A QUIET SEA

RMS TITANIC

RIVETING

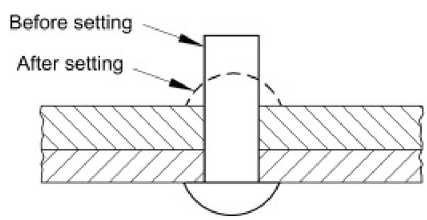
TITANIC: RIVETING

INTRODUCTION

When iron and steel ships were introduced in the 19th century, the only way to fasten them together was by riveting. In the 19th and early 20th century, construction industries relied on riveting to build bridges and erect skyscrapers. Rivets are made from round bars and have smooth shanks with different styles of heads.

Various types of rivets
Credit: V. Ryan

To close a rivet, it is first heated to a specific temperature (determined by a light-yellow color) in coke or oil-fired forges. It is then placed in carefully located and aligned holes in hull plates and frames that are temporarily bolted together. Once inserted, the rivet is held in place with a heavy steel bar, and the unformed end is set, or closed, to the desired shape and left to cool. As the rivet cools, it contracts and remains in tension. It is a permanent mechanical fastener that clamps the structural parts together.

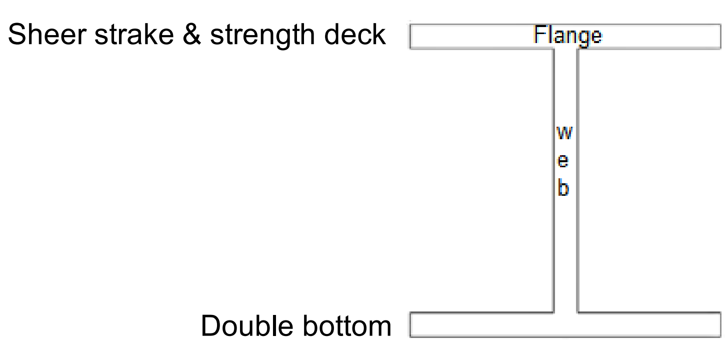


Upsetting rivet point
Credit: Science Direct

THE ENGINEERING PROBLEM

When a ship forges her way through heavy seas, she endures a multitude of ever-changing stresses. Supported on a wave at bow and stern, the hull sags midships. When supported by a wave midships, the bow and stern sag, a condition known as hogging. Add to these twisting, or torsional forces, and it becomes evident that a ship's hull must resist ever-changing stresses and strains coming from every direction, at every moment. As ships became larger, stresses amplified, making uniform and sound riveting paramount.

A ship's hull can be considered a girder, like an 'H' on its side where the top and bottom of the hull are represented by the two horizontal lines, or flanges. The vertical web connecting the flanges represents the internal structure and side shell plating.



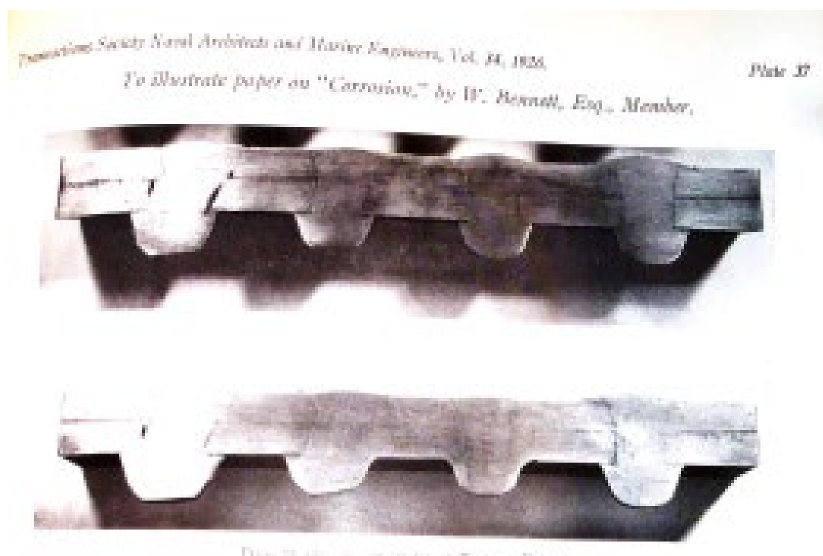
H-beam: ship's hull girder
Credit: Research Gate

When a ship is going over waves, the stresses are least at mid-depth of the hull and greatest at the double bottom and sheer strake/strength deck, the top and bottom flanges of the hull girder. Naval architects were well aware of the enormous stresses in these areas and concentrated more material to prevent buckling or cracking. Two layers of heavily riveted plating were used in sheer strake/strength deck. The double bottom was heavily framed and riveted not only to resist wave action but also to support the great weight of boilers and engines. For the various parts of the hull structure to act as a unit, riveted connections had to be made as good as possible.

MANUAL & PNEUMATIC RIVETING

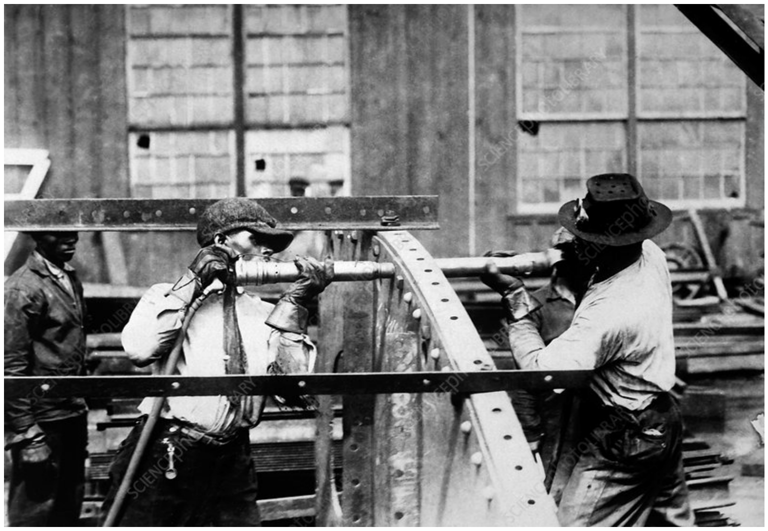
Riveting gangs were composed of five-man teams: one heater, two riveters, one "holder-on" (with a 16 lb. bucking bar) and one passer, usually a boy, to place the hot rivet into the plate. Manual riveting was performed by two men alternately striking the same hot rivet, while a third man, the holder-on, bucked it in place against the hammer blows. It took speed, skill and accuracy to make a well-formed rivet point. Still, the problem with hand driven rivets was the lack of uniform holding power; it was impossible to heat and close every rivet exactly the same every time.

Manually closing rivets with rivet hammers
Credit: Henry Robb's Shipyard



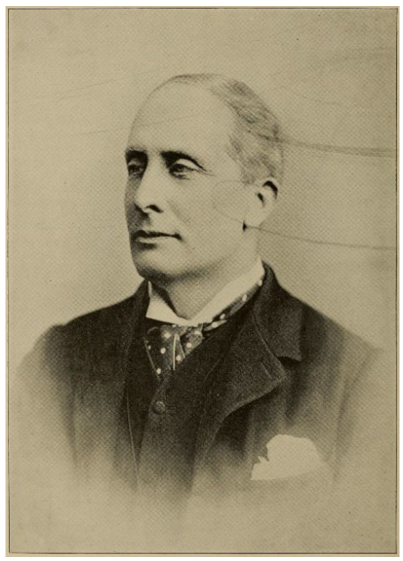
Cross-section of riveted joint showing poor workmanship
Credit: SNAME transactions 1926

Hand-held pneumatic hammers improved and economized the riveting process by eliminating one riveter. If two pneumatic hammers, each striking opposite ends of the same rivet simultaneously, were employed, then the holder-on wasn't needed. Still, there was a limit to the size of rivet such hammers could drive. Keeping the heavy rivet gun straight formed a concentric point, but if held crooked, a poorly formed, eccentric point would result, reducing the holding power of the rivet. In both manual and pneumatic riveting, the riveters returned to the previously closed rivet to deliver a few more blows while the rivet was cooling. This hardened the rivet and removed the temper, reducing the risk of the point cracking. But another drawback was battering the rivets if they were allowed to cool during closing, thereby reducing their effectiveness. Clearly, something was needed to make every rivet a perfect rivet.



Riveting with two pneumatic hammers closing the same rivet, 1918
Credit: Science Photo Library

RALPH HART TWEDDELL

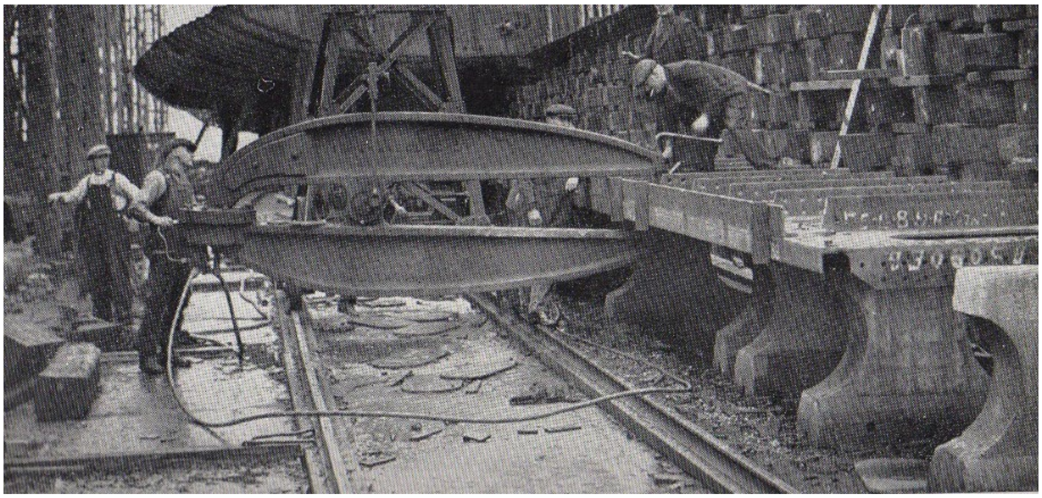


Ralph Hart Tweddell
Credit: Wikipedia

Ralph Hart Tweddell was born in 1843 in the eastern coastal town of South Shields, England. He came from a ship-owning family and considered a military career. However, he had an aptitude for engineering and pursued that instead. He apprenticed to a locomotive builder in Newcastle, not far from his home. During his apprenticeship, in 1865, Tweddell took out his first patent—to improve boiler construction methods, making them safer to sustain higher steam pressures. A proponent of hydraulic power for riveting, he designed the hydraulic riveting machine first used by the engine builders Thompson, Boyd & Co. in Newcastle. Encouraged by the success of his invention, Tweddell went on to develop a portable hydraulic riveter that could be used in bridge and ship construction. The first portable hydraulic riveter was put to work on a lattice girder bridge in 1873. It's use spread rapidly to Italy and France, where it was used to construct iron warships. Tweddell was honored for applying hydraulic power to the working of machine tools by the International Inventions Exhibition in 1885. He was a member of several engineering societies, subsequently writing professional papers on the practical application and labor-saving advantages of hydraulic power. An avid hunter and outdoorsman, he died in 1895, 2 years after sustaining serious injuries from a riding accident.

THE PORTABLE RIVETER

The first portable hydraulic riveters were used in bridge construction. Water pressure, provided by pumps and maintained by large tanks called accumulators, was used to operate the riveters. They could exert as much as 140 tons of pressure to close a rivet. Shaped like a huge lobster claw, these formidable machines would fit over the plates to rivet the joints the full depth of a plate. The great advantage of hydraulic riveting over manual riveting was that as the hot rivet was closed in one power squeeze (rather than hammered), its internal fibers were evenly formed to give the rivet great holding power. Hydraulic riveters were also much quieter than manual and pneumatic riveting. They did their work only with the audible hiss of the hydraulics.



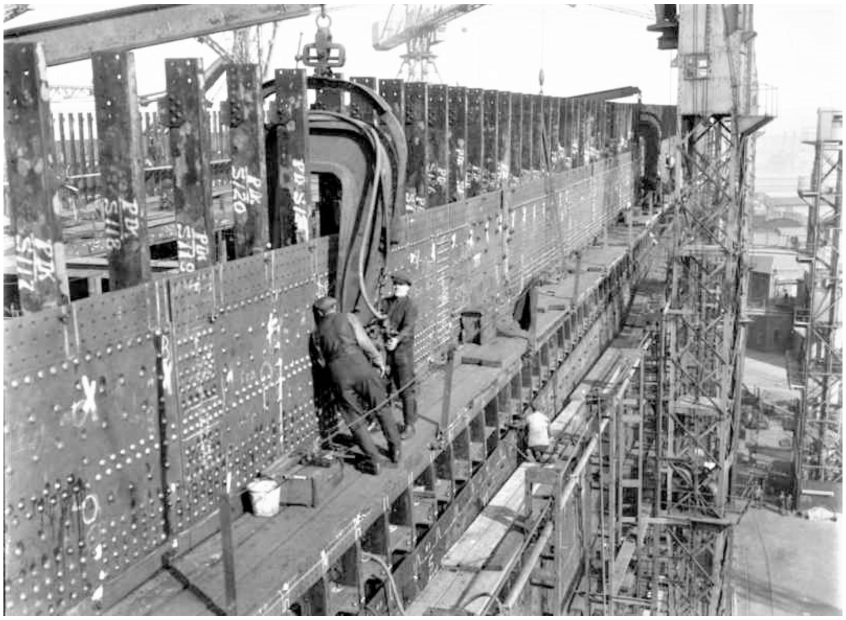
Portable hydraulic riveter in use on a ship's bottom framing
Credit: Henry Robb's Shipyard

RIVETING ON TITANIC

Titanic was built using Siemens-Martin formula steel developed by German and French engineers in the 19th century. It was the preferred shipbuilding material of the day. Siemens-Martin steel could be produced in great quantities, was uniform in quality, resisted corrosion well and possessed good elastic properties, allowing it to adjust to various stresses. It was also ideal for hydraulic riveting.

Hydraulic riveter on keel of Titanic's sister, Olympic, 1909
Credit: The Shipbuilder

It was common practice to use the biggest plates possible to reduce the number of end connections and overlaps, thereby providing as much continuous longitudinal strength for the hull as possible. Titanic's largest plates were 36 feet long and weighed about 4½ tons. The plates were generally 1" to 1½" thick, with the thicker plates located in highly stressed zones of the hull. Each plate had its own wooden template that accurately described its size and shape and the position of each rivet hole. The holes were first punched undersize, then reamed to remove brittle material in the edges caused by punching. Reaming also was used to align the holes in plates and frames and also made the holes slightly oversize to provide room for the hot rivet.



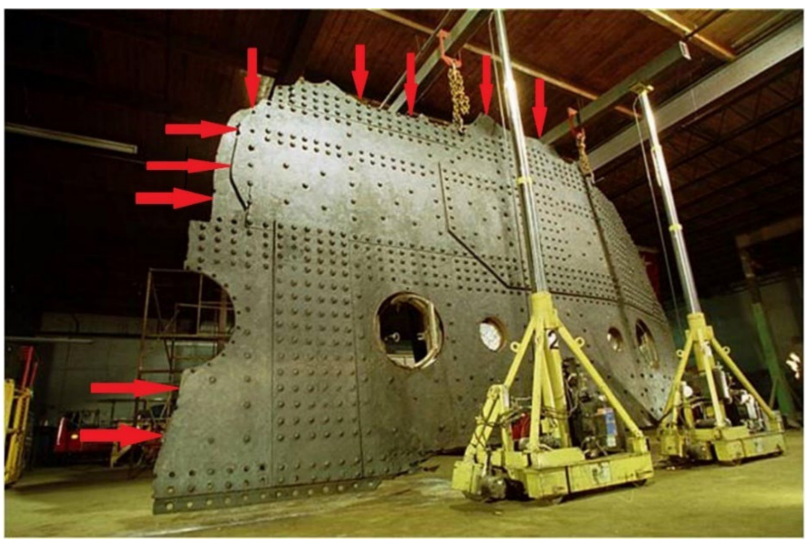
Hydraulic riveter on a large vessel in the John Brown shipyard
Credit: Ship Nostalgia

Titanic was built using millions of rivets that weighed over 1,200 tons, or about the weight of an early WW II US Navy destroyer. The largest rivets were 1¼" in diameter and were closed by hydraulic power. Hydraulic riveting was used extensively in the double bottom, sheer strake and strength deck, the latter two located at the upper portion of the hull. Many plate laps had three or four rows of rivets.

Titanic, starboard side view aft showing heavily riveted sheer strakes
Credit: Stolen History

Quality control of rivet stock was taken seriously. Selected rivets per lot were checked by three basic methods: tension tests, cold bend tests and hot flattening tests. Rivet material had to exhibit homogeneity and show no cracking or other flaws to pass the physical tests. In addition, ladle analysis to determine the consistency of the chemical composition were routinely made to assure the quality of the metal. Although hydraulic riveting produced high quality riveted connections, the large machines couldn't reach everywhere. In restricted spaces, toward the ends of the hull, manual riveting was employed. As with power-driven rivets, each rivet was checked, approved with red paint and tallied by an inspector. The riveters were paid piecework for each good rivet, so driving sound rivets was not only important for the ship but also for the amount of pay the men received. Inspectors struck a finished rivet with a ball peen hammer, listening to the sound while feeling for movement. Poor rivets were cut out and replaced, slowing the work and subtracting from the wages.

In certain low-stress areas of the hull, wrought iron rivets were used. Although slightly lower in tensile strength than steel, wrought iron rivets had certain advantages: they held heat better to permit hand riveting and were more corrosion-resistant, ductile (thus slow to fracture) and shock-resistant. Good quality wrought iron contains about 3% of iron silicate, a glass-like slag that gives wrought iron its tough, fibrous structure. Wrought iron rivets were used well into the 20th century. A drawback of riveting in general is that it doesn't develop the full strength of the plates and frames they join. This is of little consequence in low stressed areas of the hull, but to provide the riveted strength required for the highly stressed areas, elaborate and complex design enters the picture.



Salvaged Titanic hull section (inverted)
Credit: EverGreene.com

Titanic's salvaged hull section provides some insight into riveted joint design. Locations identified by red arrows show where the plates and not the rivets failed, indicating good rivet design. The hull section is part of the sheer strake and strength deck, a two-layer, multiple-riveted steel plate structure, further strengthened with large diamond-shaped steel butt straps, identified by the angled edges seen in the illustration. Investigations have shown that this section of plating may have been the last to fail during the hull's final, tortured moments before sinking.

Riveting alone doesn't make a watertight seam. To accomplish this, the perimeters of riveted plates must be mechanically caulked; no obturating material is used. In caulking, a pneumatic chisel is run along the edge of one plate to upset it against its neighbor, rendering the seam watertight. In the days before pneumatic chisels, caulking was done by hand, requiring endless strikes of hammer against chisel. Titanic's hull plates, bulkheads and other watertight structural members were sealed by caulking. Rivets were also caulked in tanks holding lubricating oil.

Caulking chisel sealing a lapped seam
Credit: SS John W. Brown

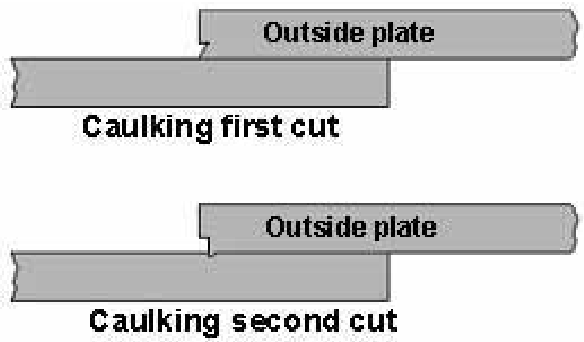


Plate seam caulked
Credit: John Oxley.org

THE RIVETERS' LOT

There were about 200 riveting gangs building Titanic. They suffered a variety of ailments, from loss of hearing to a twitching condition known as "punchy." To achieve their daily quotas, riveters had to be able to work both right- and left-handed. Paid by the rivet, they worked at a breakneck pace yet had to maintain the quality of their work for the rivets to pass inspection. Their workday was from 6:00 am to 5:30 pm, six days a week. The rules were strict, and fines were imposed for infractions, such as not making the daily quota or dishonesty in claiming a rivet count. "Boiling can"—sneaking tea boiled on a rivet furnace not at the assigned rest time—was the most common infraction. Crews were allowed 30 minutes for lunch and two 7-minute, closely timed (by a clerk) bathroom breaks. Additional time spent answering the call of nature resulted in a fine if not explained by a doctor's note. Basic protective equipment was unheard of; 246 injuries (28 severe) and 8 deaths were logged during Titanic's construction. Most deaths were the result of falls. Widows could be awarded 2 years' wages as compensation but only after proving Harland & Wolff liable, not an easy task. Yet, riveting gangs were competitive, and records for rivets driven per shift were consistently broken. One gang closed an astonishing 1,409 rivets in a single hour.

EPILOGUE

Electric arc welding, the joining of metal using an electrode, became practical in the 1890s but wasn't introduced to shipbuilding until WWI, Welding eventually supplanted riveting and caulking, greatly decreasing production times. Riveting gangs faded away, and with them the shattering din that filled the shipyards. But the great legacy of their tough and exacting work were the renowned ships that grappled with the mighty North Atlantic, braving anything the great ocean could throw at them.

Sources: Wikipedia; Harland & Wolff; History of Shipbuilding; David Darling; Encyclopedia Titanica; The Express; Steel Merchant Ships (Abbot); Surveying Historic Vessels (author); Guinness Book of World Records; The Shipbuilder 1911