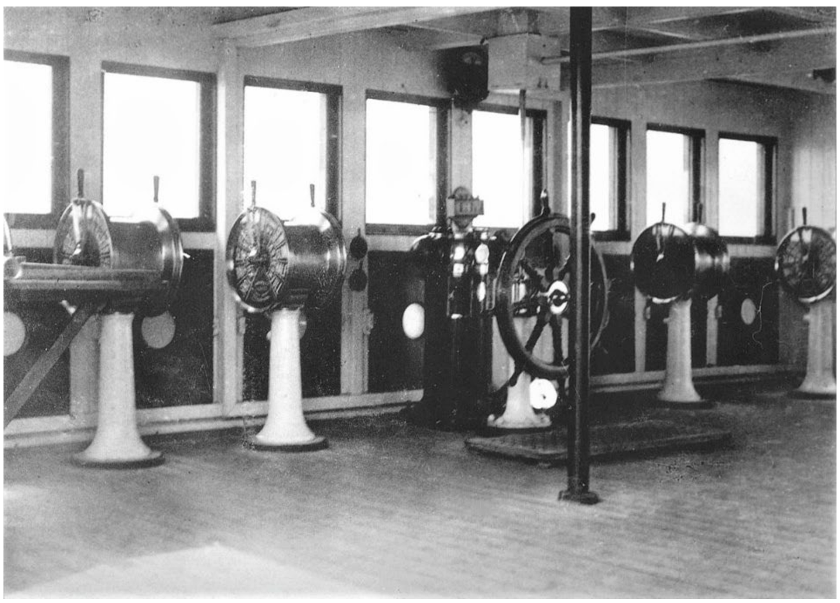
A QUIET SEA

RMS TITANIC



STEERING GEAR

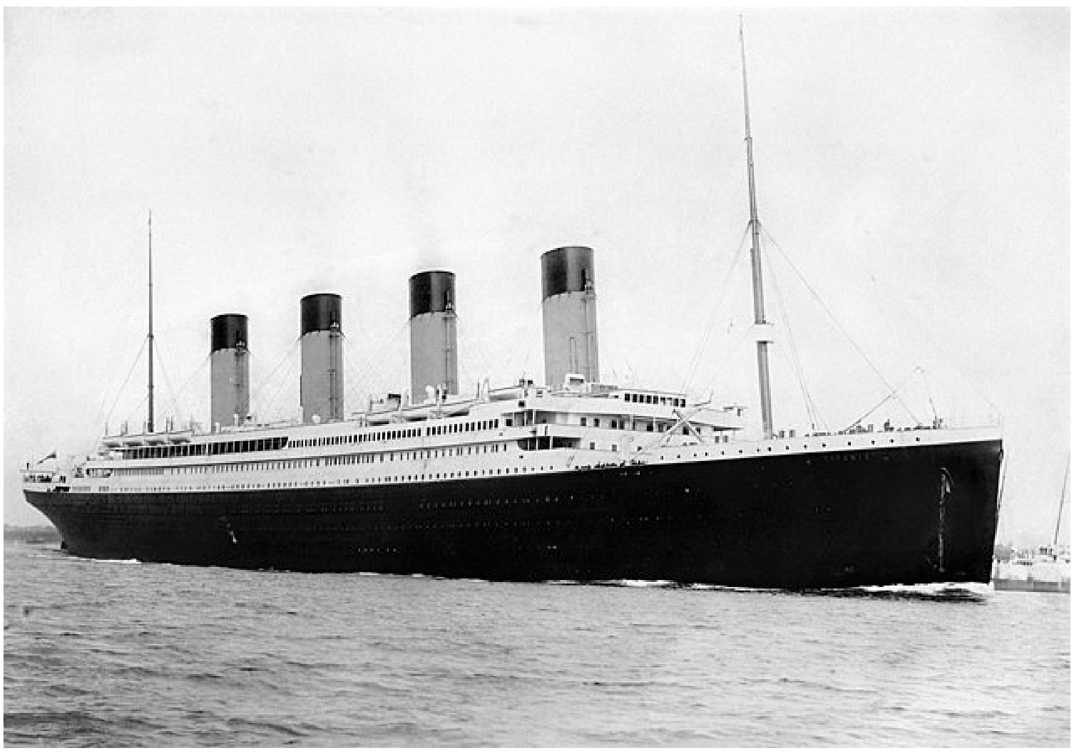
TITANIC: STEERING GEAR

INTRODUCTION

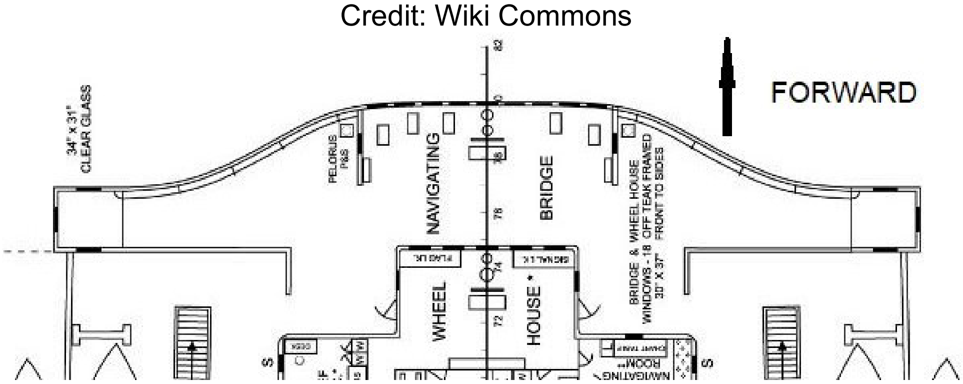
Keeping a vessel's compass course is a point of pride for the mariner. Whether handling the tiller of a racing sloop, the wheel or joystick of a tug and tow, cruise or container ship, keeping the proper heading takes skill and concentration. A powered vessel that holds her course saves time, fuel and keeps her schedule. For the weekend sailing enthusiast, it can mean the difference between winning and losing. Even with automatic steering, constant vigilance is necessary. And when maneuvering to avoid collision or in heavy weather, the efficiency of the steering gear and rudder, knowledge of what your ship can do, and how much time she needs to do it, can either avoid catastrophe or suffer disaster. With the assistance of Webb Institute, a naval architectural university in New York, A Quiet Sea will investigate the turning characteristics of Titanic.

STEERING STATIONS

Titanic was under control of the officers standing watch in the navigation bridge (aka pilothouse) located at the fore end of the superstructure. The bridge provided a clear view ahead and to port and starboard.



The navigating bridge (with closely spaced square windows) is ahead of the forward funnel.
Credit: Wiki Commons

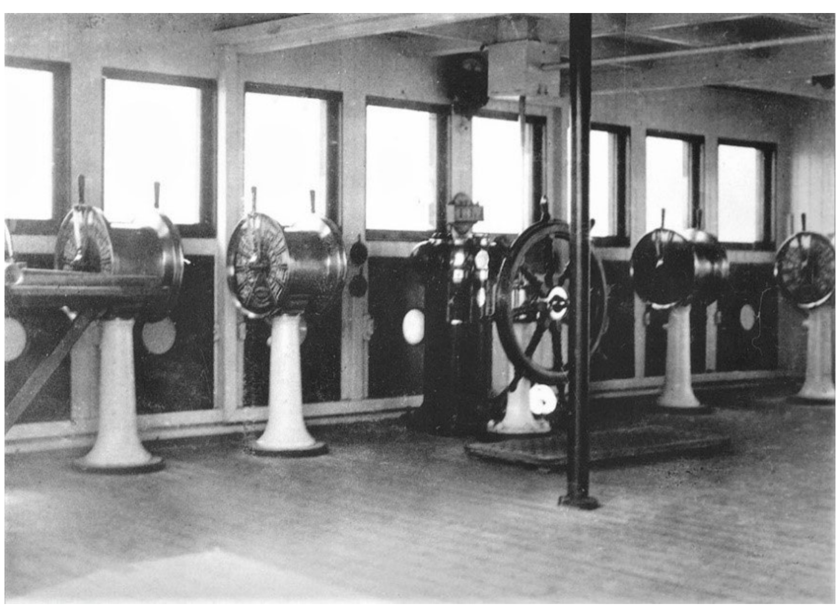


Plan of navigating Bridge and Wheelhouse
Credit: Encyclopedia Titanica - Titanic deck plans

Titanic was provided with three steering stations: a wheel on the navigating bridge, a second wheel in an enclosed wheelhouse in the after portion of the bridge, and a third wheel on the open docking bridge on the stern. The navigating bridge provided a wide arc of visibility and was used when entering a harbor with the vessel under command of the pilot, who ordered the various steering commands. The navigating bridge contained the ship's wheel, compass, whistle controls, engine, maneuvering and docking telegraphs. **(**Maneuvering telegraphs, similar to engine telegraphs, were used by the pilot to quickly transmit slow/fast, ahead and astern. Docking telegraphs were used to communicate how the dock lines should be handled.**)** The bridge also contained telephone communication to various parts of the ship, a chart room, watertight door control board, clocks and other communication and navigating devices.

Telephone communication was provided from the navigating bridge to foredeck, the crow's nest, the reciprocating engine room, the poop/aft steering station and the Chief Engineer's cabin. The reciprocating engine room was provided with a separate system of indicators to signal firing rates to the firemen and stockers forward in the six boiler rooms. This system ordered the firing rates, the frequency of stoking coal and cleaning ash from the furnaces, to regulate the steam pressure for the desired speed. Clean fires also kept cinder and smoke emissions to a minimum, an important consideration on a coal-fired transatlantic liner.

Typical engine telegraph (L) and docking telegraph (R)
Credits: Wiki Commons (L), Flickr (R)



RMS Olympic navigating bridge with wheel, binnacle/compass (ahead of wheel) and round engine telegraphs.
Credit: Wiki Commons

The wheelhouse steering station, in the after portion of the bridge, was manned when the pilot was dropped, and the ship bound for sea. It was considered important to isolate the helmsman from distractions so he could concentrate on the compass course and maintain the desired heading. Unlike when entering or leaving port, where various helm orders were given, steering at sea was focused on monitoring the compass. The officers and seamen on bridge watch kept a sharp lookout, attended to the ship's navigation and maintained contact with other watch stations throughout the ship. They also plotted the daily position, regularly compared the steering and standard compass courses for errors, performed ship checks, monitored wireless transmissions and relayed engine orders. While at sea, the bridge wheel was disconnected to avoid any unintended interference with the ship's course.

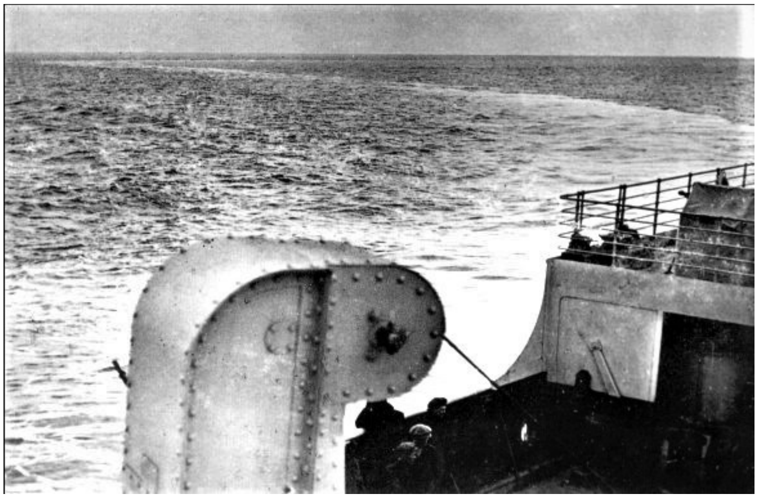
Wheelhouse (at sea) steering station. Navigating bridge through windows
Credit: Fandom

An independent emergency steering station was provided on the after docking bridge in the stern and could be used in the event of a mechanical failure to the main steering control system.

Olympic after docking bridge. (Red, docking telegraphs; blue, steering pedestal [w/o wheel]; yellow, compass).
Credit: Wiki Commons

ENGINE SPEED

The main purpose of the navigation bridge engine telegraphs was to control Titanic's speed and direction, ahead or astern. Each order--slow, half, full, ahead or astern, stop, finished with engines--was interpreted into engine revolutions by the engineers at the reciprocating engines' throttle stations. Propeller revolutions determined how quickly the ship would turn; with all three propellers turning at full speed, maximum water pressure was applied to the rudder, and the ship would respond quickly to changes in rudder angle.



Titanic wake showing turning path
Credit: Father Browne (presumed)

The center propeller was turbine-driven, and its revolutions were controlled by the amount of exhaust steam from the two reciprocating wing propeller engines. Once the reciprocating engines' revolutions were reduced to about half of their maximum 75 revolutions per minute, the turbine engine would be isolated by two large valves called change-over valves that cut steam from the turbine, generating no thrust. This arrangement was used in port where, with the center propeller idle, the large wing propellers could be rotated in opposite directions to assist in turning Titanic when in close quarters, an important part in steering Titanic in close quarters.

Titanic's sister, Olympic, showing port wing and center turbine propellers and rudder.
Credit: Wikipedia

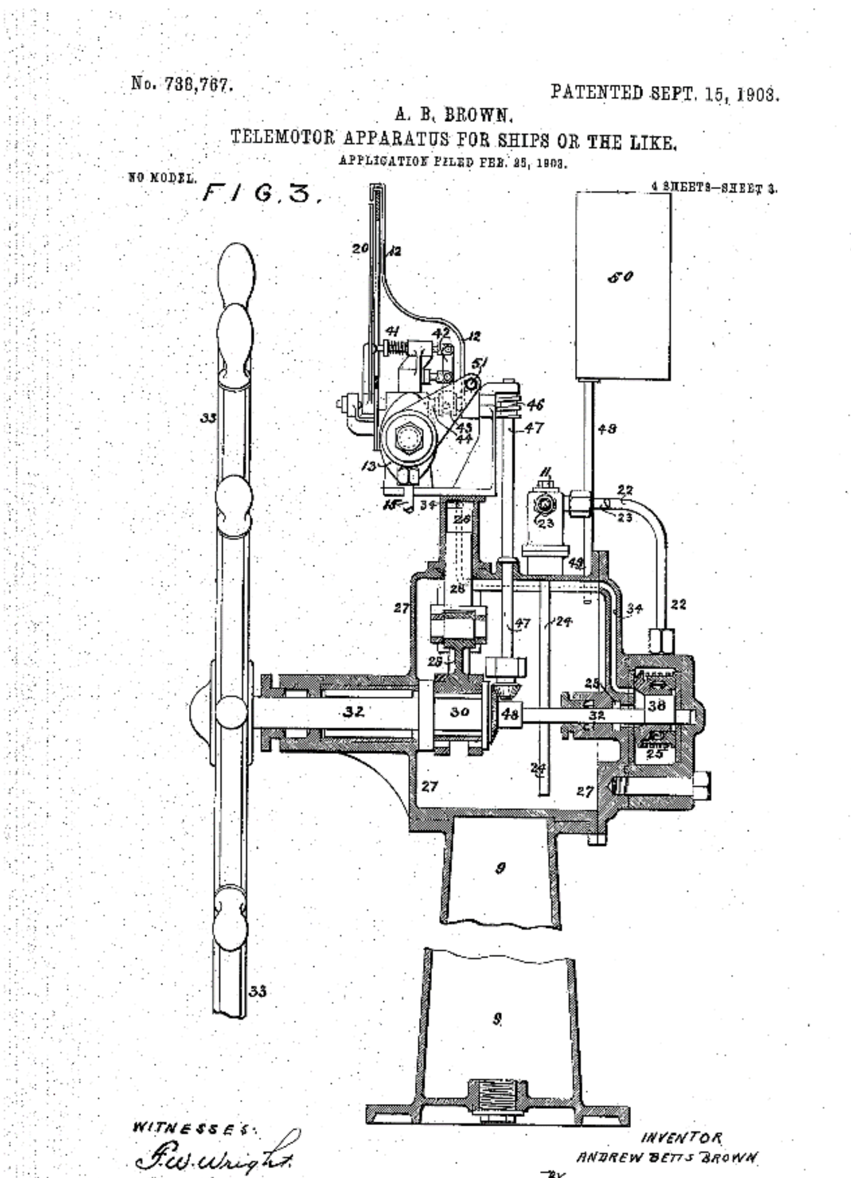
RUDDER CONTROL

No amount of human effort could directly turn Titanic's 104-ton rudder with the vessel traveling through the water. To provide the necessary power, the steering wheels were linked to steam steering engines in the stern, adjacent to the rudder. The navigation bridge and wheelhouse steering wheels were both connected to a clever device called Brown's Patented Telemotor.

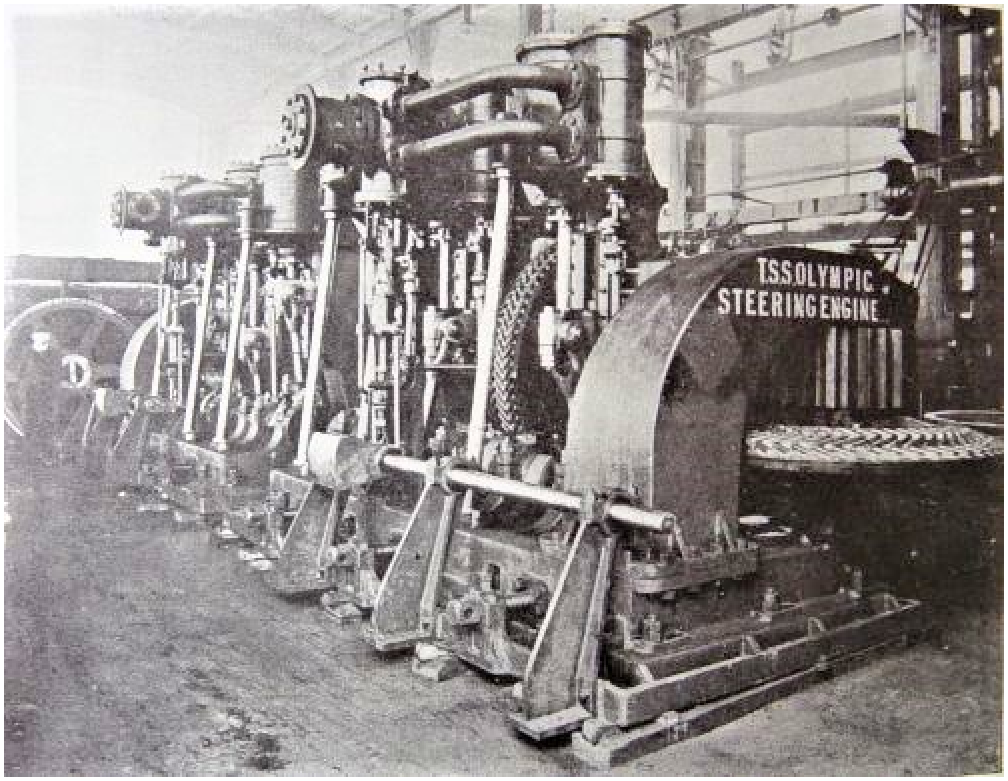
Andrew Betts Brown, National Gallery of Scotland
Credit: Wikidata

Andrew Betts Brown was born in Edinburgh, Scotland in 1841. He came from a working-class family, and his father was a bricklayer. Brown attended high school, and at age 14 joined the North British Railway Company as an engineer's apprentice. Recognized as a good student while attending night school, Brown became well-versed in physics and other sciences. He continued his education, developing an interest in hydraulic power. Earning the title of engineer when he was 20, he worked on improving steam machinery, taking out his first patent. Several years later, he became recognized as the originator of the first hydraulic overhead crane, used in bridge construction. He founded the Vauxhall Iron Works, which became one of the largest foundries in the British Empire. In his 30s, his attention shifted to marine engineering, concentrating on steering systems for ships. Prior to the 1870s, ships were hand-steered through a complex system of chains and tackles. But as ships, rudders and engines got bigger, the manually operated systems grew complex and cumbersome. Using his mechanical skills and knowledge of hydraulics, Brown could put the power of a liquid compressed in a fluid-filled pipe (push one piston to move another at the other end) to good mechanical use. His Telemotor, first patented in the early 1870s, was coupled to steam engines to move rudders. This allowed smoother steering control and was quickly adopted by steamship companies. Entering into partnerships in the 1880s with electrical engineers, his brother, David, joined Andrew and formed Brown Brothers in 1900. Brown Brothers continued developing steering systems for ships and in 1906 provided the steering gear for the famous Cunard ships Lusitania and Mauretania. When Andrew became afflicted with a lengthy and painful illness and passed away in 1906, David continued the company and went on to build the first British tanks for the World War I.

The Telemotor, a hydraulic/mechanical apparatus, pressurized a mixture of distilled water and glycerin through pipes from the navigating bridge and wheelhouse to a receiving unit at the steering engine in the stern, hundreds of feet away. Turning the wheel moved pistons, compressing the oil that operated a steam control valve at the steering engine. This action admitted steam pressure to the steering engine cylinders, swinging the rudder to the desired angle. The engine was connected to the rudder through large reduction gears that meshed teeth in the rudder quadrant, a large quarter circle steel forging in the shape of an arc fitted with gear teeth on its radiused perimeter. The quadrant moved the rudder through the tiller arms, keyed and bolted to the rudder stock. The quadrant was connected to the tiller arms with massive, shock-absorbing springs. When the rudder approached the required angle, a follower from the quadrant would return the control valve to neutral, cutting off the steam and stopping the rudder in the selected position. The proximity of the third wheel, mounted on the after docking bridge above the steering engine, allowed it to be mechanically connected to the steering engine control valve so no Telemotor was necessary.



Brown’s Telemotor, 1903
Credit: US Patent Office



TSS (Triple Screw Steamer) Olympic steam steering engines. Beveled bull gear set at right.
Credit: Wikipedia

The two steering engines, built by Harland & Wolff, were provided with reduction gears to increase torque for turning the rudder. The cast steel gears had specially cut teeth of the herringbone pattern that provided great surface area and resistance to wear for gears that constantly changed direction, as required by a ship's steering gear turning a rudder. The large bevel wheels weighed nearly two tons each.

Herringbone bull and pinion bevel gears showing complex gear tooth patterns
Credit: Wikipedia Commons

Only one engine was in use at any given time, the other kept in reserve in the event of a mechanical failure. This was possible, because the engines were mounted on a base that allowed them to slide in and out of gear via large adjusting screws. The three-cylinder engines operated at 100lb. steam pressure and were able to swing the rudder through an arc of approximately 70 degrees, 35 degrees on either side of centerline.

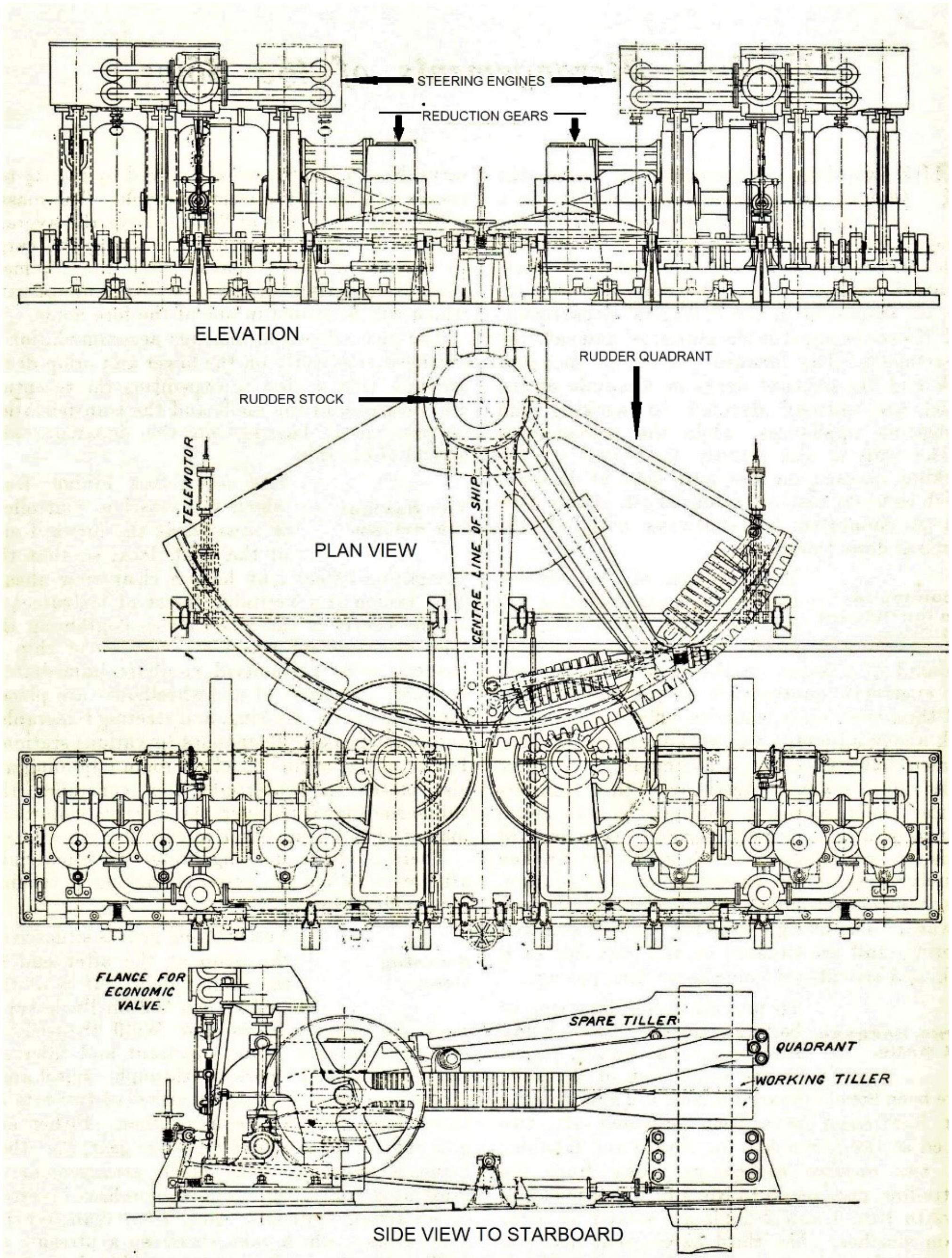


Fig. 139.—Steering Gear.

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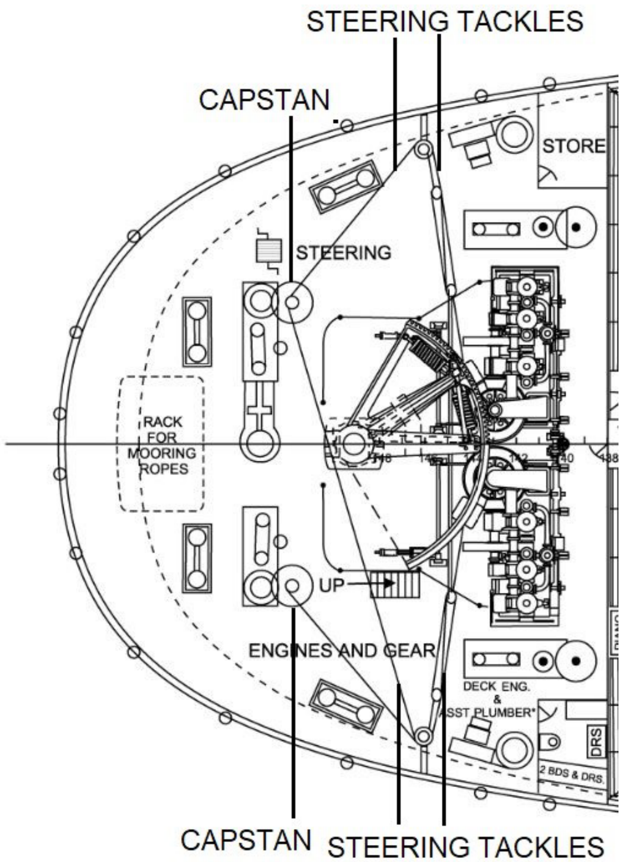
team Steering engines and quadrant.
Credit: Wikipedia (Shipbuilder, 1911 special edition)

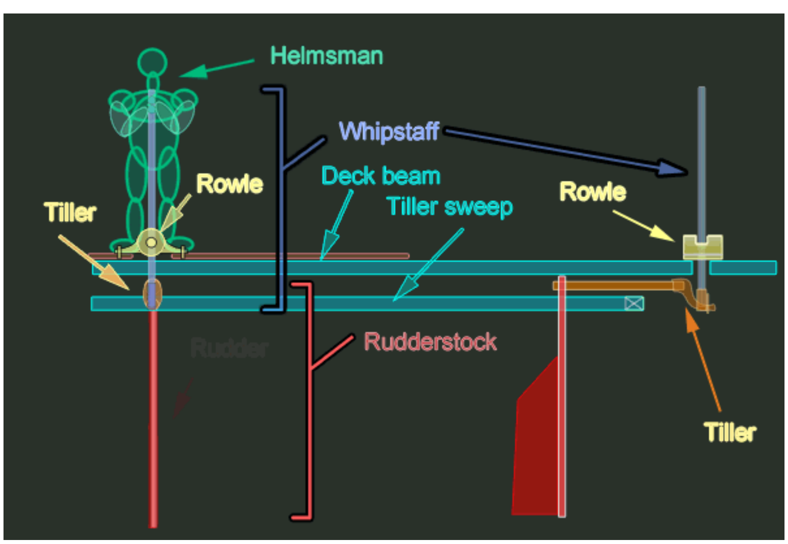
Like modern vessels, Titanic, with her two sets of steering engines, had 100% redundancy in her steering system. In extremis, Titanic had an additional back-up system: The rudder could be steered by wire and rope tackles controlled by the steam capstans adjacent to the tillers in the steering compartment, below deck in the stern. Although the capstan/tackle system couldn't be used at full speed, it gave sufficient control to get to port under normal weather conditions.



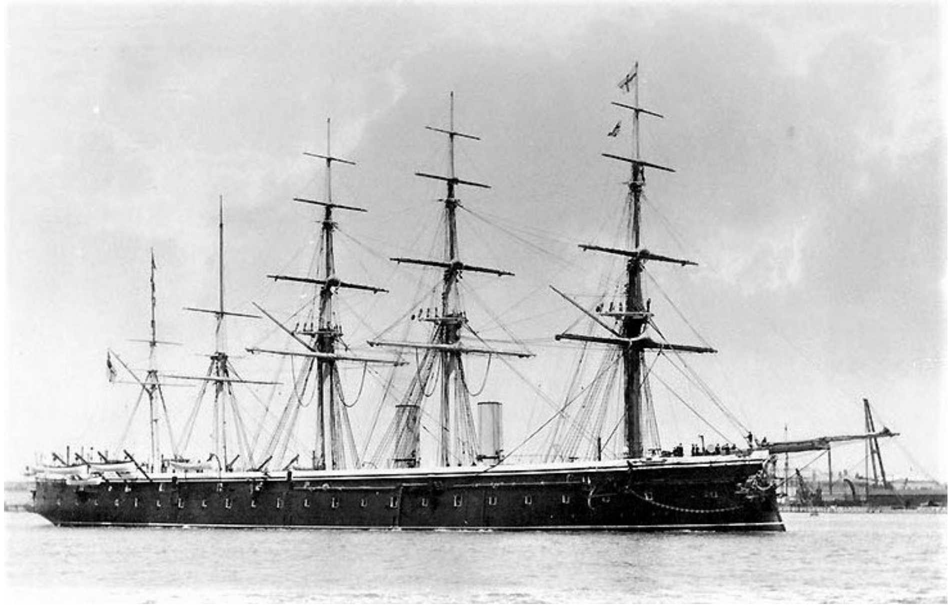
Emergency steering tackles and capstans in stern.
Credit: Encyclopedia Titanica - Titanic deck plans

STEERING EVOLUTION

For centuries, ships were steered manually, usually with a whipstaff and tiller or wheel roped to the rudder through a tiller to provide some mechanical advantage to the helmsman. As vessels became larger, they became more difficult to handle at sea and maneuver in port. Manual steering, even with scores of people engaged, wasn't up to the task. Warships, built to compete with rival powers, gained in size and weight, outgrowing their crews' muscle to handle the large rudders. Elaborate manual tackle systems were set up, but even so, the 10,000-ton 1867 armored frigate, HMS Minotaur, required nearly 80 men hauling on rope tackles to turn her rudder.

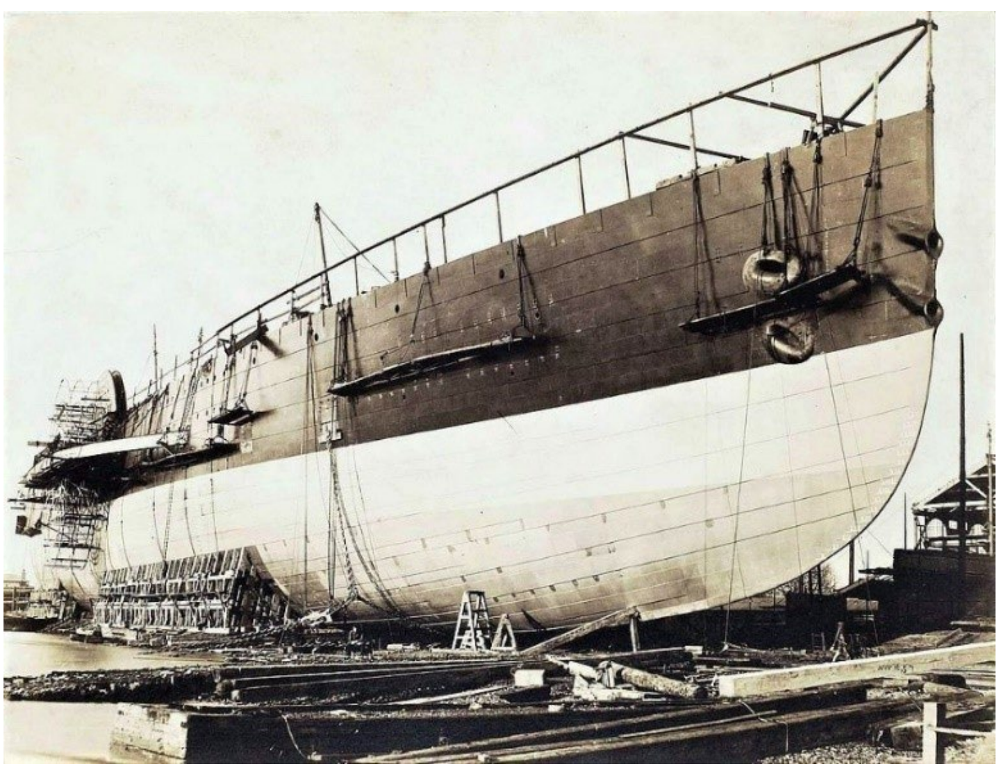


Whipstaff, tiller and rudder, 14th century.
Credit: Wikipedia



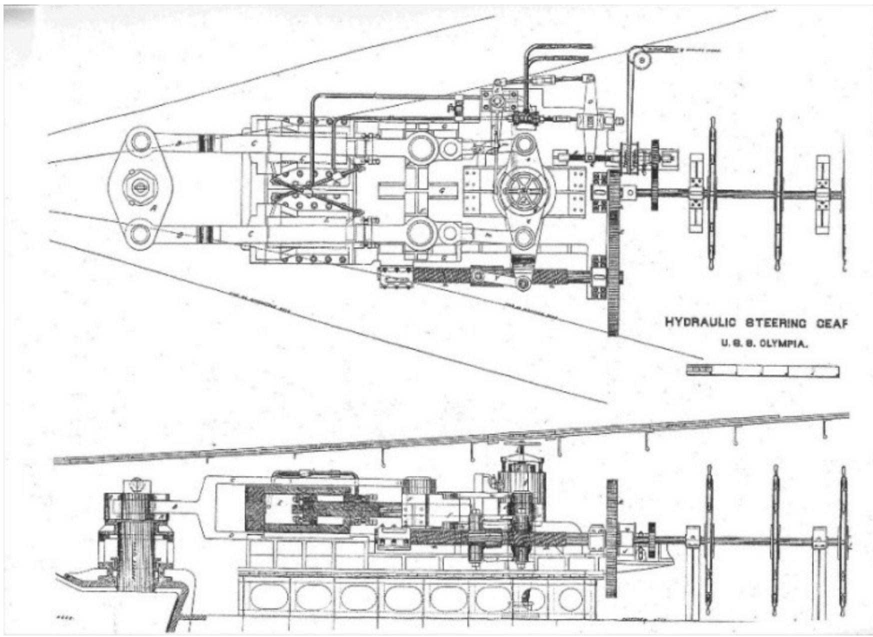
HMS Minotaur
Credit: Wikipedia

The Great Eastern, a marvel of 19th century iron shipbuilding, was, by a wide margin, the largest vessel in the world. Built in 1859 to carry 4,000 passengers non-stop from England to Australia, hand-steering the 700-foot mammoth ship with her huge rudder proved untenable. The world's first steam steering system was developed and installed in Great Eastern by John McFarlane Gray in 1867. Great Eastern was provided with a single, steam-powered screw propeller and two side-paddle wheels turned by four steam engines and spread over 55,000 square feet of sail on six masts. The combination of different engines and canvas, installed for redundancy and to complement each other, were difficult to synchronize in any useful manner, and sail couldn't be set for fear of cinders from the five funnels setting them afire. Ahead of her time and too large for her intended trade, her only success was laying the Atlantic cable. Otherwise, the largest ship for half a century was a commercial failure.



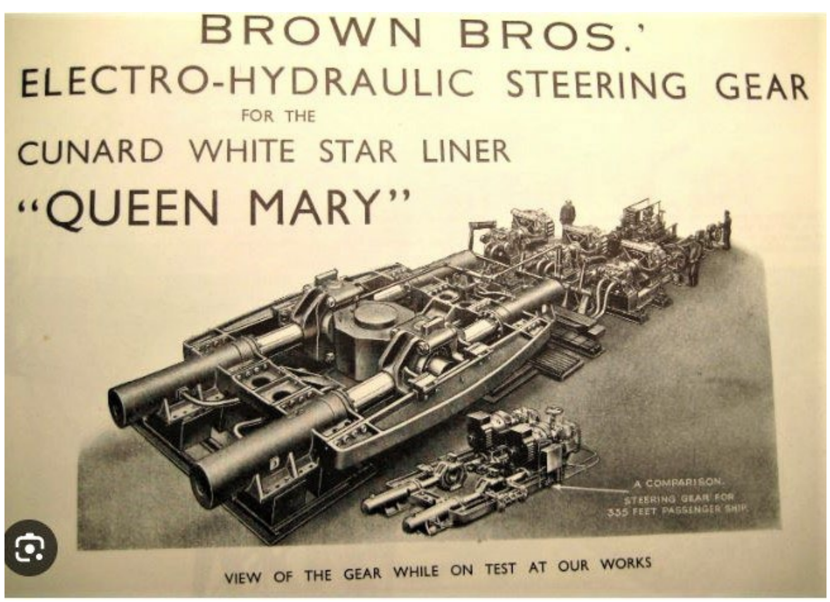
Great Eastern
Credit: Wikipedia

Steam engines geared to a rudder quadrant were superseded by steam-powered hydraulic rams, then replaced by electric motor-driven hydraulic ram systems. Fluid power reduced the number of moving parts, eliminated the need for accurately cut gear teeth, and reduced the weight and wear of the steering units. The US Navy pioneered steam-driven hydraulic steering gear in the 1889 cruiser Charleson and monitor Monterey and was fitted in Admiral George Dewey's famous cruiser USS Olympia in 1893. The installations proved compact and reliable and allowed the low-profile steering machinery to be placed under armored decks for protection.



USS Olympia steering gear under the armored deck. Note emergency wheels ®
Credit: Independence Seaport Museum

Ram-type, electro-hydraulic steering was the machinery of choice for many decades and was used on most of the large transatlantic liners after Titanic. Rather than steam-driven pumps, the electro-hydraulic units used electrically driven pumps to pressurize the hydraulic fluid. Four rams were fitted, with any two providing steering power and two on standby. Three electric pumps were provided; two supplied ram pressure, with the third serving as back-up. Several variations of hydraulic steering gear were developed that were simpler and lighter.



RMS Queen Mary (1936) Brown Bros. steering gear
Credit: The Shipbuilder and Marine Engineer (June 1936)

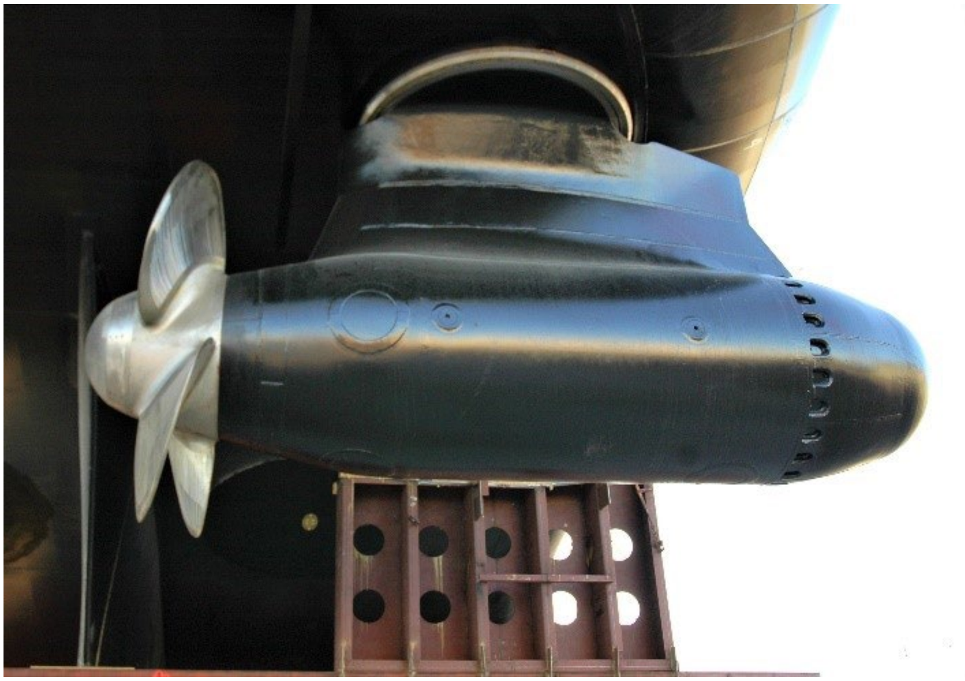
Rudders underwent changes over the decades but basically remained a vertical spade in the water. If the rudder is at a zero-attack angle (that is, in line with the fore and aft centerline of the ship), it has little effect on the ship other than providing minor corrections to maintain the course. But when swung over to turn the vessel, it imparts a turning moment that begins to rotate the hull. As the hull begins its turn, the bow wave builds up pressure on the side away from the turn, creating great resistance. The resistance of the bow wave acts as a fulcrum, and the distance between the rudder and bow creates a long lever that aids the thrust of the water pressure on the rudder to turn the ship.

Typical ship's rudder and propeller
Credit: Wikipedia

Innovation in the marine industry created a new device, the azipod (Azimuthing Electric Podded Drive). First developed in the late 1980s in Finland, the first azipod was retrofitted to a Finnish icebreaker. The azipod combines both propeller and steering into one unit and eliminates the need for an independent steering system and the long shafting associated with traditional engine-driven vessels. Unlike other drive systems, where the propelling machinery is fitted in the hull and the propeller turned by shafting, the azipod contains a powerful electric motor in the pod directly connected to the propeller. The enclosed electric motor receives its power from diesel or gas turbine generators within the ship's hull. As use grew, azipods found favor with ferry companies, because their efficiency saved fuel (nearly two million dollars per vessel) and thereby reduced emissions. Ship owners and cruise lines, always eager to reduce operating costs, included azipods in their new vessels, realizing fuel savings of 20%.

With no mechanical shafting or gearing, the units are compact, can turn 360 degrees and when facing forward (that is, the propeller pulling) are highly efficient, with good fuel economy. Queen

Mary 2, the logical heir of the long procession of transatlantic liners, is fitted with two fixed azipod units and two rotating units that steer the ship. Electricity is provided by four large 16-cylinder diesel engines turning generators with two gas turbine units as back-up power for the ship. Each azipod drive motor produces 30-40,000 horsepower.



Azipod as fitted in the United States Coast Guard icebreaker Mackinaw.
Credit: Wikipedia

Sources: The Shipbuilder, 1911 Special Edition; Titanic Ships, Titanic Disasters by William H. Garzke & John Woodward; A Night to Remember, Watler Lord; Wikipedia, Wikipedia Commons, Wiki Fandom, Wikidata; Encyclopedia Titanica Deck Plans; SOLAS (Safety of Life at Sea) Requirement for Steering Systems, Oxford Reference; The Independence Seaport Museum; ABB Industries