ATTI

UNIVERSITÀ DEGLI STUDI DI GENOVA

De_*Sign*
Environment Landscape City

a cura di Giulia Pellegri

2018

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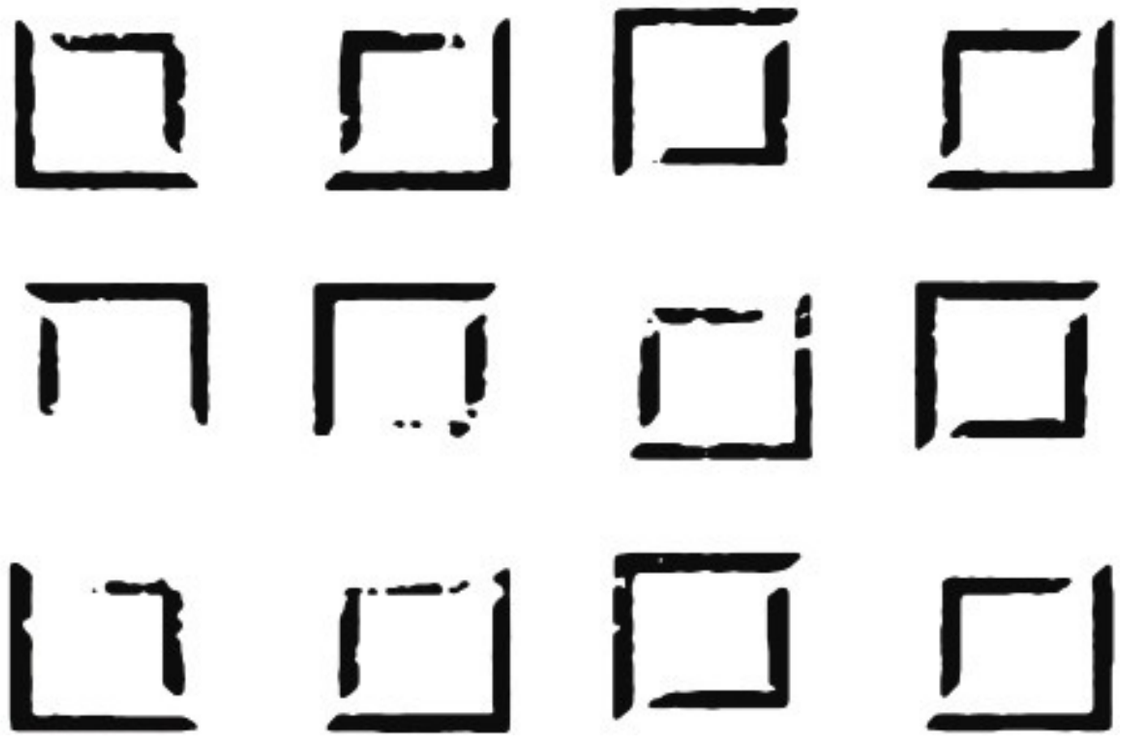
De-Sign Environment Landscape City 2018
Atti _IV Giornata Internazionale di Studi sul Disegno



Giulia Pellegri, architetto, è professore associato di Disegno presso il Dipartimento Architettura e Design DAD, della Scuola Politecnica dell'Università degli Studi di Genova.

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Isambard Kingdom Brunel, a visionary engineer who changed the history of shipbuilding

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Abstract

We agree that the full maturity of the iron shipbuilding was achieved with the SS *Great Britain*, designed by Isambard Kingdom Brunel (1806 - 1859) and launched in 1843. But there is an antecedent. In 1835 Brunel started his first incredible undertaking: the construction of the SS *Great Western*, the ship that made the first Atlantic crossing with steam-powered propulsion in 1838, and until 1839 the largest passenger ship in the world. An iron monster, framed by a cloud of white floating sails, a riveted mountain of iron, a floating volcano that emitted an infernal black smoke fueled by its 10 powerful boilers like 100 furnaces: this was the new luxury transatlantic of the new Victorian age. It was an era where the new materials, cast iron, iron and steel prevailed; an era characterized by shiny brass, glowing irons, steam engines that emitted puffs, whistles and hisses and where nothing, seemed to be impossible: every engineering challenge was faced and won. And the greatest Victorian engineer was a rather small man with very big dreams: Isambard Kingdom Brunel. Brunel was about a meter and a half tall, he was not a surprising figure, but what he lacked in height was strongly offset by enormous design and entrepreneurial skills: “he was the most intense man in the business, the greatest artist ever to work in iron”. But his most important contribution to shipbuilding was the design and construction of the SS *Great Eastern* (1854). This was another important step in the history of shipbuilding. These ships were the image of the new that advanced with giant steps. In this short note we want to tell how the ideas of a visionary engineer of the nineteenth century have turned into reality, and how this reality has changed forever the way to go by sea.

Abstract

Si è concordi nel ritenere che la piena maturità della costruzione navale in ferro fu raggiunta con la SS *Great Britain*, progettata da Isambard Kingdom Brunel (1806 – 1859) e varata nel 1843. Ma c'è un antefatto. Nel 1835 Brunel dà il via alla sua prima incredibile impresa: la costruzione del SS *Great Western*, la nave che compì la prima traversata atlantica con propulsione esclusivamente a vapore nel 1838, e fino al 1839 la più grande nave passeggeri del mondo. Un mostro di ferro, incorniciato da una nuvola di bianche vele fluttuanti, una montagna rivettata di ferro, un vulcano galleggiante che emetteva un fumo nero infernale alimentato dalle sue 10 caldaie potenti come 100 fornaci: questo era il nuovo transatlantico di lusso della nuova età vittoriana. Un'epoca dove hanno prevalso i nuovi materiali ghisa, ferro, acciaio; e poi ottoni luccicanti, ferri incandescenti, motori a vapore che emettevano sbuffi, fischi e sibili e nulla, sembravano essere impossibile: ogni sfida ingegneristica veniva affrontata e vinta. E il più grande ingegnere vittoriano fu un uomo piuttosto piccolo con sogni molto grandi: Isambard Kingdom Brunel. Brunel era alto circa un metro e mezzo, non era una figura sorprendente, ma quello che gli mancava in altezza era fortemente compensato da enormi capacità progettuali e imprenditoriali: "he was the most intense man in the business, the greatest artist ever to work in iron". Ma il suo più importante contributo fu la progettazione e costruzione della SS *Great Eastern* (1854). Si trattava di un altro importante passo nella storia della costruzione navale. Queste navi furono l'immagine del nuovo che avanzava con passi da gigante. In questa breve nota si vuole raccontare come le idee di un ingegnere visionario dell'Ottocento si siano tramutate in realtà, e come questa realtà abbia modificato per sempre il modo di andar per mare.

Introduction

It is commonly accepted that a full maturity of steam-powered iron shipbuilding was achieved with the construction of the SS *Great Britain*, designed by Isambard Kingdom Brunel (1806 - 1859) and launched in Bristol in 1843. However, before exposing the history of "a visionary engineer who changed the history of shipbuilding", it is necessary to make a brief introduction. The steam propulsion in maritime transport sees its first appearance in the eighteenth century, daughter of the "industrial revolution", thanks to the pioneering studies of Denis Papin (1647 - 1713), Jonathan Hulls (1699 - 1758), Claude-François-Dorothée, marquis de Jouffroy d'Abbans (1751 - 1832), William Symington (1763 - 1831), John Fitch (1743 - 1798), James Rumsey (1743 - 1792) and many other engineers and inventors who worked on this important project on both sides of the 'Atlantic. But the first "technological revolution" takes place on the Hudson River in America thanks to John Stevens (1749 - 1838), who designs and builds the *Phoenix*, a side-wheel steam-powered boat, and simultaneously on the Clyde in Scotland, thanks to Symington who builds the *Charlotte Dundas* for navigation on the Forth and Clyde Canal[1].In a few years there has been a revolution in shipbuilding involving engineers, manufacturers for the construction of engines, shipyards and inventors who propose and patent new propulsion systems. Oliver Evans (1755 - 1819) designed and built one of

[1] Williamson, James. *The Clyde passenger steamers: its rise and progress during the nineteenth century: from the 'Comet' of 1812 to the 'King Edward' of 1901*. Glasgow: J. Maclehose and Sons, 1904.

the first steam amphibious vehicles in 1804[2]: the *Oruktor Amphibolis*. Arthur Woolf (1766 - 1837) patents a high pressure compound engine, an invention that brings another great improvement in terms of engine efficiency[3]. Robert Fulton (1765 - 1815) uses the engine invented by James Watt (1736 - 1819) to build the first real steamboat, equipped with paddle wheels, the *Clermont*, initially known as *The North River Steamboat of Clermont*, launched in 1806, thanks to the help of Robert R. Livingston (1746 - 1813), his mentor: "in February or March 1802… that Robert Fulton… 'accidental met' Robert Livingston – the encounter that would change history" [4]. Fulton was immediately convinced that he had opened a new era in river and naval transport, and said that his invention would "certainly make an exceedingly valuable acquisition to the commerce of the Western States" [5]. Livingston and Fulton thus initiated a commercial venture that will soon extend to the US East Coast and major waterways such as the Hudson and Mississippi, generating wild competition over the management of steam navigation.

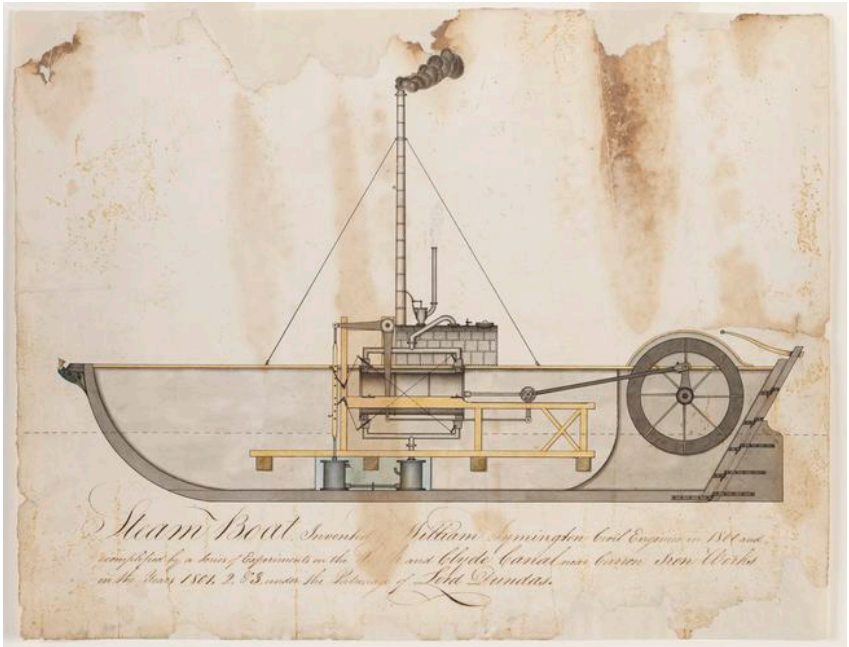

Fig. 1 - Charlotte Dundas*, sketch by William Symington (in the Museum Victoria, Australia), which incorporates the patented engine by Symington on April 1801. The design shows the 22-inch (559 mm) diameter double-acting horizontal cylinder with a 4-foot bore (1.219 mm), mounted on a wooden frame placed halfway, with a condenser and an air pump inside a water well in the hold below. At the rear of the engine there is a single paddle wheel mounted near the stern of the ship and at the center of the hull. The engine axis is supported by a roller that runs on the engine frame and is connected by a crank handle to a clutch rod that drives the valve gear and the pneumatic pump, and from a connecting rod directly connected to a crank on the paddle shaft. Behind the engine you can see, partially, a steam boiler and an iron funnel. The wooden hull of* Charlotte Dundas*, measured 58 feet (17.7 m) in length by 18 feet (5.5 m) in width, and was built by John Hall, in Grangemouth, between July and September 1802. The members metal for the engine, boiler and smokestack in rolled iron were supplied by Carron Ironworks located on the banks of the Carron, a River near Falkirk, a few miles from the construction site.*

[2] Robert Henry Thurston. *A history of the growth of the steam-engine*. New York: D. Appleton and company, 1886; pp. 157-58.
[3] Harris, Thomas R. *Arthur Woolf: The Cornish Engineer 1766-1837.* Truro: Bradford Barton Ltd., 1966.
[4] Sale, Kirkpatrick. *The fire of his genius: Robert Fulton and the American dream*. New York: The Free Press, 2001; p. 82.
[5] Owen Philip, Cynthia. *Robert Fulton: Biography*. New York: Franklin Watts, 1985; p. 198.

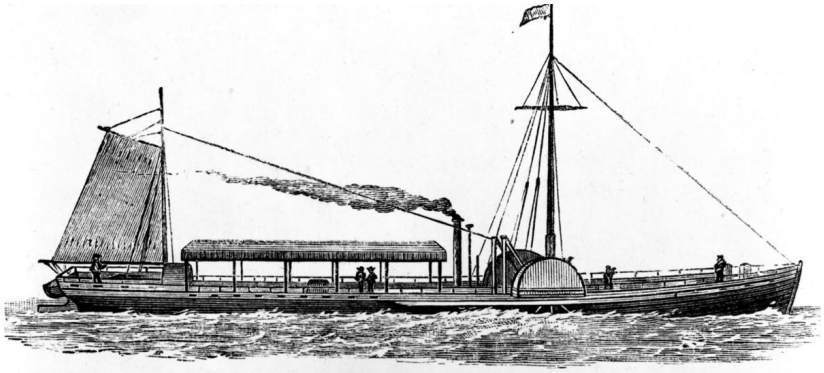

FIG. 49.—THE "CLERMONT," 1807.

Fig. 2 – Fulton's Clermont*, by Robert L. Galloway. The Steam Engine and Its Inventors: A Historical Sketch. London: Macmillan, 1881; p. 237.*

Similarly, in Europe Henry Bell (1767 - 1830) a Helensburgh engineer begins to pursue the idea that the steam engine, developed by James Watt, can also be used for the propulsion of ships. In 1812 Bell, together with John Rennie (1761 - 1821), entrusts the construction of the *Comet*, the first British steamer, driven by a steam engine that operated wooden paddle wheels, to John Wood Jr (1788 - 1860) of Glasgow[6]. The *Comet* was a steamboat of about 25/30 tons. of gross tonnage, about 12.26 meters long and about 3.43 meters wide with two pairs of paddle wheels per side driven by a steam engine of three or maybe four horsepower[7]; it was built by John Robertson (1782 - 1868) of Glasgow with a boiler designed by David Napier (1790 - 1869). The boat was also equipped with a mast that could arm a sail and in the stern it had a small cabin with seats and a table. Its name probably derives from a large comet that had been visible for several months in the years 1811-1812. The whole boat was painted in bright colors, and he its figurehead representeda woman dressed in all the colors of the rainbow.

Edward Church Jr. (1787 - 1843), consul of the United States in France, was a proponent of steam propulsion and he was a supporter of the potential of trade with these new vessels. In 1818 he built the steamer *La Garonne*, the first commercial steamboat launched in France, and the steamer *Guillaume Tell* for navigation on Lake Leman (Geneva). In 1818 the first maritime steamer in the world *Rob Roy* entered into service; it was designed by David Napier and built in Glasgow by William Denny (1779 - 1833). Purchased by a French company, and renamed *Henri Quatre* then *Duc d'Orléans*, it was the first steam ship to sail regularly in the open sea, and also the fastest boat of the era on the Clyde[8].

[6] Ransom, P. J. G. *Bell's Comet: How a Paddle Steamer Changed the Course of History*. Amberley, Gloucestershire: Amberley Publishing Limited, 2012.

[7] Subsequently, the paddle wheels were reduced to one side and the engine cylinder was modified to 32 cm in diameter and the piston stroke to 41 cm thus increasing the speed to 7 knots.

[8] *David Napier, engineer, 1790-1869 [and] an autobiographical sketch, with notes*. Glasgow: J. MacLehose, 1912; p. 52.

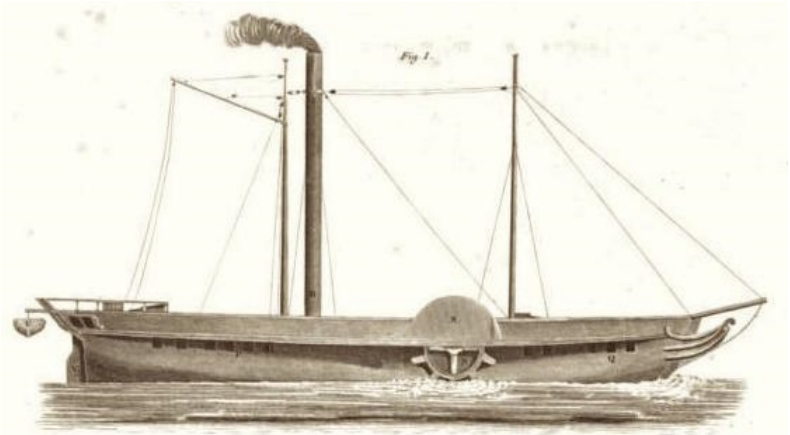

Fig. 3 - Steam boat of about 100 tons, believed to be the Rob Roy, *from Encyclopaedia Britannica: Supplement to the 4th, 5th, and 6th Editions ... With Preliminary Dissertations on the History of the Sciences ... Vol. VI. Edinburgh: Archibald Constable & Co., 1824; Plate CXVII, p. 546.*

In a few years the construction of steamboats places side by side the construction of sail sailing ships; indeed, at the beginning of this story that will definitely change the way of going by sea, the "new" and "modern" naval constructions all have a mixed propulsion system: sailing and steam. Instead, the first steam-powered ship - albeit an auxiliary - that crossed the Atlantic in 1819 (22 May - 30 June 1819) was, instead, the *Savannah*, built in New York in the United States on Fickett & Crocker shipyards[9].

Some sources say instead that *Savannah* crossed the Atlantic mainly sailing, and that otherwise the first steam ship that made the transatlantic route using only the new propulsion system was the SS *Royal William*, launched in 1831[10]. The arrival in Liverpool was told by the Times of London as follows: "The Savannah, a steam vessel recently arrived at Liverpool from America - the first vessel of the kind which ever crossed the Atlantic - was chased the whole day off the coast of Ireland by the Kite, revenue cruiser, on the Cork station, which mistook her for a ship on fire" [11].

Despite *Savannah*'s historic accomplishment, this was not a commercial success. The enormous amount of space occupied by the engine and its fuel at the expense of the load, and a certain anxiety of passengers in this form of transport by sea did not guarantee a great appreciation from the public and the foreign trade companies. Because the ship was too small to carry the fuel needed for the crossing (the availability was only 75 tons of coal[12]), much of the journey was still done sailing!

In the following years there was a frenetic succession of patents, projects and achievements in the field of steam propulsion that will influence throughout the nineteenth century the construction of boats first and then ships, all with steam propulsion. In Europe, efforts are being made to equip the fleets, especially the merchant ones, with the revolutionary "steam".

Many years later, doubts about the use of steam propulsion failed when two English-built steam

[9] Watkins, Elfreth. *The Log of the Savannah. Report upon the condition and progress of the U.S. National Museum during the year ending June 30 ...* Smithsonian Institution, United States National Museum. Washington: G.P.O., 1890; pp. 611-639.

[10] In the essay by Elfreth Watkins we read that the SS *Royal William* was the third steam ship that made the Atlantic crossing; the second was the *Curacoa* of 350 tons of gross tonnage left from Antwerp on 12 August 1828; cfr. Elfreth Watkins, *op. cit.*, p. 638.

[11] Watkins, Elfreth, *op. cit.*, p. 632.

[12] Watkins, Elfreth, *op. cit.*, p. 628.

ships with side-wheel propulsion, the SS *Great Western* - a wooden steamer, designed and built by Isambard Kingdom Brunel, a British engineer - and the SS *Sirius* built in 1837 by Robert Menzies & Sons, crossed the Atlantic reaching New York in 1838, using only steam power. Not only that, the *Great Western*, made the first crossing of the Atlantic with only the strength of the steam and it conquered the primacy of the Atlantic crossing with the shortest time taken. This is not the place to trace an exhaustive history of the early years and the evolution of the construction of steamboats; it is a complex undertaking and requires extensive treatment. For this reason the reader is referred to some reference texts among those mentioned in the note[13].

Isambard Kingdom Brunel, a visionary engineer

Hitherto employed in the construction of machines and civil engineering, the iron found employment in shipbuilding when the wood began to be scarce, especially in England - then the largest shipbuilder, necessary to manage the immense colonial empire -, when at the same time there was a great need for new ships. Nonetheless, there had been considerable prejudice in adopting a material, iron, which was considered unsuitable to build something floating (iron and steel have a specific gravity that is considerably greater than water) to achieve a boat designed to sail. Few engineers and shipbuilders immediately understood that the iron would have allowed - thanks to the best characteristics of mechanical behaviour with respect to wood - the construction of ships that are certainly lighter for the same size compared to those in wood, but also more resistant and more large, thus producing the advantage of increasing the displacement and the quantity of transportable goods.

The first boat built entirely with the iron hull was the *Vulcan*, launched in England at Faskine, Airdrie, in 1819 on the banks of the Monkland Canal. It was designed by John Robinson of Edinburgh and built by Thomas Wilson (1781 – 1873)[14]. The Vulcan was a barge and it had a long life (over 60 years); in fact, it was first used for passenger transport between Edinburgh and Glasgow and then it was converted back to the transport of coal along the English coasts. In the following years the construction of iron boats attracted the attention of the engineers and shipbuilders who sensed the potential of the new material. In 1820 the *Aaron Manby* was the first steam ship with an iron hull; it was built on a project by Aaron Manby (1776 - 1850)[15], his son Charles Manby (1804 - 1884) and Charles Napier (1786 - 1860), eccentric naval officer who had conceived the idea of building a fleet of steam ships for service on the Seine.

[13] An interesting compendium on steam propulsion from its origins to the mid-nineteenth century is found in: *The Encyclopædia Britannica*, Vol. XX (1842). See: "Steam Navigation", pp. 686-711. For further information see also: George Henry Preble. *A Chronological History of the Origin and Development of Steam Navigation*. Philadelphia: L.R. Hamersly, 1883; Fletcher, R. A. *Steam-ships, the story of their development to the present day*. London: Sidgwick & Jackson, ltd., 1910; Kennedy, John. *The History of Steam Navigation*. London: Charles Birchall, 1903.

[14] See: The Inventor of the Iron Ship in *Marine engineer and naval architect*, Vol. 8. London: Office for advertisements and publication, 1887; pp. 304-305; see p. 305.

[15] Chaloner, W. H. & W. O. Henderson. Aaron Manby, Builder of the First Iron Steamship in *Transactions of the Newcomen Society*, Vol. 29 , Iss. 1, 1953; pp. 77-91.

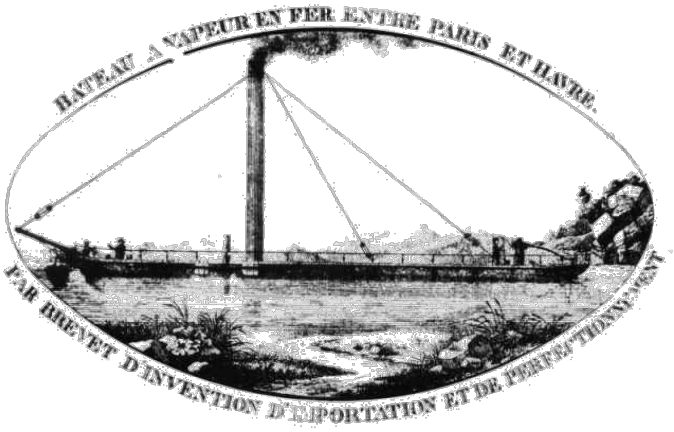

Fig. 4 - The first steam ship with an iron hull: the Aaron Manby*, built for the service on the Seine. The ship had a tonnage of 122 tons, a length of 32 meters, a width of 5.2 meters (maximum of 7 meters, including paddle wheels), and was powered by a propeller with a power of 30 Hp. The propulsion was guaranteed by two wheels of 3.7 meters in diameter with blades of 0.76 meters wide, and could develop a speed of 8/9 knots. Its flat-bottomed hull consisted of a 6.4-mm-thick iron plate attached to an L-shaped iron rib. It had only one wooden bridge and had a bowsprit. The distinctive profile of the ship was accentuated by the smokestack, a 14 meter-high iron pipe. The engine was oscillating, designed and patented (British patent No. 4558 of 1821) by Aaron Manby and had a draft of about 30 cm less than any other steamboat [Dumpleton, Bernard.* The Story of the Paddle Steamer. *Melksham: Colin Venton, 1973].*

In a few years, the construction of iron ships joins that of traditional wooden boats; the first steam is associated with the propulsion sail, then over the years thanks to a growing number of inventions and patents, slowly supersede the propulsion to sail so much that the twentieth century will see quickly set sail sailing. It is precisely in the 19th century that the genius of Brunel and the birth of the modern steamer were born in the panorama of engineering and maritime transport.

The full maturity, or the awareness that iron shipbuilding would be the turning point in shipbuilding, was achieved with the construction of the SS *Great Britain*, designed by Isambard Kingdom Brunel, an eccentric engineer from Portsmouth, and launched in 1843[16].

Brunel had design and engineering in his genes. Son of the French civil engineer Marc Isambard Brunel (1769 - 1849)[17], the young Isambard worked with his father for the construction of the Thames Tunnel from Rotherhithe to Wapping, in the east of London. He later designed (1929) the Clifton Suspension Bridge, suspension bridge over the River Avon, but his original design was rejected on the advice of Thomas Telford (1757 - 1834) and the bridge was completed in 1864, after Brunel's death. He worked on the Great Western Railway (GWR) linking Bristol and London and designed and built the viaducts at Hanwell and Chippenham, the Maidenhead Railway Bridge (the Great Western Railway bridge over the Thames at Maidenhead, Berkshire, 1838), the Box Tunnel (railway tunnel in western England, between Bath and Chippenham, built for the original route of the Great Western Railway, 1836-41), the Paddington Station in London (Great Western Railway Terminal, 1854), the Royal Albert Bridge on the Tamar River at Saltash (also called Brunel Bridge or Saltash

[16] Dumpleton, Bernard and Muriel Miller. *Brunel's Three Ships*. Melksham: Colin Venton, 1974; Chicago: University of Chicago Press, 2013.

[17] Clements, Paul. *Marc Isambard Brunel*. London: Longmans, Green & Co, 1970[1].

Bridge, 1855-59), and the Temple Meads Station in Bristol (1840), using a 2,130 mm wide track gauge instead of the 1,435 mm canons resulting in more comfortable and faster travel[18].

But there is a previous history. In 1835 Brunel started his first incredible undertaking: the construction of the SS *Great Western* steamer, the ship that made the first Atlantic route with steam only in 1838[19]; and that until 1839 was the largest passenger ship in the world[20]. An iron monster, framed by a cloud of white floating sails, a riveted mountain of iron, a floating volcano that emitted an infernal black smoke fueled by its 10 boilers, as powerful as 100 kilns: this was the new luxury liner of the new age Victorian. An era where the new materials prevailed: cast iron, iron, steel and then shiny brass; incandescent irons, steam engines that emitted puffs, whistles and hisses, and nothing seemed to be impossible: every engineering challenge was faced and won. The immensity of the Crystal Palace (1851) or the new girdered, tubular, suspended iron bridges or the tunnel under the Thames, the "Crystal Palace pneumatic railway" (1864)[21] - designed by Thomas Webster Rammell (c.1814 - 1879) - built inside the Crystal Palace and then developed by Alfred Ely Beach (1826 - 1896) for New York, they were the image of the new that advanced with giant steps. And the greatest Victorian engineer was a rather small man with very big dreams: Isambard Kingdom Brunel. Brunel was about a meter and a half tall, not a surprising figure, but what he lacked in height was heavily compensated by his great planning and entrepreneurial skills. "He was the most intense man in the business, the greatest artist ever to work in iron. He smoked 40 cigars per day and slept 4 hours per day".

In the same year, 1838, three other ships had completed the Atlantic crossing with steam propulsion: *Sirius*, *Royal Williams* and *Liverpool*. But the one that picked the most attention was the Brunel's *Great Western*. The *Great Western* was launched on July 19th, 1837 and completed in 1838. It was built, on behalf of the Great Western Steamship Co., to perform service on the Atlantic routes. It proved to be an efficient ship, enough to be taken as a model for the construction of similar steamers (even the *Britannia* of Cunard Line was a reduced version of the *Great Western*), and competitive enough to gain the archetype of the blue ribbon in 1843[22]. The *Great Western* was built in the

[18] Brunel, Isambard B.C.L. *The life of Isambard Kingdom Brunel, civil engineer*. London: Longmans, 1870.

[19] On March 31, 1838, the *Great Western* set sail for Avonmouth (Bristol) to begin its maiden voyage to New York. Before reaching Avonmouth, however, a fire broke out in the machine room; Brunel was wounded and was disembarked at Canvey Island. Although the fire was turned off and the damage to the ship was minimal, more than 50 passengers cancelled their reservations for the Bristol-New York trip and when the Great Western finally left Avonmouth, it only embarked 7 passengers, those who still trusted in the new system of transport.

[20] The *Great Western* was to have a twin ship, tentatively called *City of New York* [Vernon Gibbs, Charles Robert. *Passenger Liners of the Western Ocean: A Record of Atlantic Steam and Motor Passenger Vessels from 1838 to the Present Day*. New York: John De Graff, 1957[2]; p. 41 (London: Staples Press, 1952[1]].

[21] It is the pneumatic railway of the Crystal Palace, an experimental railway that developed inside the Crystal Palace Park in the south of London in 1864.

[22] The rival company British and American Steam Navigation Co. competed, with the *Great Western*, the steamer *Sirius* who arrived in New York on 22 April, before the Brunel steamer, despite the coal was exhausted, but using the furniture of the cabin, wooden accessories and even a tree. Everything was burned by the crew, pushed by his Commander to win the race. The *Great Western* arrived the following day, with still 200 tons of coal on board. Although the term Blue Riband ("Blue Riband of the Atlantic") had not yet been coined, it entered, in fact, in use many years later (1890), *Sirius* is often considered the first record holder of the Atlantic crossing at a speed of 8.03 knots. However, *Sirius* kept the record for one day just because the *Great Western* journey was faster, sailing at 8.66 knots. The delay was due only to the fire on board. During the voyages in the years 1838-1840, the *Great Western* travelled the average journey in 16 days at a speed of 7.95 knots to the west and New York and in 13 days and 9 hours, at a speed of 9.55 knots towards Bristol. See also: Vernon Gibbs, Charles Robert. *Passenger Liners of the Western Ocean: A Record of Atlantic Steam and Motor Passenger Vessels from 1838 to the Present Day*. New

Patterson & Mercer shipyard in Bristol and it had a tonnage of 1,340 tons. (subsequently brought to 1,700 after some changes to the size of the steamer); it was 71.6 meters long (then 76.73 meters[23]), 17.59 meters wide including paddle wheels, had fifty watertight compartments and a maze of bulkheads, and installed a 2-cylinder engine system designed by Henry Maudslay (1771 - 1831), and built by Maudslay, Sons and Field of Lambeth Marsh, London, and had a power of 750 Hp. The propulsion, guaranteed by two paddle wheels, could reach a speed of 8.5 knots in optimal sea conditions. It was also equipped with four masts that were used for auxiliary propulsion and also to stabilize the ship and always ensure a set-up such that the blades fished steadily and continuously, and there was no waste of energy produced by the steam engine. The *Great Western* could taken in 128 passengers with twenty staff members and a crew of 60 men. In 1836, supported by a group of Bristol investors, Brunel and his friend Thomas Richard Guppy (1797 - 1882) founded the Great Western Steamship Co, to start a line of steam ships on the Bristol-New York route.

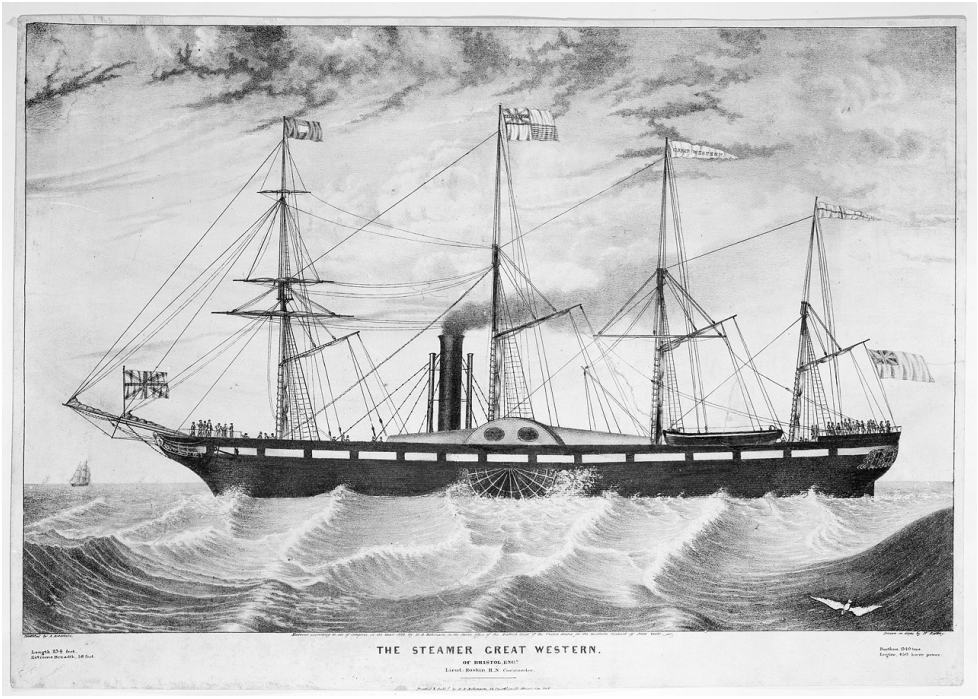

Fig. 5 - Lithography depicting the SS Great Western*, first transatlantic steamship [National Maritime Museum, Greenwich, London].*

York: John De Graff, 1957[2]; pp. 41–45 (London: Staples Press, 1952[1]). On the history of the first transatlantic navigations see also: Kludas, Arnold, & Dietmar Borchert. *Das Blaue Band des Nordatlantiks: der Mythos eines legendären Wettbewerbs*. Hamburg: Koehlers Verlagsgesellschaft, 1999.

[23] In the years 1839-40 it was subjected to a profound overhaul and lengthened by about 5 meters, at the same time increasing displacement to 1,700 tons.

The idea of starting a regular transatlantic liner service was in question in those years by different shipowning groups; in fact, the rival British Steam Navigation Co. was established during the same period. The design of the *Great Western* aroused, at its appearance, not a few controversies from the critics who claimed it was too big. The principle that Brunel adopted was the following: the loading capacity of a ship increases as the cube of its dimensions, while the resistance to water increases only as the square of its dimensions, therefore - according to the engineer from Portsmouth - it was necessary to build large ships, according to him more efficient in consumption, which is very important for long trips across the Atlantic. Despite the technical and technological innovations, it was still a wooden ship with steam propulsion and paddle wheels and four masts to hoist the auxiliary sails. The sails were not only to provide auxiliary propulsion, but they were used to keep the ship in a uniform position in rough seas and to ensure that both paddle wheels remained immersed in water, guiding the ship in a straight line.

Fig. 6 - This image shows the SS Great Britain *at the time of the launch on July 19, 1843, the largest ship in the world ever built. The event had great renown so much that the company that owns the steamship, the Great Western Steam Ship Company, organized an event attended by an impressive crowd and among the personalities who participated in the launch, including the Prince Consort Albert of Saxe-Coburg-Gotha , husband of Queen Victoria (1819 - 1901). Lithography from a painting (c.1843) by Joseph Walter (1783 - 1856) conserved at the SS Great Britain Trust.*

Brunel's second major project was the construction of an all-iron ship: the SS *Great Britain*[24]. The construction of the *Great Britain* was started at Bristol. It was a steamer of about 3,400 gross tons and a nominal power of 1,000 Hp. It was a truly daring human work of art that would change the history of shipbuilding; *Great Britain* was the longest passenger ship in navigation from 1845 to 1854. Designed by Brunel, Thomas Richard Guppy, Christopher Claxton (<1804 - >1842) and William Patterson (1795 - 1869) for the Great Western Steamship Co. and built in a basin of dry dock specially adapted to Bristol.

[24] Claxton, Christopher. *History and Description of the Steam-Ship Great Britain, Built at Bristol for the Great Western Steam-Ship Company*. New York: J. Smith Homans, 1845. See also: Corlett, Ewan. *The Iron Ship: the Story of Brunel's SS Great Britain*. London: Conway Maritime, 1975.

The construction of the *Great Britain* was almost certainly influenced by the *Rainbow*[25], a steamer that operated on the English Channel, the largest iron-hulled ship in service that occasionally flew to Bristol. SS *Great Britain* was the first ocean ship to have propeller propulsion and an iron hull, and when it was launched in 1843, it was the largest ship in operation. On July 19, 1843, among the screams of thousands of people Prince Albert of Saxe-Coburg-Gotha (1819 - 1861) hurls a bottle of wine against the ship's hull and pronounces the name by which the ship was known: *Great Britain*[26].

The designers led by Brunel launched themselves into the construction of the largest of any ship that existed at the time[27]. The trees were built of iron, fixed to the deck with iron joints, hinged at the base to allow their lowering and thus reduce the resistance sailing with strong winds against. Likewise, the rigging was done with iron cables instead of the traditional hemp, always with the aim of reducing wind resistance[28]. The bridge had parapets to railing so that the water could drain easily and at the same time the overall weight of the ship was smaller[29]. The ship's hull was designed by Brunel in a highly redundant manner, with ten longitudinal beams at the keel and robust iron ribs measuring 15.2 × 7.6 cm; the reinforcement plates of the iron keel were 2.54 cm thick and the rivets were double. In addition, the ship had a double bottom and five iron watertight bulkheads[30]. The quantity of iron used, including that used in engines, amounted to about 1,500 tons[31]. The *Great Britain* was equipped with two engines supplied by Maudslay, Sons and Field and by Francis Humphrys with John Hall and Sons of Dartford, installed halfway and it had a total weight of 340 tons[32]. The *Great Britain* had the novelty of propeller propulsion. The propeller propulsion was introduced after the experimentation started on the SS *Archimedes*, built by the Propeller Steamship Company by Francis Pettit Smith (1808 - 1874)[33]. In this regard we read: "In her it was incontestably proved that a three or four-bladed screw was a decided improvement on one of six blades, and that without any propeller at all the Great Britain was a triumph of naval architecture as a sailing ship, which of course cannot be said of a modern Atlantic, or, in fact, any ocean passenger screw steamship"[34]. Brunel, convinced of the new propeller propulsion system, abandoned the paddle wheel drive, although they were already in an advanced state of construction for *Great Britain*. According to Brunel, the propeller drive gave numerous advantages including: lighter and smaller machines, with the effect of achieving significant fuel savings; machinery with the center of gravity lower than wheel systems and consequently increased stability of the ship; less resistance to motion thanks to the absence of the bulky paddle wheels and better manoeuvrability

[25] *The Engineer*, March, 29 1901; pp. 318-319.
[26] *Illustrated London News*, July, 29 1843 (Vol. III); p. 73.
[27] Fox, Stephen. *Transatlantic: Samuel Cunard, Isambard Brunel, and the Great Atlantic Steamships*. New York: Harper Collins, 2003; p. 148.
[28] Claxton, Christopher. *History and Description of the Steam-Ship Great Britain, Built at Bristol for the Great Western Steam-Ship Company*. New York: J. Smith Homans, 1845, pp. 19–20.
[29] Fox, Stephen, *op. cit.*, p. 152.
[30] Fox, Stephen, *op. cit.*, p. 150 e Claxton, Christopher, *op. cit.*, p. 5.
[31] Claxton, Christopher, *op. cit.*, p. 5.
[32] Claxton, Christopher, *op. cit.*, p. 18.
[33] Pettit Smith and Brunel worked together for several months to find the right propeller to use on the SS *Great Britain* [Fox, Stephen, *op. cit.*, p. 148, p. 151].
[34] *The Engineer*, November, 26 1897; p. 525.

of the boat; continuous efficiency of the propeller compared to paddlewheels influenced by wave motion and load; finally, propeller propelling machinery was cheaper. On the *Scientific American* of 28 August 1845 we read: "If there is any thing objectionable in the construction or machinery of this noble ship, it is the mode of propelling her by the screw propeller; and we should not be surprised if it should be, ere long, superceded by paddle wheels at the sides". The interior was spread over three bridges, the upper two for passengers and the lower one for loading. The two passenger bridges were divided into bow and stern compartments, separated by the engines and the boiler, placed in the middle of the ship. Originally it carried 120 first-class passengers (26 of them in single cabins), 132 second-class passengers and 130 officers and crew members. On July 26th, 1845, the ship embarked on its maiden voyage to New York, a journey that completed in just over 14 days. In fact, his first trip lasted 14 days and 21 hours, at an average speed of 9.25 knots, about 1.5 knots slower than the record set at that time, and completed the return journey in 13 days and half, again a not exceptional time[35]. But Brunel's biggest and most utopian enterprise was the planning and construction of the SS *Great Eastern*. The *Great Eastern* was born from a brilliant idea of Brunel. His goal was to make long journeys to Australia with a ship that could travel around the world without needing to refuel[36]. Affectionately called the "great babe" by its eccentric designer, and the fruit of the work of thousands of workers, the *Great Eastern* lived, however, longer than its designer. Unfortunately, Brunel died only four days after the first sea trial of his large ship. In 1854 the construction of the *Great Eastern* in Millwall, London began, by J. Scott Russell and Co. It was another important step in the history of shipbuilding. According to Brunel, such a large ship would have benefited from economies of scale and would have been both fast and cheap, requiring fewer crew members than the equivalent tonnage of smaller ships. Moreover, according to its designer, the *Great Eastern* could compete with the fast clippers that dominated the routes to the East. Brunel had imagined an imposing ship: in his notebook he wrote "Say 600 feet x 65 feet x 30 feet" (183,88 × 19,81 × 9,14 meters). The *Great Eastern* would have been by volume, four times larger than any ship at the time in service. But Brunel did a lot more. The length of this ship was 211 meters[37], 25.30 meters wide and with a draft of 6.10 meters discharge and 9.15 meters at full load, it had a displacement of 18,915 tons and 32,160 tons fully loaded[38]; 4 blade motors with a nominal power of 1,000 HP and a propeller propulsion system with an additional engine of 1,600 HP rated power. The paddle wheels were 17.07 meters in diameter and the four-blade propeller was 7.32 meters in diameter. The total power has been estimated at 8,000 Hp. In addition, it was also equipped with a sail propulsion to be used in case of need. It had six trees (which were called the days of the week: Monday was the front tree and Saturday the mainsail, for a sail area of over 5,435 square meters of sails, armed with schooners, with a square main sail on each tree, a bow on the front tree and three square sails on trees n. 2 and n. 3 (Tuesday and Wednesday).

[35] Fox, Stephen, *op. cit.*, p. 153.
[36] Rolt, Lionel Thomas Caswal. *Isambard Kingdom Brunel*. London: Longmans, 1957; New York: St. Martin's Press, 1859; p. 237.
[37] The length of 211 m. it was only surpassed in 1899 by the 215 meter RMS *Oceanic*, while its gross tonnage of 18,915 tons was only surpassed in 1901 by the RMS *Celtic* with 21,035 tons. of gross tonnage.
[38] Dawson, Philip S. *The Liner: Retrospective and Renaissance*. London: Conway Maritime Press, 2005; p. 37.

The setting of the sails proved to be unusable at the same time as the paddle wheels and the propeller they were in operation, because the hot exhaust of the five chimneys (subsequently reduced to four) would have set them on fire. Its maximum speed was 13 knots. The hull was entirely in iron, double-walled, a feature that would no longer be seen in a ship for almost 100 years, made of 2 cm thick slabs of iron and with ribs every 1.83 meters. Internally the hull was divided by two longitudinal bulkheads and other transverse bulkheads divided the ship into nineteen compartments, and developed on four bridges. The iron plates were expressly laminated at Millwall to build this large ship, and had variable dimensions from 2 tons to 2½ tons of weight; the widest plate measured 8.23 meters in length by 1.30 meters in width and 3 cm in thickness. It was the largest ship ever built at that time (1858) and had a transport capacity of 4,000 passengers, capable of navigating for thousands of miles without stopping for refueling, and employing 418 crewmembers. He also landed 18 lifeboats, brought to 20 after 1860. "She has made in all eight or ten trips with passengers across the Atlantic. She has carried troops to Quebec. In 1863 she knocked a hole 83ft. long in her bottom on Montauk Point. In 1860 she encountered the storm in which she lost her paddles and broke her rudder head. A sensational story was told at the time about the fitting of jury steering gear by an American engineer, Mr. Towle, which, like many other sensational stories, is not true"[39]. The hull lines of this ship were designed by John Scott Russell (1808 - 1882), a Scottish naval engineer. On June 17, 1860, after two test trips in 1859, he set off on his maiden voyage from Southampton to New York. Born for the service with the Far East, she actually made her first trips to the Atlantic: "She was designed for the Far Eastern trade, but there was never sufficient traffic to put her into this. Instead, she was used in the transatlantic business, where she could not compete in speed and performance with similar vessels already in service"[40].

Fig. 7 a, b – The SS Great Eastern *was a luxurious ship, that's how the dining room and lounge inside it appeared, probably at Arklow in 1870 [Source: National Library of Ireland]. The interior was divided into three bridges, the upper two for passengers and the lower one for loading. The two passenger bridges were divided into bow and stern compartments, separated by the engine and the boiler placed in the middle of the ship.*

[39] *The Engineer*, May, 7 1886; p. 349.
[40] Buchanan, R. A. *The Great Eastern Controversy: A Comment. Technology and Culture*. Vol. 24, N. 1 (Jan. 1983): pp. 98–106.

On his maiden voyage of eleven days he carried 35 paying passengers, 8 "dead heads" (non-paying passengers) and 418 crew members. Among the 35 passengers, there were eight company officials and two engineers, Zerah Colburn (1832 - 1870) and Alexander Lyman Holley (1832 - 1882); the trip lasted 10 days and 19 hours. After returning to England the *Great Eastern* was chartered by the British Government to transport troops towards the Canadian Dominion. The *Great Eastern* had a long life and overcame incredible adversities. On August 27th, 1862, the immense steamer suffered an accident similar to that of the RMS *Titanic*, but did not sink. The hull hit an unknown rock off the coast of Long Island, which opened the outer hull for a width of 2.74 meters and a length of over 25 meters. However, the inner hull of the *Great Eastern* remained intact, and the steamboat gone up to New York sailing for a whole day with a deep gash of water; it was repaired with a metal box used to close the leak and returned to Liverpool on January 6th, 1863. Many other Atlantic crossings followed, but the competition between the shipping companies and a fierce price war made the *Great Eastern* no longer competitive, the losses increased and the steamer was disarmed. Purchased by Daniel Gooch (1816 - 1889), it was entrusted to the fledgling Great Eastern Steamship Co., and chartered to Telegraph Construction and Maintenance Co. In 1837 the electric telegraph was developed independently in Europe and North America. However, telegraphic communication lines between Europe and North America, however, were still limited by the time taken by a ship carrying a message to cross the sea: at least 10 days. Within two decades, both continents were crossed by cables that connected almost all the major cities of the two continents, allowing day-to-day communications between almost all the urban locations of the countries that faced the two Atlantic shores. Thus it was decided to use the *Great Eastern* as a cable ship. So, at the end of his career (1865) *Great Eastern* was then converted into a cable ship. From 1866 to 1878, under the command of Captain Robert Halpin (1836 - 1894), the ship placed over 2,600 miles of submarine telegraph cable from Brest to St. Pierre-Miquelon (1869) and from Aden to Bombay (1869-1870)[41]. He ended his life as a floating music hall and advertising billboard (for the famous Lewis's department store) in Liverpool, and was demolished in 1889-90.

[41] Cfr. *The Engineer*, June, 18 1869; p. 424; *The Engineer*, May, 7 1886, pp. 349-50; May, 14 1886, pp. 369-70; October, 15 1886, pp. 302-03.

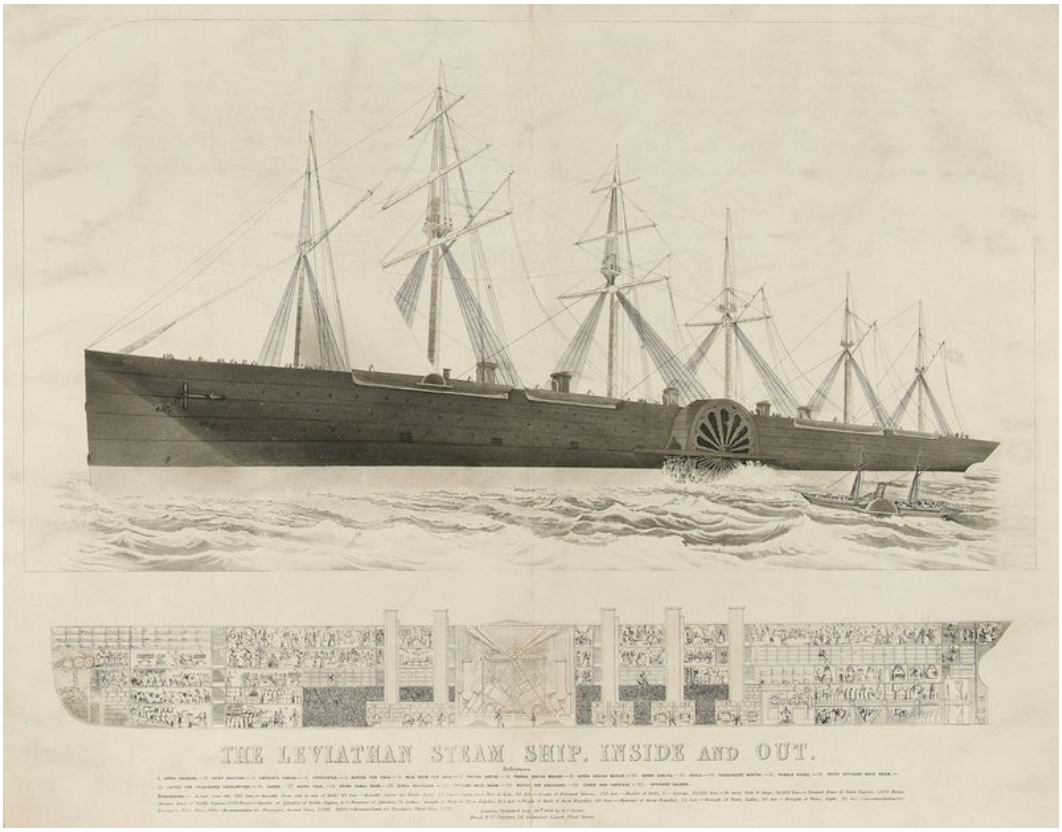

*Fig. 8 - The steam ship "*Leviathan*" (* Great Eastern *), National Maritime Museum, Greenwich, London.*

Conclusion

Brunel's contribution to shipbuilding has shown how the ingenuity and design invention of this 19th-century engineer has enabled him to achieve important results from a constructive, mechanical and technological point of view. The experimentation of advanced construction techniques in shipbuilding, the introduction of new technologies such as screw propeller propulsion, the use of iron in the construction of ever larger ships, has actually shown how the intuitions of Brunel, romantic dreamer of the Victorian age, have paved the way for a new way to go by sea. In the second half of the nineteenth century all the forecasts of Brunel came true and in the space of only fifty years, steam navigation surpassed that of sail sailing in the maritime transport of passengers and goods. The iron ships supplanted those of wood, but above all the ships became bigger and more able to travel longer and longer routes without a stop. A scientific-technical-technological revolution that has deeply influenced engineering and shipbuilding, thanks to many enterprising inventors, designers, builders, entrepreneurs, but above all to the genius of Isambard Kingdom Brunel, a pillar of 19th century engineering, ingenious and versatile civil, railway and naval designer.

Fig. 9 - Isambard Kingdom Brunel at the Launching of the SS Great Eastern *(first called* Leviathan*, for its gigantic size). In order from left to right: John Scott Russell, Henry Wakefield (- 1899), Isambard Kingdom Brunel, Edward George Geoffrey Smith-Stanley, 14th Earl of Derby (1799 –1869) [Photo by Robert Howlett (1831 - 1858) [The J. Paul Getty Museum].*

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