasted until 1855, when finally she became unsafe through the rusting of her plates. She was followed by a few other iron-hulled vessels, but they were all small and another twenty years were to pass before reluctant shipowners could be convinced that iron had so many advantages over wood that it was worth adopting for large ships as well as small.

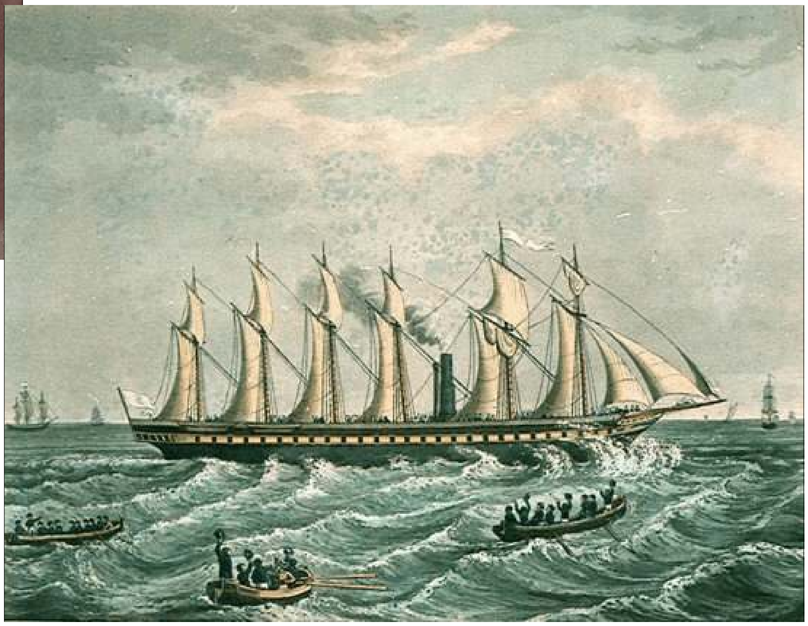
Apart from the obvious fears that iron, because it is heavier than water, was an unsuitable material for shipbuilding, there were other reasons for the delay in its adoption. The science of engineering had yet to perfect a method of bending iron to a desired shape, and the only methods available at the beginning of the nineteenth century were casting in a mould or working when red hot by hammering. These methods frequently led to fractures because of the uneven quality of the iron. There was no knowledge as yet of any means to prevent rusting, which was accelerated by contact with seawater, and it was also quickly discovered that encrustation of the bottom by barnacles and weed occurred considerable faster on an iron hull than on a wooden one. And finally there was the effect of the iron hull on the magnetic compass. So great a mass of magnetic material was certain to throw a compass out, and as yet there was insufficient scientific knowledge of the behavior of compasses to provide an antidote.

Yet the advantages of iron were so obvious that many shipbuilders did not share the conservative views of shipowners, and devised a means of incorporating it in a wooden hull in what was known as ‘composite’ building. One of the great drawbacks of the standard wooden hull was the massive framing needed to provide adequate longitudinal and athwartships strength. This framing was a great source of unnecessary weight in a ship. The composite ship had an inner framework consisting of iron keelson, frames, knees and deck beams to which the outer wooden planking, keel and decks were secured, thus providing not only a considerable saving in weight, but also a big increase in stowage space through the elimination of the thick wooden framing. It was a compromise that lasted only until shipowners at last overcame their reluctance, and went all-out for the iron ship.

The first sign of a decline in the continued dominance of wood for large ships came in 1838, with the building of the 400-ton iron ship *Rainbow* for trade between London, Ramsgate and Antwerp. Her immediate advantage was that she could stow in her holds nearly twice as much cargo as a wooden-hulled ship of the same size, and she proved herself to be a good ship at sea, safe and easy to handle. And with her iron hull she was not subject to the perpetual small leaks endemic in all wooden vessels due to the working of the hull planking. But the final seal of approval was set in the following year, when Isambard Brunel persuaded the directors of the Great Western Railway Company to follow up their successful *Great Western* with an even larger ship, to have an iron hull. This was the *Great Britain*, and he keel was laid at Patterson's shipbuilding yard at Bristol in 1838.



Isambard Brunel

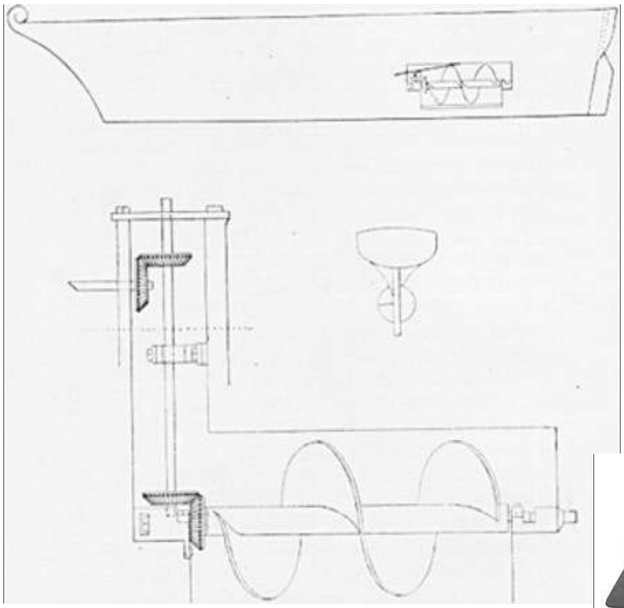


SS Great Britain

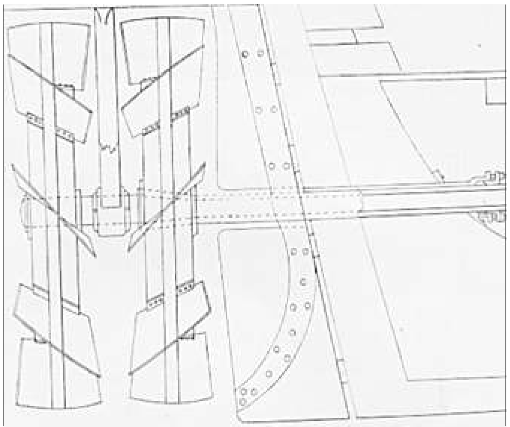
With the *Great Britain*, Brunel showed all the contemporary naval architects how to design their ships in metal and how to use the new material to provide enough hull strength for ships of rapidly increasing size. In the *Great Britain* he stipulated an iron keel of great strength, nearly 1 in. Thick and 21 in wide, and her hull plating varied in thickness between 3/8 in and 3/4 in. The plates were riveted to frames made of angle iron, and longitudinal hull strength was provided by two fore-and-aft bulkheads carried up to the level of the main deck, and athwartships strength of five bulkheads across the whole width of the ship. These athwartships bulkheads were made watertight so that the hull was divided into six watertight compartments, as an additional safety measure.

Only in warships was the use of iron delayed, for test carried out at Portsmouth in England had shown that, while a cannon ball fired at short range at iron plating 3/4 in thick had no difficulty in penetrating it, 8in of oak would stop it. And, as the average thickness of a wooden warships hull planking was 18in, the advantages of retaining wood for warships was obvious. Moreover, wrought and cast iron, the only known methods at the time of bending iron to the desired shapes, showed a tendency to crack or shatter under gunfire - a fatal flaw in a warship, forces were at work which would compel navies to make the change, particularly the development of the gun from a short-barrelled weapon discharging a solid ball at a relatively short range to a longer-barrelled piece firing an explosive shell over greater distances. But the day for this transition had not yet arrived, and until it did, the wooden warship remained in many ways just a larger version of the warship of 200 years earlier.

All these early steamships, whether with wooden or iron hulls, were driven through the water by paddlewheels, either a single one at the stern, as in the *Charlotte Dundas*, or by a pair of wheels, one on each side of the ship. There were considerable disadvantages in the use of paddlewheels, the principal one being that when a ship rolled in a seaway, each paddle-wheel (if she had two), would alternately be lifted out of the water, putting a tremendous strain on the engine. And, as they projected outside the hull of the ship, they were easily damaged by careless handling or by other accidents. For warships they were largely useless, since a single hit on a paddlewheel would at once cripple the ship. It was these obvious disadvantages which led several inventors to try to devise a means of ship propulsion which would be permanently submerged, and thus capable of driving the ship without putting a varying strain on the engine or providing an easy target for an enemy gun.



Archimedes screw



Above & left:
Ericsson's propeller.

The principle of the Archimedes screw was well known, and it was an adaptation of this principle which finally produced the answer. A very early attempt to produce a marine propeller was John Shorter's invention of 1800, but it suffered from a clumsy form of chain drive and a very long shaft which required a buoy at the end to support it in the water. Four engineers are usually credited with the invention of the ship's propeller, the Englishman Robert Wilson, the Frenchman Frederic Sauvage, the Swede John Ericsson, and another Englishman Francis Pettit Smith. They all took out patents for their inventions between 1833 and 1836. It was Francis Smith's propeller which was at first most widely used by shipowners, though an improved design patented by Ericsson in 1818 was the final winner, when he demonstrated its efficiency in a small steamer aptly named the *Archimedes*.

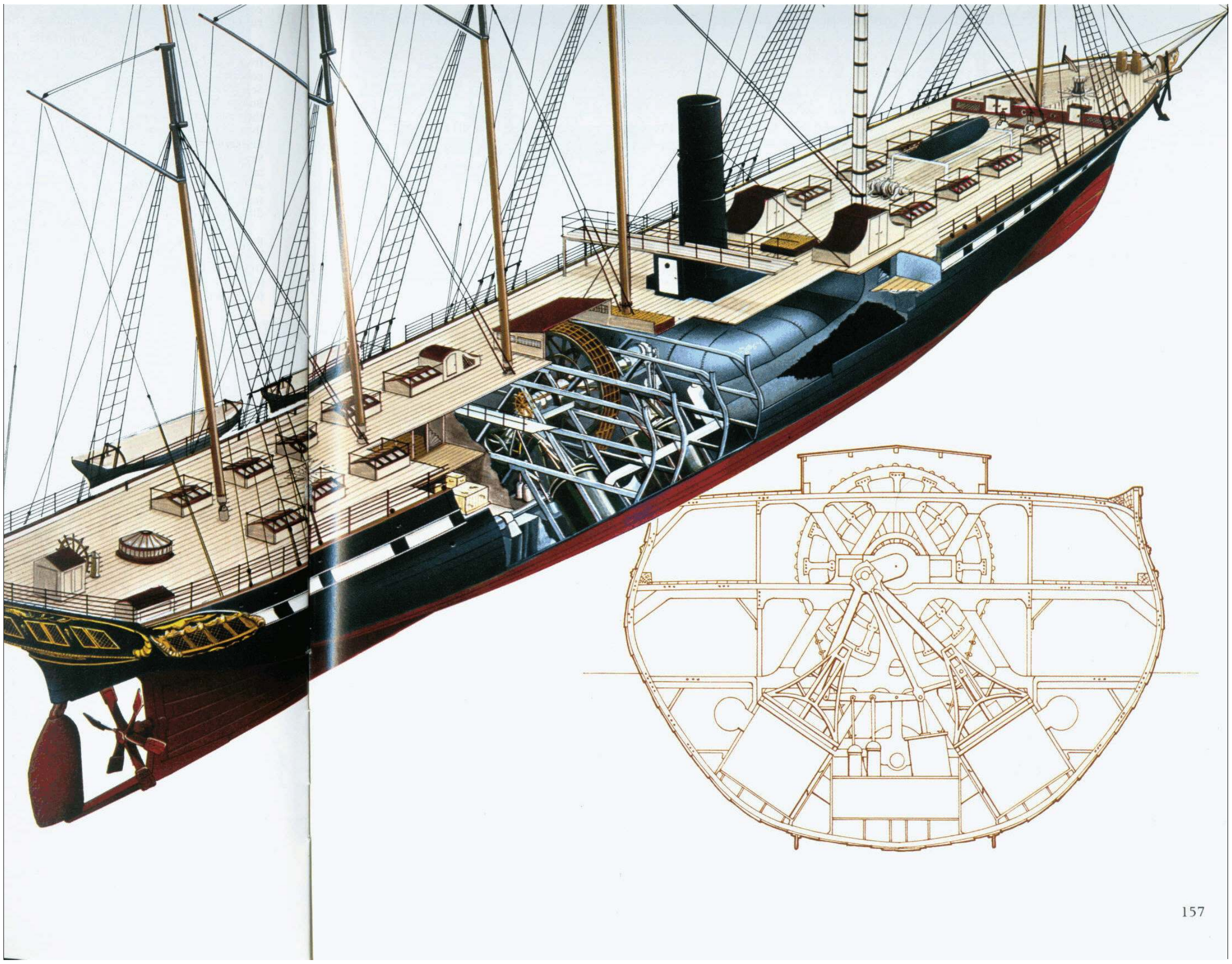
Isambard Brunel, who had laid the keel of his Great Britain in 1839, had designed his ship for propulsion by paddlewheels, but he attended the trials of Ericsson's propeller on the Archimedes and was quickly convinced of its superiority as a means of ship propulsion. The building of the Great Britain was stopped while Brunel prepared new plans and began a series of experiments on various models of propellers to find the one most suited to his ship. The Great Britain was a large ship for her day, displacing 3,620 tons, on an overall length of 322 ft. and a maximum beam of 50 ft. 6 in. As a result of his experiments, Brunel gave her four engines, developing 1,500 horsepower, which drove a six-bladed propeller of 16 ft. diameter at 53 revolutions per minute. Steam from the boilers was fed to the engines at a pressure of 15 lb/sq in.

Like all steamships of her time, except for the smallest, the *Great Britain* was fitted with masts and sails. By 1840's the steam engine had proved itself on thousands of voyages, long and short, but in general most shipowners, and almost all passengers, felt less happy than engineers about trusting their ships and themselves entirely to mechanical propulsion. So sail was carried, mainly as an insurance against breakdown. The *Great Britain* could spread 15,000 square feet of canvas on six masts, but although she crossed and re-crossed the Atlantic many times during her service as a passenger ship, only once did she have to rely on her sails to complete a passage, when her propeller dropped off in mid-ocean.

The "Great Britain" lies on the rocks in Dundrum Bay.

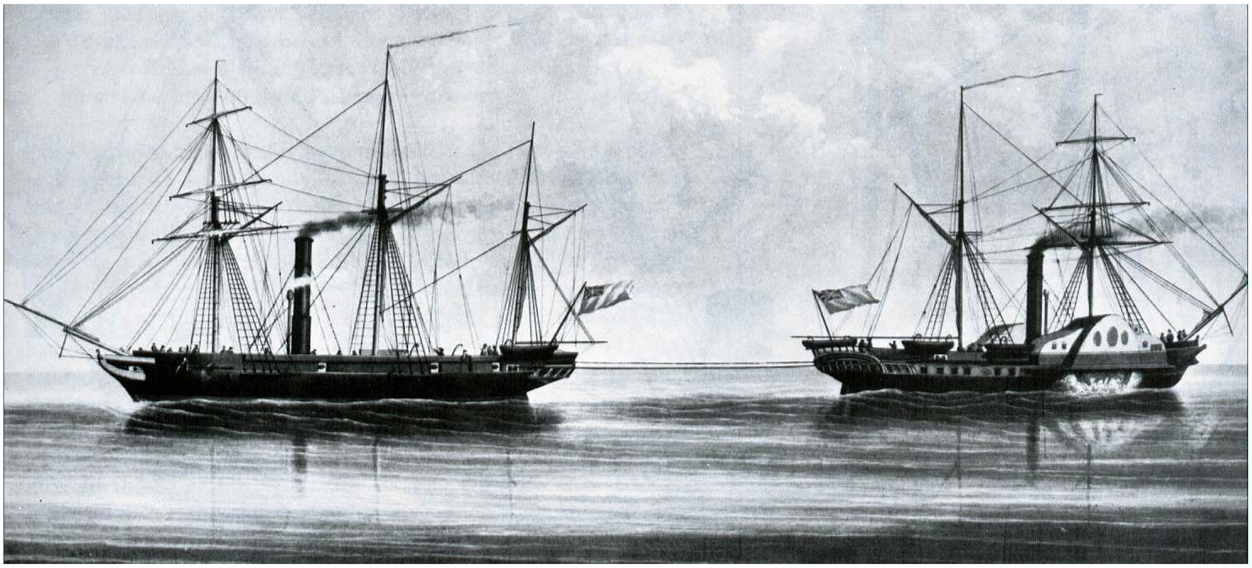
If there were still any who doubted the superiority of iron over wood as a shipbuilding material, the *Great Britain* put their anxieties to rest. In September 1846 she ran aground on the rocky coast of Ireland at Dundrum Bay, due it is said to excessive deviation of her compass caused by the iron in the hull. She went ashore at the top of spring tides, and it was not until six months later that there was another tide high enough to float her off. All through the winter she lay on the rocks, battered by the winter gales, conditions which would have reduced any wooden ship to matchwood. When she was refloated and docked, it was discovered that her hull was hardly strained at all.

To avoid some of the loss caused by having her off the Atlantic service for so long, the Great Western Railway Company sold the *Great Britain*. Her new owners refitted her with smaller and more economical engines, and until 1886 she operated steadily between Liverpool and Australia. During that year she was damaged in a heavy storm off Cape Horn and was towed to the Falkland Islands and grounded in Port Stanley, to act as a coal hulk. Finally, in 1970, enough money was raised in Britain to salvage her and bring her home to Bristol, where she is preserved to this day as a monument to the genius of her brilliant designer.



The “Great Britain” seen here when first built. The cross section and cutaway show two of her 88-in cylinders and the chain drive to the propeller shaft. She had a crew of 130, could carry 600 tons of cargo, Passenger capacity 252.

THE SAIL & THE PADDLE
PART II



The tug-of-war between the screw-driven *Rattler* (left) and *Alecto* (right) was more of an exhibition to convince public opinion than a scientific test, as the Royal Navy had already ordered seven screw driven ships by March 1845.

So far as the merchant ship was concerned, the propeller was almost universally recognised as the most efficient mans of ship propulsion, but the warship in general remained wedded to sail. This was to some extent understandable, particularly in Britain, which had emerged from the last great war as undisputed master of all the oceans. She still maintained the largest fighting fleet in the world, and the officers and men who had manned that navy in war were still serving in it. A radical change from wood and sail to iron and steam meant starting the navy again from scratch, with the present superiority of numbers wiped out at a stroke. But with the invention of the propeller the overriding objection to steam propulsion in warships, the vulnerable paddlewheel, had been removed , and the steam engine at last had to be admitted into naval ships.

But it was not admitted without a struggle by traditionalists, and there was still much argument in naval circles in all countries as to weather the propeller was really superior to the paddlewheel. The argument was finally settled in 1845, when two virtually identical frigates of 880 tons, H.M.S. *Rattler* and H.M.S. *Alecto,* were both fitted with engines of 220 horsepower, that in H.M.S. *Rattler* driving a propeller and that in H.M.S. *Alecto* a pair of paddlewheels. In March of that year the two ships had a race over 100 miles which the Rattler won by several miles. In a later test, the two ships, tied together with a towing hawser, set off under full engine power in opposite directions. The *Rattler* with her propeller towed the *Alecto* stern first at a speed of 2.7 knots - conclusive proof that a propeller not only drove a ship faster, but also exerted considerably more power.

So wooden warships, or at least those of Britain, were fitted with steam engines, although they still retained their full complement of masts and sails. The installation was achieved by bringing the ships into drydock, cutting them in half, and lengthening them to accommodate engines and boilers. But, whereas, in the merchant ship, masts and sails were fitted as an auxiliary source of propulsion, for use if the engine failed, in the warship it was the engine that was an auxiliary source of power, for use if the wind were blowing in the wrong direction. In France, the only other nation with a comparable navy, the adoption of the steam engine, even as an auxiliary source of power, progressed much more slowly. By 1854, only nine years after the *Rattler-Alecto* trials, the entire British fleet sent into the Baltic at the start of the Crimean War was fitted with engines; the entire French fleet in the Baltic still relied entirely on sail.

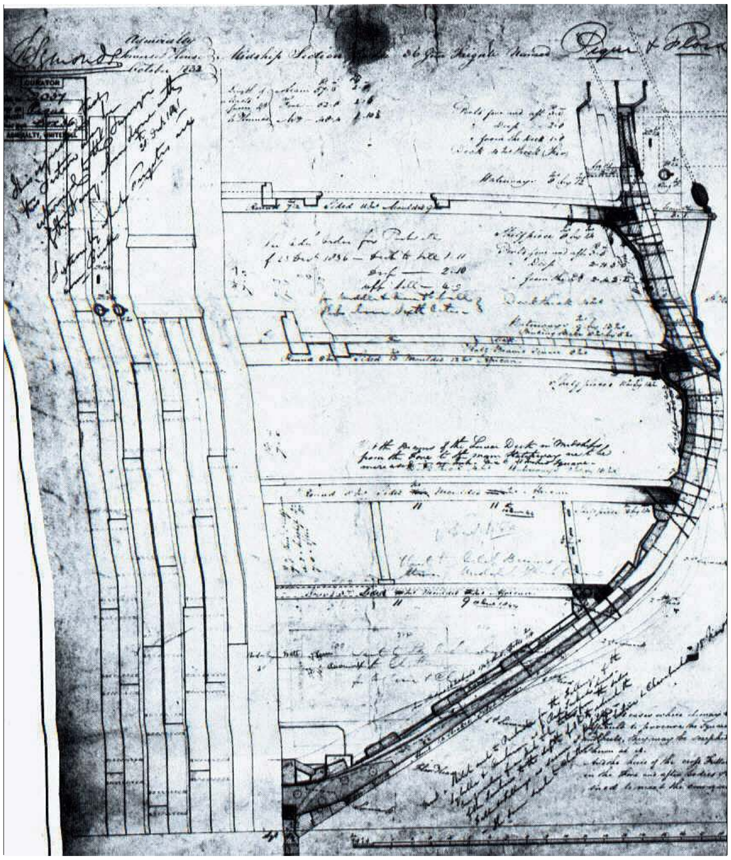
Although the propeller had emerged as the best means of transforming engine power into motion through the water, one problem remained unsolved. The fitting of a propeller entailed making a hole for the shaft in the ship's sternpost, and technology could not yet ensure watertight fitting. There were cases where ships leaked so badly through their stern gland that they had to be beached to save them from sinking. (Wooden-hulled ships faced an additional hazard. Since the vibration of the propeller could shake the sternpost to such an extent that the seams of the planking near the stern opened up and let the sea in.) It was not until 1854 that this particular problem was solved by John Penn, an engineer whose marine steam engines were widely used in ships. Penn discovered that *lignum vitae*, the hard, smooth wood of the guaiacum tree, which grows in the West Indies and has self-lubricating properties, was ideal for the purpose of lining stern glands. It also suffered very little wear as the propeller shaft revolved inside it. It was used for lining stern glands for the next forty years, until the more modern metallic packings were introduced.

It has been mentioned earlier that, in general, navies were slow to implement the advances in shipbuilding which the first half of the century brought, but this does not mean that no improvements in naval shipbuilding were made. The best wooden warships were still those built by France, mainly because, with the exception of the United States, she built appreciably larger than other maritime nations. As late as 1845 the British laid down a 74-gun ship of the line on the exact model of a French ship which they had captured in 1794, so great was their belief in the superiority of French design. But in the meantime the Royal Navy had found a naval architect of genius. As a commander, William Symonds had been given permission by the British Admiralty in 1825 to build a corvette to his own design, and the resulting ship, *Columbine*, of 18 guns, was so outstandingly successful that Symonds was promoted. His success as a designer might have ended there had not the Duke of Portland given him a commission to build a yacht. Named *Pantaloon*, she was such a success that she, too, was purchased for the navy and adapted as a 10-gun brig. Symonds was then instructed by the Admiralty to design more ships,


Corvettes

including a fourth-rate of 50 guns, and their general excellence resulted in his being knighted and made Surveyor of the Navy, responsible for all warship design. Within the next fifteen years he was responsible for the design of more than 180 warships.

Symonds's designs owed their great success not only to improved methods of construction, which brought a great increase in structural strength, but also to an improved underwater shape, much less full and heavy than had been previously the case. To some extent he followed the French lead in building large, not so much in overall length as in beam and depth, so that his ships, though shorter than the French, were broader, roomier, and higher between decks. The loss of speed which a shorter overall length might have incurred was more than made up for by the improvement in shape of bottom, which gave his ships a much cleaner run through the water. Another of his improvements was the introduction of a system for standard sizes for masts and yards, so that they became interchangeable, not only between ships of the same class, but also between ships of different classes, 'though not of course for the same purpose. Thus, for example, the topsail yards of a second-rate ship of the line were cut to the same size as



The midships section of the 36-gun frigates *Pique* and *Flora* - sister ships built to the same plan (1832). This is a typical 'Symondite' hull form.

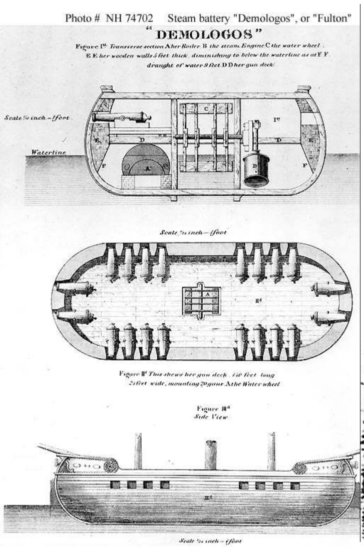
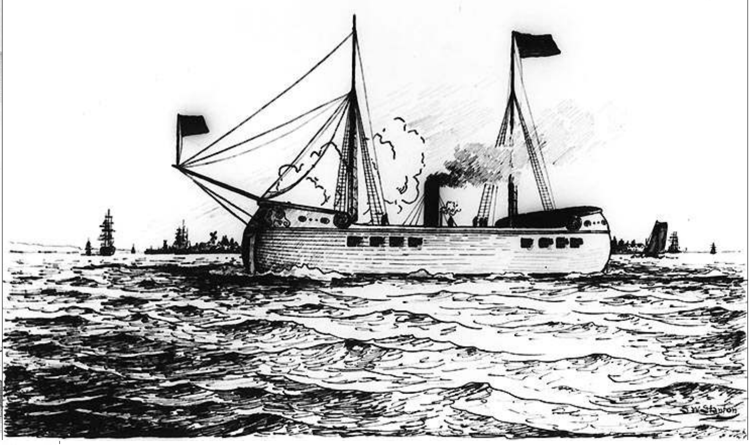


Photo # NH 74702 Steam battery "Demologos", or "Fulton"

Photo # NH 65461 Steam battery "Fulton", or "Demologos". Artwork by Samuel Ward Stanton

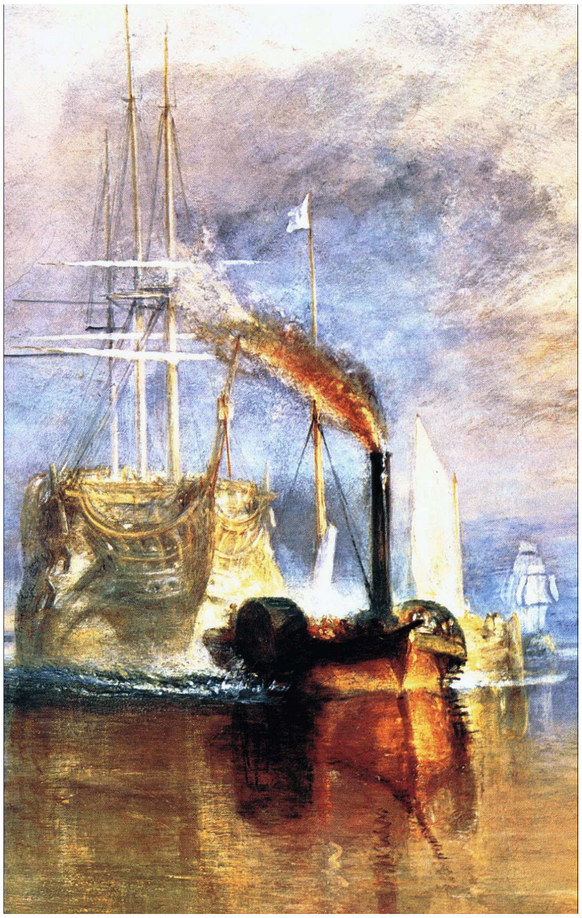
The *Demologos* later the *Fulton*.



the main yards of a frigate, and so on. By this means the eighty-eight different sizes of masts and yards maintained for the Royal Navy were reduced to twenty, with no loss of efficiency.

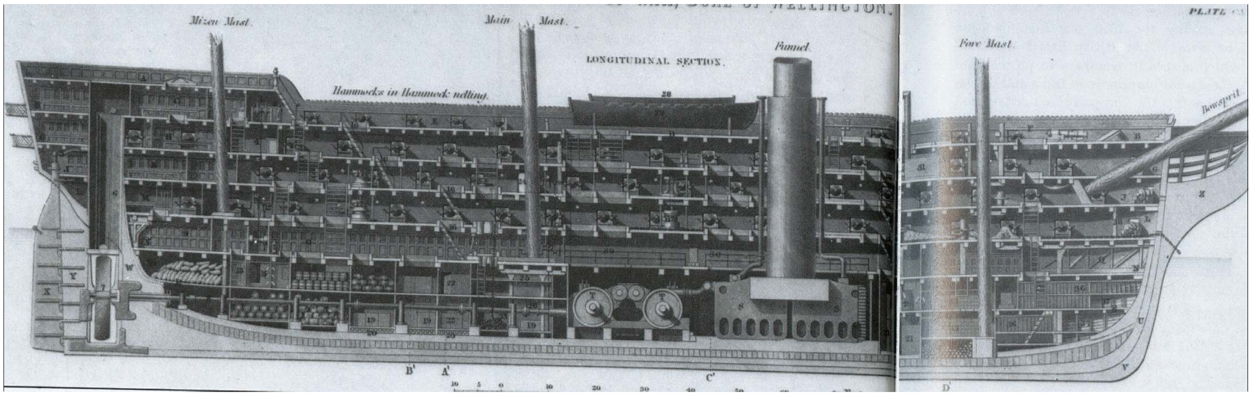
Although, in general, the fighting navies of the world turned their backs on the revolution in shipping brought about by the introduction of the steam engine, there were some small exceptions. The young United States Navy led the way with the *Demologos*, [above] launched in 1814, but completed too late to take part in the war then being fought against Britain. Designed by Robert Fulton (later she was renamed *Fulton*), she was a queer-looking vessel with two wooden hulls abreast, in one of which was the engine and in the other a boiler, and a paddlewheel mounted between them. She carried an armament of 30 guns designed to fire red-hot shot. She finally blew up in a dockyard explosion.

Britain adopted steam for her navy only reluctantly and, at first, purely for auxiliary services. It was Brunel who at last talked the Lords of the Admiralty out of their ultra-conservative attitude, and in 1822 the *Comet*, a wooden paddle steamer of 238 tons equipped with a Boulton and Watt engine of 90 horsepower, was built by contractors in the dockyard at Deptford. She was joined later by the *Monkey*, a similar paddle steamer of 212 tons, which had been built commercially at Rotherhithe and was purchased into the navy. The two vessels were used solely to tow the sailing men-of-war out of harbour when the direction of the wind made it impossible to sail out. In fact, the British Admiralty carried its disapproval of the steam engine to the extent in the official Navy List, and requiring the contractors who built the ships to supply engineers with them.



Turner's *Fighting Temeraire tugged to her Last Berth to be Broken Up* is a fitting contrast between the old and the new. During the Crimean War steamers had to stand-by to tow the lumbering three-deckers in and out of action.

France, Russia and Italy followed the naval lead of Britain by building or acquiring small steam vessels for use with their navies as auxiliaries, but, since in the world strategic situation their navies were of less account than that of Britain, they could afford to experiment. Naturally, their experiments produced nothing revolutionary in the naval sphere; in general they were, like Britain, reluctant to tinker with their capital ships until they knew that they could be sure of the effect. Nevertheless, in Britain, the Surveyor of the Navy was instructed in 1832 to design a steamship, the first to be built in Britain in a naval dockyard by naval personnel. She was the *Gulnare* of 306 tons, mounting three guns, built of wood with paddlewheel propulsion. She was followed by other small steam gunboats, but until 1840 none were built above 1,000 tons, or with anything but a small armament. As they drew very little water, less than 5 ft. they were thought to have a naval use for inshore bombardment purposes, the risk of damage to their paddlewheels by enemy gunfire being accepted.



Inboard profile of the 131-gun 1st rate *Duke of Wellington* (1852). The addition of a propeller and machinery to a three-decker's hull made for cramped conditions between decks.

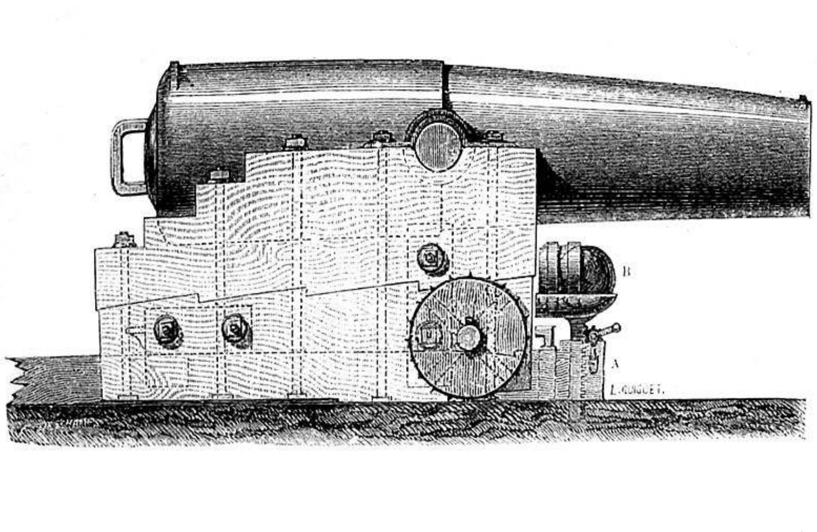
Not all British naval officers were as reluctant as the Board of Admiralty in London to face the implications of the marine steam engine, and in 1825 Lord Cochrane submitted a memorandum asking for 'six steam vessels, having each two guns in the bow and perhaps two in the stern, not less that 68-pounder long guns'. Such a squadron would have proved a formidable weapon against fleets of sailing men-of-war, and if built might well have speeded up the change-over from the sailing to the steam navy, which in fact took another half century. Only one of the six, the *Perseverance*, was built, and not for the British navy, but for the Greek. She played a useful, if fairly unspectacular, part in the Greek War of Independence against Turkey.

Iron did not enter into the Royal Navy's calculations until 1840, when the Admiralty purchased the iron-hulled steam packet *Dover* for no very clear purpose. No trials were carried out with her, and she was not used with the fleet. In the same year, three small iron gunboats were built, each mounting 2 guns, and with paddlewheel propulsion. But they were not followed up with anything larger, even though the way had been shown by John Laird, the Birkenhead shipbuilder, who had designed and built an iron frigate which he offered to the British Admiralty. (On the refusal of the Admiralty even to consider the purchase, she was sold to the Mexican navy.)

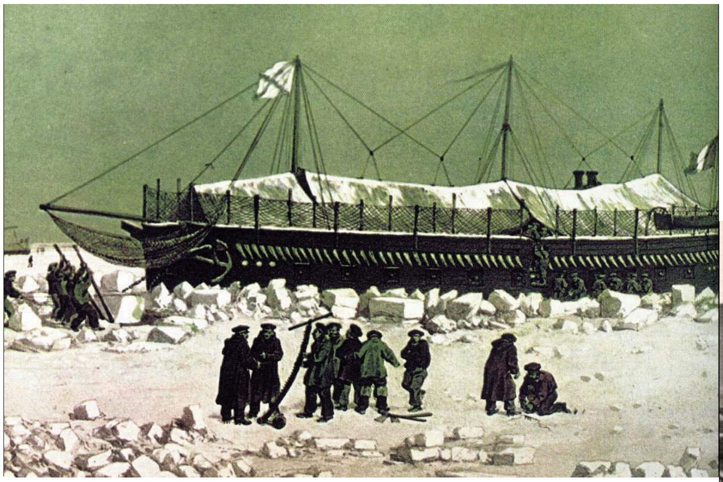
Yet the time was coming when the force of public opinion, particularly that of the shipping companies, would drive the Admiralty to begin using iron for warships larger than small gunboats. Orders were placed in 1846 for three iron steam frigates of 1,400 tons, the *Birkenhead*, *Simoon* and *Megaera*, the first fitted with paddlewheels and the other two with propellers. They never made it as warships, for gunnery experiments with an iron hull indicated that iron was still liable to break up and fracture when hit with solid shot, and the three were completed as troopships. (The *Birkenhead's* tragic end off Danger Point, between Simonstown and Cape Town, in February 1852 is still well remembered.)

So it was back to the wooden hull for the British navy, even though some other navies were persevering with iron, backed with a thick lining of teak or oak to provide additional resistance against damage by solid shot. In Britain, the wooden ships of the line continued to be brought into the dockyards to be lengthened to take an engine and propeller, even the oldest ships being converted to steam. The *Ajax* and *Horatio*, both launched as long ago as 1809 and thus relics of the Napoleonic War, were two of the oldest; another was the *Nelson*, launched in 1814. The first British wooden ship of the line to be designed from the start to incorporate an engine and propeller was the 80-gun second-rate *Agamemnon*, laid down at Woolwich in 1849 and launched in 1852. But in every case, except for that of the smallest vessels, a British warship converted to steam still retained her full complement of masts, yards, and sails as her main means of propulsion. Her engine was a very secondary affair, and elaborate and time consuming arrangements were made to enable the propeller to be raised out of the water whenever she was to use her sails, in order to eliminate the drag exerted by the screw and retain the ship's sailing performance. It was not until 1861 that the lifting propeller was abandoned in the Royal Navy.

It was no sudden change of heart about the properties of iron that in the end forced every navy in the world to drop the use of wood for warship building; it was the development of a new form of gun and the outcome of its first use in actual conflict that brought the change. The naval gun during the first half of the nineteenth century remained the gun with which Nelson had won his battles - big muzzle-loading cannon, firing solid round shot. Explosive shells, fired parabolically from mortars, were used solely for bombardment and never considered as a ship-to-ship weapon. But in 1822 a French general of artillery, Henri-Joseph Paixhans, wrote a book called *Nouvelle Force Maritime et Artilleris*, in which he advocated the firing of explosive bombs from the normal naval gun, giving them a flat trajectory instead of a parabolic one, and thus converting the explosive shell into a ship-to-ship weapon. His gun was given its first serious test in 1824, against the old, moored frigate *Pacificateur*, and proved remarkably successful. In 1853 Paixhans' guns were used for the first time in battle, when a Russian squadron of wooden-hulled ships armed with the new French guns encountered at Sinope, in the Black Sea, a Turkish squadron of Wooden-hulled ships armed with conventional naval guns firing solid shot. It was not just the defeat of the Turkish squadron which opened the eyes of the world's navies, but the fact that the explosive shells fired by the Russian ships set all the Turkish ships on fire and they burned down to the waterline.



The lesson of Sinope was underlined two years later at the bombardment of the Kinburn forts in the Crimea. After Sinope the French constructed a flotilla of floating batteries, protected with iron armour, and at the Kinburn bombardment three of them, the *Devastation*, *Tonnante* and *Lave*, steamed to within 1,000 yards of a fort. It turned out that they were relatively impervious to the Russian fire, and they emerged unscathed from a position in which any wooden-hulled



One of the French floating batteries frozen in during the winter of 1855-56 in the Black Sea, after Kinburn.

British iron-hulled armoured floating batteries.

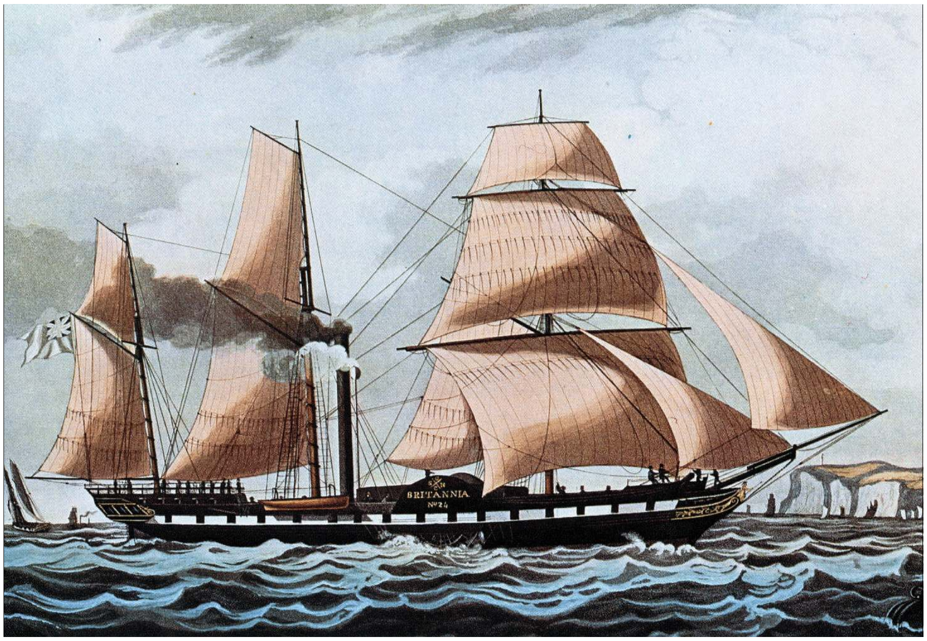
warship in the world would have been blown to bits.

This demonstration of the advantages of iron construction in modern war conditions could not be ignored, and Britain was the first to put this experience to use by building, in 1856, the first iron-hulled armoured warships in the world - the *Terror*, *Thunderbolt*, Erebus and *Aetna*. They were designated 'armoured batteries' and built to a tonnage of 1,950, with an overall length of 108 ft., a beam of 48 ft. 6 in., and a drought of 8 ft. 10 in.. They mounted 16 smooth-bore muzzle-loading 68-pounder guns, and their 200-horsepower engines gave them a speed of 5.5 knots. It was perhaps a small beginning, but the navies of the world had learned their lesson and began to catch up with merchant navies, which had taken to iron with enthusiasm more than twenty years earlier.

Before leaving the iron warship, mention should be made of the British East India Company, which also built warships to protect and enforce their trade monopoly in India and China. It was 1839 that the Company first considered using iron for their warship hulls, and in that year they approached the Birkenhead shipbuilder John Laird to build iron warships for service in the Far East. One of these was the *Nemesis*, a ship of 660-tons, armed with two 32-pounder pivot guns (at the time an innovation in the mounting of guns, when the normal practice was to mount them on wooden carriages in broadside batteries). Although the *Nemesis* only drew 5 ft. of water she made her way out to India under her own steam via the Cape of Good Hope, and during the First China War (1841-42) was taken over by the British Navy and gave excellent service during the naval operations.

Although during the first half of the nineteenth century the world's trade was expanding fast, it was not yet at a stage where shipowners, except monopoly companies like the East India Companies, could contemplate the building of fleet of ships. It was an event in Britain that first introduced this possibility. Until 1838 the mail for overseas had been carried in Post Office 'packets' (small ships built and run by the government solely for the purpose). These were sailing ships, but by this time it was obvious that the steamship was superseding the sailing ship in the commercial sphere and that, in any service where speed and reliability were essential, the day of the sailing vessel was over. Rather than bear the cost of constructing new steamships to carry the mails, the British government decided to put the carriage out to tender by any ship-owner able to guarantee a regular steamship service that would carry the mails to their destination. The value of the contract was enough to provide the shipowner with a sound economic basis for starting a regular ferry service.

The Government offer of the transatlantic mail service attracted two bidders. One was the Great Western Railway Company, which already owned the *Great Western*, on a regular run between Bristol and New York, and had laid down a larger ship, the *Great Britain*, destined for the same service; the second bidder was a Canadian merchant from Halifax, Samuel Cunard, who owned a number of sailing ships. When the terms of the mail contract were advertised, he crossed to Britain and joined forces with Robert Napier, one of the best known marine engineers of the day, to bid for the contract. His tender for it included a clause that, if successful, he would build four ships and would guarantee to operate a regular service between Liverpool and Boston of two voyages a month, summer and winter. With his tender accepted, Cunard formed a company with the shipowners George Burns, of Glasgow, and David McIver, of Liverpool, and placed orders with Napier for four wooden paddle steamers, each with an overall length of 207-ft. and a tonnage of 1,156, and with an average speed of 8.5 knots. These were the *Acadia*, *Britannia*, *Caledonia* and *Columbia*, and they began their transatlantic service in 1840.

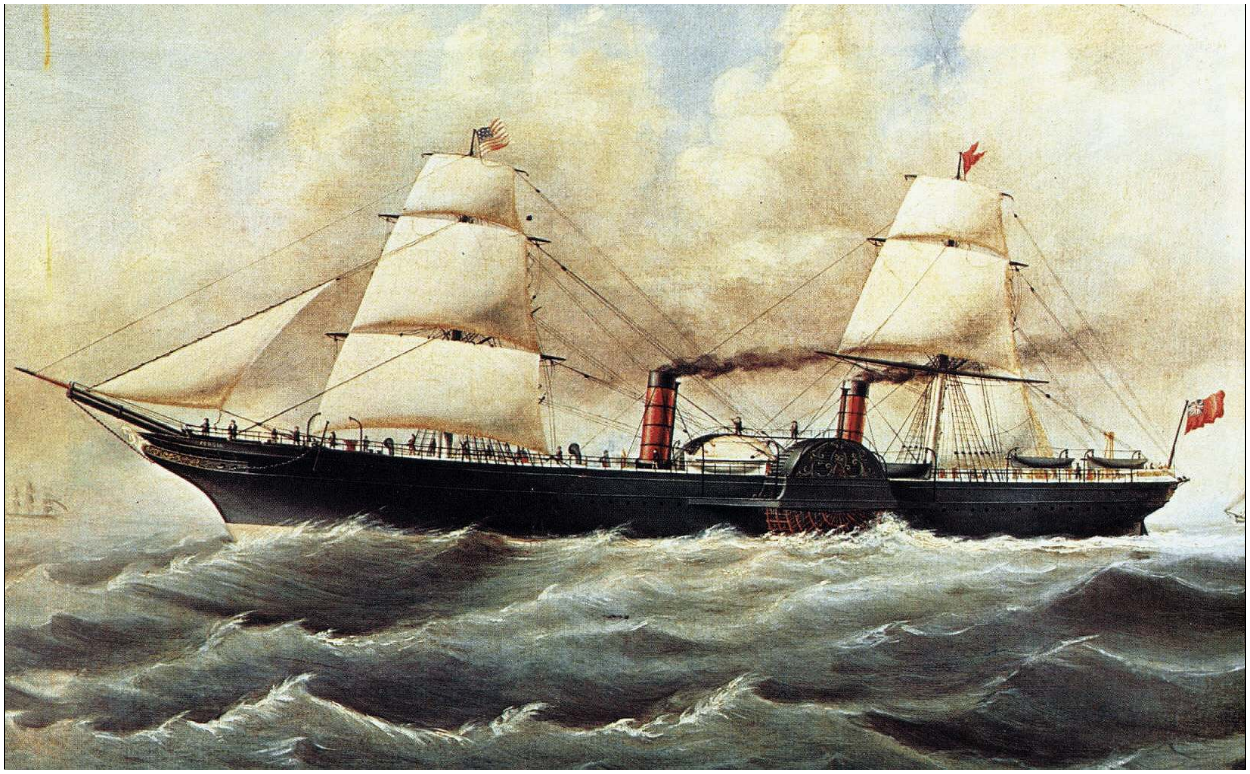


Britannia, the Cunard paddle steamer. This was the beginning of the "liner."

It proved so popular and profitable that four years later the company built the *Hibernia* and *Cambria*, both of them larger and faster than the first four. The *Hibernia*, in fact, was the first ship to cross the Atlantic in less than ten days, and was also the first to use the port of New York instead of Boston.

Four years later, with the transatlantic trade still growing, another four ships were built, each of them having a tonnage of 1,820 and a service speed of over 10 knots. So much of the trade was now coming to the Cunard Line that the United States decided to encourage their own shipowners to compete by offering their own mail carriage contract. It was given to the Collins Line, which built four new steamers of over 3,000 tons each, the *Arctic*, *Atlantic*, *Baltic* and *Pacific*, all of them with a small margin of speed over that of the Cunard ships. But though they were fine ships, Cunard replied to the challenge by building the *Africa* and *Asia*, both of around 2,000 tons, and now with twelve ships in his shipping line he was able to offer a much more frequent transatlantic service. Moreover, tragedy befell the Collins Line when the *Arctic* collided with the French steamer *Vista*, and sank with the loss of 323 lives, and when the *Pacific* sailed from Liverpool with 156 people on board and was never seen or heard of again.

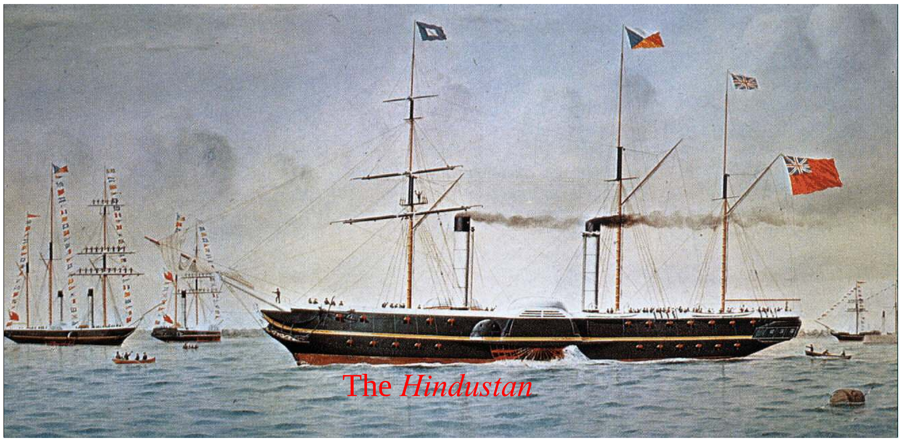
In the face of these disasters the Collins Line built the *Adriatic*, larger and faster than the other Collins ships, but so expensive to build that the company went heavily into debt. And it was at this moment that Cunard unveiled his master stroke, the *Persia*. She was the first transatlantic liner to be built with an iron hull, and at her launch was the biggest ship in the world. Her appearance on the Atlantic killed the Collins Line dead.



The paddle liner *Persia* (1863) gave the Cunard Line mastery of the North Atlantic. She was the biggest ship in the world for a time and also the first liner with an iron hull, but she was one of the last of the big paddle steamers.

It was a government mail contract which gave birth to another of the great shipping lines, the Peninsula & Oriental Steam Navigation Company. It began with Robert Bourne, who had a contract for the carriage of the internal mails in Ireland, which he operated with stage coaches based on Dublin. Bourne bought a small 206-ton steamer, the *William Fawcett*, to carry the mails across the Irish Sea. The company he formed was the City of Dublin Steam Packet Company, and in 1826 he appointed two young men, Brodie Wilcox and Arthur Anderson, who ran a shipping agency, as his London agents. A second small steamer bought by the company was the *Royal Tar*, and she was used to carry cargoes to Spain and Portugal during the Spanish and Portuguese civil wars. Her reliability and regularity so impressed the Spanish government that they asked for a regular steamer service to be inaugurated and , with the British Government offering a contract to carry the mails to the Iberian Peninsula in 1837, Wilcox and Anderson formed the Peninsula Steam Navigation Company, whose first ship was the *Iberia*, a paddle steamer of 516 tons with an engine developing 180 horsepower. In 1840 the Peninsula Steam Navigation Company was offered the mail contract to Egypt and India. *Oriental* was added to the Company's name, and two more steamers, the *Oriental* of 1,674 tons and the *Great Liverpool* of 1,311 tons, were built to carry the mails through the Mediterranean to Egypt. In 1842 the Suez-Calcutta service was inaugurated by the *Hindustan*, of 2,017 tons, and in the same year the company gained the government mail contract for Australia. With this extension of their Indian route to Singapore, they were now poised to become the most powerful shipping force throughout the Far East.


The *Iberia*


The *Hindustan*

There were other shipping lines starting to operate to different parts of the world around the same time, for these were the years which saw the beginning of the industrial revolution with its immense upsurge of world trade. It was the start of a golden age for shipping, and the next fifty years were to see more changes and more development in the size, design, and power of ship than had occurred during the whole of the previous 2,000 years.

THE SAIL & THE PADDLE

[PART III]

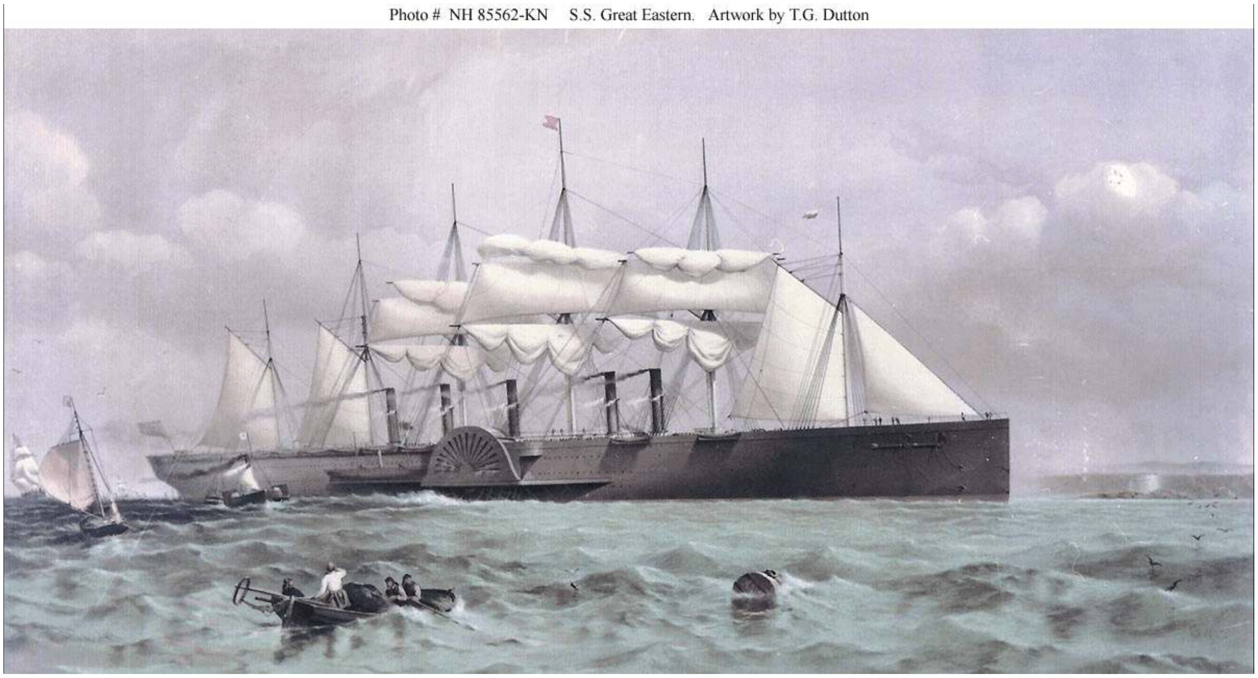


Photo # NH 85562-KN S.S. Great Eastern. Artwork by T.G. Dutton

The *Great Eastern*

THE GREAT SHIP

In the early 1850's three brilliant engineers gathered together to air their views about the future of the merchant ship. One of them was Isambard Kingdom Brunel who, with the successful *Great Western* and *Great Britain* already to his credit, was the most influential ship designer in England. He realized that, although there was a limit to the size to which a wooden ship could be built because of the strength, or lack of it, in the building material, this limitation did not apply when a much stronger building material was used. Iron was this stronger material, and with it ships much bigger than the biggest wooden ship ever built could be constructed.

In Brunel's estimation there was, too, a definite need for a very big ship. Emigration was on the increase, the main destinations at this time being the United

Scott Russell (left) and Brunel (second from right at the first attempt to launch the *Great Eastern* in 1857.

States and Canada. On the other side of the world, in Australia and New Zealand, there were immense areas of uninhabited land which, it seemed to Brunel, were ready and waiting to receive Europe’s dispossessed multitudes. They would need ships to take them there and ships to bring their produce back to Europe after the land had been cultivated.   And as the numbers grew, so also would grow the volume of trade with Europe, all of which would have to be carried across the oceans in ships.

The second engineer concerned was John Scott Russell. He had become interested in the maritime side of engineering in 1834 when he was consulted on the possibilities of introducing steam navigation on the Edinburgh and Glasgow Canal. He owned a shipbuilding yard at Millwall, on the River Thames, but his greatest interest lay in the study of wave-formation. From many experiments, carried out both with models in a tank and with full-sized vessels on a canal, he established that there was a connection between a vessel’s wave-making properties and her resistance to forward motion, and that a ship could be driven faster and more economically by designing her underwater hull shape to create the last possible wave disturbance.

The third engineer associated with the new ship, albeit to a lesser extent than the other two, was William Froude, who had been an assistant to Brunel in 1837 when he was principally a railway engineer. After nine years, Froude left the railway to devote himself to the study of ship behaviour and hydrodynamics, working on very similar lines to Scott Russell.

The new ship was therefore designed with an underwater shape that conformed to the principles of Scott Russell and Froude, and an overall size that met Brunel’s requirement for accommodation for 4,000 passengers, and space for 6,000 tons of cargo and enough coal for a voyage to Australia or India.

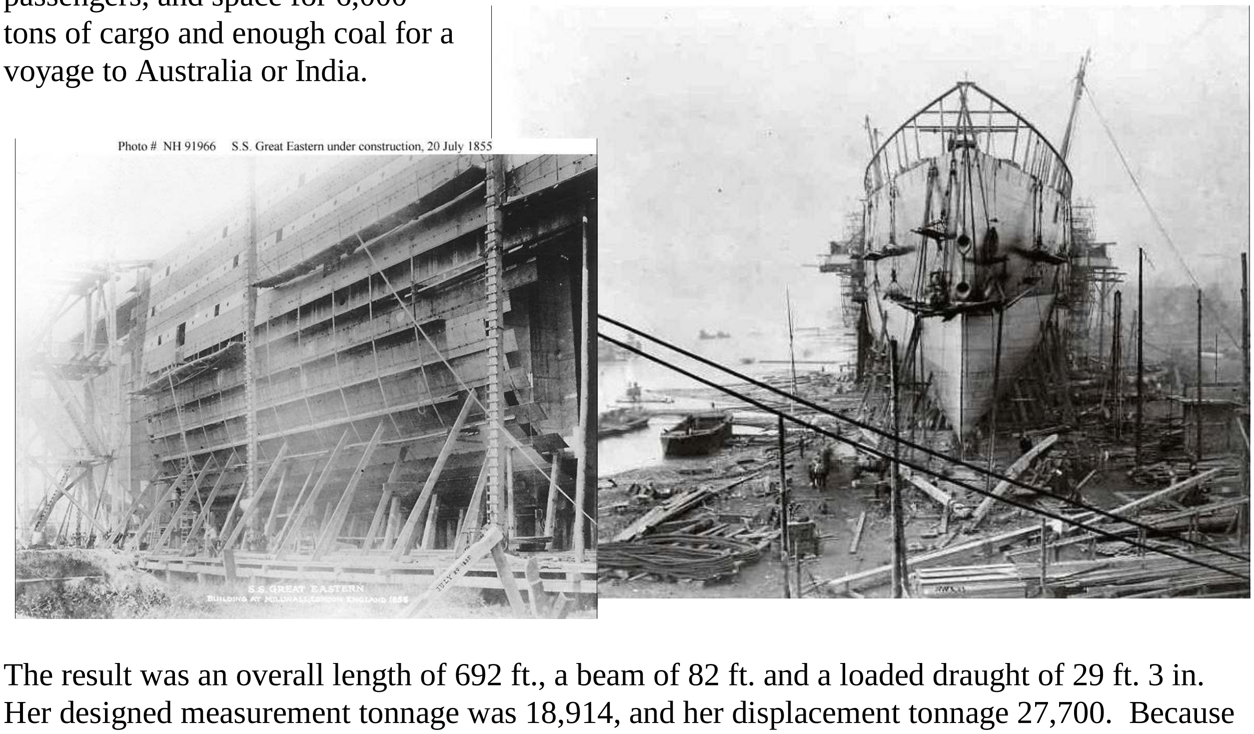
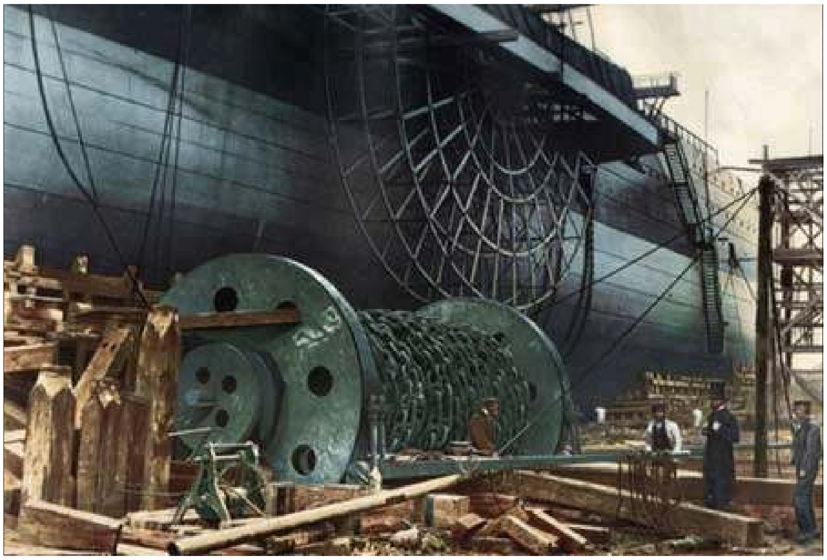


Photo # NH 91966   S.S. Great Eastern under construction, 20 July 1855

The result was an overall length of 692 ft., a beam of 82 ft. and a loaded draught of 29 ft. 3 in. Her designed measurement tonnage was 18,914, and her displacement tonnage 27,700. Because of her great size she was to be named *Leviathan*, and an idea of just how revolutionary was the increase in size which Brunel had proposed can be gained from the fact that the biggest ship in the world hitherto had an overall length of 375 ft. and a designed tonnage of 3,300. In tonnage

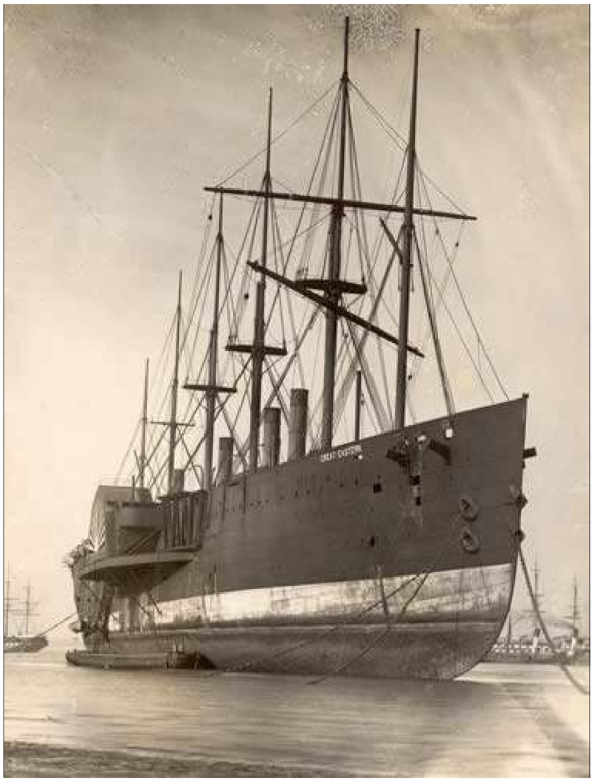


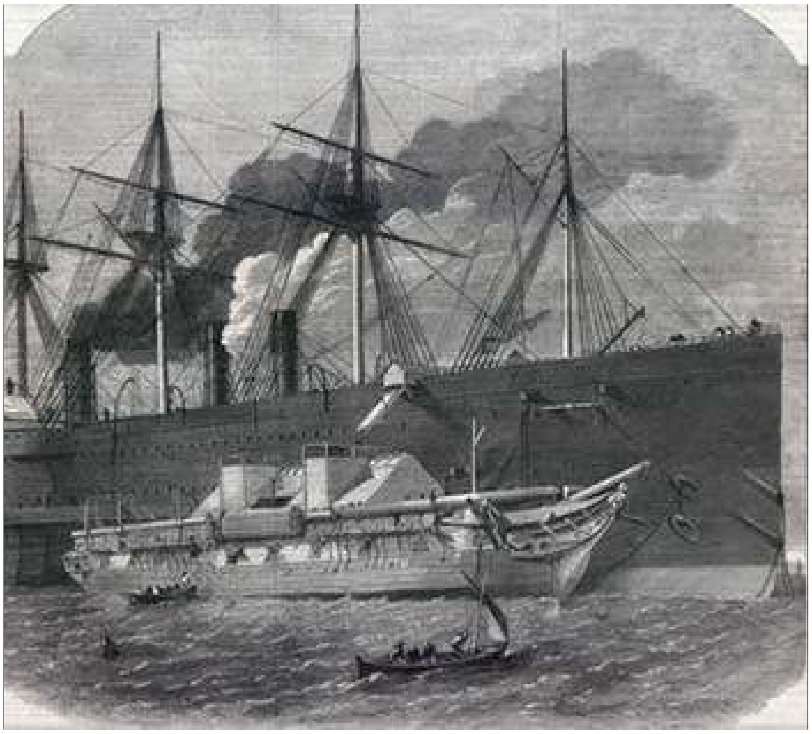
terms, *Leviathan* was to be more than five times as large as any ship yet built.

Brunel persuaded the Eastern Steamship Navigation Company that her construction was a feasible commercial venture, and her keel was laid in Scott Russell’s shipyard at Millwall. Because of her great length, it would be impossible to launch her in the normal way, stern first, as the Thames at Millwall was not wide enough, and so she was built broadside on to the river, and would eventually have to be launched sideways.

During building, her name was changed from *Leviathan* to *Great Eastern*. So many difficulties arose during construction that her cost rose enormously. More than one company associated with it was forced into bankruptcy, including Scott Russell’s shipyard, and Brunel’s own health broke down as a result of the constant worries associated with her building. She was finally ready for launching in 1858, but even this went wrong. After moving a few inches down the slipway, she stuck. Large hydraulic presses had to be built, to push her, and wire cables on winches mounted on the opposite bank of the Thames, to pull her. Finally, weeks later, she floated off on a very high tide.

Her new owners [the original company having gone bankrupt] decided to use her on the Atlantic run, and her cabins and saloons were fitted out at considerable expense, and with great luxury, for the period. By the time she was ready for her maiden crossing, Brunel himself had died from a heart attack. He was, perhaps, fortunate in not living to see the unhappy fate of his great ship. On her first voyage to America, she attracted no more than thirty-six passengers, instead of the 4,000 for which she had been built, and once at sea she rolled so heavily that prospective passengers refused to travel in her. She was taken out of service after a short period, and found no employment until 1865, when Sir Daniel Gooch chartered her to lay the first electric telegraph cable across the Atlantic. In all, she laid four cables across the Atlantic, and another from Aden to Bombay.





The *Great Eastern* being loaded with cable in 1865.

At the end of her cable-laying career, she lay at Milford Haven for twelve years, until she was bought by a firm for visitors. She was fitted more or less in her original state, her grand saloon was used as a music hall, and there were side-shows in her cabins and a merry-go-round with a steam organ installed on her upper deck. It was a sad end for a once proud ship, but even in her new guise she did not pay. At the end of the summer she was laid up, and two years later sold for breaking-up.

Yet, commercial failure that she was, the *Great Eastern* marks a very important milestone in the history of ships. She proved Brunel's theory that with iron as a shipbuilding material there was no limit to the size of ship that could be built. Her construction introduced the principle of the cellular double bottom, and she was the first ship to fit a steering engine, at that time a novel means of overcoming the pressure of water on the rudder, but now a universal feature in all ships of any size. And, perhaps most important of all, she was the first large ship whose underwater shape was designed according to the principles of hydrodynamics. It was, at this time, admittedly an inexact science, but after the *Great Eastern* both Scott Russell and William Froude continued their work on the wave-line theory, and it is on this theory that all modern ship design is based.