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# **ENGINEERING HISTORY PAPER #116**

## **“ENGINEERING AND THE PROPULSION OF BOATS AND SHIPS”**

**by Andrew H. Wilson**

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#74/2024

**ENGINEERING AND THE PROPULSION**  
**OF BOATS AND SHIPS**  
by Andrew H. Wilson

September 2024

## **Abstract**

Canoes, rafts, little boats, bigger ships, and some quite enormous ones, have been sailing the rivers, lakes, seas and oceans of the world for a very long time and have been associated with all kinds of human activity, both peaceful and warlike. This paper is mostly about the historical development of the engineering of the propulsion of boats and ships, from the human and wind kind to the diesel electric. But since it has not been possible to include every kind of boat/ship or system used historically, and all aspects of marine engineering, its contents should be considered illustrative rather than fully analytical or historical. There are no illustrations, but a short glossary has been added at the end of the paper.

## **About the Series**

Principally, the Cedargrove Series is intended to preserve some of the research, writings and oral presentations that the author has completed over the past half-century or so but has not yet published.

## **About the Author**

He is a graduate in mechanical engineering (1949) and the liberal arts (1954). Now in his mid-nineties, he has held technical and administrative positions in industry in the United Kingdom and technical, administrative, research and management positions in the Public Service of Canada, from which he retired in 1986.

He became actively interested in the history of engineering on his appointment to chair the first History Committee of the Canadian Society for Mechanical Engineering (CSME) in 1975, now almost 50 years ago. He was later president of CSME, and of its 'parent', the Engineering Institute of Canada (EIC). He has also chaired the CCPE's Canadian Engineering Manpower Council (CEMC), the Canadian Association for the Club of Rome (CACOR), and the History Committees of CSME and EIC.

### **By way of introduction...**

Defined as a separate kind of engineering, the marine variety is the branch that deals with the construction and operation of the power plant and other mechanical equipment of seagoing craft, docks and harbour installations. It makes use of 'bits' of other 'conventional' disciplines and sub-disciplines of engineering, such as mechanical, electrical and electronic, chemical and civil, plus thermodynamics, strength of materials, fluid mechanics and dynamics, propulsion, robotics and instrumentation. Two other disciplines of engineering are usually considered parts of the marine environment: *ocean engineering*, which includes the engineering concerned with oceans and seas and their coastlines, including port facilities and unique structures such as the Dutch Delta Works; and *naval architecture*, which deals with the design, construction, loading, stability, and the repair and maintenance associated with boats and ships. For the purposes of this paper, however, the engineering discussed will be limited to propulsion systems for sea-, lake- and river-going vessels.

Also, to be clear, boats have been included in the definition of 'vessels', since a 'boat' may be defined as a small (or very small) ship, often wooden-hulled and sometimes powered by humans or sails rather than engines. Historically, boats have been creatures of the rivers and the lakes, and less so of the oceans and seas. Again, except possibly naval vessels, individual ships have tended to be unique, or almost unique, and to have only a few 'sister' ships. Speaking of naval vessels, submarines are often called 'boats.' And yachts can be called 'boats.'

For these reasons, the text that follows includes information on a very large number of vessels. But, engineering-wise, this only scratches the historical surface. To do otherwise would require a much longer and much more detailed paper.

Finally, it must not be forgotten that, even today, much of the world's trade is still carried by ships. And to me, the variety of engineering that actually goes into one of today's giant container or cruise ships (as well as many smaller vessels) can provide a pretty complete selection of the 'engineering experience' that the individual mechanical, marine or electrical engineer or naval architect can ask for during his/her career.

### **The earliest boats...**

...included the Penne Canoe - from the Bronze Age (3300 BC to 1200 BC) - a hollowed-out tree trunk, and the predominantly British coracle, a six-foot diameter circular, one-person vessel - first used around 2000 years ago - that provided for both motive power and steering by means of an oar. However, the Sumerians, some two millennia earlier, may have developed the first sailboats. And the Rome-and-

Carthage Wars of around the same time did contribute to the tactics of the early Mediterranean naval battles. Coracles, by the way, are still in use in small numbers in countries such as Wales.

As long ago as the Iron Age (700 BC to BC/AD), hide boats, rafts and primitive sailboats were being powered by winds and tides and by humans in areas round the world. The Phoenicians, Greeks and Romans in the Mediterranean, the Vikings of Northern Europe, the Arabs from the Persian Gulf and the Indian Ocean, and those living around the Australian continent may have been the first to explore, trade, fish and fight using these vessels. It has been said that the world's first marine engineer was Archimedes (287-212BC), but his influence was really on fluid mechanics and not on shipping.

At roughly 1000 AD, we have the early Inuit contributions to boatbuilding: the kayak and the umiak. The former, for one or two people, was wooden structured, skin-covered, oar-propelled and steered. The latter was also skin-covered, oar-propelled and steered, but carried a crew of around six, and had shallow draft.

This was also the time of the longships of Viking fame, which were used mostly for exploration, fishing and raiding and, led by Leif Ericson, were the first to explore what is now Newfoundland and the continental mainland to the west of it...in other words, THEY discovered America! These, together with other predominantly 'modern' boats, were about 60-feet long, of oak, shallow draft and low weight, with longitudinal wooden planks whose edges overlapped (clinker-built) - a construction technique that originated in Scandinavia. These boats could be (square-rigged) sail and/or oar-driven by as many as 60 men at a time, and steered by a rear-facing oar. Some had decorative head-pieces. Some timbers were steam-bent to fit the internal concave sides of the boat. These boats were also built with carvel construction; that is, the individual planks in their hulls were fixed to a frame and abutted one another, providing a smoother surface to the sea than the alternative clinker construction. Carvel's other advantage was that it could carry more sail and could accommodate broader and longer hulls - although, for a given hull strength, a clinker boat was lighter. The main disadvantage was that it required caulking between the planks, which could lead to leakage. (However, clinker remains popular today for small vessels.)

Known to the West since the end of the 13<sup>th</sup> century, were contemporary vessels of a different design: the family of Chinese junks. They had (the first) single stern rudders and four unstayed masts, with a lug sail-type rig, reefed from the top downwards.

### **The story continues...**

The next 200-300 years brought a variety of engineering and organizational revolutions to the world, notably the Renaissance and the Age of Exploration, with emphasis on the intellectual world assisted by the fruits of the printing press, the work of people like Leonardo da Vinci, and the exploration and development of the American and Asian Continents. They saw, for example, the transition from warships and cargo ships that could be propelled by rows of oarsmen, to those that carried their crews to new destinations and, hopefully, home again, in ships with single masts and large triangular lateen sails as well as square ones, and steered by single, vertical rudders rather than oars.

The 15<sup>th</sup> century also saw the design of the *caravel* ship type emerge from Portugal's fishing fleet, with its two or three masts and both square and lateen sails. Also, masts formerly made from single spars could now be made of two or three. It was this type of ship, encouraged by Portugal's Prince Henry the Navigator, that undertook lengthy voyages of exploration - for example, two of them were the *Nina* and *Pinto* that took part in Columbus's famous first trans-Atlantic voyage in 1492. Columbus' third ship, was the *Santa Maria* - a Spanish merchant ship - and the largest of the three. Her rig was a square main sail, a lateen on the mizzen, and a square spritsail on the bowsprit.

In 1497, England's King Henry VII granted letters patent to John Cabot for a tentative westward voyage to the Orient. His ship was the three-masted *Matthew*, with square sails on its fore and main masts and a lateen one on the mizzen. Cabot discovered Newfoundland and Cape Breton Island.

Another 15<sup>th</sup> century contemporary ship type was the *carrack*, of Dutch origin, used on long-distance trading routes - also three-masted, with two square sails and a lateen mizzen.

The *galleon* first appeared as a ship type in England around 1530, although the first ones were probably built in Spain. They were longer and narrower than carracks, which apparently added to the ships' ability to sail to windward, and had redesigned foc'sles (or forecastles).

These next 300 years (1500-1800) also established *two* main types of vessel in Europe: the warship and the merchant ship. And as trade grew, the need for larger ships also grew. One of the best known of the warships was the *Mary Rose*, launched in 1510, and sunk in battle in 1545. In 1970, the remains of the vessel were discovered and a program of recovery and preservation put in place for the remains of the ship.

England's King Henry VIII (1509-47) began a program of warship design that assisted his daughter, Elizabeth, with the construction of her navy. One of them was *The Great Harry*, a large carrack, launched in 1514, and refitted and rebuilt in 1539 to carry 21 heavy guns. Renamed *Edward*, for Henry's successor, Edward VI, she was destroyed by fire at Woolwich in August 1553.

Launched in 1576, and first named the *Pelican*, she became the *Golden Hind* of Sir Francis Drake in 1578, half-way round the first English circumnavigation of the globe. She was a three-masted galleon, square-rigged on fore and main masts, lateen on mizzen, with a spritsail. She was intended for preservation but, by 1660, had rotted away.

The use of hammocks for sleeping on ships began around 1600, based on Central American experience. Previously, sailors had slept on the filthy, heaving decks.

The *Mayflower* was a galleon, used normally for trade between England and continental Europe, before her famous voyage in 1620 to America, after which she is thought to have resumed trading. She was three-masted, square rigged, with a lateen mizzen sail. A replica is still being exhibited.

The *Sovereign of the Seas* was the brainchild of England's King Charles I and shipwright Phineas Pett, and was launched in 1637. She was three-masted and lavishly decorated, had square-rigged fore and main masts with topgallants plus a lateen-mizzen with topsail, spritsail and bowsprit topsail. She was the first warship to carry 100 heavy guns. Over 230 feet long, with a beam of 46 feet, and with ample sails, she was still sluggish in the water and unable to keep pace with other warships. She was completely rebuilt in 1660, and again in 1685, but was destroyed by fire in 1703, at Chatham. Design-wise, she was the forerunner of many later warships.

The *frigate*, as a ship type, first appeared in Holland and England around 1660. With clinker upperworks. It was three-masted and square-rigged with a lateen mizzen, square topsail, spritsail and bowsprit topsail, and a single rudder. It was relatively undecorated and minimally armed.

Collier brigs and vessels like them appeared regularly on the coasts of England and Continental Europe, beginning in the late 17<sup>th</sup> century, continuing into the 18<sup>th</sup>. Flat-bottomed, they could sit on beaches at low tide.

The *Victory* was a 104-gun, first rate Royal Navy ship-of-the-line and the masterpiece of Sir Thomas Slade. She was launched at Chatham, England, in 1765, but was not commissioned as a warship until 1778. Basically three-masted and square-rigged, in the 1780s she became the flagship of Lord Howe at Gibraltar during the American War of Independence. She was rebuilt between 1800 and 1803. When she returned to the Mediterranean, she became the flagship of Admiral Nelson, and took part famously in several naval actions, including the Battle of Trafalgar in 1805, at which Nelson was killed. *Victory* was subsequently refitted and saw further naval service, until 1812. In 2024, she is still commissioned, and remains in drydock at Portsmouth.

The (American) *Turtle* was the world's first submersible vessel, built in 1775 by revolutionary David Bushnell. Its purpose was to serve (during 1775-6) as a means of attaching explosives to the hulls of British vessels to destroy them in harbour. George Washington provided the funds for developing and testing it. Its many moving parts were built by a skilled New Haven clockmaker, Isaac Doolittle. It weighed 91 kg., was 3 metres long, with a 1 metre beam, and was propelled by a hand-cranking operator. Its propeller (essentially an oar) was a watercraft first. The explosive mine was to be detonated by a clockwork mechanism. But the *Turtle's* endurance was only 30 minutes. Its hull was constructed like a barrel. The operator would travel inside it, operating it with hand and foot controls. The one *Turtle* attack that was attempted, however, failed. The eventual fate of the vessel is unknown. But it led eventually to the development of the submarine.

Having reached the end of the 18<sup>th</sup> century, we have also reached the transition from sail to steam. But before we make it, we should take note of two people and several ships from earlier times that significantly influenced the Steam Age when it arrived in force.

One of two was Thomas Newcomen, the English inventor of the atmospheric steam engine, the first practical fuel-burning engine, in 1712. His engine, which he created using ideas first generated by Savery and Papin, was applied to the then current problem of flooding in coal and tin mines. A lay preacher, Newcomen's church connections were used to spread word about his engines. Essentially, Newcomen used a cylinder containing a vacuum to draw down a piston that would work a beam engine. A company was formed to look after his 'engine' affairs. By 1733, there were approximately 125 'Newcomen' steam engines operating.

The other was James Watt, born in Scotland in 1736, who was impressed by the waste of steam in the Newcomen engine at the University of Glasgow, and was asked to look into it. His response was to design a separate condenser connected to the cylinder. He patented the process. Newcomen engines continued to be built, and to outnumber Watt engines, but some had separate condensers! Watt had improved the situation, and especially after Fulton's successful American steam vessel in 1807, the *Clermont*, and John Molson's Canadian one, the *Accommodation*, on the St. Lawrence River in 1809. From then on, it was one major propulsion improvement after the other, to the double, triple- and quadruple-expansion steam engines, to steam turbines, diesel engines, and the diesel-electric propulsion systems common in many of today's ships. Watt also made other engineering advances, including the development of the double-acting piston, and an engine-speed governor.

It should be recalled, however, that the *very first* steamboat was Scotland's *Charlotte Dundas*. This vessel - a single sternwheel paddler with a horizontal engine - towed barges on the Forth & Clyde Canal, beginning in 1801. It should also be recalled that, in pre-railway days, boats and ships took much of the carrying trade, that many of the early ships were 'paddlers,' either side- or rear-, and that work on the screw propeller for ships began way back in the late 17<sup>th</sup> century and continued until 19<sup>th</sup>, when the *Archimedes*, built by Henry Wimshurst of London in 1839 and became the world's first steamship to be successfully driven by a screw propeller.

The *Durham* freight boats that were in use in North America from the beginning to the later 18<sup>th</sup> century, became associated with Durham Township, Pennsylvania, and were used, for example, by Washington when he crossed the Delaware. They were flat-bottomed and double-ended, but no plans exist, and they were replaced by larger, similar, craft after the Erie Canal opened. In 1825. They were also used on the St. Lawrence, Niagara, Saint John and Delaware Rivers and Lake Erie. They had crews of three or more, and were propelled by oars and sails.

*York* freight boats were used extensively inland by the Hudson's Bay Company (HBC) during the 19<sup>th</sup> century to carry furs and trade goods across the Canadian Prairies; they were sturdier than canoes. They were usually 46 feet long, had a crew of 6-8, were of heavy construction, had a pointed bow, and a flat bottom. They were modelled on a Scottish Orkney Viking longboat, but were named after the HBC's York Factory. They had a removable single mast, which could carry a large sail (which could be used as a tent at night). But they were too heavy to be carried manually and had to be portaged overland. *York* boats were still in use in the 2000s.

*HMS Bounty*, which began life as a merchant vessel, was built in Hull, England, in 1784. She became a naval ship three years later. Under Capt. Bligh, she began bringing breadfruit from Tahiti to the West Indies. The famous mutiny took place on April 28, 1789, and the Pitcairn Island story began. *Bounty* was burned, with her breadfruit plants. She was 90 feet long, with a beam of 24 feet, and a single rudder. She had three masts and was square-rigged, with four guns as armament, and a crew of 45.

The *USS Constitution* - a frigate built in Boston in 1797 - was exceptionally large, square-rigged with three masts and two gun decks. She served first in the Mediterranean, and then in the North Atlantic, including during the war of 1812. She acquired the nickname, 'Old Ironsides.' She served again in the Mediterranean in the 1820s. Slated for break-up in 1830, she was saved by her reputation and served until the end of the century. She still cruises Boston Harbour each Fourth of July.

American, Robert Fulton, built his first steamboats in France, but found little appetite for his invention. Returning to the U.S., he was more successful - in 1807, with the *Clermont*, with which he began the first regular river service, as noted above. The first Canadian steamboat service was established by John Molson on the St. Lawrence in 1809.

The early 19<sup>th</sup> century also saw the beginning of the timber trade in Canada's Ottawa River Valley and the Lower St. Lawrence River, spearheaded by men like Philemon Wright, E.B. Eddy and J.R. Booth. Red and white pine stands were cut in the Upper Ottawa during the winter, the logs squared, and eventually formed into giant rafts that were floated down the two, then ice-free, rivers to Montreal and Quebec. As many as 30 men lived aboard these rafts to guide them on their month- or six week-long trip, to break them up to pass obstacles such as rapids, to use facilities such as timber slides, and to reassemble them for the next part of the trip. The rafts were powered by the current, by oars, and occasionally by sails. The immediate destinations of the wood might be sawmills. The ultimate ones were mostly abroad.

As an aside, and contemporaneously, it should be noted that the *Red River Cart* was used extensively as a two-wheeled 'land boat' by Metis people in the Canadian Prairies, especially in the mid-to-late 1800s. It was named after the river in Manitoba. During the fur trade, these carts would replace York boats as the main method for hauling goods for long distances overland. When tied together, they formed trains. They could also be used as temporary homes during long trips. They could operate 'in brigades' for long journeys. Built of wood, they were tied together with leather, sinew and rope. The two shafts were attached to the body of the cart and strapped to a pony, horse or ox. The carts were also buoyant and could be floated in water. In winter, they could become sleighs. The wood and leather in their construction made them noisy...and their 'squeal' was audible for miles, since their axles were never greased!

Some other notable vessels of the early 19<sup>th</sup> century include the following:

The *Beagle* was one of Britain's largest contemporary class of warships, with three masts, barque rig, square sails on fore and main and spanker on mizzen., plus 10 guns and a crew of 70, and was launched in 1820.

The *James Watt* (1821) was the first steamship entered in Lloyd's Register of Shipping. She was a side-paddler, with three masts, and 104 feet long. She served the Leith-London route. Her engines developed 100 hp.

The *Royal William* was built at Quebec in 1831 and was one of the first vessels to cross the Atlantic using steam as well as sail. She had a wooden hull, was three-masted, had barquentine rig, and was a side-paddler with a single 200 hp engine. Until 1838-39, when she was sold to Spanish owners, and the arrival on the Atlantic of the Brunel's *Great Western*, she was the largest vessel of her kind (see below).

### **Later 19<sup>th</sup> Century Ships and Shipbuilders...**

The era of large passenger/cruise steamships actually began in the 1840s with an increase in the numbers of transatlantic crossings. But It could also be associated with the three steamers built by engineer and shipbuilder, I.K. Brunel (1806-1859) who, earlier and famously, had done much to build England's Great Western Railway.



The first of these three, the *Great Western*, was launched in England in 1837. She was a wooden side-paddler that, in 1838, first crossed the Atlantic, in 15 days...eventually making 70 crossings. She had four masts, one square-rigged, the others fore- and aft-rigged. She was broken up in 1857.

Brunel's second steamer, the *Great Britain*, was the biggest iron ship of her time - launched in 1843 - his first to be driven by a screw propeller, and the first screw ship to cross the Atlantic. She had six original masts, a single propeller driven by a four-cylinder steam engine...and a crew of 300. In 1852, a change of ownership occasioned a change of engines and a reduction in the number of masts. The performance of her iron hull apparently confirmed the value of this use of iron in ship construction.

Brunel's third steamer was the *Great Eastern*, launched in 1858. The giant of her day, she was almost 700 feet long, had six masts - the second and third square-rigged, the others fore-and-aft - and four funnels. She carried 4000 passengers or 6000 tons of cargo on the Atlantic run. She had a double iron hull and 10 watertight bulkheads. She was so large, she had to be launched sideways into the Thames. She was also unique in having both paddles and a screw propeller, with separate steam engines for each drive. But commercially, she was a failure. Her engines, for example were insufficiently powered, and she was too big for the contemporary tugboats. Her greatest value, as it happened, was as a transatlantic cable-layer, in the 1860s. Brunel died before she was completed. She was broken up in 1888.

In the 1850s, New England - and New Bedford in particular - provided the home ports for several hundred vessels engaged in whaling and sealing. Most spent years away from home. One of them was the *Charles W. Morgan*, completed at New Bedford in 1841. A three-master, she worked for 70 years, and has been preserved for viewing since 1941.

The HMS *Agememnon*, completed in 1852, was an early British warship that became a prototype for later steam-powered warships. She was the flagship of the British Black Sea Fleet during the Crimean War. She was also the ship involved in the first, failed, attempt to lay a transatlantic cable, but took part in the successful second one.

The American submarine *H.L. Hunley* was built in 1863, during the Civil War, in Mobile, Alabama. The main section was based on a cylindrical steam boiler, with tapered ends added. She was powered by hand-cranking a single screw by a crew of eight, with a ninth at controls in the forward section. At each end, there were ballast tanks. An iron keel was bolted to the base. The water depth was monitored by a mercury gauge, and a compass was used to navigate under water. Taken to Charleston for testing, several crews were lost. In 1864, she sank an enemy vessel, but lost her crew in doing so.

The *Cutty Sark* was launched at Dumbarton, Scotland, in 1869. Her hull was built of wood and iron. She had three masts and carried sail that enabled her to reach a speed of 17 knots, and be one of the fastest of her day. She was assigned first to the China tea trade and took part in its annual races from China to England. But eventually these ships were not allowed to use the newly opened Suez Canal to the Far East. In all, she had had eight years in this trade by the time when she and other clippers were dropping out of that race. She then moved to the Australia-Britain wool trade. In 1895, she was sold to Portuguese owners and continued to operate for them for another 27 years. She was sold again, and in 1936 became a training ship in England. She was eventually retired and moored on the River Thames. Since 1949, she has been preserved in a specially built drydock.

The first liner to be called the *Oceanic* was built by Harland & Wolff, Belfast, in 1870 for the North Atlantic run. It was also the first White Star Line ship. She had four masts and a single funnel. Her propulsion was by means of a single shaft, driven by a steam engine. Unusually, her accommodation was particularly spacious. After four years on the Atlantic run, she was transferred to the Pacific. She was scrapped in 1896.

The *Turbinia* was the small ship which engineer (later Sir) Charles Parsons used to demonstrate his invention of the steam turbine. Only 100 feet long and 44 tons displacement, this vessel was designed originally to be the testbed for that engine. First demonstrated in 1884, the steam turbine was intended originally to generate ship-board electrical power (which it did!). It was also thought to be useful in the development of marine power plants (which it was!). Spectacularly, the *Turbinia* made its debut, uninvited, at Queen Victoria's Diamond Jubilee Naval Review at Spithead in 1897, when it outraced the pursuing naval ships. In 1960, it was put on permanent display at Newcastle.

The second liner to be called the *Oceanic* was also a White Star liner, built in 1899 by Harland & Wolff at Belfast. She had two propeller shafts, and triple expansion steam engines. Winning a Blue Riband may have been her original intention, but this was never attempted. So, again, accommodation got special attention! She was to be the biggest ship of her day, and remained in service until the outbreak of World War I, when she became an armed merchant cruiser, but was wrecked only a few weeks later.

The research ship *Discovery* was launched as a wooden whaling ship at Dundee, Scotland, in 1901, based on the design of her namesake that had carried the 1897 Arctic Expedition. She was driven by a single propeller, and had a triple-expansion steam engine and three masts. Her hull was reinforced, and both her propeller and rudder could be lifted clear of any potential ice damage. She made her first voyage to the Antarctic in 1901-04, under Captain R.F. Scott, following which she was sold to the Hudson's Bay Company, which used her for voyages between Britain and Canada. She was inactive during World War I. From 1923 to 1931, she was used for research, and was laid up twice before becoming a training ship on the Thames. By 1986, she had been restored to her 1926 appearance and placed on permanent display at Dundee.

First Sea Lord since 1904, Admiral Fisher was a gunnery expert with both a naval and a scientific mind. He was also the 'father' of the *Dreadnought* class of capital ships, understood the need for big, fast ships, armed to the maximum...and set about getting them for the Royal Navy. They 'arrived' as battlecruisers - his *dreadnoughts*. A prototype was built secretly and quickly, but it soon became the standard for the new class. The *Dreadnought* was also the first large naval ship to have quadruple screws and steam turbines for propulsion. For the next few years, they were built at the rate of 3 or 4 a year.

The steel-hulled first Canadian Pacific RMS *Empress of Britain* was completed by the Fairfield Shipyard on Glasgow's River Clyde in 1906. The first of three ships to have the name, she was 570 feet long with a beam of 66 feet, carried 1500 passengers in three classes, and was one of the fastest liners then afloat. She had a quadruple expansion steam engine, two funnels, two propellers, and a service speed of 24 knots. She served principally on the North Atlantic routes between North America and Europe. In 1912, less than two weeks after the *Titanic* was struck by an iceberg and sank off Newfoundland, the *Empress* had a similar, but very much less damaging, encounter. And several weeks later, she collided with the collier *Helvetia* in a fog in the St. Lawrence estuary. Requisitioned at the beginning of World War I, this *Empress* served as a troopship throughout. Sent back to Fairfield for fuel conversion from coal to oil and passenger accommodation modernization in 1919, she returned to Atlantic service in 1920. In 1924, she was renamed the *Mountroyal*. She made her last Atlantic crossing in September 1929 (for a total of 190), was sold in June 1930 to a Norwegian company, and scrapped.

The Cunarder, RMS *Lusitania*, also completed in 1906, this time by John Brown & Company at Clydebank, was the biggest ship of its time, and the most luxurious. By 1907, she held both east- and west-bound Blue Riband speed records for the Atlantic. Over 700 feet in length, she was powered by four steam turbine-driven propeller shafts, and had four funnels. However, on 7 May 1915, she was sunk by a German submarine off the coast of Ireland.

The RMS *Titanic*, steel-built by Harland & Wolff, Belfast, has been mentioned above because of her spectacularly negative encounter with an iceberg, off Newfoundland, on her maiden voyage in April 1912 - in spite of being the largest ship of the day, having a double bottom and 15 transverse watertight bulkheads. She also had four funnels, one of them false. Her propulsion unit was a triple expansion steam engine, plus a low-pressure turbine, and three propeller shafts.

The aircraft carrier, HMS *Eagle*, was originally laid down as a battleship in 1917, but became an aircraft carrier when rebuilt in 1918 and, in 1922-23, when a full flight deck was added. She was the first carrier with an island superstructure. She had four propellers, driven by steam turbines, and was capable of 24 knots. She was sunk in August 1942 while defending a Malta convoy.

At the time of her launch in August 1918, the British battleship, HMS *Hood* was the largest warship in the world, and remained so through the interwar years. She was designed originally as an enlarged version of the class of the *Dreadnought* battlecruisers. She was also destined to become one of the most famous, as well as one of the fastest, with a speed of 32 knots. She was, however, poorly protected, and an appropriate reconstruction scheduled for 1939 was cancelled. She was involved in the war in North Africa in 1940, and was refitted later that year. In May 1941, together with the battleship *Prince of Wales*, she was sunk in an engagement in the Denmark Strait by the German raiders, the *Bismark* and *Prinz Eugen*. Her machinery included steam turbines and four propellers.

The experimental *Hydro-Dome IV (HD-4)* was a 'true' hydrofoil, built of wood and aluminum by Alexander Graham Bell and his team of researchers at Baddeck, Nova Scotia, in 1919. It was driven by two 250 hp gasoline aero-engines and two airscrews (not water propellers!). It captured the world water-speed record in 1919 at 71 mph and held on to it for over 20 years. Bell's attempt to interest naval authorities in hydrofoils failed...until the coming of the experimental *Bras d'Or* in 1953!

The *Ile de France* was the first major passenger liner to be built after World War I, in 1927, in France. She set new standards for elegance and luxury - the 'ocean liner style!' From 1928 to 1930, she also carried a catapult-launched seaplane, for mail and passenger emergencies. During World War II, she was converted by the British into a troopship. She was handed back to her owners in 1947 to be rebuilt, and to re-enter North Atlantic service in 1949, until 1959, when she was sold to Japan for scrap.

The *Rex* was the biggest passenger liner ever built in Italy, for the Italia Line, in the early 1930s, to provide Genoa-New York service - 'the sunny southern route.' But she was also intended to win a Blue Riband, which she did, and held it until France's *Normandie* took it from her. The *Rex* was powered by four propeller shafts and geared turbines, delivering 136,000 hp. She had two funnels.

The RMS *Queen Mary* was the first of two Cunard-White Star 'Queens,' launched by John Brown at Clydebank (in 1934), at the height of the Depression. She was built to take the Atlantic's Blue Ribands, and eventually (in 1952) held the record both ways. She served during World War II as a troopship and, postwar, completed 1001 Atlantic crossings in commercial service. She was sold in 1967 to the city of Long Beach, CA., as a hotel and recreation facility. Her tonnage was over 80,000 gross, and she had three prominent funnels. Her propulsion had four propeller shafts and geared turbines.

France's *Normandie*, launched 1935, was the largest liner of her day, with the most powerful machinery (four shaft-turbo-electric and 165,000 hp), three raked funnels (the third being a ventilator), and the only French ship to win a Blue Riband (which she lost to the *Queen Mary*). Laid up in New York in August 1939, she was taken over by the U.S. Navy in 1941. She was destroyed by fire in New York Harbour in February 1943, and sold for scrap.

The *Bismarck* (Blohm & Voss, Germany, 1939) was built to challenge the reigning French battleships, but ended up outgunned by the British ones. Her first was also her last combat mission, in 1941. On May 24, the British *Hood* and *Prince of Wales* engaged the *Bismarck* and the *Prinz Eugen*. The *Hood* was sunk. The *Bismarck* temporarily shook off her pursuers and headed for St. Nazaire. She was located again on May 26. Late in that day, an aerial torpedo from a plane belonging to the *Ark Royal* damaged her. On 27 May, she was attacked by two British battleships and sunk by torpedoes from a British cruiser. The wreck was located in 1989. She had been propelled by three shafts, driven by geared steam turbines.

Sister ship of Germany's *Bismarck*, the *Tirpitz* was also built in 1939. She spent much of her brief career hiding from the British in Norway's fjords. The RAF finally destroyed her in 1944. She had three Brown-Boveri geared steam turbines.

The British battleship *Vanguard* was built by John Brown on the Clyde and launched in 1944. She was the biggest, heaviest, fastest, most expensive and last battleship the Royal Navy ever built. Commissioned in 1946, and reputedly even better than the USNs *Iowa*, she was decommissioned after ten years, and scrapped in 1960. She had four propellers, driven by Parsons steam turbines.

The first RMS *Queen Elizabeth*, built for the Cunard Line, was launched in 1940 by John Brown, Clydebank, and immediately became a troopship. Her commercial service, on the North Atlantic run, began at War's end but, by the 1960s - as a result of competition from the new jet aircraft - she was assigned to cruising in winter. She was refitted for cruising in 1965, and did so until 1968, when she changed hands, ending up in Hong Kong, and becoming an ocean-going university. But she caught fire in HK in 1972, capsized, and was scrapped. She had two funnels. Her propulsion was four-propeller shafts, driven by four geared steam turbines generating 160,000 hp. Her service speed was 29 knots.

The *Iowa*-class of battleships date from the 1940s and were the largest and fastest ever built for the U.S. Navy. They were built at the New York Navy Yard and the first one entered service in February 1943. Its one construction restriction was that this class of ships should make passage through the (then) Panama Canal; that is, their beams should not exceed 100 feet. In compensation, their lengths were extended, but their speeds were not affected, and they had long, narrow bows. In other words, this restriction did not affect their performance, and there is a famous photograph showing just how closely the *Iowa* itself cleared the sides of a Panama lock!

An increase in the calibre of its guns also increased their effective range. The *Iowa* could also carry large numbers of light AA-guns, although most were removed at the end of WWII. The *Iowa* was reactivated in the 1950s and, again, from 1983 to 1990. In this latter period, she carried surface-to-surface guided missiles. She also carried massive amounts of fuel! The *Iowa* had four propeller shafts, each driven by a General Electric geared turbine.

Built as a passenger liner for the Union Castle Line by Harland & Wolff in 1938, before being converted to an escort carrier (for aircraft) in 1942 by Swan Hunter, the *Pretoria Castle* was the largest of them. She could operate 15 bomber and 6 fighter aircraft, but never saw combat and served mostly as a training ship. She reverted to merchant service in 1947. She had two propeller shafts, driven by Burmeister & Wain diesel engines.

The *Type VII* ocean-going submarines (including the *U47*) were the most numerous in the German Navy during WWII - a total of 715 being built in five variations. They were 'saddle-tank' types, divided into six watertight compartments, were highly seaworthy ships, and very maneuverable. They had five 21-inch torpedo tubes (4 forward, 1 back), 22 torpedoes, a speed of 18 knots on the surface, 7 knots submerged, and a crew of 48. The *U47*, in particular, penetrated the British anchorage at Scapa Flow and sank the battleship *Royal Oak*. In March 1941, *U47* itself was sunk by depth charges fired by an aged British destroyer. *U47* had two propellers driven by diesel engines and electric motors.

The *Type XXI* submarines were the best ocean-going boats the Germans produced during WWII, faster submerged than they were on the surface. 121 of them were built, by Blohm & Voss, and *U2501* was the first commissioned, in June 1944. She never saw service. She was scuttled in May 1945 at the very end of the War.

The *fourth* warship to be named *Nautilus* was also the world's *first* nuclear-powered submarine, although she had a conventional hull, to avoid unnecessary risk. Her keel was laid in June 1952. She was launched in January 1954, and commissioned in September of that year. Essentially, she was the brainchild of Captain, later Admiral, Hyman G. Rickover, of the USN Naval Reactors Branch. She went 'under way' for the first time on nuclear power in January 1955. She had two propeller shafts, powered by a single reactor, generating 15,000 hp, and could travel at 23 knots submerged. In August 1957, she began her first voyage of over 1000 nautical miles under polar ice and, in August 1958 became the first ship to reach the geographic North Pole. She participated in several NATO exercises and, in 1962, took part in the naval blockade of Cuba. Decommissioned in 1980, she was designated a National Historic Landmark in 1982 and became the first exhibit at the Groton Submarine Museum. Meantime, submarine tactics for naval warfare were being changed as a result of experience with the *Nautilus*.

The *Andrea Doria* (Italy, 1953) was a modern, well-run ship, that had a very short life. She perished in a foggy, unexplained Atlantic coast collision in July 1956. She was the first Italian liner to join the postwar Mediterranean-North Atlantic Service. Her propulsion was by two-shaft, geared steam turbines.

In 1957, a British aircraft carrier, launched in 1945, was refitted with an angled deck and transferred to the Royal Canadian Navy as the *Bonaventure*. In the 1960s, she adapted to an ASW role. Between 1966 and 1967 she was further modernized with new radars and better deck aircraft-handling equipment, but was paid off in 1970. She had two propeller shafts and geared steam turbines...and four boilers!

Holland-America's liner, the *MS Rotterdam*, was launched in 1958 and was designed to operate in the Atlantic during the summer and as a cruise ship during the winter months. She was the flagship of the Line, and was the first passenger ship of any size to have exhaust uptakes rather than funnels. She had two propeller shafts, driven by geared diesel-electric units. She was sold in 1997 and continued her usual service. (Another *Rotterdam* replaced her in the H-A Line.)

The Soviet icebreaker, *Lenin*, of 16,000 tons displacement, with a length of 440 feet, a beam of 91 feet, and a crew of 240, was the world's *first* nuclear-powered surface vessel. Launched in 1957 and completed in 1959, she operated for the next 30 years along the north coast of Russia, and for years without refuelling. Her powerful machinery was suited to icebreaking. Originally, the *Lenin* was powered by 3 OK-150 reactors (using only 6 lbs. of U-235 per 100 days of sailing), that provided power for 3 propeller shafts and a speed of 18 knots. In 1965, there was a loss-of-coolant incident, and in 1967 a coolant system leak. In 1970, the 3 reactors were changed for 2 of the OK-900 type, which provided steam for 4 turbo-generators, which provided power to 3 sets of motors driving the 3 propellers again for a speed of 18 knots. Her decommissioning in 1987 was hastened by the thinning of her hull due to ice friction. The *Lenin* became a museum exhibit, the arrangements for which were completed in 2005. Overall, Russia has commissioned a dozen nuclear-powered icebreakers.

The *Savannah* - built in 1959, completed in 1962, and named after the first steamship to cross the Atlantic - was the world's *first* nuclear-powered freighter. A 15,000-ton ship, she had a single propeller shaft with a geared turbine, driven by steam raised using a nuclear reactor, and generating 15,000 hp. She was built as an experiment. Her initial commercial service was heavily subsidized and was uneconomical.

Italy's *Leonardo da Vinci* was built in 1960 as the replacement for the *Andrea Doria*, until 1976. She then changed lines and moved to full-time cruising, uneconomically, and was laid up in 1978. After a fire on board, she was scrapped in 1979.

In 1963, the Government of Nova Scotia commissioned the building of the exact replica of a 1921 wooden two-masted gaff-rigged topsail fishing schooner and racer, *Bluenose II*, by a Lunenburg shipbuilder. The original *Bluenose* had been wrecked off Haiti in 1946.

The *Queen Elizabeth 2* was the last Cunarder built, by John Brown at Clydebank in the late 1960s, but she was not accepted by the owners at first for transatlantic passenger service, although she did contribute to the style of giant cruise ships that came later. She was costly for her owners, and was the subject of several threats of terrorism. In 1975, she had engine failure off the Bermuda and, the following year, was partially crippled by an engine-room fire. In 1982, however, she performed successfully as a troopship during the Falklands War. Refitted and re-engined, she then became a cruise ship. She had a single funnel, and a service speed of 29 knots. Originally, her propulsion was driven by two geared steam turbines – replaced in the 1980s by diesel-electric units. She was sold in 2008, restored, and has served as a world-class entertainment, hotel and tourism facility in Dubai.

The *Glomar Explorer* was a heavy-lift ship built (for the CIA) in the USA in 1973 to raise at least portions of a Russian ballistic missile submarine that had sunk in the Pacific off Hawaii. She was partially successful in her endeavours. She had a two-shaft diesel electric power plant, generating over 13,000 hp.

The four ships in Russia's *Kirov* class have been labelled 'among the most powerful warships afloat,' and the world's largest cruisers, but not all of the four have been simultaneously operational in their anti-submarine role. One of them, the first, was also called the *Kirov*. She was completed in December 1980 and fired missiles from 12 launchers. The ship's propulsion system is based on a combination of nuclear and steam power, with two reactors and two boilers. In 1990, the *Kirov* suffered a major nuclear accident that put her out of service. She was used in 1998 to provide spares for the only other active ship in the class, but the following year she recovered her equipment.

The Dutch-owned *Jacob Maersk*, launched in 1991, was one of a small class of independently-owned multi-tankers, highly automated, with independent free-standing tanks in her four holds, each lined with polyurethane to minimize damage. Each hold had a forced-air dryer. Centrifugal pumps were fitted to help handle cargo. She also had a bow thruster. Propulsion was by a single propeller shaft and a 16,000 hp diesel engine.

In 1992, the 73,000 tons gross *Majesty of the Seas* was the third of three identical ships purpose-built in steel in France for one-week Caribbean cruises for over 2000 passengers, by the Royal Caribbean Cruise Lines of Norway. She was propelled by a single 28,000 hp diesel-driven engine and shaft.

At the close of the 20<sup>th</sup> century, the Royal Caribbean's *Voyageur of the Seas* was the world's biggest passenger ship, at a registered tonnage of 137,000 gross, and a length of 1000 feet. Built in Finland in 1998, with accommodation for almost 4000 people on 14 decks, and including an ice hockey rink big enough for games. She also had 84 miles of pipework, 1864 miles of electrical cabling, and 75.6 megawatts of power to help run three electrical propulsion motors slung beneath the hull...and a shopping mall to rival on-shore malls. She was built in Finland in 57 weeks by a work force of 10,000!

### **Finally...**

Modern commercial shipping has been dominated by two ship types: the intermodal containership, and the very large cruise ship, both usually over 1000 feet in length.

Bulk cargoes like grain or coal are transported unpackaged. Break-bulk cargoes, on the other hand, are usually manufactured and are packaged. However, by grouping the cargoes in containers (1,000 and 3,000 cubic feet), each container is secured to the ship one at a time. By 2009, about one-quarter of the world's break-bulk cargoes were transported in containers.

Containership capacity is measured in twenty-foot equivalents (TEUs). There are now several classes of container ships, including the two called *Panamax*, related to the dimensions of the Panama Canal.

The container 'business' began as long ago as 1766 in a very small way. The world's first designated containership was launched in the UK in 1931. The first post-WWII ships were often converted oil tankers. The first commercially successful containership was owned by American Malcolm McLean, who built his fleet, starting in the mid-1950s. He also adapted ships to carry containers, beginning in 1956. The world's first purpose-built containership was actually built in Australia in 1964. Modern containerships, of which there are seven major size categories, can carry over 24,000 TEUs., and the largest of them are over 1300 feet in length. They carry only 20ft., 40 ft., and 45 ft., containers, the latter carried only above decks. Their engine rooms, usually located in the after part of the ship, contain the main engines, fresh water and sewer systems, electrical generators, fire pumps and air conditioning equipment. The ships may last for as long as 40 years.

Today's very large passenger and cruiseships had their origins in the mid-19<sup>th</sup> century and later with lines such as the P&O Steam Navigation Company and Cunard Lines in Britain, the German Hamburg-America Line, the United States Line, and with some very large ocean liners, such as the *City of New York*, the *Kaiser Wilhelm der Grosse*, the second *Oceanic*, the *Lusitania*, the *Mauritania* the *Titanic.*, the *Normandie*, and the *Queen Mary*. The sinking of the *Titanic* and the *Lusitania*, and *World Wars I and II* brought about pauses in the building of very large cruise/passenger ships. On the other hand, prohibition in the United States encouraged cruising beyond three nautical miles! In the 1930s, the largest cruise operations were the Nazi Party's!

The post WWII generation of massive cruise/passenger ships began in the late-1980s - for example, the *Sovereign of the Seas* in 1987 and the *Voyageur of the Seas* in 1999, the *Queen Mary 2* in 2003, the *Oasis of the Seas* in 2009, and the *Icon of the Seas* in 2022. Essentially, the post-WWII increase in large (and cheaper) passenger aeroplane flights served to curtail the slower passenger ships and contributed to the increase in budget-priced cruising, but also to the floating holiday resort, as well as to the rise of cruise lines generally, such as the Royal Caribbean Cruises, the Norwegian Cruise Line and Princess Cruises.

Once again, the engine rooms of the cruise ships contained the necessary propulsion and electrical-generating, fire prevention and fighting equipment, plus what was needed for the comfort and entertainment of the passengers.

Lastly, it should be noted here that the shipbuilding discussed in this paper is mostly American and British, with some European added. And it has had plenty to say to indicate the transitions between the powering ships by oars, sails, steam, steam turbines, diesel and diesel-electric propulsion. But the rest of the world has not been forgotten - just omitted due to lack of space! Suffice it to note that there has been active shipbuilding, for example, among Great Lakes yards for at least a couple of centuries. The yard at Collingwood, Canada, for example, opened in 1882 and closed in 1986. It built mostly freighters - some 200 of them, as well as warships, peaking during WWII. It was also noted for its sideways launchings. So, this paper is *illustrative*, it is not fully historical.

### **A Short Glossary...**

...has been included to cover some nautical terms with which the lay reader may not be familiar:

Lateen sail: origin Arab, Egypt/Persian Gulf; a triangular sail, running fore-and-aft, mounted at an angle to its mast; arrived in the Eastern Mediterranean in the 2nd century AD; enabled square-rigged ships, which were inefficient before the wind, to harness headwinds and enabled them to tack into the wind; ships with both square and lateen sails were considered to be 'full-rigged.'

Mizzen mast: the mast aft of a ship's main mast.

Lug sail: four-cornered, quadrilateral in shape, with a yard at the top, supported by the mast; commonly used in sailing dinghies and small yachts.

Spritsail: a four-sided, fore-and-aft sail supported at its highest point by the mast and a diagonal running spar (the sprit).

Bowsprit: the spar extending forward from the ship's prow.

Top gallant: the section of a square-rigged sailing ship's mast immediately above the top mast.

Gaff rig: the wooden spar at the top of a sail, extending diagonally from the mast, allowing for larger sail area and improved control - harnessing the wind more effectively.

Spanker: the fore-and-aft sail on the mast nearest the stern of a schooner.

Forecastle (foc'sle): the upper deck of a ship, forward of the foremast (usually the sailors' living quarters).

Carrack: a European merchant ship of the 14<sup>th</sup> to the 17<sup>th</sup> centuries; Columbus' *Santa Maria* was a carrack.

Caravel: a small, speedy sailing ship, with both square and lateen sails; Columbus' *Nina* and *Pinta* were caravels.

Bireme: an oared warship or galley, used most often for military purposes, having two superimposed tiers of oarsmen on each side; steered by a rear-facing oar.

Trireme: of the same length as a bireme, but with as many as 180 oarsmen in three tiers on each side; it could also have a large square sail; its bow was a battering ram of bronze; steered by a submerged rudder, controlled from the deck at the stern.

Galleon: a large, multi-deck, multi-purpose ship used, for example, by the Spanish and Portuguese for expeditions (eg to the Philippines), and warlike purposes, in the 14<sup>th</sup> to the 18<sup>th</sup> centuries.

Barquentine: a schooner-type vessel with three or more masts.

Clipper: a fast mid-19<sup>th</sup> century sailing ship, used for long-distance trade and transportation.

Bathyscaphe: a vessel designed for operations in deeper water than submarines.

Blue Ribands: popular accolades given, mostly during the 1930s, to trans-Atlantic passenger liners for the fastest crossings (both ways) between New York and Southampton.

Island superstructure: the Command Centre of an aircraft carrier, placed on the starboard side of the vessel's deck and out of the way of the aircraft taking off and landing.

Intermodal transportation: moving freight by two or more modes of transportation.

RMS: Royal Mail Steamer.

Displacement tonnage: a ship's weight equal to the weight of water it displaces (in long (2240 lbs.) tons).

Gross tonnage: is calculated by measuring a ship's volume and applying a mathematical formula.



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