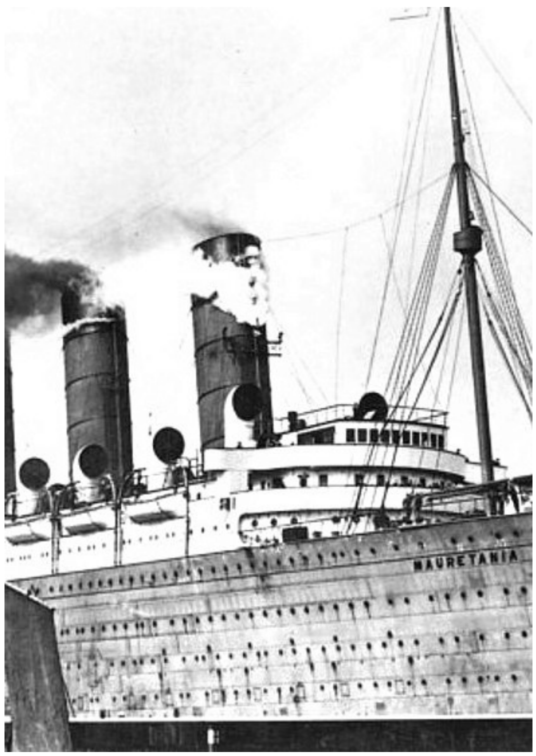
A QUIET SEA

RMS TITANIC



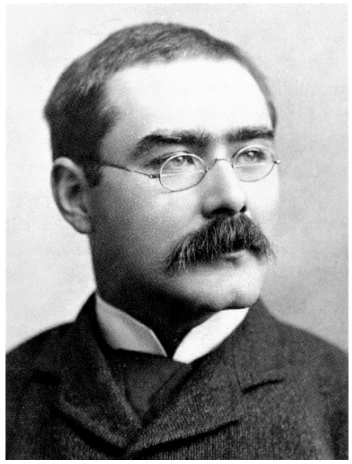
RMS Mauretania

SONG OF STEAM

TITANIC – SONG OF STEAM

INTRODUCTION

"Lord, Thou hast made this world below the shadow of a dream, An', taught by time, I tak' it so - exceptin' always Steam. From coupler-flange to spindle-guide I see Thy Hand, O God - Predestination in the stride o' yon connectin'-rod." * MacAndrew's Hymn, Rudyard Kipling



Rudyard Kipling (1865-1936)
Credit: Wikipedia

Water has the rare ability to be a solid, liquid or gas within a narrow temperature range. It freezes and boils at 32 and 212 degrees Fahrenheit, respectively. In the presence of various temperatures, water molecules can increase or decrease their activity, and this determines the amount of kinetic energy released. It evaporates above freezing temperature, and becomes a powerful, expansive and invisible gas when superheated, developing tremendous power to propel ships through the heaviest seas.

STEAM'S ORIGINS

Tradition has it that the mathematician, musician and statesman Archytas (435/410–360/350 BC) converted heat to motion by propelling a wooden dove along wires. An unconfirmed statement, attributed to Aulus Gellius, made 5 centuries after Archytas's death, declared that "*Archytas the Tarentine, being in other lines also a mechanician, made a flying dove out of wood. Whenever it lit, it did not rise again.*" Greek scholars have not verified this claim and have reservations regarding its veracity.

Archytas
Credit: Wikipedia

Little is known of Greek mathematician and inventor Heron of Alexandria (60 AD). Some of the devices he created were the first vending machine (to distribute water for ablutions) and a wind-powered organ. But he is chiefly remembered as creator of the first demonstration model of a reaction steam turbine: the aeolipile.

Heron of Alexandria
Credit: Wikipedia

Heron's engine, the aeolipile
Credit: Wikimedia Commons

Archytas's dubious flying dove and Heron's novel aeolipile raised the question of steam energy derived from boiling water, but the devices had no practical application, and progress stopped. It would take time before others would devise the means and machinery to put this force to use.

Records suggest attempts to use steam power prior to Heron. Some speculated on the use of heating water into steam, but losses through the uninsulated devices destroyed any efficiency and rendered them useless.

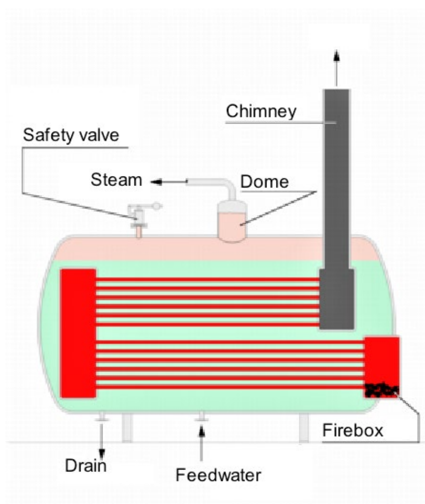
In 1125, claims were made in France of air- or steam-powered objects; drawings of steam-powered cannons and steam bombs, considered futuristic weapons, were found in Leonardo da Vinci's papers (1487-1490). The 16th century Ottoman polymath Taqi ad-Din contemplated a meat spit powered by a jet of steam, an early turbine. As original as these ideas were, there is little in the way of recorded success, and the machines wasted most of their energy, if they could move at all. Jerónimo de Ayanz y Beaumont, who pioneered diving and diving bells, is said to have constructed the first steam injector in 1607. He proposed drawing poison air from mines by directing steam out of a pipe positioned to suction tainted air and send it to the surface. It was said that he tried this steam pressure principal to remove water from a Spanish mine, but there is no record of success.

MAKING STEAM

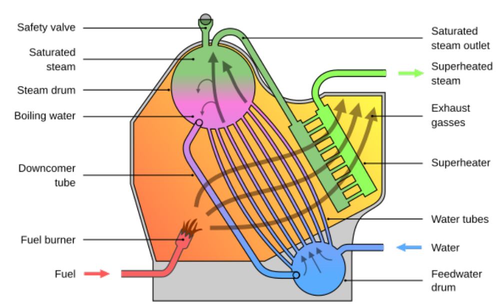
Carefully controlled steam pressure is key for maintaining desired engine revolutions. Too much or too little steam pressure wastes fuel, boiler feed water and risks damaging the equipment. To get a ship across the ocean, the boilers must continuously produce great volumes of steam to fill the cylinders to push the pistons, turn the paddles or propeller, and keep the ship moving. A simple home-style pressure cooker is a common example of controlled steam pressure at work. When the pressure builds, a relief valve on the sealed cover begins rocking back and forth just enough to maintain the internal pressure at about 8-15 pounds per square inch (psi); the jiggling relief valve indicates that the pressure cooker is properly doing its job. Incorporating steam power into industry requires a variety of skills: professional design, metallurgy, casting, forging and machining to make the component parts.

The first boilers, able to produce a pound or two of steam pressure, were closed containers with an external fire. The steam followed a pipe sending it to a crude engine. In Heron's day, boilers and what they powered were little more than interesting toys. The boiler remained an undeveloped curiosity. With the advent of deep mining centuries later, steam was seen as a source of power to pump water out of mines. Tank boilers were developed, with a cylindrical shell holding the water to be heated and fired with coal or wood in a furnace integral with the boiler unit. To improve efficiency, the fire tube, or Scotch boiler was invented for early locomotives and steamships. In this unit, a set of tubes, surrounded by water, carry the heat from the furnace to make steam. In a variant on the fire tube boiler, the watertube boiler, water is held within tubes surrounded by the furnace fires, thus producing steam. Watertube boilers are lighter than Scotch boilers, raise steam faster and operate at higher pressures. First developed in the late 1790s, the watertube boiler came into its own with the arrival of the turbine engine in the early 20th century. Modern watertube boilers superheat the steam by passing it through another set of tubes. Initially made from wrought iron, steel became the material of choice in the late 19th century because of its higher tensile strength.

Haystack boiler
Credit: Wikipedia

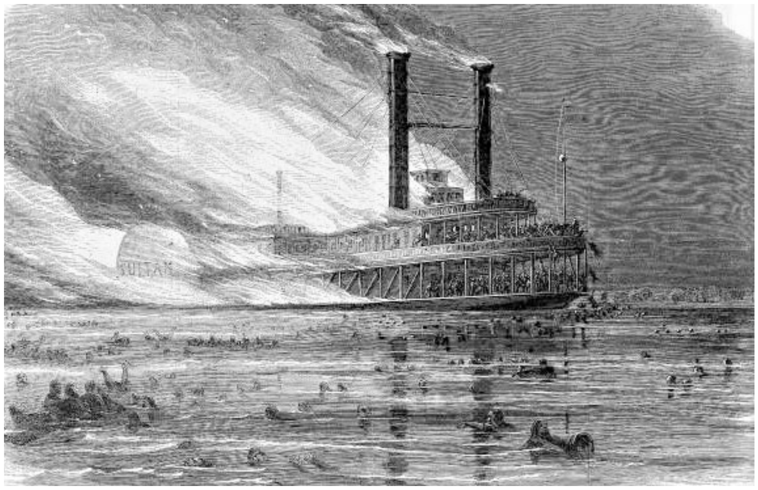


Firetube boiler
Credit: Wikipedia



Watertube boiler
Credit: Wikipedia

The desire for higher and higher pressures tested the limits of boiler metallurgy, and explosions were common. Allowing the boiler water to become low, a flameout in the firebox (which would allow explosive gases to build up), faulty safety valves, and poor design and materials all contributed to boiler failures. The boiler explosion aboard the American riverboat Sultana in April 1865 was a monumental tragedy. Built in Cincinnati, Ohio in 1863, Sultana was a modern sidewheeler powered by state-of-the-art fire tube boilers. They operated at much higher pressure than conventional boilers but required very close tending. Operating on the Mississippi River, there was a considerable risk that river sediment would collect and disrupt the even distribution of water around the firetubes, and create hot spots that would threaten their strength. Departing St. Louis, Sultana stopped in Vicksburg, Mississippi, to pick up union soldiers paroled from Confederate prison camps. Heading to New Orleans, one boiler began leaking, and Sultana turned back for repairs. These were temporary and poorly done. Sultana was grossly overloaded, with nearly 2,000 persons on board, and her hull suffered structural strain. On the night of April 27, 1865, Sultana's boilers suddenly exploded, destroying her topsides and collapsing her decks; the wooden sidewheeler immediately caught fire. A southbound steamer happened by and began rescuing those who survived in the freezing water. Sultana drifted for 5 hours before sinking on the riverbank. Her captain and numerous crew members perished. Nearly 1,600 were lost; about 900 were saved. Causes of the explosion were determined to be uneven passenger movement, which caused Sultana to heel, depleting water in the boilers on the high side of the vessel; low boiler water levels; faulty material in the firetubes; and the poor repairs done in Vicksburg.

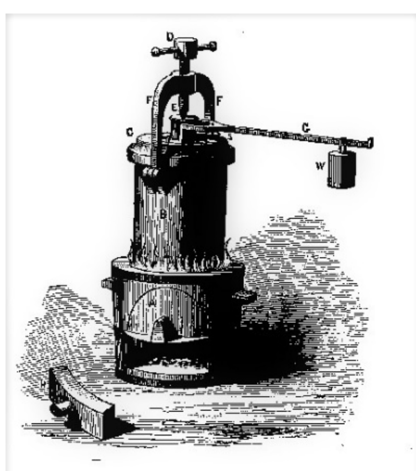


Sultana disaster
Credit: Wikipedia

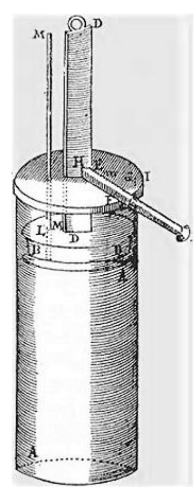
THE PIONEERS OF PRESSURE

Over 1,600 years would pass between Heron's spinning sphere and the first pressure cooker designed by Denis Papin in 1679. Called a steam digester, the device used steam pressure to remove fat from bone and was the precursor of the autoclave. A long lever and movable weight atop the cylinder determined the pressure. Working and consulting with other mathematicians, physicists and chemists, Papin contemplated using a vacuum to preserve food and wondered if it could be converted into mechanical motion. His first attempt, in 1690, consisted of a closed cylinder incorporating a piston, the first of its kind. A quantity of water was heated, converted to steam and moved the piston up. When the cylinder was cooled, the steam condensed, lowering the piston. In one stroke, Papin converted expanding pressure and vacuum into mechanical motion.

Denis Papin (1647-1713)
Credit: Wikipedia

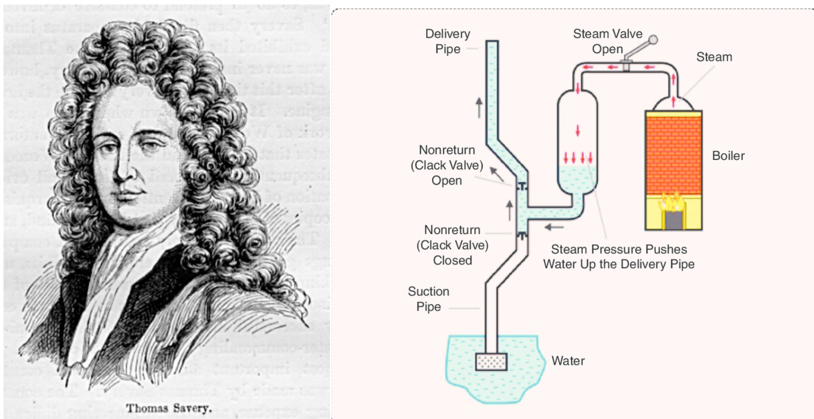


Papin digester
Credit: Wikipedia



Papin first steam engine
Credit: Wikimedia Commons

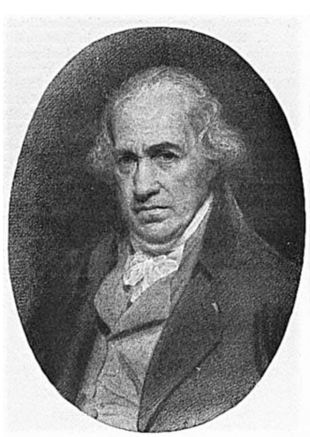
He went on to develop a more sophisticated engine using more direct steam pressure. Expanding on this idea, in 1689, Papin suggested that air could be compressed using bellows to provide air for occupants in a diving bell. (One hundred years later, his idea became a reality.) When religious strife in 1687 France revoked the rights of Huguenots, forcing Papin in 1689 to flee to England and Germany, he secured a teaching position and turned his skills to developing vessels propelled by engine-driven paddlewheels. Although his inventions and ideas were accepted by the Royal Society, they withheld funding, and he descended into poverty. Through his correspondence, it is believed that he died in 1712 and was buried in England in an unmarked grave. His work, and that of his English contemporary Thomas Savery (1650-1715), laid the path for future inventors of steam machinery. The next big step came with Thomas Newcomen.

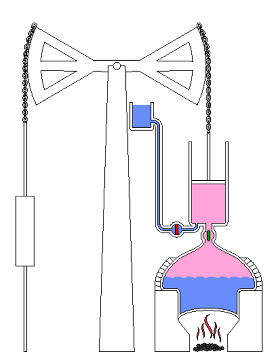


Thomas Savery (1650-1715) and his fire engine steam pump
Credits: Wikipedia (L) and Research Gate (R)

THE ATMOSPHERIC ENGINE

Building on Thomas Savery's steam pump design from the late 1690s to extract water from mines, Thomas Newcomen developed the first practical atmospheric engine. Rather than have the steam interact directly with water to move it, Newcomen incorporated Papin's piston to do the work and a walking beam to transmit the power to the water pump. Newcomen's basic engine worked on the principle of low-pressure steam admitted to the bottom of the cylinder, expanding and lifting the piston with steam pressure (the cylinder had an open top). At the end of its upward power stroke, cold water was injected into the cylinder, condensing the steam, creating a vacuum to pull the piston down with ambient atmospheric pressure providing the weight (14.7 psi at sea level) on the piston top. With the engine piston moving down, it lifted the pump piston in the mine through the walking beam and raised the water to the surface.


Thomas Newcomen (1664-1729)
Credit: Wikipedia


Newcomen's atmospheric engine.
Steam (pink), water (blue)
Valves open (green), valves closed (red)
Credit: Wikipedia

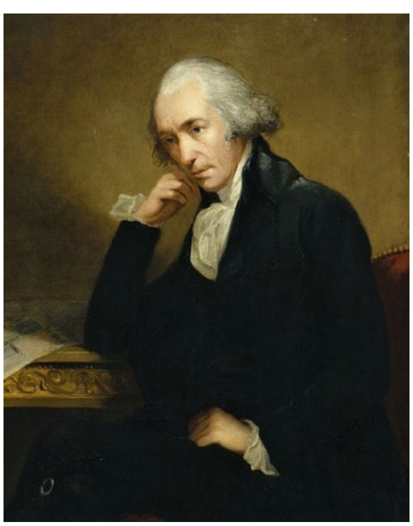
Newcomen's work with steam engines became wildly known and supported. However, Savery's patent for his "fire engine" was in effect until 1833. Newcomen entered into partnership with Savery to operate under his patent, but receive little compensation. As a result, Newcomen fell into obscurity, passing away in 1729. By the time Savery's patent expired, there were more than 130 Newcomen engines, operating under Savery's patent, in service in British and European mines. Although cumbersome, it pushed the technological limits of the day, Newcomen's engine underwent improvements, with larger cylinders and operating capacities, and the design provided pumping services for another 75 years.

BREAKTHROUGHS – A HEAD OF STEAM

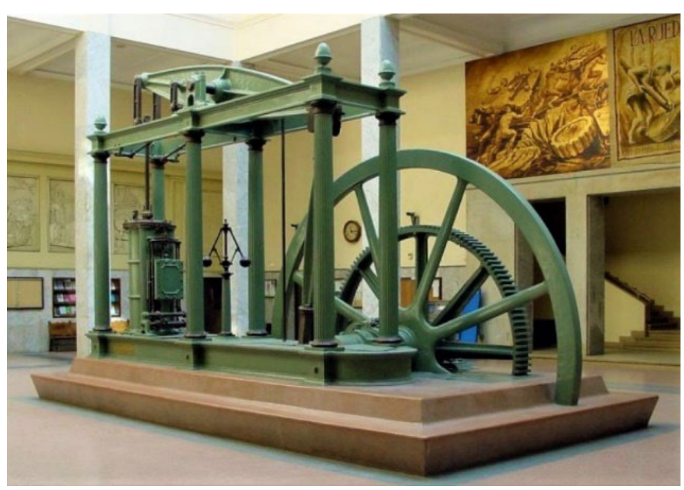
For all its widespread use and longevity, Newcomen's engine was woefully inefficient. The low pressure of the water-saturated steam was only used on one side of the piston, effectively eliminating the useful area to develop power by half. Using both sides of the piston and converting linear to rotary motion were the next important steps in the evolution of steam machinery.

James Watt worked at the University of Glasgow as an instrument maker. He restored and produced instruments for measuring distances, theodolites for land surveying and navigational devices such as compasses and quadrants, becoming the premier instrument maker at the school. The inefficiency of the atmospheric engine occupied many engineers of the day. Studying the engines then in use, Watt realized that the cycles of heating and cooling the cylinder destroyed the power and efficiency of the machinery. Experimenting with a Newcomen engine, Watt learned its shortcomings and was determined to build a better engine. He did so by using a double-acting piston—one that takes steam pressure from both sides—and finessing the transfer of linear to rotary motion through use of a crankshaft, building a separate condenser that wouldn't affect the heat in the cylinder, and creating specialized valve linkages. The great advantage of his engine was that it could do far more than pump water; it had the potential to move things. But, how to gauge an engine's power was the great unknown. The idea germinated with Thomas Savery in his book, "A Miner's Friend":

"So that an engine which will raise as much water as two horses, working together at one time in such a work, can do, and for which there must be constantly kept ten or twelve horses for doing the same. Then I say, such an engine may be made large enough to do the work required in employing eight, ten, fifteen, or twenty horses to be constantly maintained and kept for doing such a work..." **



James Watt (1736-1819)
Credit: Wikipedia

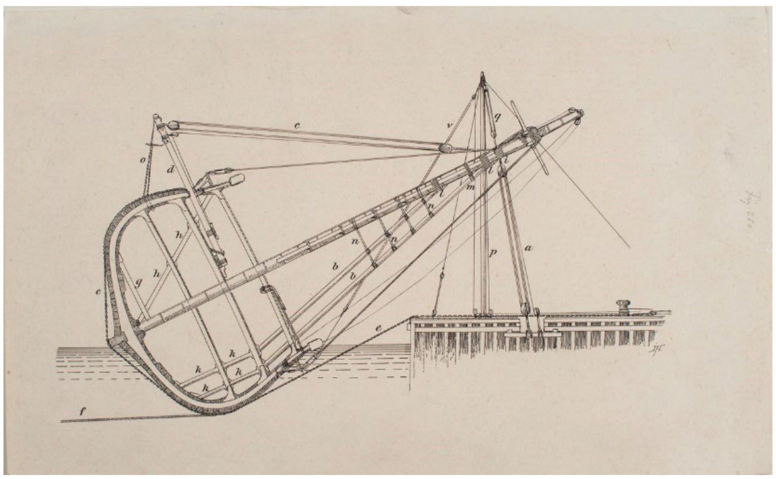


The Watt steam engine
Credit: Wikipedia

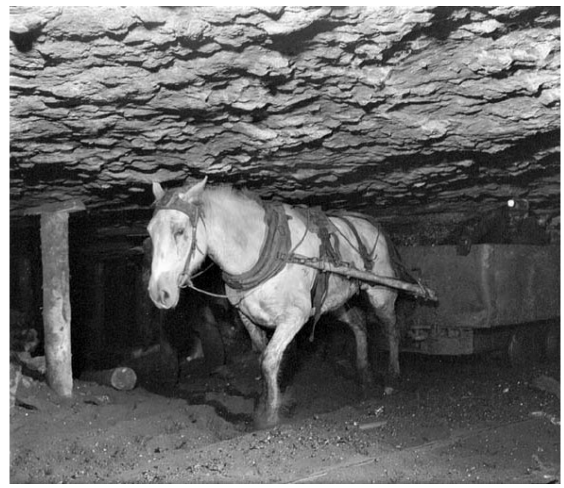
James Watt and others took the next step—ascertaining the power of a steam engine compared with the strength of a horse.

HORSEPOWER

In the pre-industrial era, horse power was ubiquitous throughout Britain, Europe and America. Horses were used to heave down (careen) floating ships to work on the ship's bottom by tramping around large capstans rigged to mast tackles. They towed canal barges, did farm work, powered threshing machines, worked in transportation and other industries. When steam engines were developed, more horses worked much harder to provide fuel for the engines' boilers. Beginning in the mid 18th century, tens of thousands of "pit ponies" moved coal out of British mines. Horses worked in every industry, their lives shortened by cruelty in peace and war.



Careening a ship
Credit: Wikipedia



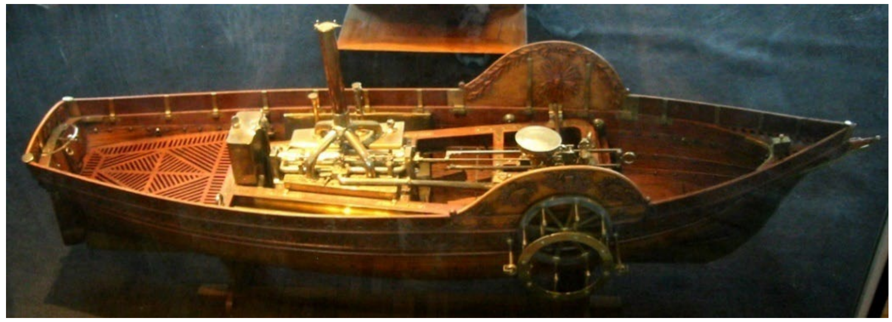
Coal mine, 'Pit pony'
Credit: Wikipedia

It was fitting that the horse, with its strength and endurance, would be the gauge to determine the output of a steam engine. Relying on the most basic work that horses did in mills for his calculations, Watt took the dimensions of a grinding mill wheel arm, about a 12' radius, or 24 feet in diameter (75' circumference). A horse could turn the wheel about 2.5 times a minute, or a little less than 150 times an hour. Incorporating some guesswork, he distilled the horse's pulling force to be about 180 pounds. As crude as Watt's math was at the time, his 1 horsepower was the standard of power used in the centuries ahead.

MOBILITY

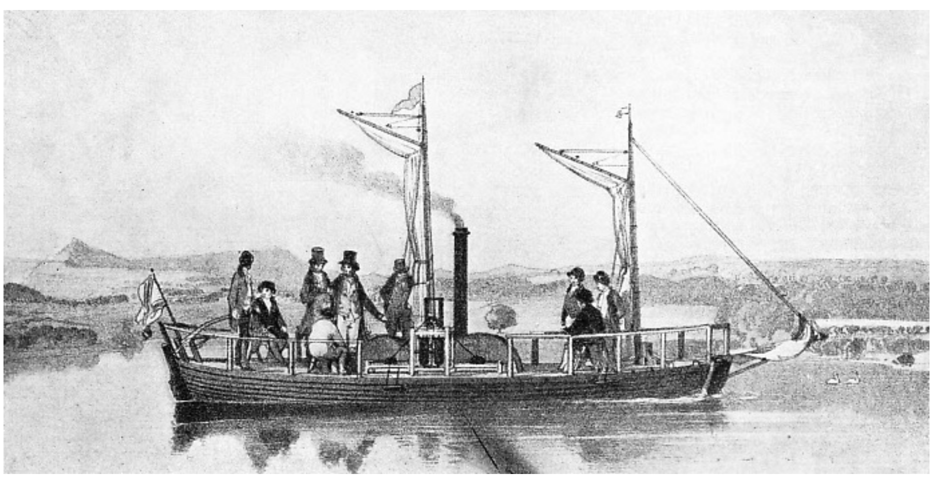
The great advantage of the horse was that its power was held in one mobile unit. Not so with cumbersome steam engines. The challenge was to fit the necessary machinery into one vehicle. An early attempt to put steam to use on water occurred in 1763. William Henry, gunsmith in the 13 colonies, built a sternwheel steamboat. Casting off from Lancaster, Pennsylvania, the sternwheeler promptly sank due to the weight of its machinery. In 1774, a French nobleman, Claude de Jouffroy, built a steam-powered vessel. Introduced in 1776, the 42' Palmipede broke down after a few minutes, and her wooden hull leaked badly from the weight and vibration of the machinery. Jouffroy considered jet propulsion using an engine-driven pump but chose a Newcomen engine. Oars with hinged blades would feather on the forward stroke and open on the back stroke to propel the boat forward, much like a paddling duck. Undaunted, in 1783, he built the Pyroscaphe, equipped with a double-acting engine and the first paddlewheels. The boiler leaked (a common problem in steam machinery of the time), but eventually, Pyroscaphe managed to carry passengers who signed on as witnesses.

Claude de Jouffroy (1751-1832)
Credit: Wikipedia



1784 Jouffroy-built model of Pyroscaphe
Credit: Wikipedia

About the time of Jouffroy's Pyroscaphe, Patrick Miller (1731-1815), a wealthy banker, designed a prototype for the King of Sweden of a super warship with sails and paddlewheels between two catamaran hulls. He built a huge model of his design: the Experiment of Leith. The ship's hull, masting and rigging was out of proportion, and the paddlewheels had to be protected from debris with a big bow net, slowing the vessel down to a crawl. The ship's rudders were poorly placed and couldn't turn the ship. Undaunted, Miller stayed loyal to his catamaran hull design and built a small pleasure steamer in 1788. Called the Double Pleasure Boat, Miller's vessel had the engine on one hull and the boiler on the other. The two paddlewheels were housed fore and aft in boxes on the centerline between the hulls.



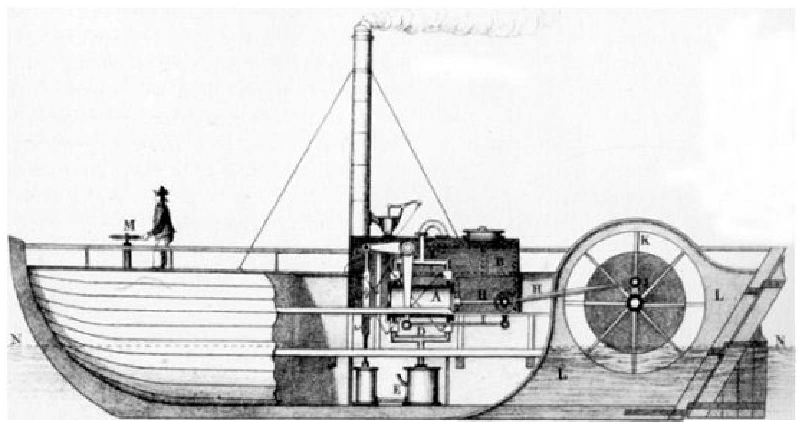
Patrick Miller's catamaran steamboat
Credit: Wikipedia

Miller's engine was built by William Symington, who went on to build the first practical steamer capable of towing other vessels through canals. After his work with Miller, Symington found financial backing through Thomas Lord Dundas. Dundas had extensive business interests and was the government official of the Forth and Clyde Canal Company. Increasing the flow of trade through canals by employing towing vessels was in his interest, and his support was essential.

Symington and Captain John Schank, of the Royal Navy, built the first vessel to operate as a towboat in a canal. The Charlotte Dundas, named after Lord Dundas's daughter, had successful trials, but the machinery didn't live up to expectations. A second boat, also the Charlotte Dundas, was built and fitted with Symington's advanced machinery design. Vastly improving on Watt's engine, he designed horizontal machinery with a low profile. It was considered "without doubt the most compact and efficient marine steam engine up to that time (unknown source)." At 65' long, Charlotte Dundas showed what she could do by towing two loaded sloops nearly 20 miles in just under 10 hours. Although a resounding success, fears about what the paddle steamer's wake would do to the canal bank brought the project to a close. Charlotte Dundas had her machinery removed and served as a dredge to the end of her days.

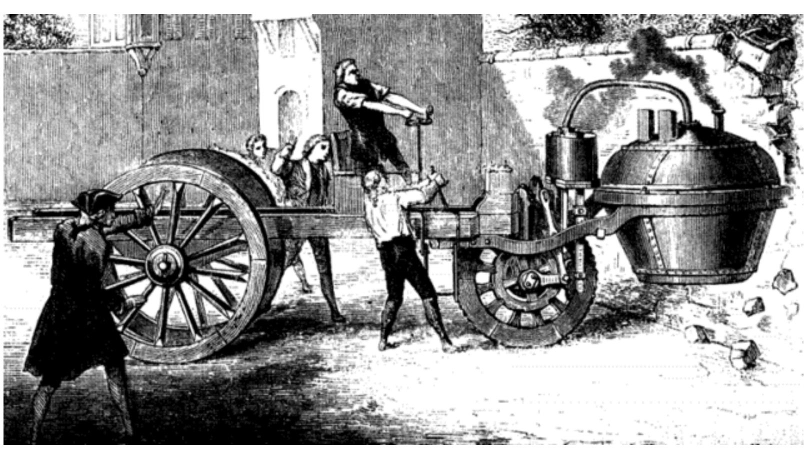
With the demise of canal towing, Symington joined a business venture and designed and built a pumping engine for a mine. The project collapsed, and with no backers for future prospects, he fell into debt and ill health. The House of Lords, aware of his contribution, awarded him two payments as a pension. His health declined, and he died in his daughter's home in 1831.

William Symington (1764-1831)
Credit: Wikipedia

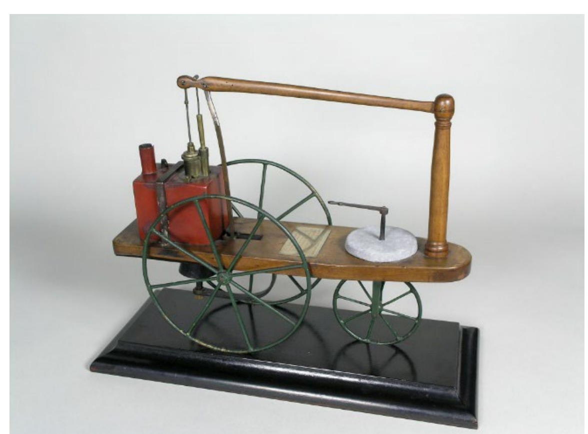


Sternwheeler Charlotte Dundas
Credit: Wikipedia

Somewhat more success was seen on land. Higher boiler pressure was key in building a practical locomotive. In 1770, Nicolas-Joseph Cugnot (1725-1804), inventor and a captain in the French army, built the first successful steam-powered automobile. Following in his footsteps, William Murdoch built a model steam carriage for transportation.



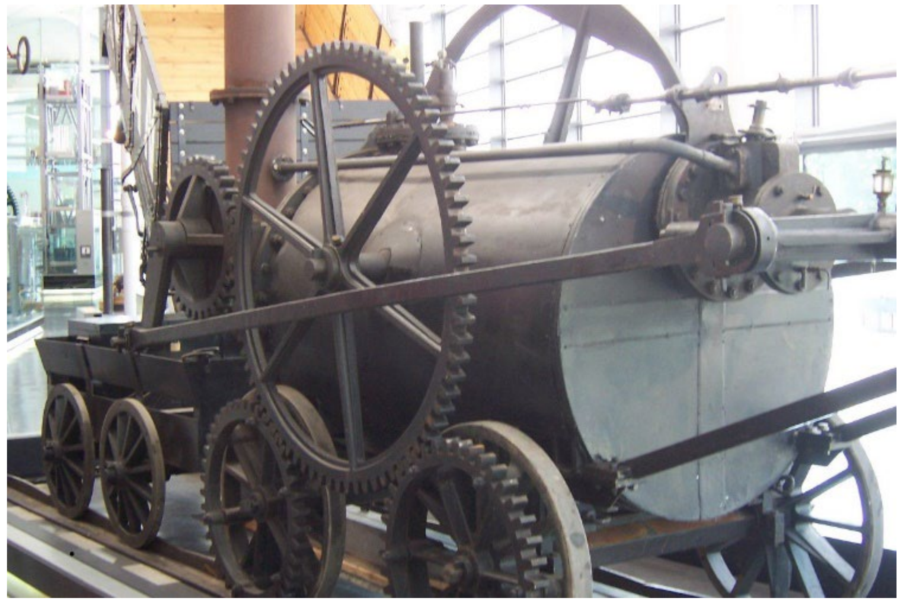
Cugnot's steam car 1770
Credit: Wikimedia Commons



Murdoch's model steam carriage 1784
Credit: Wikipedia

Mining engineer Richard Trevithick understood that higher steam pressures gave a greater power-to-weight ratio, resulting in more compact machinery. With metallurgy and boiler construction methods improving, Trevithick, a neighbor of Murdoch's, discussed the future possibilities of machinery and was likely intrigued with Murdoch's model carriage. In addition to a smaller and lighter engine, Trevithick incorporated the boiler onto the frame of his locomotive. He dispensed with the condenser and exhausted the piston steam up the boiler stack. This improved draft and made for a hotter fire, higher pressure developing enough power to pull a load. Although 30 psi was unheard of, Trevithick made it work. He also sought to make improvements for the maritime world. He considered iron for ships and drydocks, iron navigational buoys, and using boiler steam for onboard cooking.

Richard Trevithick (1771-1833)
Credit: Wikipedia

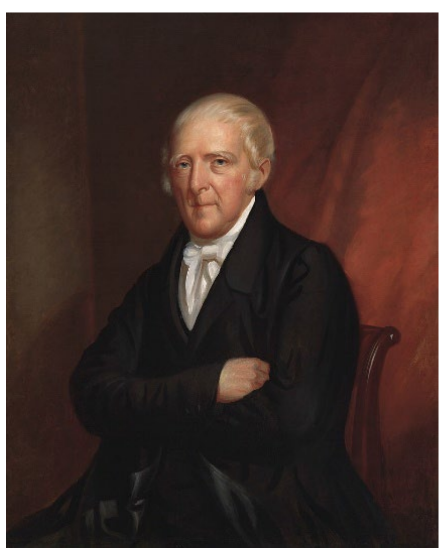


Trevithick's 1804 locomotive
Credit: Wikipedia

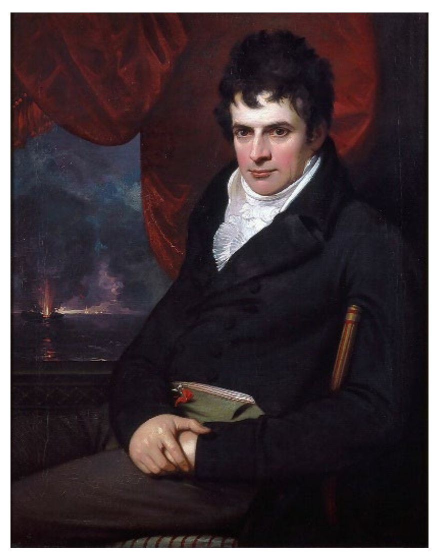
ACROSS THE POND IN AMERICA

The names most closely associated with early steamboat development in America are John Fitch, John Stevens and Robert Fulton.

John Fitch (1743-1798)
Credit: Wikipedia



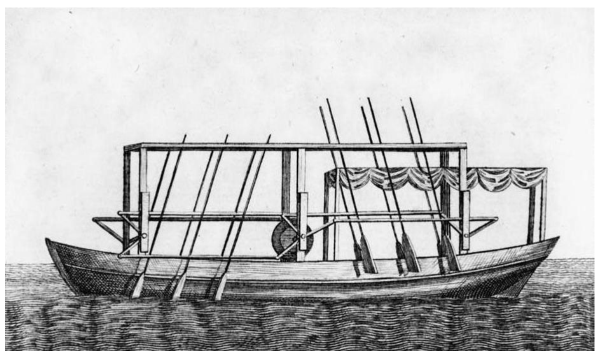
John Stevens (1749-1838)
Credit: Wikipedia



Robert Fulton (1764-1815)
Credit: Wikipedia

JOHN FITCH

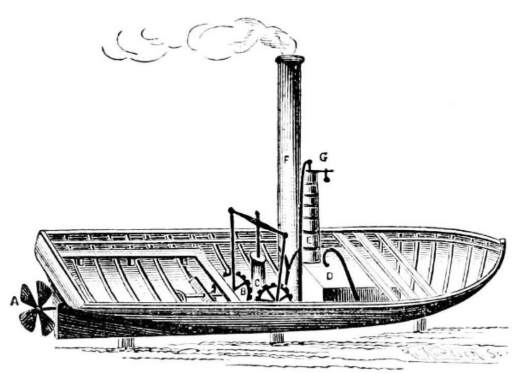
Clockmaker, inventor, gunsmith and engineer John Fitch built a 45' steamboat that successfully ran on the Delaware River in 1787. Members of the Constitutional Convention witnessed the event. The Perseverance, using mechanical oars (called ranked paddles) for propulsion, managed 4 mph. The delegates offered muted but polite comments. After a series of legal battles with competitors, Fitch received his first steamboat patent 4 years later. He followed up with a bigger vessel suitable to carry passengers and cargo, making runs between Burlington, NJ and Philadelphia, PA, a distance of about 20 miles. Fitch continued building and operating steamboats, improving their design and mechanical propulsion systems; paddlewheels followed the oars, and a propeller followed the paddlewheels. Underestimating operating and building costs, Fitch took his skills to France, where he earned a steamboat patent. Arriving just in time for the Reign of Terror in 1793, he relocated to England. Having no success, he returned to America to reestablish his steamboat work but couldn't convince supporters of the economic viability of his vessels. Confronted with legal troubles over land, and with financial support for his projects lacking, Fitch fell into alcoholism and opium and died in 1798.



Perseverance 1787
Credit: Wikipedia

JOHN STEVENS

Col. John Stevens III came from a politically influential family from New York City; his father served in the Continental Congress. As a young man, Stevens was a captain in George Washington's army and advanced to the rank of colonel upon his discharge. At the age of 22, he was admitted to the New York City bar, specializing in patent law. Acquiring land through a public auction seized from Tories, Stevens settled in what became Hoboken, NJ. With his interest in engineering, Stevens built a steamboat in 1802 propelled by a revolutionary rotary engine (possibly an early turbine) turning a screw propeller. But the leaky engine defeated him, and he reverted to a conventional piston engine—but he kept his screw propeller.

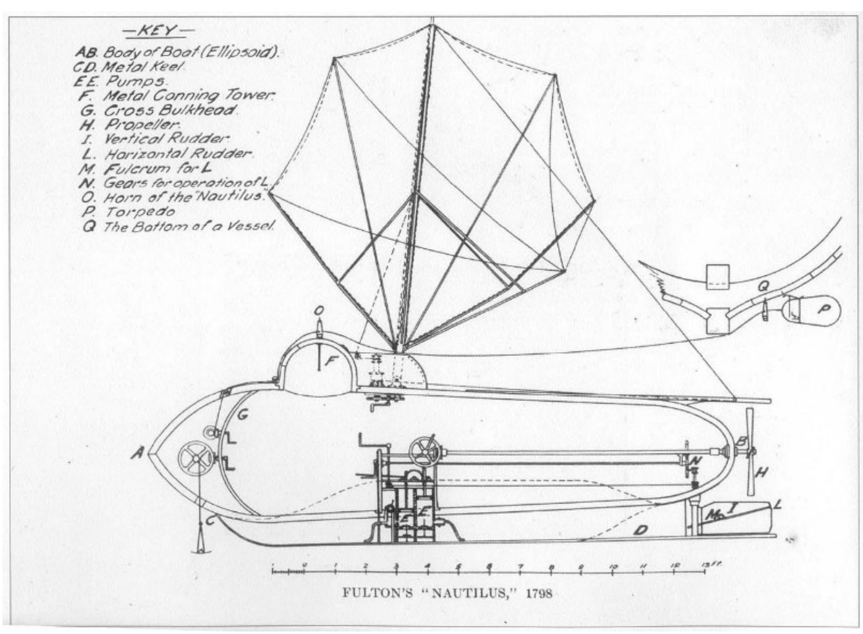


Stevens's first single screw steamboat
Credit: Wikisources

Two years later, Stevens built the first twin screw steamboat, Little Juliana, which operated on the Hudson River. In 1807, he built the larger, sidewheel steamer Phoenix, able to carry passengers in cabins. Prohibited from operating in the area by the Fulton/Livingston steamboat monopoly, Stevens's son, Robert, took Phoenix on an open water passage from New Jersey to operate the boat in Philadelphia. Eventually, Little Juliana was able to operate on the Hudson River between Hoboken and New York City, the first service of its kind in the United States. In later years, Stevens gained a monopoly on New Jersey railroads. Interested in steam locomotives, he built one for his own use and ran it on a track on his land. Stevens died at his home in Hoboken, NJ in 1838. Of note, in 1870, one of his sons (Edwin) founded Stevens Institute. the first technical college in America.

ROBERT FULTON

Perhaps the most famous American steamboat inventor was Robert Fulton, who became known as the father of steamboat navigation. A native of Pennsylvania, he was a prolific artist of landscapes and portraits and earned enough to support himself and buy a home for his family. As a boy of 12, Fulton developed an interest in steam machinery through William Henry, a Pennsylvania state delegate. Fulton showed evidence of tuberculosis when he was 21 and traveled to Europe on the advice of a physician. There, he honed his artistic skills and focused on his mechanical interests and canals. An acquaintance with a wealthy cotton industrialist enabled him to secure financing for his interests in canals. However, he gave up his ideas of dredging machines and inclined planes to haul vessels overland after some initial failures. He then became interested in submarine warfare and steamboats. Heading to Paris in 1797, he studied languages and established himself as an artist and inventor designing a hand-powered submarine, Nautilus, for Napolean Bonaparte.

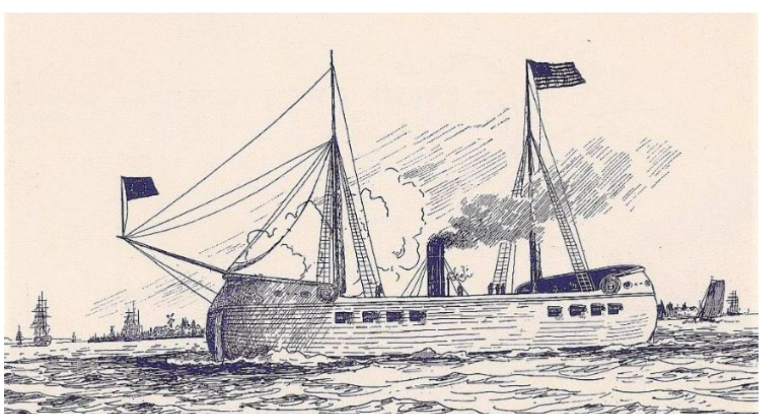


Fulton's Nautilus
Credit: Wikipedia

The French authorities turned down Fulton's proposals a number of times. To sweeten the pot, Fulton said he would not accept payment until his submarine successfully sank a surface vessel. He was allowed to build his undersea warship and test it on the river Seine in 1800. While in France, he met American diplomat Robert Livingston, also with an inventive bent. Fulton found in Livingston a convenient and helpful collaborator. Their first 66' steamboat operated briefly before she sank. Moving temporarily back to England to produce weapons of war, Fulton left for America in 1806. Again, teaming up with Livingston, they successfully built the famous Clermont. Designed to run between New York City and Albany, she could make the trip in better than a day and a half, with or against the current. Livingston, using his political and lawyerly skills (he negotiated the Louisiana Purchase), secured an exclusive right to provide passenger service on the Hudson River. Nicknamed Fulton's Folly, Clermont, over 140' in length, proved herself on August 17, 1807 when she departed for Albany with a full complement of 60 passengers on her maiden voyage. The fare was 5 cents for a 32-hour trip at 5 miles per hour.

North River Steamboat (aka Clermont centennial replica, 1909)
Credit: Wikipedia

Fulton's partnership with Robert Livingston and his brother Edward (a former New York City mayor) enjoyed a monopoly in the passenger trade between New York City and Albany. They could seize and impound other boats attempting to ply the waters of the Hudson River. Shifting their attention to the Mississippi River, they also established river service between New Orleans, Louisiana and Natchez, Mississippi. And they built sturdy boats capable of navigating the Ohio River between Cairo, Illinois and Pittsburgh, Pennsylvania. Fulton revived his interest in warfare and built the first steam-powered warship, USS Demologos. A catamaran-hulled vessel with a paddlewheel between the twin hulls, she was built to guard New York Harbor during the War of 1812. The war ended before she was even designed, but she was eventually finished in 1816. Her only assigned trip was taking President James Madison on a tour of New York Harbor. A few years later, the machinery was removed, and she was laid up in reserve. Robert Fulton died of tuberculosis shortly after, and the ship was renamed Fulton in his honor. She ended her days in the Brooklyn Navy Yard when her magazines exploded in 1829, killing 48 men.



Demologos
Credit: Wikimedia Commons

SAVANNAH—THE FIRST TRY

For a steamship to make it across the North Atlantic under steam power alone was beyond reach in the early 19th century. The Savannah, built in 1818 in New York, was an auxiliary sailing vessel equipped with a 90-horsepower steam engine and two paddlewheels that could be folded like fans when the ship was under sail. Savannah had berths for 32 passengers in 16 cabins. Making the first steam-assisted (her engine ran about 10% of the time) passage from Savannah, Georgia to Liverpool, England, the steam hybrid modestly showed the potential of steam power. Her machinery and 100 tons of coal and wood for fuel took up vast space in the 100' foot hull, reducing her earning capacity. Despite a visit and endorsement by President Monroe, her maiden voyage did not convince a fearful public of the practicality of steam propulsion, and she left on her maiden voyage without passengers.

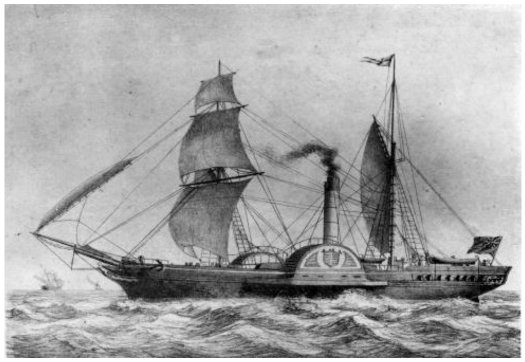
SS Savannah
Credit: Wikipedia

Even finding crew was difficult; sailors called her a "steam coffin." Nevertheless, she began her successful trip to England on May 22. Making around 10 knots, she passed the Pluto, sailing to Europe. As Savannah went by, Pluto's crew gave her three cheers. Nearing Ireland, Savannah encountered Royal Navy vessels. Although initially bewildered by what they saw as a volume of smoke, Navy observers were impressed with her performance. She received a great welcome in Liverpool and toured Denmark, Sweden and Russia. Despite her popularity, she showed no sign of being a commercial success. Returning home on November 30 after a rough passage, Savannah had her engine removed. Running as a sailing packet, she ran aground and was lost on Long Island, NY in 1821. Sixteen years would pass before another steam vessel would cross the North Atlantic.

SIRIUS--STEAM ALL THE WAY

Sirius, named after the Dog Star, was a steam sidewheeler built in Scotland in 1837. Larger and fitted with more powerful machinery than SS Savannah, she was designed for the short sea route between London, England and Cork, Ireland. With a two-cylinder engine rated at 500 horsepower, Sirius could steam at 12 knots, or 14 mph. She held 450 tons of coal, and at an economical speed of just under 8 mph, her range was over 3,300 miles. Her machinery incorporated a condenser that allowed boiler fresh (feed) water to be recycled and kept clear of salt contamination. Previous vessels used ocean water that required periodic stopping to permit cleaning out the boiler of salts.

One drawback was her high coal consumption. Competition was fierce, and other vessels were being built to be the first steamship to cross the Atlantic. Chartered to replace the bankrupt British Queen, Sirius was heaped full of coal and left on April 4, 1838 with 45 passengers and a determined crew to beat her much larger rival, Great Western. Sirius's crew stretched their coal and managed to beat Great Western by 1 day, securing the honor of being the first vessel to cross the Atlantic under steam alone.

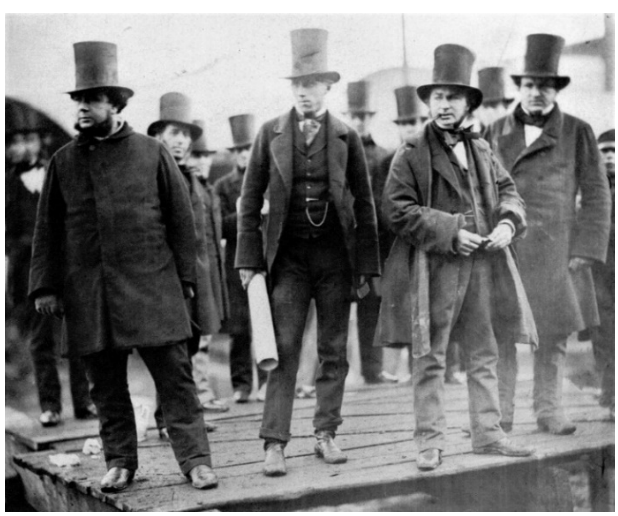


SS Sirius (1837)
Credit: Wikipedia

Considered too small to maintain a viable Atlantic schedule, Sirius returned to her short sea duties. In 1839, her owners submitted a bid to the British Admiralty for a Halifax, Nova Scotia mail service. It was rejected, because Sirius was considered too slow to maintain the service schedule. Continuing her Irish Sea service, Sirius was wrecked after hitting rocks in heavy fog in the winter of 1847. She backed off, and while steaming to shore, hit more rocks and was a total loss. Of 111 on board, 91 were saved. All that remains of Sirius is her paddle shaft, on display in Cork, Ireland.

BRUNEL & RUSSELL

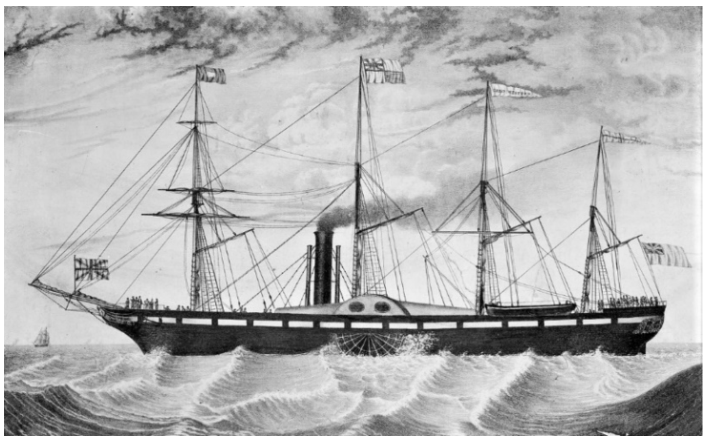
Isambard Kingdom Brunel and John Scott Russell were among the celebrated engineers of the 19th century. Their influence in design and construction in civil engineering and naval architecture was unmatched. Their boundless construction and scientific prowess included great bridges, tunnels, viaducts, steam carriages, the early science of fluid dynamics, steam navigation, railroads (including a pneumatic railway), building design, factory machinery, hospitals, sanitation and artillery. Their crown jewel was the construction of the immense steamship, Great Eastern, in 1859.



Isambard Kingdom Brunel (1806-1859), second from right
John Scott Russell (1808-1882), with roll of drawings
Credit: Wikipedia

GREAT WESTERN

Brunel's first steamship was the Great Western. Built to cross the Atlantic, the heavily built four-masted vessel's wooden hull was strengthened with iron strapping. Conducting trials in March of 1838, the ship was heading to her home port of Bristol when a fire was discovered in the engine room. It was quickly put out, but not before Brunel was seriously injured in a fall. Passengers scheduled to travel on the ship backed out, and only seven paying passengers stayed on board. Great Western arrived in New York 1 day behind Sirius, having left 4 days after the smaller vessel. Great Western was a success and established design criteria for a generation of paddle steamers. She maintained her schedule for 8 years and crossed the Atlantic 45 times. But, when her owners' fortunes collapsed, she was sold and put on a South American service before being converted to a transport in the Crimean War. She was dismantled for scrap in 1856.



Great Western
Credit: Wikipedia

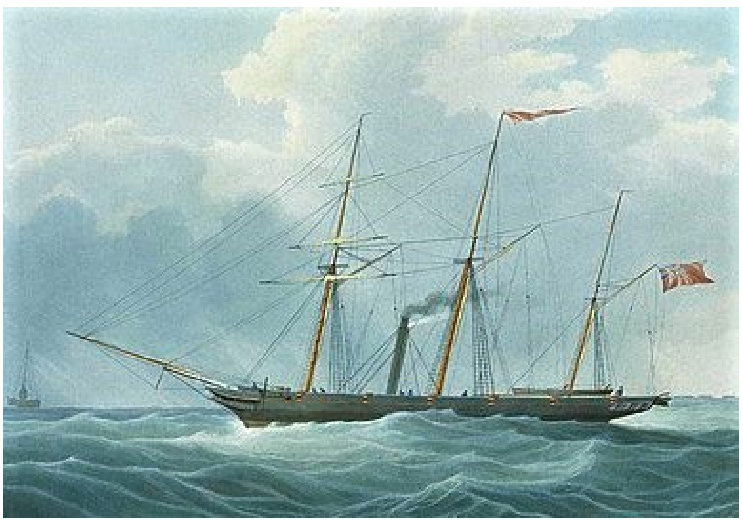
John Scott Russell was focused on ship hull design and how to reduce frictional resistance of water against the hull. It came down to either moving water forward, with a round bluff bow, or cleaving through it with a sharp hollow bow. He also considered the shape of the stern to reduce resistance. Although it seemed to make sense that the displaced water could fill in just as easily after the bow cleaved it, Russell discovered that flat but somewhat rounded transverse sections in the stern allowed the wake to easily leave the hull without creating eddies and undo drag.

During the heyday of clipper ships in the 1850s, hulls could be made faster by having long, hollow bow entries. But, full advantage of Russell's hull design couldn't be realized, because sailing vessels were somewhat double-ended, and the sterns were essentially shaped like the bows: deep, long and hollow. Incorporating Russell's flatter hull form wasn't possible. Also, the hulls' fine lines reduced cargo capacity, so more modest hull shapes were adapted. Russell's "wave line theory" experiments in 1848 revealed variations in wave frequencies, identifying and confirming the theoretical work of Christian Doppler in 1842. With his railway work winding down, Russell turned his attention once again to shipbuilding.

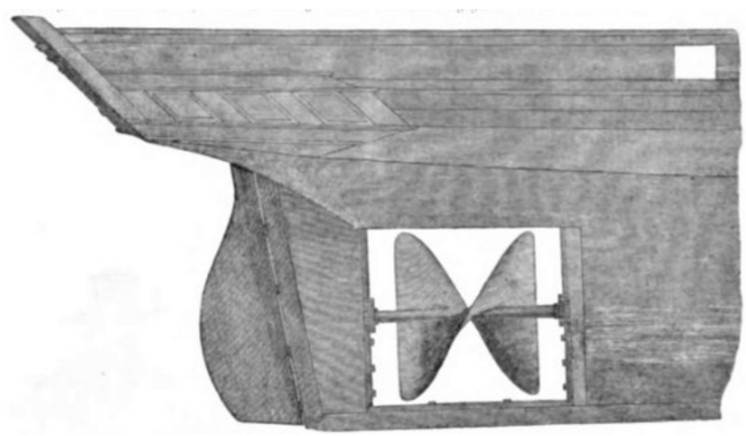
GREAT BRITAIN

Brunel was eager to build a second vessel. Learning that the 213' packet ship Rainbow of 1838 was built of wrought iron, Brunel sent two colleagues to evaluate her performance. They returned, true believers in iron ship construction. Brunel became one too and made his next project an iron ship.

It was about this time that Russell got into shipbuilding, incorporating his wave theory into ship construction. Eventually buying his own shipyard, he built two vessels for Brunel for the Australian trade. Great Western, Brunel's first ship, carried enough coal to comfortably cross the Atlantic, but he wanted his second ship to have greater fuel radius. It was falsely believed that an iron ship would never pay on an ocean route, because of its weight and the amount of coal that would be needed. But, the strength of iron was so much greater than wood, an iron ship would actually be lighter. Without the need for huge timbers to provide structural strength, iron allowed for smaller members that would provide additional volume to carry more cargo, fuel and passengers. Iron ships also were less prone to flexing than wooden hulls, reducing the risk of leaks and damage. Riveted iron hulls were more homogenous and elastic and recovered from the huge strains imposed by ocean waves. Brunel first considered paddlewheels but switched to a propeller after observing the single-helix iron propeller of the wooden topsail schooner Archimedes. Brunel was also influenced by John Penn, prolific engine builder and screw propeller designer for the Royal Navy. John Penn was contracted to build the Great Britain's propulsion machinery.



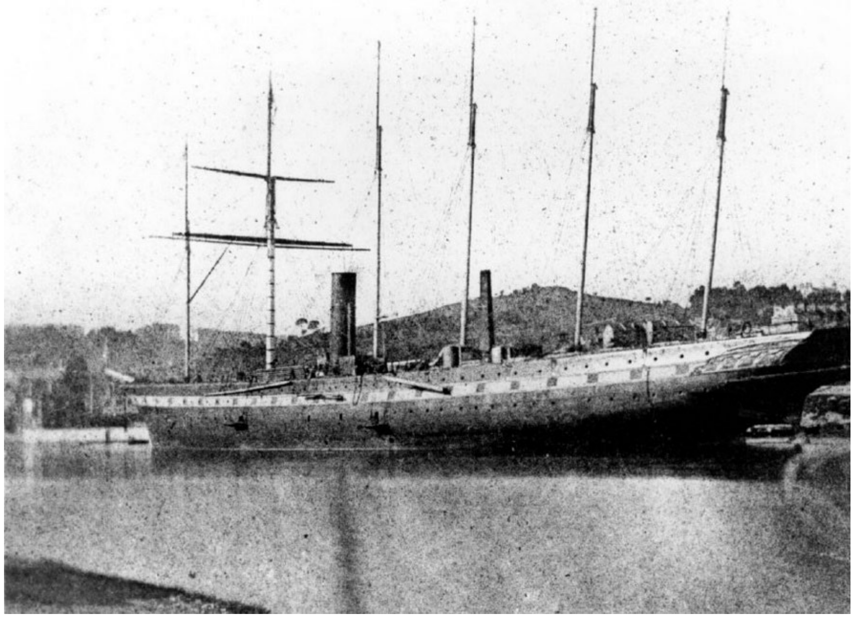
SS Archimedes
Credit: Wikipedia



SS Archimedes helix propeller
Credit: Wikipedia

Brunel immediately saw the advantages of screw propulsion. The machinery was more compact, improving stability and the ship's ability to withstand rough conditions. It saved weight by not requiring additional components to turn cumbersome paddlewheels; it got rid of paddle boxes, which were prone to damage; and there was more room for cargo and unencumbered passenger areas. Moreover, the fully submerged propeller was far more efficient than paddles and less affected by rolling in rough seas; with the machinery low in the hull, the ship was more stable. Brunel enhanced his propeller design, decreasing the blades from six to four; it was over 15' in diameter.

Great Britain was the largest ship in the world, longer than a football field and half as wide. Penn's 1,600 horsepower engine was the most powerful of its day and revolved the single propeller shaft placed deep within her hull. She had a double hull and watertight compartments, making her immensely strong and safe. Her six masts could spread canvas to use the wind when necessary. Launched in 1843, the ship began regular service to New York from Liverpool. At nearly 3,700 tons displacement, she had a crew of 130 and carried nearly 300 passengers. On her maiden voyage, Great Britain took just 14 days to arrive in New York.



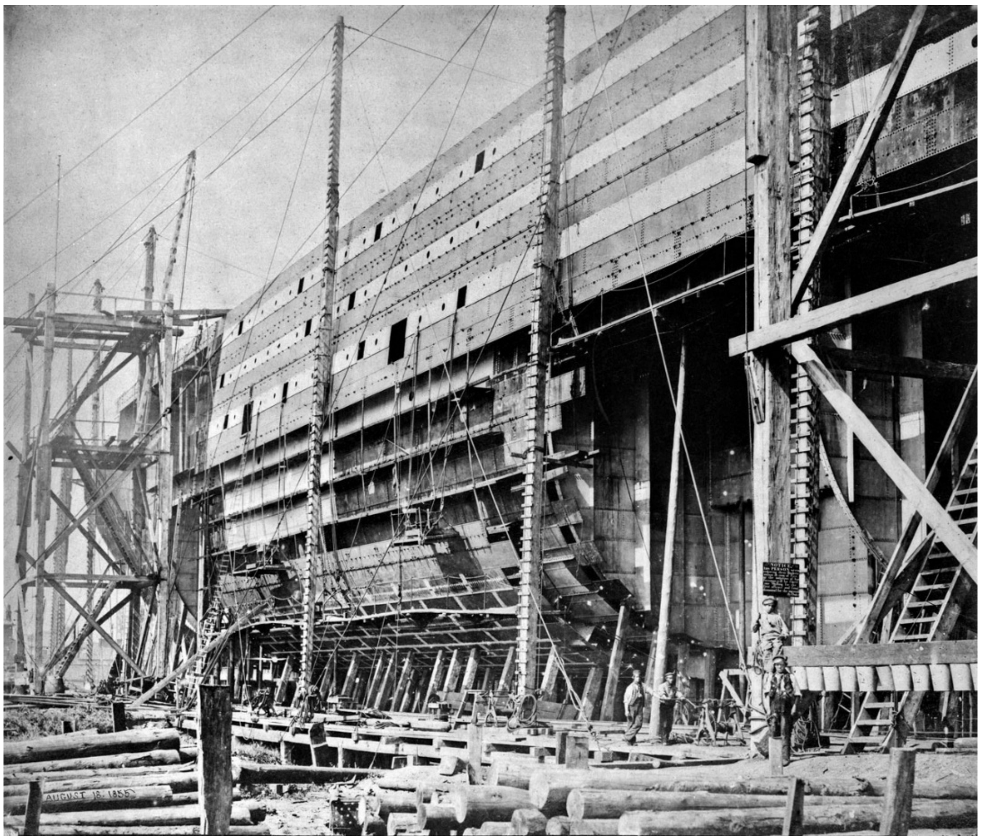
SS Great Britain
Credit: Wikipedia

Great Britain's second passage took only 13 days; she averaged 13 knots. Unfortunately, she ran aground on her fifth voyage. An inaccurate chart put her on the northeast shore of Ireland. Everyone was evacuated, and a series of structures were built to protect the hull from heavy seas. She endured for nearly a year; her strained plates let sand enter the hull, but there was little other damage. Finally hauled off and repaired, the unfortunate event cost the company dearly; it lost the mail contract. Great Britain was put up for sale and sold for a fraction of her building cost. Refitted, she made another trip to New York, then was transferred to the Australian run. After a stint as a troopship in the Crimean War, she resumed her passenger service. By 1870, her passenger days over, she carried coal. Stripped of her machinery, she was converted to a sailing vessel. She made her last trip in 1886, being wrecked in the Falkland Islands at the southern end of South America. But the old ship wasn't yet done. Stripped of her upperworks and spars, she was used as a coal bunker and wool storage for 50 years. Scuttled in 1936, Great Britain was rescued, placed on a barge and towed home to Bristol. Restored, she survives today as an outstanding example of the mid-19th century engineer's daring and expertise.

SS Great Britain preserved in Bristol
Credit: Wikipedia

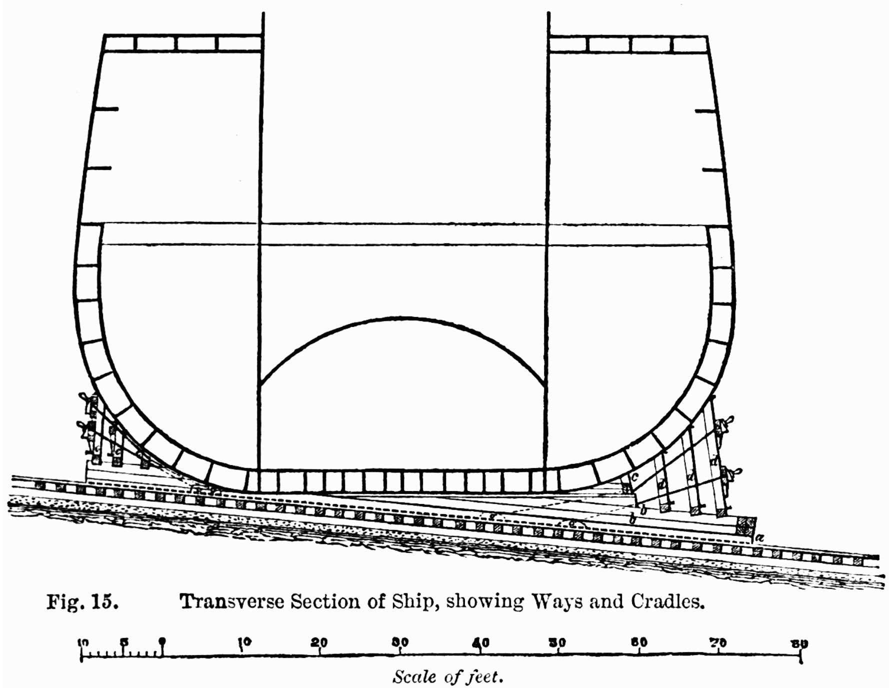
GREAT EASTERN

The United Kingdom ruled the waves and crisscrossed the globe with extensive trade routes: from the Americas to the Middle and Far East and Australia. Sailing vessels had no fuel concerns. Using the wind, they could stay at sea as long as ship and crew were sound and provisioned. Power vessels had to carry their wind in their coal bunkers, and refueling ports were few on oceanic routes. To exploit worldwide business opportunities, larger ships were needed that could carry enough fuel to make a non-stop passage to India and Australia. In the 1850s, a vessel with such capabilities would be immense and tax the building and design abilities of the day. Brunel and Russell took up the challenge. They built a vessel with an immensely strong double hull and excellent subdivision.



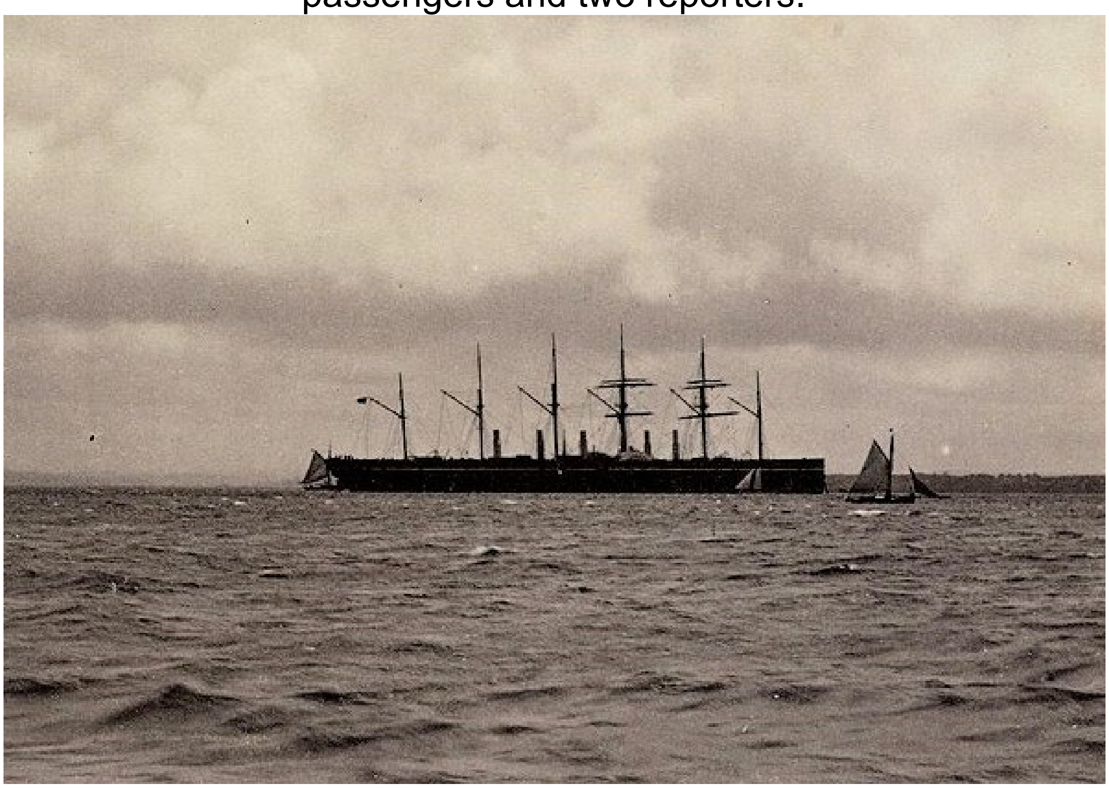
Great Eastern showing complex hull structure
Credit: Wikipedia

Brunel first contemplated a 600’ ship, six times bigger than the largest ship afloat at the time. Teaming up with Russell, the dimensions grew to nearly 700’ long and 32,000 tons displacement, powered by a single screw and two paddlewheels 60’ in diameter. Four engines were fitted, two each for the propeller and paddlewheels, producing a total of 8,000 horsepower, enough to drive her at 14 knots (16 mph). She carried six masts and spread over 18,000 square feet of sail. The goal was to garner the lion’s share of trade to India and Australia in one grand technological sweep. Able to bunker 15,000 tons of coal, the Great Eastern was capable of a non-stop passage to Australia without refueling. She could carry 4,000 passengers and lift thousands of tons of cargo. Brunel and Russell had their differences; Russell wanted to avoid a land-to-water launch and advocated building the ship in a drydock, but none large enough existed, so Brunel developed a sideways launching system.



Launch cradle transverse arrangement for Great Eastern
Credit: Wikipedia from the Life of Brunel

Russell underbid the work and suffered financial losses that further strained his relationship with Brunel. Great Eastern proved difficult to launch; there were several accidental deaths. She was finally afloat on January 1, 1858, 2 months after the first launch attempt. American and Canadian ports were keen to receive the new ship, but New York prevailed by undertaking extensive dredging and pier construction to accommodate the vessel. Preparing to leave for her maiden voyage, she suffered a boiler explosion that killed six firemen. Brunel had invested his life and reputation into his “Great Babe,” and the news was too much for the 53-year-old engineer; he died of a stroke shortly after. She sailed on her maiden voyage with only 35 passengers and two reporters.

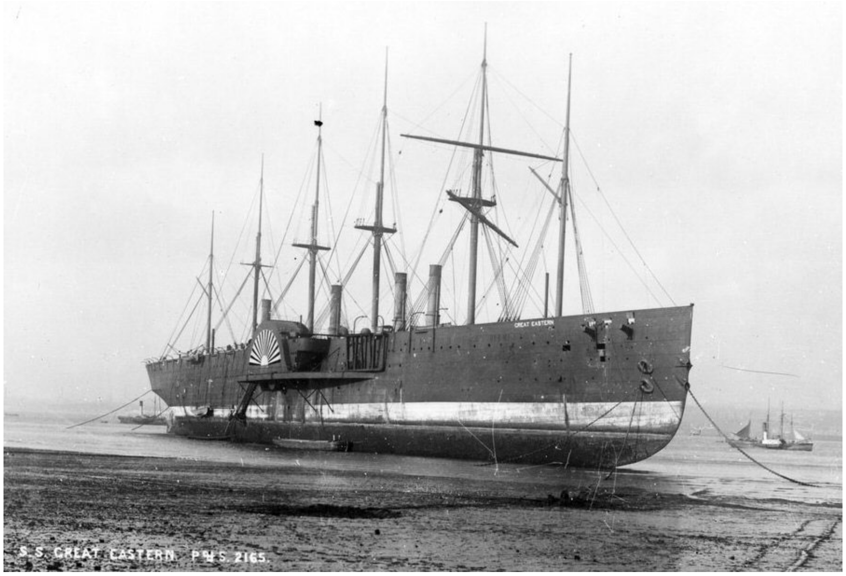

Great Eastern preparing for her maiden voyage
Credit: Wikipedia

Although well received by a large crowd in New York, Great Eastern did not do well on the New York run. She was seriously damaged during a hurricane, then hit a submerged rock off Long Island in 1862. This required expensive in-the-water repairs using an external cofferdam to seal the hole, so men could work in dry conditions on the hull plating with the ship afloat. Bringing in minimum profits and sailing well below her passenger capacity, Great Eastern proved to be the technological marvel that was an economic flop. Eschewing the profitable immigrant trade for a higher end market, Great Eastern lost money and was put up for auction in 1864.

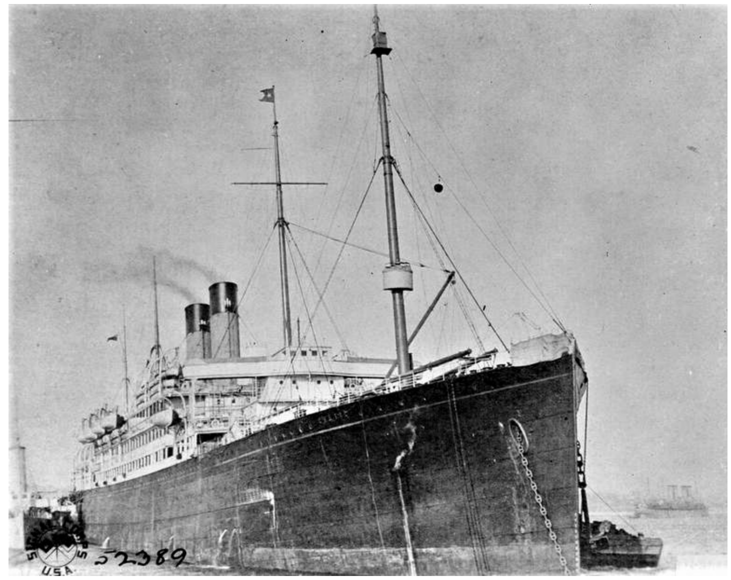
Great Eastern dining saloon
Credit: Wikipedia

Purchased by some of her former owners, she was rented out to Cyrus Field, who planned to lay telegraph cables across the Atlantic. Great Eastern was modified for the work and laid the first successful Atlantic cable from Ireland to Newfoundland. With her huge holds, cable laying was the perfect job, and she crisscrossed the Atlantic with cables until 1869, when her economic viability was hobbled by the opening of the Suez Canal.

Before the Suez Canal, ships had to sail south in the South Atlantic and round the Cape of Good Hope for access to the Indian Ocean and points east. Or goods had to be unloaded in the eastern Mediterranean and carried overland to the Red Sea. Unable to use the canal because of her great beam and paddlewheels, Great Eastern was returned to her previous liner service. However, she was unable to earn a profit. Laid up and idle, she found herself in the way of waterfront development and was fast becoming an eyesore. Being afloat, she had accumulated hundreds of tons of marine growth and became the focus of naturalist Henry Lee, who studied the marine creatures who called Great Eastern home. Sold at another auction in 1885, she became an advertising venue for a department store. She wound up at the Liverpool Exhibition where, after hitting a tug, she was sold to salvage interests. Many schemes, none realistic, were submitted for the aging ship, but in 1888, she was sold for scrap. It took a year and half to dismantle her. The last bits were removed in 1889, but not before a rumor circulated that the body of a trapped riveter (or two) was found in her double hull. The tale was never proven but remained part of Great Eastern lore. White Star's Oceanic was the first ship to exceed Great Eastern in length, in 1899. Two years later, the White Star liner Celtic was the first ship to exceed Great Eastern in tonnage.



Great Eastern for scrap
Credit: Wikipedia



RMS Celtic
Credit: Wikipedia

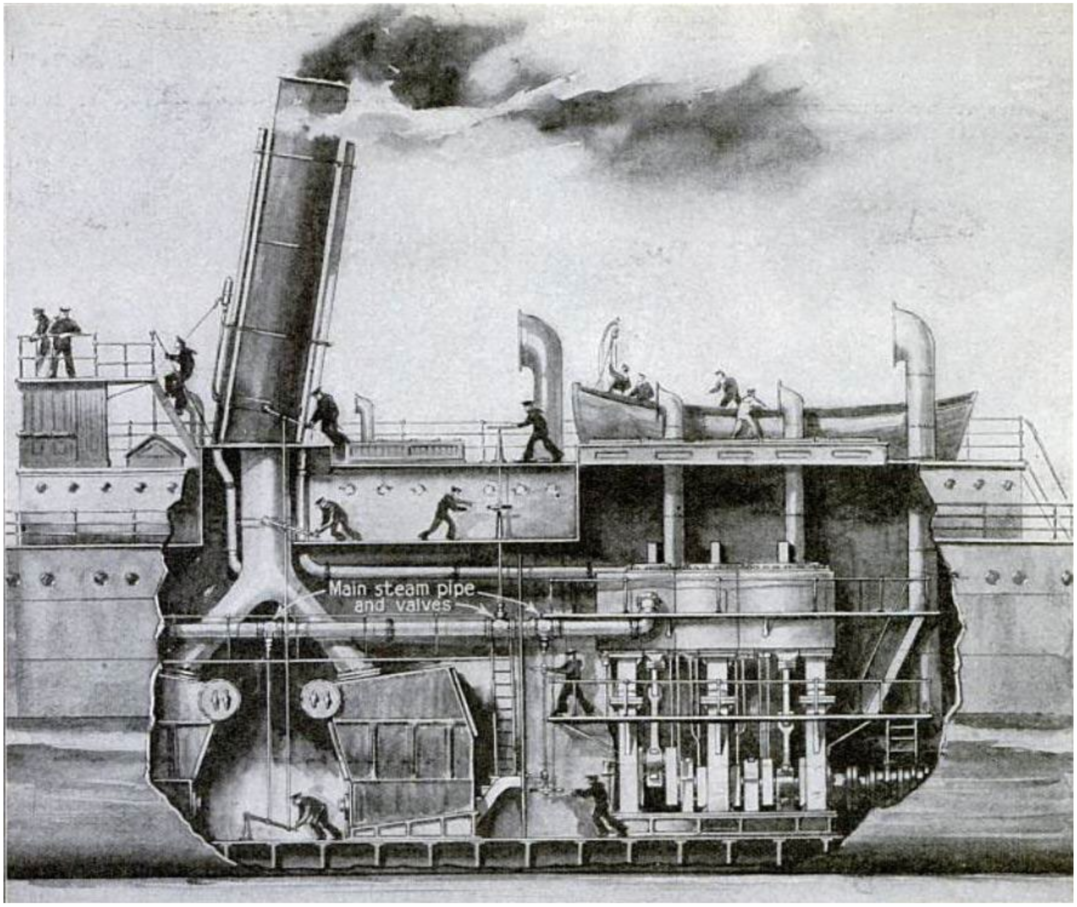
THE FIRST & SECOND INDUSTRIAL REVOLUTION (1760-1914)

The promise of more goods made by machines at cheaper prices became an obsession in Great Britain in the mid 18th century. Aided by new methods of banking and finance, the science of manufacturing, from chemical advances to iron making to textiles, using steam and water power, greatly increased the output of goods and expanded trade. Great Britain led the way in maritime expansion, innovation, inventions and manufacturing techniques. Wealth followed, and an affluent class emerged that controlled shipping and manufacturing. The hopes and promises of increased production were not universally realized, however. An exploited labor force maximized profits, but social benefits (decent housing, sanitation, disease prevention, childhood education) lagged behind material production.

During the Second Industrial Revolution, new ship construction methods came to the fore. Britain, being timber poor from centuries of resource exploitation, led the way in the mid-19th century with strong iron ships capable of resisting the racking and vibration from bigger machinery. Larger ships with greater earning capacity were envisioned. They would require powerful machinery to satisfy the demands of the transatlantic ferry schedule. Innovation in marine steam engines took off by leaps and bounds, producing a cavalcade of innovative engine designs. Mechanics and engineers brilliantly adapted to this new environment.

MARINE STEAM ACCELERATES

Design innovation in marine steam engines proliferated, especially in the latter half of the 19th century. Engines came in several basic configurations: vertical (crankshaft above the engine), inclined (the head of the engine in the hull bottom, crankshaft at deck level), horizontal (head and crank at the same level) and inverted (with the crankshaft below the engine). Horizontal and inclined engines, less susceptible to vibration, were developed to keep the center of gravity low. They were useful in warships, where a low engine was easier to protect against gunfire. These works culminated in the great steam reciprocating engines that saw their zenith in the premier liners of Europe and Britain of the early 20th century.



Cutaway of steam vessel with an inverted steam engine (crankshaft below pistons) and boilers (under funnel)
Credit: Wikipedia

TYPES OF 19TH CENTURY ENGINES

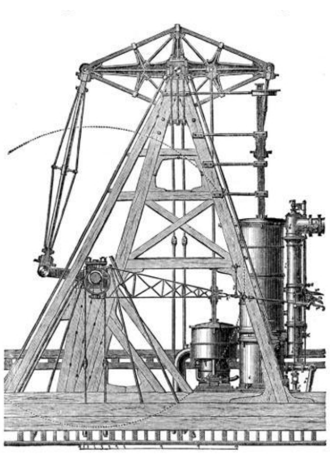
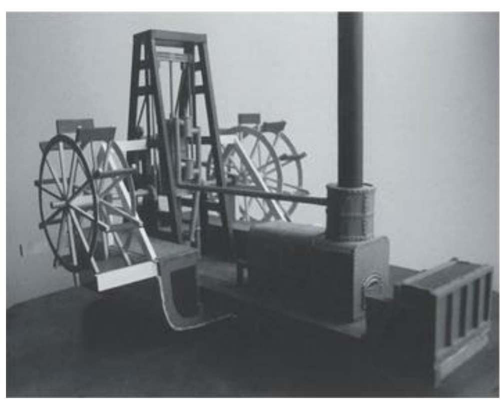


Fig. 180.—Beam-Engine.

Walking-beam-engine
Credit: Wikipedia


Crosshead engine
Credit: Wikipedia

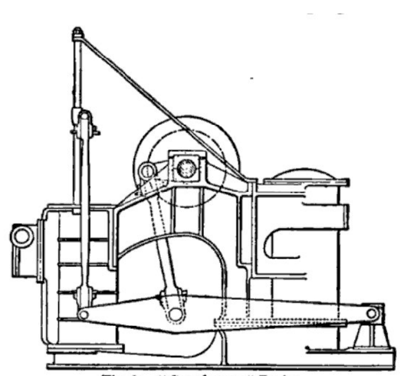
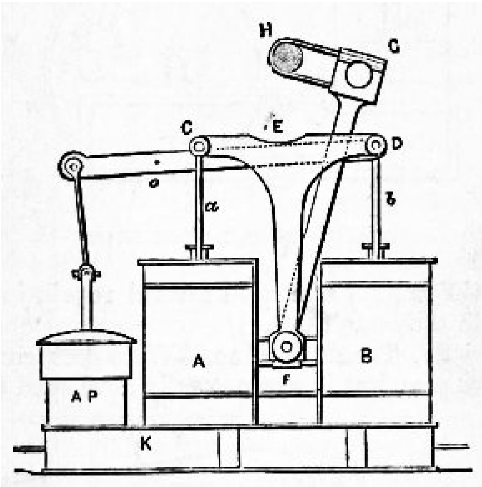
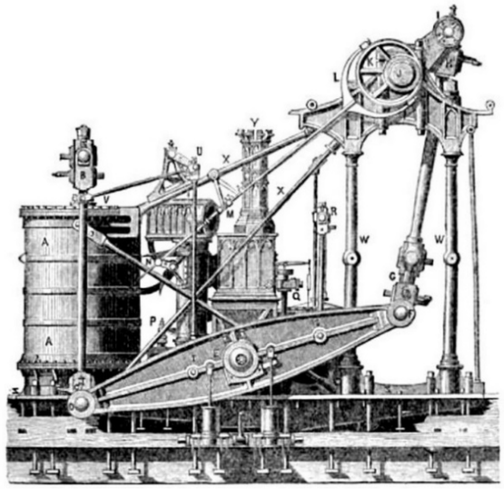


Fig. 3.—"Grasshopper" Engine.

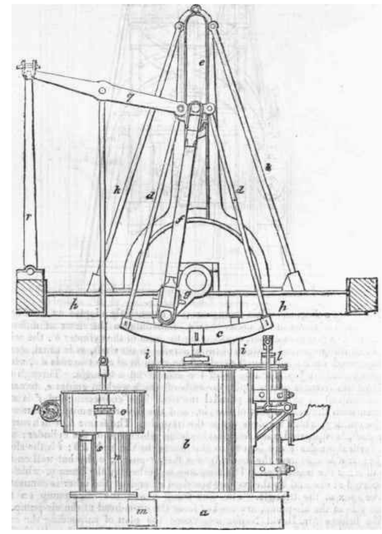
Grasshopper engine
Credit: Wikipedia



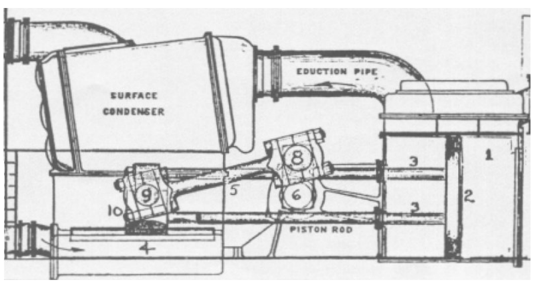
Siamese engine
Credit: Wikipedia



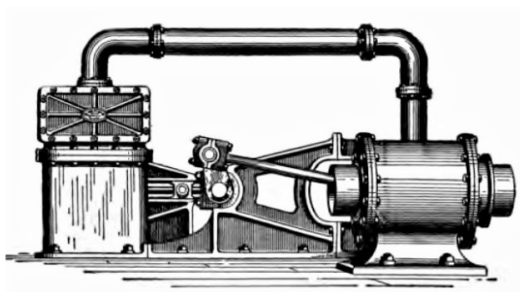
Side lever engine
Credit: Wikipedia



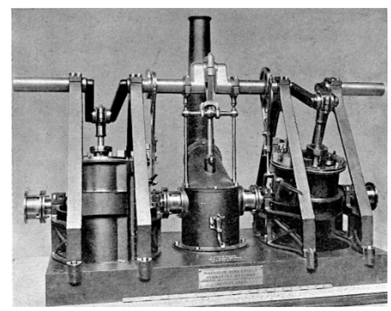
Steeple engine
Credit: Wikipedia



Emory back-acting engine
Credit: Wikipedia

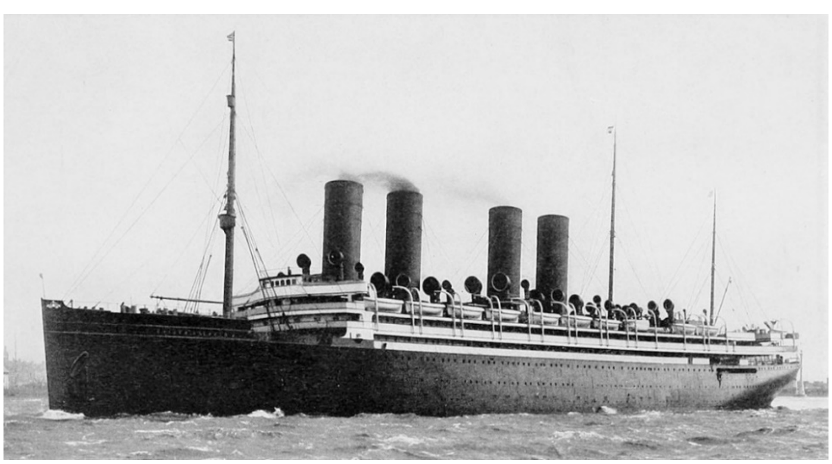


Trunk engine
Credit: Wikipedia

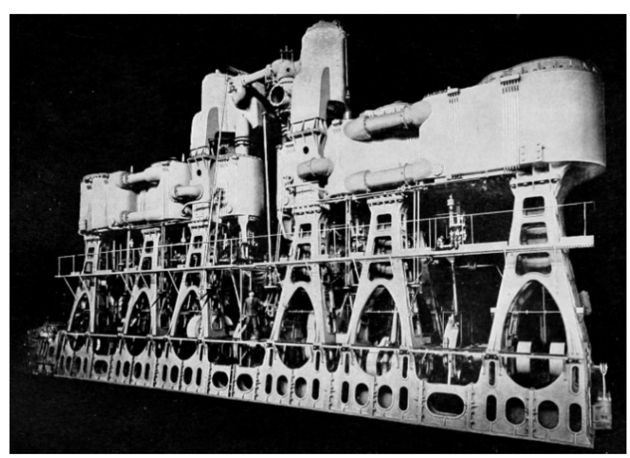


Maudsley oscillating engine
Credit: Wikipedia

The apotheosis of the marine reciprocating engine was probably the installation aboard the two big German sister ships Kaiser Wilhelm II (1902) and Kronprinzessin Cecilie (1906). These twin-screw liners, built to be converted to armed merchant cruisers in wartime, were fitted with four quadruple expansion engines, two on each shaft, delivering a total of 31,000 horsepower. The engines could be operated independently in case of damage. Steam was taken at 225 psi and was expanded four times to get as much energy as possible. The machinery was complex, with thousands of moving parts.



Kaiser Wilhelm II
Credit: Wikipedia



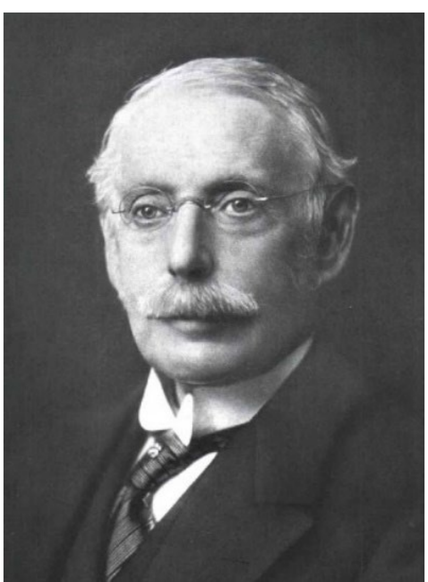
Paired quadruple reciprocating machinery
Credit: Wikipedia

THE STEAM TURBINE

The turbine made its dramatic debut at the 1897 Spithead Naval Review for Queen Victoria's Diamond Jubilee. Battleships, cruisers, destroyers and other naval vessels lined up to salute the queen on her yacht Victoria & Albert, and her guests aboard the premier Cunard liner Campania. Three hundred yachts joined with numerous excursion vessels to view the 165 British and foreign ships and 50,000 sailors. American newspapers declared the naval review to be a spectacle without parallel in history. It came with a surprise: a diminutive vessel, long and narrow, darting between the great battleships. Called Turbinia, she was the brainchild of Charles A. Parsons (1854-1931). Evading the patrol boats assigned to guard the battleships, she tore through the water at the unheard-of speed of 34 knots.

Turbinia (foreground) surprises the fleet, 1897
Credit: Wikipedia

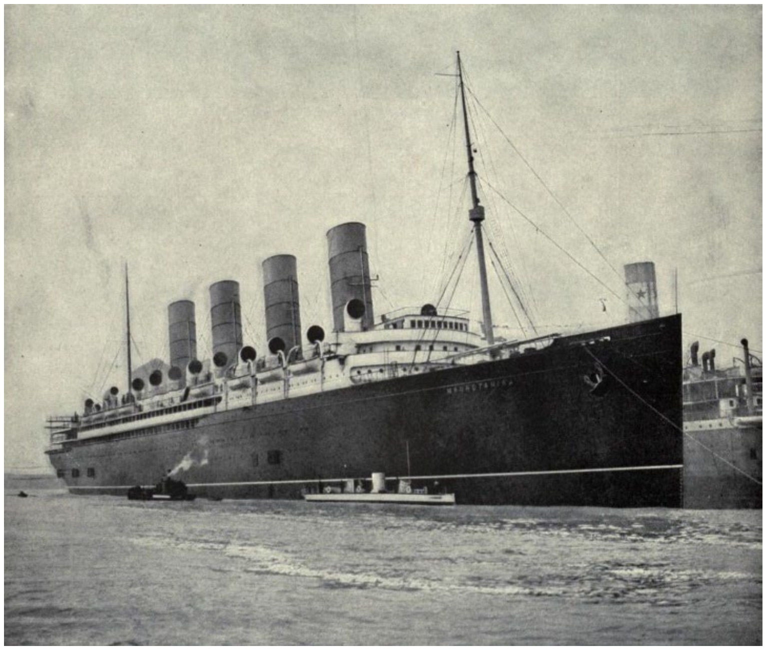
Parsons had built his first turbine in 1884. It turned 18,000 rpm, and he connected it to a generator to produce electricity. Ten years later, his revolutionary engine powered Turbinia. Rather than pistons, connecting rods and crankshafts, the turbine had one moving part: a rotor surrounded with fan blades. Rather than steam expanding in stages, directed by piping and determined by piston size, the steam pushed against circumferential rotor blades in the manner of a pinwheel, traveling through and expanding smoothly on ever larger diameter rotor blades.



Charles A. Parsons
Credit: Wikipedia

Turbinia
Credit: Wikipedia

When an unsuccessful test caused the Royal Navy to ignore Parsons, he made numerous improvements—and decided to present his nimble vessel in an eye-catching entrance before the Queen, her entourage, and especially the Navy. In less than 10 years, Parson's turbines were installed on the two Cunard greyhounds, Lusitania and Mauretania.



RMS Mauretania with Turbinia alongside
Credit: Wikipedia

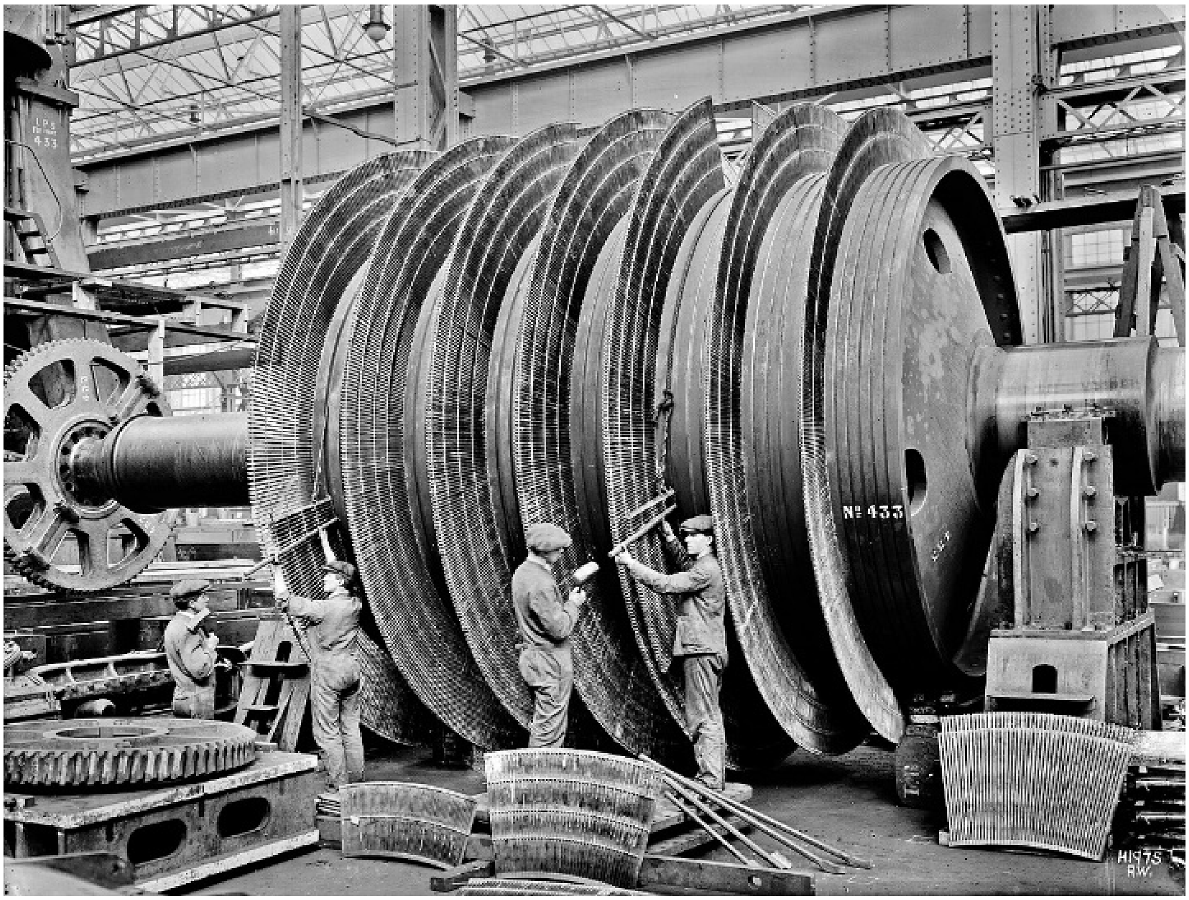
Power had increased 40-fold, and both ships won the Blue Riband of the Atlantic for the fastest crossings. The turbine became the dominant propulsion unit for most transatlantic and other liners. It also powered Dreadnaught, the first all big gun fast battleship in the Royal Navy.

Turbines required less manual attention, and the cacophony and slinging water and oil were replaced by relative quiet and cleanliness. But the turbine had drawbacks. It could not be reversed and required separate astern blades so a vessel could stop or maneuver. This complicated the machinery. To be efficient, turbines had to spin at high speed, but propellers operated efficiently at low revolutions to reduce vibration and prevent the violent tearing of water known as propeller blade cavitation (where the speeding blade tears the water and it implodes on the surface of the propeller blade, damaging it). Early turbines were direct-drive, heavy, large in diameter and slow to match propeller revolutions. Eventually, gear cutting was perfected, and turbines (still with separate reverse turbines) could be kept small, rotating at their preferred high speed, while the propellers could revolve at their efficient low speed.

Turbines also had the advantage of exhausting at a lower steam pressure than reciprocating machinery. When the advantages of reciprocating and turbine machinery were joined, combination machinery was born.

COMBINATION MACHINERY

Reciprocating and turbine combination machinery was attractive to ship operators. Considered more economical than pure turbine or reciprocating machinery, the system also had the advantage over turbine propulsion of using the two wing propellers capable of full speed astern and ahead, a distinct advantage in close quarter maneuvering. A low-pressure turbine would take exhaust steam from the engines and use it to a lower pressure before it was sent into the condenser, improving fuel economics. In 1908, the first combination machinery was installed in the New Zealand steamer Otaki. The ship had three propellers; the outer ones were driven by reciprocating machinery, while the center propeller was powered by a low-pressure turbine. Otaki's sisterships had two shafts with standard reciprocating machinery. The combination system was more expensive to install, and there are no records regarding fuel economy between the sister ships. But other vessels were built with combination machinery, and White Star experimented with two sisters in 1909, Laurentic and Megantic. The former, with combination machinery, proved more economical. The decision was made to power the first superliners of the Olympic class with combination machinery.



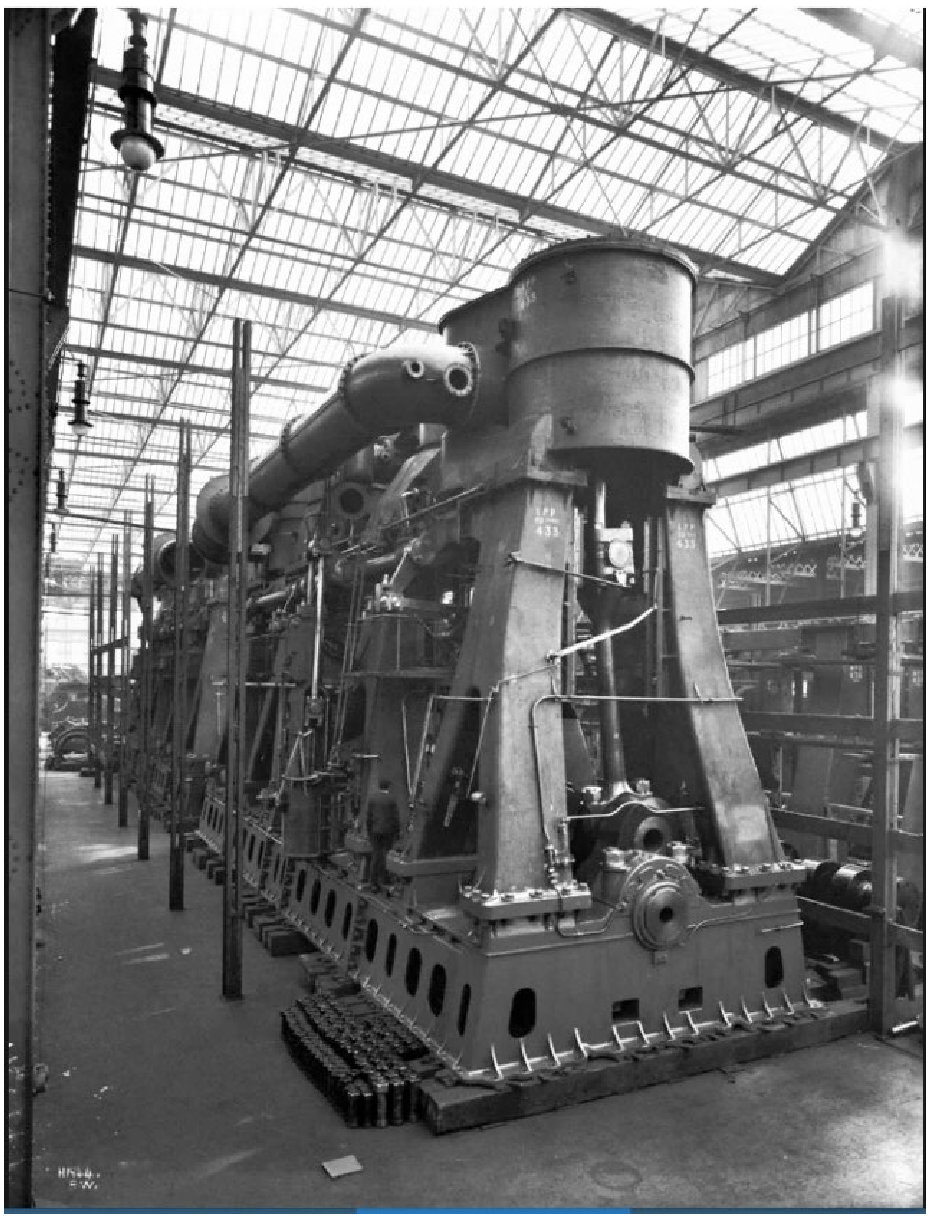
Turbine rotor with blades being attached on Titanic's younger sister, Britannic.
Credit: Wikimedia Commons

TITANIC

On Titanic, each of its two triple-expansion, four-crank reciprocating engines weighed in at about 1,000 tons, and the two engines could develop about 30,000 horsepower. The turbine engine was 420 tons and developed 16,000 horsepower, after taking exhaust steam from the two reciprocating engines. The estimates were conservative, and at full power, 55,000 horsepower could be developed.

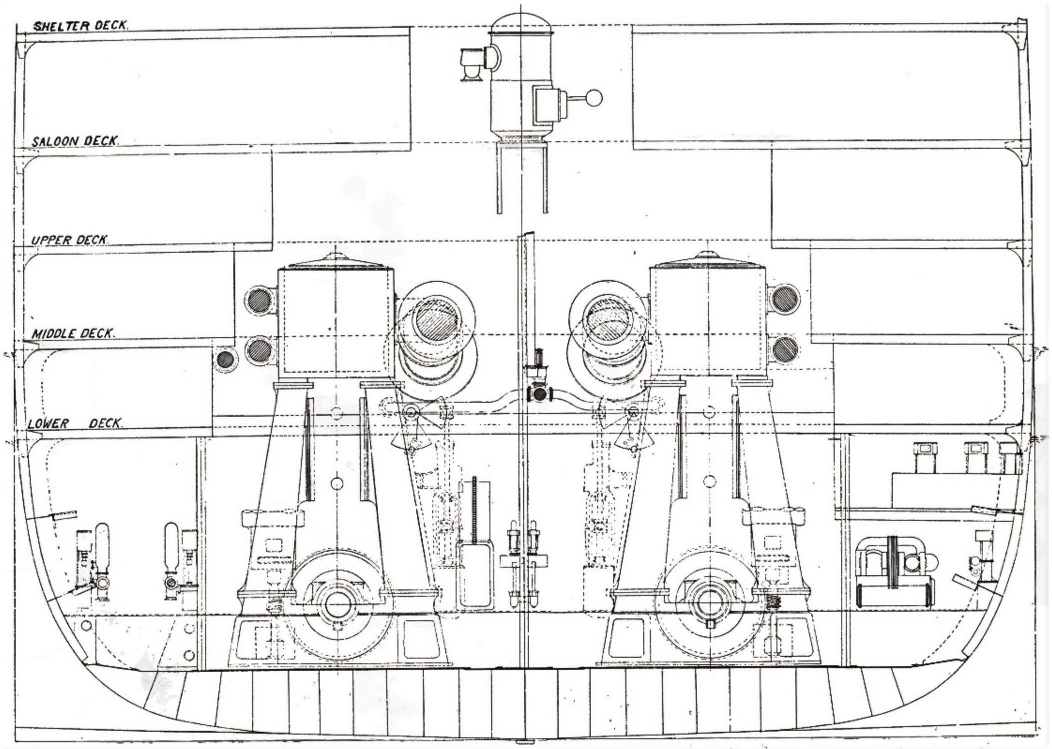
In the reciprocating machinery, the steam was expanded in three stages, hence triple expansion. The pistons used the steam pressure from 215 psi to 9 psi. There were four pistons: high pressure, intermediate pressure and two low pressure pistons with a 6'3" stroke, the distance the piston traveled up and down. To permit the steam to expand and do its work before exhausting, the low-pressure stage had to have sufficient area to accept the expanding steam. One huge piston would be cumbersome, so the engines were balanced on what was known as the Yarrow, Schlick and Tweedy systems. Rather than one big piston, the required area was divided by two, with one low pressure piston fitted at each end of the engine for the last expansion stage. At this point, the steam left the engines at 9 psi. The turbine took this 9 psi and used it down to 1 psi, then exhausted into the condensers that cooled the steam into fresh water for reuse in the boilers. In the process of traveling through the reciprocating engines and turbine, the steam expanded to about 100,000 cubic feet in volume.

The turbine was only used at sea, not in port. When the ship cleared harbor, and the reciprocating engines were turning at about half their full 75 revolutions, the turbine engine was cut in, receiving the reciprocating engines' exhaust steam. This was accomplished through two change-over valves that directed the engine exhaust steam from the reciprocating engines to the turbine to the condensers. Only then could Titanic run up to her full revolutions and speed. The procedure was reversed as Titanic entered port: the reciprocating engines were slowed, the changeover valves shifted to exhaust the reciprocating steam directly into the condensers, and the machinery operated as a two-engine reciprocating unit, the turbine propeller being idle.

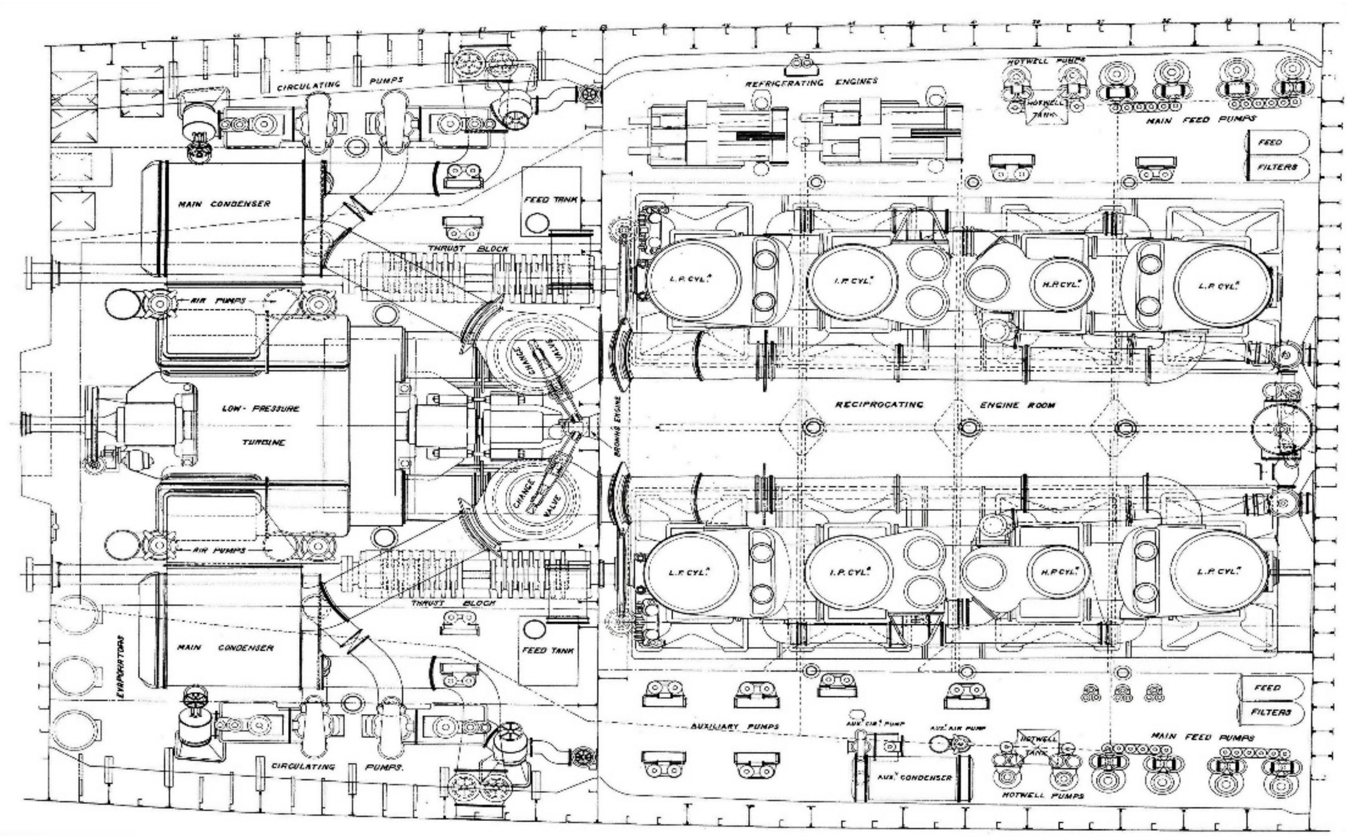


One reciprocating engine for Titanic's younger sister, Britannic.
Credit: Wiki Fandom

The two reciprocating engines were housed in their own compartment, while the turbine occupied the space immediately aft. The three engines were not mechanically connected. Steam was the only link that made the units work together.

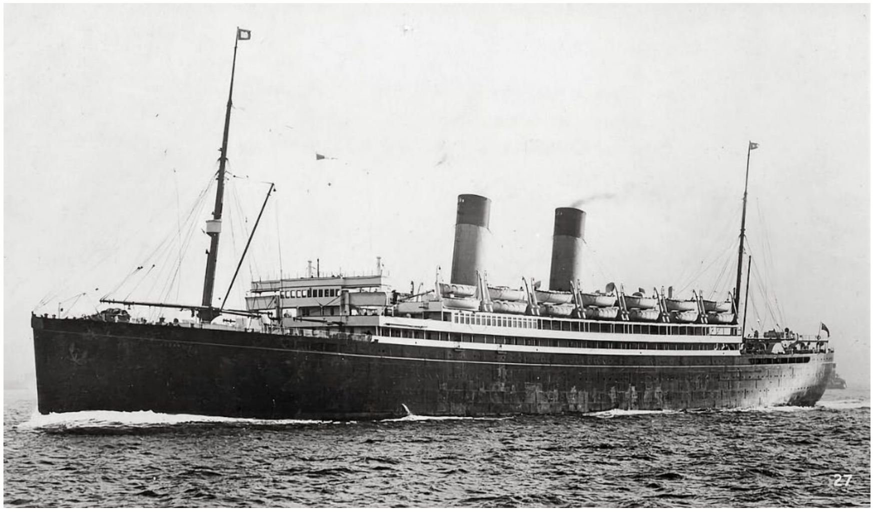


Section through reciprocating engine room
Credit: Shipbuilder, 1911 special edition



Plan of engine room showing reciprocating engines forward, turbine aft
Credit: Shipbuilder, special 1911 edition

Although not taking as daring a technological step as Cunard with their turbine ships, White Star had success with combination machinery. Nevertheless, it was in use for barely 20 years. The last steamship built with the system was White Star's 1927 Laurentic. (The first Laurentic, also with combination machinery, was built in 1909 and sunk during WW1).

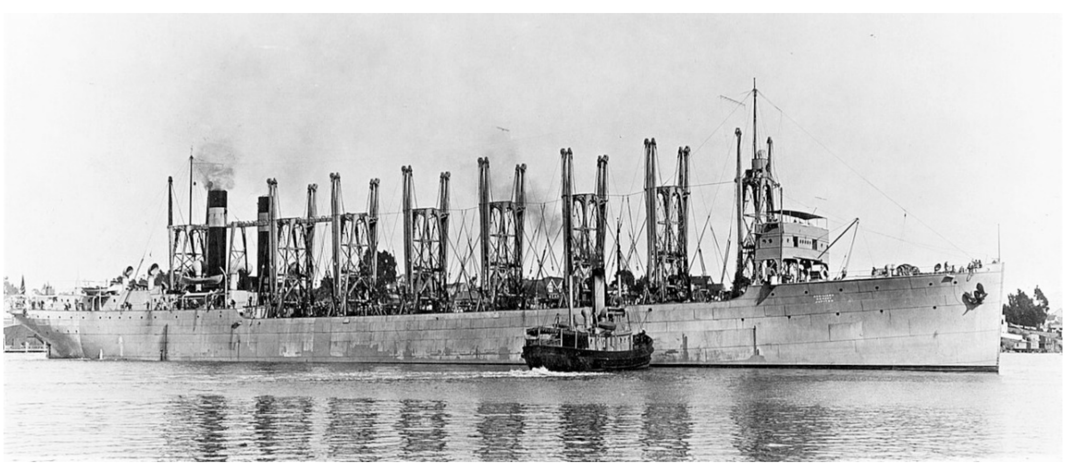


SS Laurentic (1927)
Credit: Wikipedia

The advent of accurate gear cutting and higher steam pressures, impossible to use in a traditional steam engine, led to the demise of combination machinery. About the time that combination machinery was in its heyday in Titanic and her sisters, turbo-electric machinery and Skinner Unaflow engines were making their appearance.

TURBO ELECTRIC

The efficiency of high-speed turbines could not be denied. Marine turbine-driven generators appeared, and Lusitania and Mauritania were each fitted with four Parsons units. In 1911, the US Navy took the audacious step of fitting turbo-electric propulsion to the twin-screw collier USS Jupiter. In this system, the fast-turning turbine spins a generator to produce electricity for an electric motor coupled to the propeller shaft. This arrangement requires more machinery, but the efficiency of the turbine and the flexibility of an electric motor supply the same power in reverse as ahead. Difficulties between the turbines and electric motors that surfaced during trials were resolved by design modifications.



USS Jupiter
Credit: Wikipedia

By 1920, Jupiter's power plant proved reliable and the Navy converted her to the USS Langley, their first aircraft carrier. The Navy further extended its turbo-electric ambitions in the 1917 battleship USS New Mexico, with other turbo-electric powered battleships to follow. The Navy converted two battle cruisers into two large, fast aircraft carriers, USS Lexington & Saratoga. Their speed of 34 knots was unmatched by any other large naval vessel.

USS New Mexico
Credit: Wikipedia

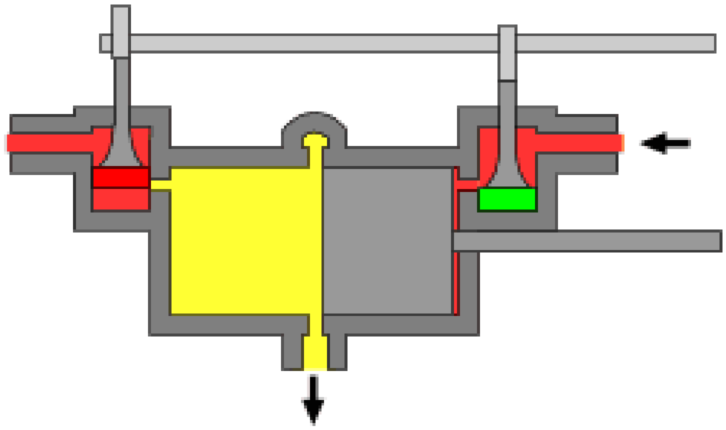
USS Lexington
Credit: Wikipedia

Catching the eye of French naval architects, turbo-electric power had its greatest expression in their giant 30-knot liner Normandie of 1935. Her power plant could produce up to 200,000 horsepower, and she captured the Blue Riband for the fastest crossing on her maiden voyage. Normandie survived until 1942, when she burned while undergoing conversion to a troopship at her berth in New York City.

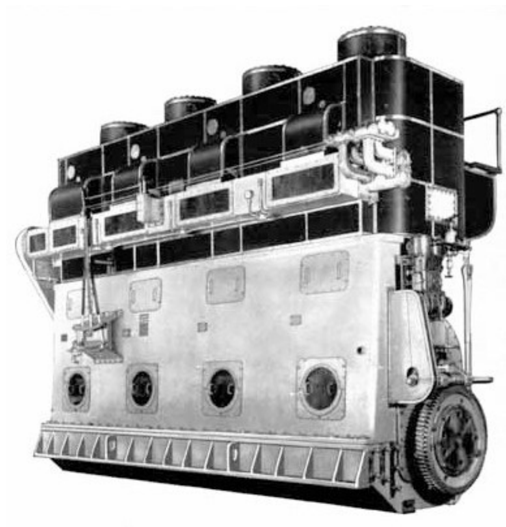
SS Normandie
Credit: Wikipedia

SKINNER UNAFLOW

The Skinner Unaflow design gave promise to piston engines when it appeared around 1909. It retained the appeal of the steam engine's simplicity, reversibility and flexibility of speed range. The enclosed Skinner engine had certain design advantages that kept the steam cylinder from cooling by not expanding the steam through stages like traditional steam engines. This maintained the temperature of the steam. Each piston received steam at temperature and pressure at each end of the cylinder through poppet valves (much like in an automobile gas engine) and exhausted into the condenser through cylinder ports into a manifold. Because the cylinders are hotter where the steam enters them at the ends, they are cooler in way of the exhaust ports, resulting in some distortion. To compensate, the cylinders are slightly egg-shaped in this area, so the piston won't jam. Skinner engines revolve nearly 80% faster than traditional steam engines. Their valve gear, which admits steam into the cylinders, is very complex, and the engines are somewhat finicky. They do not tolerate any water in the cylinders, and the temperatures must be evenly maintained; otherwise, the engine could jam and destroy itself.



Skinner engine operation
Credit: Wikipedia



Skinner Engine
Credit: Skinner Engine Company manual

The Skinner company produced a compound Unaflow engine in the late 1940s. Great Lakes ferries and 50 US Navy Casablanca class escort carriers were fitted with Skinner engines. The last surviving installation is in the coal-burning Great Lakes ferry SS Badger, built in 1952. Her two engines use steam at 470 psi, much higher than the 200 psi that former reciprocating engines were capable of using. To comply with environmental rules, efficient coal burning reduces ash deposits, and they are kept on board until the vessel docks. The ash is then removed and used to make cement.

SS Badger
Credit: Wikimedia Commons

THE LAST HURRAH

Just when it seemed that the steam engine was being consigned to technological oblivion, along came World War 2. The unprecedented naval building programs were matched by merchant ship construction that provided vast cargo tonnage for the war effort. The Liberty ship, a vessel designed to be prefabricated in sections and quickly built, arose first in the United Kingdom, then reached its zenith in the United States. Designed to last for only 5 years, more than 2,700 Liberty ships were built, about three every 2 days for the duration of the war. Initially, it took over 200 days to build one ship. With improved prefabrication techniques, the time was reduced to about a month and a half and sometimes less. As a showpiece of industrial prowess, the SS Robert Peary was built in less than 5 days. This was limited to the basic hull and machinery; much finish work remained. Still, it amounted to 7,000 tons of steel worked into one ship, an engineering feat by any standard. The labor force was augmented by thousands of untried female shipyard workers who quickly learned the necessary skills to build the ships.

Although the steam turbine was the engine of choice in the merchant marine, the close machining tolerances required for the gearing slowed production. Warship construction was consuming those skills, so a fast alternative was needed, something that could be produced by companies other than engine builders. Enter the tried-and-true marine steam engine. Interchangeability in parts was key, and 18 companies combined to produce a robust, 140 ton, three-crank, 2,500 horsepower triple-expansion reciprocating steam engine that merchant engineers and crews already knew how to operate and maintain. Turning just over 75 rpm, these workhorse engines pushed Liberty ships at a steady 11 knots, or just under 13 mph. Two Liberty ships remain: the John W. Brown in Baltimore, MD, and the Jerimiah O'Brien in San Francisco, CA.

Typical Liberty ship
Credit: Wikipedia

Liberty ship engine
Credit: Wikipedia

EPILOGUE

"The Ship that Found Herself," by Rudyard Kipling, was published in the Idler Magazine in 1895. This short story tells of a new Scots freighter, Dimbula, being readied for her maiden passage across the Atlantic. Impressive in her new paint and sound construction, she is much admired by those who built and own her. But she will not become herself until her individual parts are tested and learn how to work together. They are as egotistical strangers; each feels superior to its neighbor and indispensable to the ship as a whole.

Steam is their wise counsel. Leaving for New York with 4,000 tons of cargo, Dimbula encounters a rolling sea for the first time. Deck beams, plates, frames, rivets, and the engine are confused by the roll and pitch from the first Atlantic swell. Unused to the new stresses, the complaining begins. Rather than pulling together to cope with the building seas and wind, they retreat into the comfort of their own importance. But as the storm builds, their vanity is replaced with fear. Steam steadies and calms them. It sets an example by calmly doing its job, providing power for the engine and keeping Dimbula on track. The ship takes a thrashing; each member is gripped with anxiety. Steam urges them to not to be so rigid but to bend, stretch and shift to accommodate the various strains. She slows to a crawl, pitching, slamming and rolling throughout 16 days of the heaviest seas.

New York finally comes into view. Dimbula has lost some boats, the paint is streaked with rust, there is damage to her bridge and deckhouses, and her "three copper ventilators look like hats after a fight with the police." *** As she enters the harbor, Dimbula passes the outbound premier ships of the Atlantic. All give the required passing signals, and Steam, having worked on many of those ships, runs up the steam pipe to signal back. Then Dimbula speaks with a new, fully grown voice. She has been through the rugged school of the North Atlantic and has found herself.

Through the decades, each bit of steam machinery was the result of trial, error, failure, adversity and personal misfortune. About a century passed between Clermont's paddlewheels splashing up the Hudson River and Titanic's triple screws churning through the Atlantic. Impressive progress, in the great Song of Steam. * * * *

Cover sheet – RMS Mauritania Credit: Wikimedia Commons

*Opening lines of MacAndrew's Hymn (1894) by Rudyard Kipling. Credit: Rudyard Kipling's Verse, Doubleday and Company, Inc. 1940 edition. The Scots engineer in Kipling's poem is mesmerized by the mystical, almost divine power of steam. It is the stabilizing power in his life as described throughout Kipling's extended narrative.

** Sir Thomas Savery, The Miner's Friend

*** Excerpt from The Ship that Found Herself

****Lord, send a man like Robbie Burns to sing the Song of Steam (MacAndrew's Hymn, Rudyard Kipling)

Sources: Steam, 1893 & 1897 editions, Babcock & Wilcox Co. New York & London; Steam at Sea by Denis Griffiths, Conway Maritime Press, London 1997; Modern Steam Engines by Joshua Rose, Henry Carey Baird & Co. Philadelphia & Sampson Low, London 1887; Steam Engine Design, International Correspondence Schools 1896; Wikipedia; Wikimedia Commons; Penn State University; The Grenfell Record (Australian newspaper), The Lusitania Record.

In memory of William J. Paparella
2nd Assistant Engineer Liberty Ship SS Zane Grey