An International Historic Engineering Landmark

S.S. GREAT BRITAIN

1843

Bristol, England

Tuesday September 25th 1984

The American society of Mechanical Engineers

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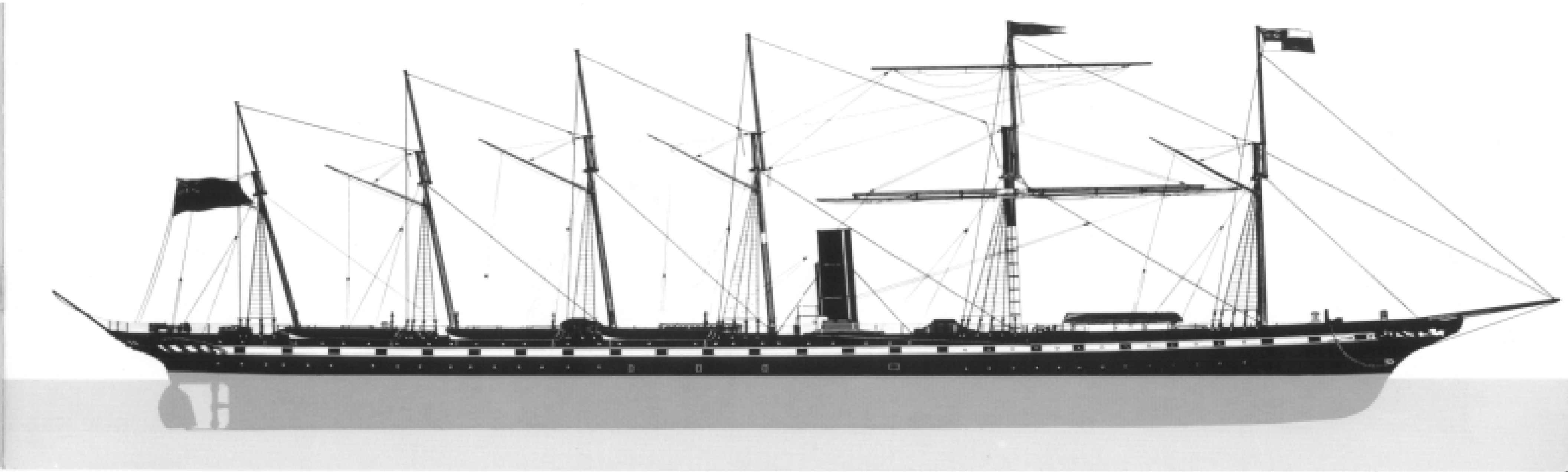


Bristol, midway between Iceland and the Iberian peninsula, had by 1400 become, and for four centuries remained the second port in the kingdom because of its face to the west. As Britain's industrial centre shifted northward, the southwest declined to have Bristol lose its old position of leading Atlantic port to Liverpool. Bristol had welcomed the age of steam on the seas by building first the wooden-hulled but iron-strapped paddleship GREAT WESTERN (1837) of 750 ihp that was conceived as a "western extension" of the railway line from London. Exhilarated by the success of this largest and most powerful ship of the world, an even greater ship was laid down in 1839. She would be

I. K. Brunel, at Millwall shortly before the attempt to launch the **Great Eastern**

the GREAT BRITAIN (1843), and in 1845, the first iron-hulled screw-propelled vessel to cross any ocean. The GREAT BRITAIN was the pioneer screw steamer of the "Atlantic ferry" service from the Old World to distant lands. New York was the earliest focal point, but ports beyond Cape Horn and the Cape of Good Hope were added soon. Both ships were the creations of Isambard Kingdom Brunel (1806-1859), one of the most innovative engineers of the nineteenth century whose boldness overshadowed his business acumen: he would also build the GREAT EASTERN, 1858.

Going from the idea of a ship larger and better than the GREAT WESTERN to what would debut as the GREAT BRITAIN was a long and painful process. By the time the iron keel-plates were laid in July of 1839, Brunel had made five design studies, the first two involving wooden hulls. The definitive design for construction had a paddle-propelled, iron-hulled vessel of 3270 gross register tons, some 2.4 times greater than the GREAT WESTERN's 1340 grt, and with an overall length of 322 ft, 86 ft more than her predecessor's, By any standard, the new ship would be the largest in the world. The momentous decision to abandon paddle propulsion in favour of the recently developed screw propeller came with December of 1840.

The decision to build an iron hull had forced the Great Western Steam Ship Company, established in 1836 as an off-shoot of the Great Western Railway Company of which Brunel was chief engineer, into the shipbuilding business; no conventional shipyard had experience in working with iron, only recently available in substantial plate sizes and rolled sections such as angles. Iron meant dealing with material that had to be smithed to shape and fastened with rivets.

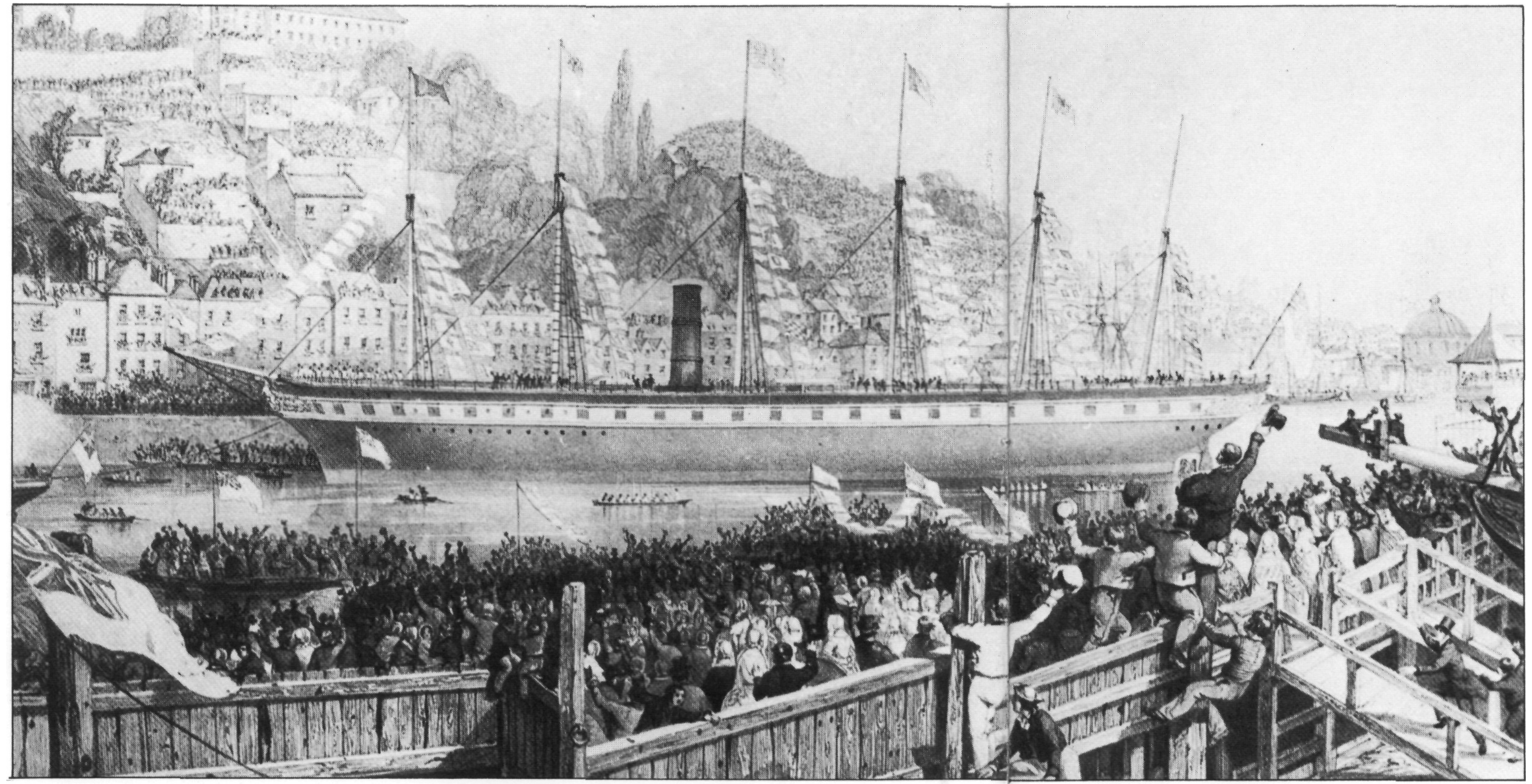
When first projected, the intention was to name the ship the CITY OF NEW YORK, but soon MAMMOTH seemed more appropriate. She became the GREAT BRITAIN by 1842, well before her floating out ceremony ("launch") of July 19,1843. Practical difficulties (narrow locks, narrow river) unrelated to construction would make it December 1844 for the first sea-trials. They were quite satisfactory, 12V2 kn with the ship handling beyond expectation. Later, she would turn nearly 14 kn.

Following five months of exhibition, much of it in London, the ship went to Liverpool to embark passengers and cargo for her maiden voyage, destination New York. The passage was made in 14 days and 21 hours at an average speed of $9^{x}k$ kn in the face of westerly gales and fog. The trip was a conspicuous success, and she was visited by more than 21,000 during her nineteen-day lay-over; a new era had been confirmed.

We cannot here follow the ship's long and adventurous life up to 1886 and the Falkland Islands where she took refuge, but must turn to practical matters that define her hull and engine and rehabilitation. The ship GREAT BRITAIN involves two components of which the most apparent is the innovative iron hull with its external gear dominated by six masts; the hull you see is original. All this was moved by the second element, a long-vanished and curious engine that was the most powerful in its day and turned a propeller that too was unique. No original engine drawings are extant, but the novelty and size of the propulsive system occasioned engravings and descriptive writings from which a set of working drawings could be prepared, although some uncertainties remain. The facsimile engine, incomplete at this date, will be of fully realistic appearance, with all mechanical parts operational so that the whole can be moved, although not worked by steam.

The hull has no central keel in the manner of a wooden ship. Instead there is a cellular and double bottom composed of ten longitudinal members (the deepest is 39 in.) and angle iron frames or ribs (the largest is 6 x 3.5 x % in.) rivet-connected; iron plates over the longitudinals form the lowest or platform deck (inner bottom), and overlapping 11/16 in. double-riveted plates of about 6 x 3 ft form the outer bottom or skin of the ship. Five transverse water-tight bulkheads (a novelty) compartment the hull to give a very stiff structure and allow comprehensive pumping arrangement. Two docking keels 110 ft long and 9 ft off the centreline hold the ship level without blocking or shoring when on a docking grid. Diagonal bilges at bow and stern tended to reduce wave resistance and remind of the Maier-form of the 1920s.

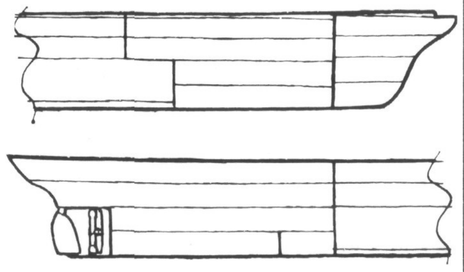
The launching of the **Great Britain** *at Bristol on 19 July 1843. The ship was 'floated out'from the dry dock in which she was built*



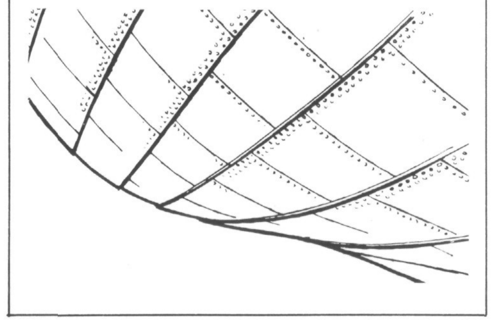
Some 1700 sq yd of canvas (over one-third acre) were canied on six masts. The last four were hinged to the deck, for gear underneath such as boilers, engine and propeller shaft stood in the way to stepping these masts on the keel in conventional fashion. All masts had wire rigging - then considered an aberration by traditionalists - that was set up with dead-eyes, the rigging screw or turnbuckle being yet to come. The rig was that of a six-masted schooner apart from a square sail also canied on the second mast. Aside from the square mainsail that required 20 men aloft to furl, the other loose-footed brailing gaff mainsails could be handled from deck by a watch of 20 seamen. Of the seven lifeboats, four were of iron with built-in buoyancy tanks, certainly something new. The other boats were of wood, and the capacity of the lot is judged to have been 480, accommodation for a passenger list of 360 and a crew of 120.

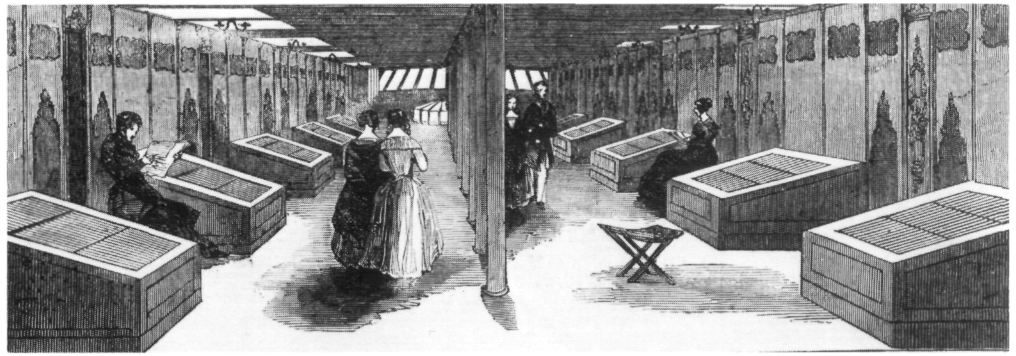
Passenger accommodations were on two decks, promenade and saloon, divided into fore and aft sections by the boiler-engine complex that extended up to the top or weather deck. A modicum of natural light

BULKHEADS Five bulkheads ran across the inside of the *Great Britain's* hull, and there were two short longitudinal ones on either side of the engine-room. She was one of the first ships to be given such bulkheads which, besides giving great strength to the hull, also divided up the interior space into watertight compartments, which could be sealed by watertight doors.



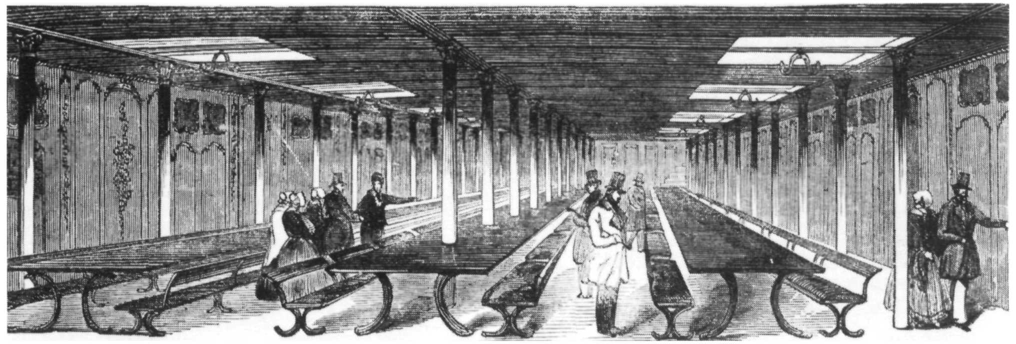
IRON PLATES The hull was constructed of wrought iron plates 6 ft x 2 ft 6 in approximately, riveted to metal frames. The piates overlapped each other, a method known as clinker-built, which gave fifteen per cent more strength than if the plates had been laid edge to edge. Since the plates were close-riveted the whole hull was virtually hand-built and has always been remarkably watertight.





Looking aft through the original Promenade Deck of the **Great Britain** *with staterooms or cabins ranged along each side. The box fittings gave light to the Dining Saloon below.*

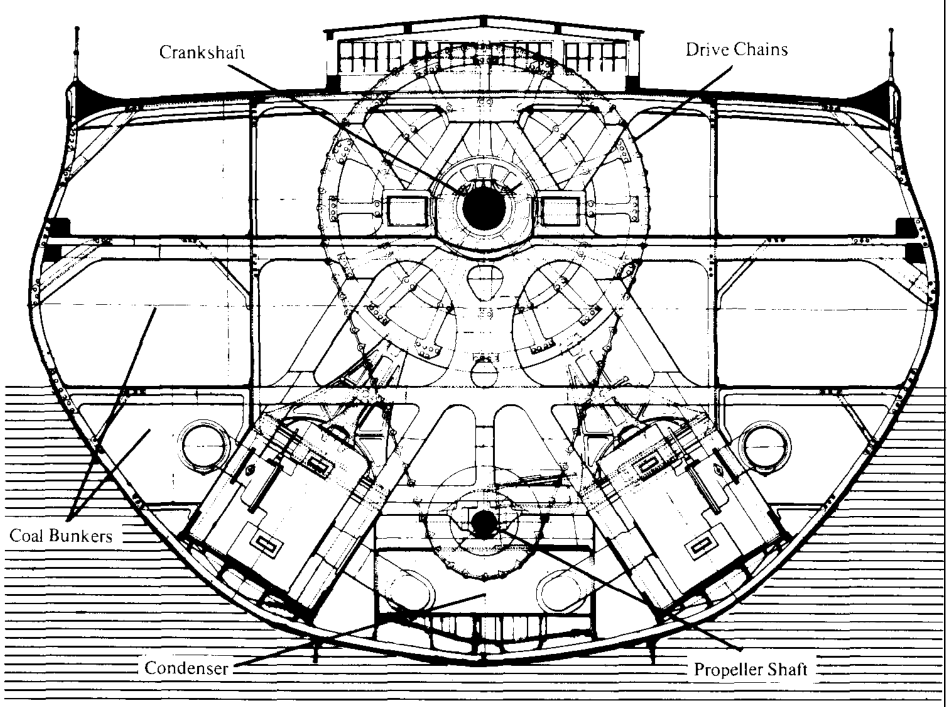
The Dining Saloon.



reached the promenade deck through glazed gratings on the weather deck above; gratings in the promenade deck feebly served the saloon deck below. The furnishings were simple in style and functional in purpose.

It is difficult to try to imagine the proposed paddle engine. It was to be a two-cylinder trunk engine of exceptional dimensions – 110 in. bore and 96 in. stroke – to the design of a patentee named Francis Humphreys. Circumstances led to a Company decision to build the engine also, and a shop was set up with Humphreys as engineer in charge. He found that no existing tilt or helve hammer had the capacity to forge the intermediate paddle-shaft of his dimension. In his despair he consulted James Nasmyth, the eminent machine and engine builder, asking whether he might dare to use cast iron. This was out of the question, but Nasmyth's further reply made history, for he sketched out the steam hammer as a new tool for forgings of singular size.

At about the time of this crisis, Brunel, ever-alert to the latest, became aware of promising tests of screw propellers that he followed with experiments of his own. The evidence persuaded him to scrap the paddle-wheel idea in favour of screw propulsion. Furthermore, this would give a sleeker ship, for the excrescent paddle-wheels accounted for an increase of the ship's width of perhaps 25 ft over the nominal breadth of 50.5 ft. Humphreys was ordered to abandon his partially completed paddle-engine that he hoped would make his name, and design instead a screw engine. Between the past labours and anxieties and perhaps disappointment of hopes, the new plan "proved too much for him and a brain fever carried him off after a few day's illness", as Nasmyth would write. With the cancellation of the paddle-engine project, there was no immediate need for Nasmyth's steam hammer in Britain, and France became the first to reduce the idea to practice.



ENGINES AND DRIVE There were four cylinders working in pairs and inclined inwards and upwards at an angle of 60°. The pistons were 88 in in diameter and worked with a 72 in stroke to drive an overhead crankshaft. On this crankshaft was a wheel 18 ft in diameter and 38 in wide which, by a system of endless chains toothed on their inner side, turned a smaller 6 ft wheel on the propeller shaft below.

Having an expensive and a now-idle engine manufactory on their hands, the Company would build the screw engine too. The design that was adopted was that of Brunel's father's patented Triangle engine (M. I. Brunel No. 4683, June 26, 1822). As built, the engine was a four-cylinder, two-crank inverted-V type with an included angle of 60 deg, the ends of the inverted-V finding their space in the turn of the bilge. The bore and stroke were 88 in. and 72 in., respectively; the bore was probably the largest ever to go to sea. Machining of the cylinders was done on the Nasmyth vertical boring mill that had been built for the purpose of machining the "large cylinders" of Humphreys' rejected trunk engine.

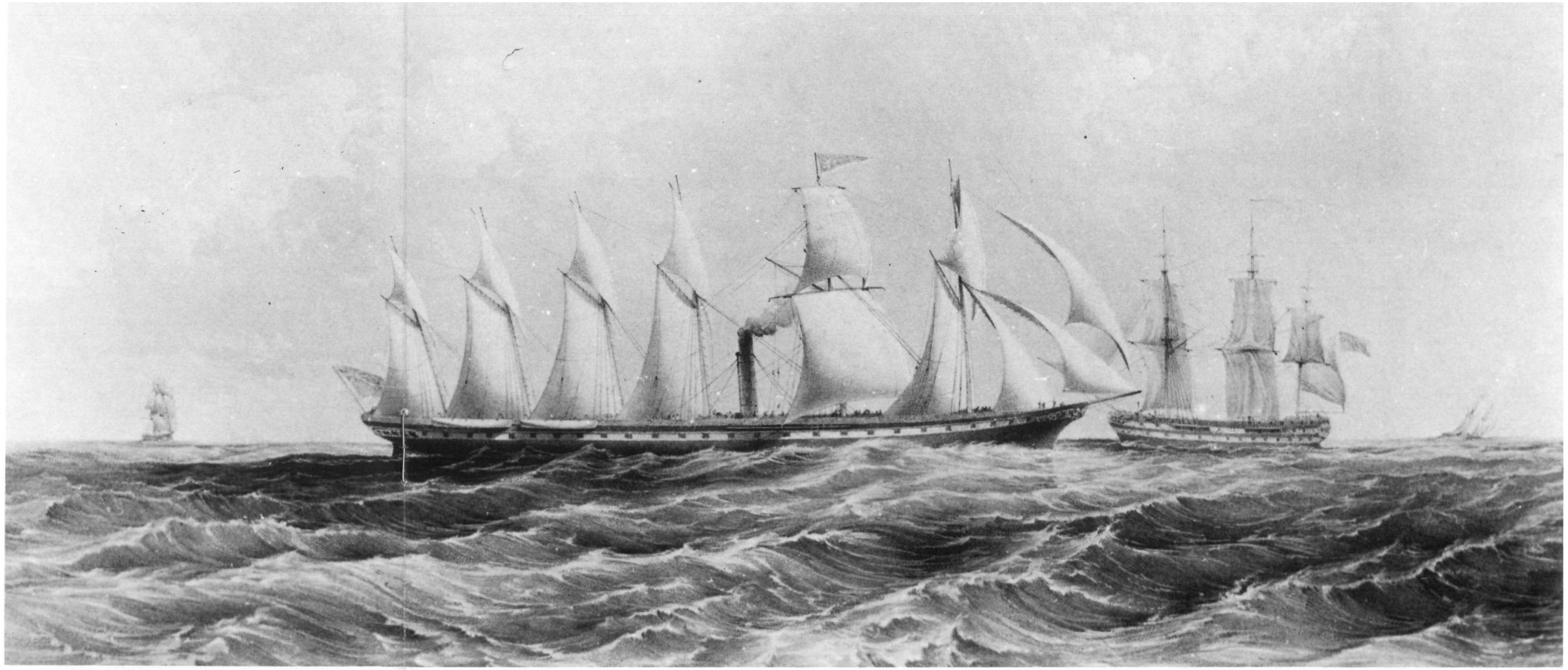
An inverted-V design has the crankshaft overhead, the connecting rods reaching up to it. The crankshaft, about 22 ft overall, had a diameter of 24 in., with an overhung crank at each end, the main bearings being inboard of the cranks, each of which shared a cylinder pair ("engine"). Drilled holes in crankpins, webs and shaft (the latter was of 10 in. diameter) were the water-passages connected to telescoping tubes at the ends of the crankpins to provide water cooling.

Two massive athwartship frames forming part of the hull structure canied the main bearings. The crankpins were not cylindrical, but had spherical bearing surfaces to avoid possible lateral forces on the connecting rods. At about the middle of the crankshaft there was the power take-off, an 18 ft 3 in. diameter sprocket wheel of 38 in. face from which four sets of inverted pitch chains (weighing seven tons in all) looped down to partially wrap around a 6 ft diameter sprocket drum on the first section of the propeller shafting that lay between the cylinders. When the engine turned at its normal speed of 18 rpm, the propeller shaft received 53. The odd gear ratio (hunting tooth) was to ensure greater evenness of wear on the teeth than would an integral multiple such as 54:18. Smooth and noiseless running of the chains derived from the wooden teeth of the sprocket wheels, teak in the upper and lignum vitae in the lower.

Designed to work expansively at a ratio of 6:1, the engine took steam at 5 psig. A surviving indicator card shows cutoff at about one-third stroke: the mean effective pressure works out at 11.75 psi with 27.5 in. hg vacuum. For 18 rpm, the total horsepower came to 1870.

The valve-gear was driven by the familiar eccentric, Murdoch's invention of perhaps 1798, the superior Stephenson-Howe link-motion not coming until 1842. Each cylinder pair had its own jet condenser and air pump with 45.5 in. piston of 6 ft stroke, actuated by a Watt-like parallel motion driven from a link off the crankpin. When exhausting air and pumping condensate against the discharge head to waste it over the side, the force on the piston was of the order of 30,000 lb.

The **Great Britain** *under steam and sail on one of her early voyages across the Atlantic*



Sea-water was used in the athwartships boiler forward of the engine; it was 31 ft wide, 34 ft long and nearly 22 ft high, rising from the floor plates to within 8 ft of the weather deck. It consisted of three longitudinal and independent sections. Both ends of each section had four furnaces, giving a total of 24. Steam was furnished to a common header, but since each section was independent of the other two, a section could be cut off for blowing down to reduce the salinity of its water, the engine being steamed by the other two sections. Flue gases went up a central "chimney" of 8 ft diameter that extended 38 ft above the weather deck. The feed-water heater was a short casing around the stack under the weather deck; the feed water entered the boilers under gravity head, possible because of the low steam pressure. The engine received steam from 28 in. port and starboard lines emerging from the header.

The shafting between engine and propeller was in three sections, of which the first, the drum or lower sprocket-wheel shaft, has had brief notice. This was a solid forging over 25 ft long with 16 in. journals earned in the engine framing. The 6 ft sprocket drum was at midlength; forward of this was an attached gun-metal disk of 2 ft diameter that bore against an iron thrust-block secured to the framing. The transmitted load has been estimated at 10t for a speed of 12 kn, but would have been substantially higher when coming up to speed. This thrust bearing was water-lubricated from a pressure-fed cavity in the centre of the plates, the water escaping radially. The shaft ran through a water-tight gland in the after engine-room bulkhead to mate with the intermediate shaft.

This second section was a hollow shaft - really a torque tube for it had no bearings - of 32 in. external diameter. It was built up of two strakes of 3/4 in. plate formed with circular arc sections that were assembled into tube form with countersunk rivets.

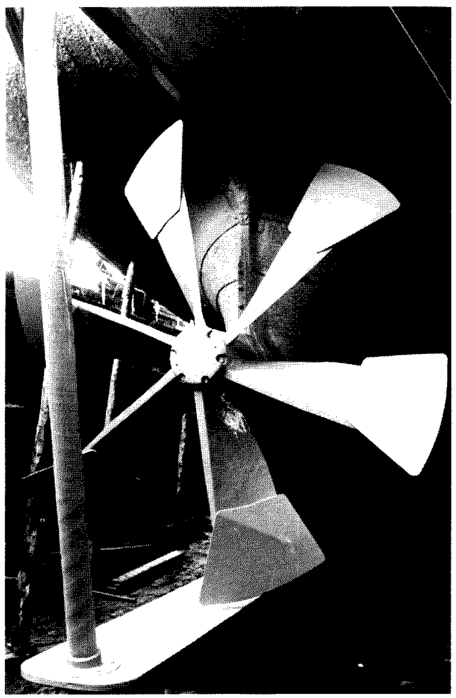
Finally, the tailshaft, nearly 26 ft long. A solid forging again, of 18 in. diameter, its journals were supported in bearings secured to heavy timber frames. A last bearing bolted to the sternpost was made watertight with leather packing kept in place by a gland.

The 15 ft, 6 in. diameter propeller was of built-up construction. Six arms welded to a heavy boss canied palms or blades of % in. iron having a total area of 56 sq ft set for a pitch of 25 ft. Despite its awkward look, its efficiency was surprisingly high, as model tests of recent times have shown.

If the screw was unlovely, the rudder was not. It was semi-balanced and streamlined. with a mean height going on 14 ft and a mean width of 7 ft. 6 in., the stock being raked aft. The lower end was supported on a strake from the ship's bottom. A 6 ft tiller under the weather deck was fitted with proper tackle that led to the weather deck and geared drum with the steering wheel. The rudder's performance was most satisfactory when under steam. but somewhat tender when sailing.

From the ship's subsequent long career and survival to this day it is evident that the first large iron hull embodied worthy principles. Over the course of years the dressing of the hull changed mightily: the ship was re-engined. then de-engined and finally given full-ship rig in 1882. But when still a steam-auxiliary passenger and cargo vessel on the Britain-Australia run, she made some 30 voyages between 1853 and 1876 in addition to serving in the Crimea (1856) and trooping in the Indian Mutiny (1858). Finally. at the start of her 47th voyage. the outward passage from Penarth (Wales) with coal for San Francisco, the engine-less ship spent a futile month trying to get around Cape Horn. Badly battered. and suffering also from an earlier fire in a cargo hold she made it back to Port Stanley hoping to effect repairs. Because of the limited facilities in the Islands she was declared a constructive total loss and sold to the Falkland Islands Company as floating wool and coal storage-hulk. a service that would extend from 1886 to 1933. It is said that during World War I she helped coal part of the British fleet before the first battle of the Falkland Islands. By 1933 her wooden decking was badly deteriorated, and her function as stores hulk was assumed by a younger ship that had also survived a hard time off the Horn in 1931 to find ultimate refuge in Port Stanley.

The reproduction 1843 propeller

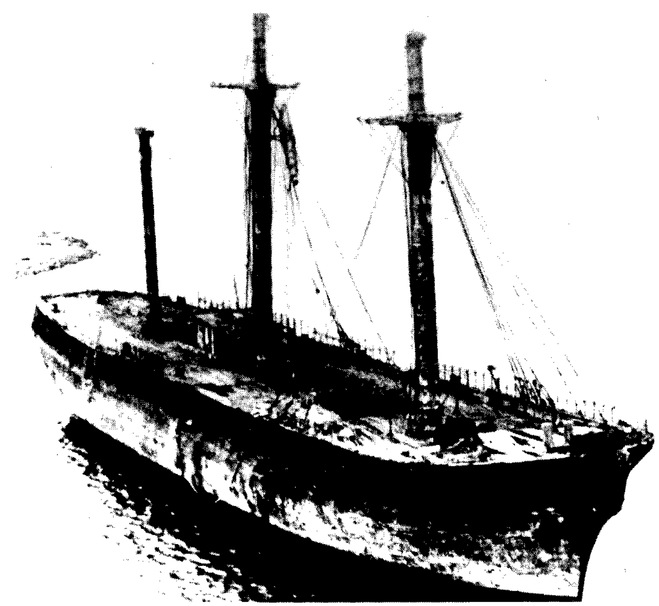


The Islanders' reluctance to abandon the old ship led the Governor of the Islands. Sir Henniker Heston, to commission a cost estimate for restoration and preservation in 1936, but the figure proved too much for the locals, The still-floating ship was regretfully towed to nearby Sparrow Cove. deliberately holed to sit in shallow water, and declared a Crown Wreck, becoming a well-known and well-beloved landmark regarded with affectionate pride.

In 1966 Mr William Swigert Jr and Mr Karl Kortum of San Francisco (the GREAT BRITAIN's destination in 1886) conducted a preliminary survey with the idea of bringing the ship to her once-familiar port-of-call. At a meeting of the Brunel Society in 1968 a salvage-feasibility study was proposed, and when the S.S. GREAT BRITAIN PROJECT became viable, Messrs Swigert and Kortum gave their support to the Project Committee chaired by Mr Richard Goold-Adams. That same year Dr Ewan Corlett, naval architect, made a survey of the ship to find her basically well and suitable for salvage. a confirmation of opinion expressed in his letter to *The Times* in November 1967. a letter that had aroused a great deal of interest.

Projects are founded upon enthusiasm and hope. but to reduce fervour and wishes to reality requires more than simple dedication to a dream; operating funds are needed to bring a distressed ship to its final port that restoration may begin. The signal contribution to the cause came from Mr. Jack Hayward, who in 1969 backed his spirited statement – "I'll see the ship home" – with £150.000: the vast salvage operation was ensured.

Beached in Sparrow Cove



As for the voyage home, the possibility of doing the tow on her own bottom was considered and then prudently rejected in favour of towing her on a submersible pontoon better able to cope with heavy weather. A salvage and tow contract was made with the Anglo-German consortium Risdon Beazly Ulrich Harms, Ltd. Salvage experts, pontoon and tug arrived in March 1970. The work began with patching of the hull to regain floatability, and removal of the masts (weighing 45 tons) to reduce weight and windage. While it took but a day to pump the ship. bad weather delayed docking the hull on the pontoon "Mulus II" (250 ft long and 79 ft wide) until mid-April. The Governor. Sir Cosmo Haskard, released the Crown Wreck to Lord Euan Strathcona, the representative of the new owners, the S.S. Great Britain Project. With the departure of "their" ship, the Islanders felt a great sense of loss they tempered with understanding and rejoicing: the ship would have security and further life once back in the cradle of her birth.

Voyage 47, begun in 1886, would be completed with a 7400-mile, eight-week passage home by the tug "Varius". Undocked from the pontoon at Avonmouth, the ship was towed up-river on her own bottom to pass under Brunel's Clifton Suspension Bridge for a final benediction on her way to the dock from which she had emerged 127 years before, to the day, the 19th of July.

Much has been accomplished since that day in 1970 when the sorry-looking hull returned to Bristol to begin her slow convalescence. Recovery is associated with, and dependent upon many restoratives administered by hundreds in doses large and small. Strong support from industry in the form of money, materials, services and reduced-cost contracts has been salutary. Important too are the voluntary workers who have given their time and effort for needful but unglamorous, tedious and dirty jobs. And, of course, proceeds from other sources, such as cash donations, legacies and income from visitors.

But above all the steady process of reconstruction derives from the devotion of the principals of the S.S. Great Britain Project.

All this means that the ship does not lie in state but is holding court while regaining vigour and the look of youth. For the visitor, there is an inner satisfaction and sense of reality in walking about, in seeing and touching this link with the past instead of merely reading a story of past glory.

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July 1984

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The **Great Britain** *passing beneath the Clifton Suspension Bridge, also a Brunel design*

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The S.S. Great Britain

Principal Dimensions and Statistics

Length (excluding bowsprit): 322 feet.

Breadth overall: 51 feet

Tonnage: 3443 burthen, 1016 net registered (on which her dues would be paid).

Accommodation: After saloon 110 feet long; forward saloon 61 feet long; after dining saloon 98 feet 6 inches long; forward dining saloon 61 feet long.

Capacity: 252 passengers with berths (360 could be carried if necessary but not all with berths); 26 single cabins, 113 two-berth cabins. Crew 130. Cargo 1200 tons. Coal bunkers fore and aft and alongside the engines – 1000-1200 tons.

Cost: (1843) Construction £117,295 6s 7d. Building facilities at her dock: £53,081 12s 9d. Widening the Bristol locks: £1,330 4s 9d.