The Building and Sinking of the RMS Titanic

Course No: B03-013
Credit: 3 PDH

Robert Steelhammer, P.E.

CED CANADA engineering.ca
CPD FOR THE PROFESSIONAL

Continuing Education and Development, Inc.

P: (877) 322-5800
info@cedengineering.ca

TABLE OF CONTENTS

Introduction and Background

Icebergs in the North Atlantic have long caused problems for ships. When it comes to an iceberg, only about eleven percent of it is above the water line and can be seen. Many vessels have been lost over the years due to collisions with icebergs. Between March 1841 and February of 1902, there were eight ships presumed sunken due to the icebergs of the Grand Banks near Newfoundland. There were another three collisions between 1873 and 1907 involving icebergs causing damage or loss of a ship in the North Atlantic. Some other maritime incidents involved White Star Line. Avoiding icebergs was dependent on visual watches that darkness or foul weather made even more difficult. The most common sighting distance was one nautical mile, which is slightly over a mile. It can be seen with this sighting distance how weather such as rain or fog could affect the visibility, and thus the time to make evasive maneuvers.

Some of these disasters involved icebergs off of Grand Banks. One of these was the steamer President, that was crossing from New York to Liverpool in March 1841. It was assumed lost to icebergs off the Grand Banks with 120 on board. Another was the City of Glasgow that was traveling from Liverpool to Philadelphia in March 1854 with 480 on board. Two years later, the Pacific left Liverpool for New York with 185 on board. In May 1870 the City of Boston left Boston for Liverpool with 191 on board. In February 1892, White Star steamer Naronic left Liverpool for New York. Four years later, the steamer State of Georgia left Aberdeen for Boston. In February 1899, the steamer Allegheny from New York to Dover, England is lost. Three years later, the steamer Huronian left Liverpool for St. Johns and disappears. These were all assumed lost due to icebergs off Grand Banks. In November 1879, Guion steamer Arizona left New York for Liverpool with 509 aboard. Arizona hits an iceberg at 18 knots while crossing Grand Banks, but makes it to St. Johns under her own power 36 hours later. On May 6, 1909, the Canadian steamer Lake Champlain stuck an iceberg near Grand Banks with unknown number of injuries.

There were other incidents that did not involve icebergs. For example, on April 1, 1873, White Star Line Atlantic ran aground 15 nautical miles Southwest of Halifax, Nova Scotia. It diverted there instead of New York due to low fuel and heavy seas. Atlantic capsized with 547 deaths. In June 1904, an excursion steamboat named General Slocum caught fire going through Hell Gate on the East River in New York. More than 1,000 people died. On March 1, 1907, White Star Line Suevic ran aground near Land's End in Cornwall. Part of the ship was salvaged. The steamer Republic collided with the liner Florida on January 22, 1909 off of the Massachusetts coast. Only 6 fatalities resulted due to the advent of wireless sets, and the White Star Baltic coming to rescue.

The RMS (Royal Mail Ship) Titanic was a British passenger ship that sank in the North Atlantic on April 15, 1912, after striking an iceberg. The passenger liner was four days into her maiden voyage from Southampton, United Kingdom to New York City. The Titanic was said to be unsinkable, as dubbed by the popular press, and the largest passenger ship to sail the ocean. The Titanic represented the largest moving man-made object. It was the second of three Olympic

class liners operated by White Star Line. These were the Olympic, Titanic, and Britannic. The Titanic could carry 3,547 people and the design was based on a revised design of the Olympic.

The Titanic's maiden voyage began on April 10, 1912. There were stops at Cherbourg Harbour in Northwestern France and Queenstown, Ireland on April 11, 1912. Passengers boarded at both ports. The Titanic then proceeded westward across the Atlantic with 892 crew members and 1,320 passengers, for a total of 2,212. Some resources put the number at 2,240 "souls" on board and others put the number at 2,223. Souls was the term used in the shipping industry at the time, usually in association with a sinking. Less than 1/3 of these would survive the disaster that occurred just south of the tail of the Grand Banks where the Titanic collided with an iceberg. This was approximately 400 miles southeast of Newfoundland.

The questions remain about whether the sinking was the fault of design or faulty ethics. A discussion of the accident and the design may give some insight. The story of the Titanic does have its heroes and villains. The Titanic was found under 12,000 feet of water in 1985 by Robert Ballard of the Woods Hole Oceanographic Institute. It was found to be broken into two pieces in opposite directions.

White Star Line

White Star Line was originally formed in Liverpool, England in 1845 and established itself in the Australian trade. This was done with one ship by 1852. White Star Line went bankrupt in 1866-1867 and its assets and name were purchased by Thomas Henry Ismay, father of J. Bruce Ismay. Thomas Ismay formed the Oceanic Steam Navigation Company (OSNC) in 1869. OSNC contracted with Harland & Wolff shipbuilders to construct two new steamers, Oceanic and Atlantic. They began service in 1871 and were the largest steamers in the Atlantic. Harland & Wolff partners bought shares of White Star and took seats on their board of directors, and vice versa, thus establishing the relationship between Harland & Wolff and White Star Line.

In 1902-1903 White Star was absorbed by the International Mercantile Marine (IMM), formed by J.P. Morgan. Joseph Bruce Ismay served as the President of IMM from 1904 until 1912, when he was forced to resign after surviving the Titanic disaster when so many died. He had helped load some of the boats before getting into one of the collapsible boats (collapsible lifeboat C) as it was being lowered to launch. He had been instrumental in getting the number of lifeboats reduced despite the recommendations to the contrary. He also boarded the lifeboat, despite the order that women and children first, by maintaining that there were none close. Witnesses challenged his assertion. He was the Managing Director of White Star Line at the time the Titanic sank and was on board as a voluntary passenger, according to his Senate testimony.

The Titanic was built as a response to competition with Cunard and Hamburg America. White Star Line's main British competition was Cunard that had the ships Mauretania and Lusitania. In 1907, the Lusitania was the largest and fastest passenger ship in the world. They decided to

compete based on size and luxury, instead of speed. Speed was compromised on the Titanic to give the passengers a smoother ride without the competitor's vibration stemming from an outdated propeller design.

White Star Line was sold in 1926 to Royal Mail Line. Royal Mail Line was absorbed by Cunard Line in 1935. All White Star Line records were lost.

Design Team of the Titanic

The design of the Titanic was directed by William Pirrie, a director of Harland & Wolff and White Star Line. The design team of the Titanic was originally headed by Alexander Carlisle. He was the designer of the Oceanic in 1899, and was Chief Draftsman and general manager of the Harland & Wolff shipyard. His sister was married to William Pirrie, also known as Lord Pirrie. He began as an apprentice in 1870, became General Manager in 1890, and became the Chairman of the Board of Directors at Harland & Wolff in 1907. Mr. Carlisle suddenly retired in 1910 after disputes with Lord Pirrie over the number of lifeboats. Mr. Carlisle was most often thought of as responsible for much of the internal design of the ships.

After Alexander Carlisle's retirement on June 30, 1910 the leadership of the design team was taken over by Thomas Andrews, a naval architect and Lord Pirrie's nephew. He was most often referenced as the designer of the Titanic, likely because he perished in the disaster. He had previously been the Chief Draftsman for Harland & Wolff. Andrews was thought of as being responsible for the structural design of the ships. Andrews' deputy, Edward Wilding, was responsible for calculating the ship's design, stability, and trim. Mr. Wilding was Harland & Wolff's Senior Naval Architect.

Design and Building of the Titanic

The design for the Titanic and Olympic was approved on July 29, 1908. It was approved by J. Bruce Ismay and other White Star directors. Thomas Andrews incorporated some of the latest features into the design. He led a team of draftsmen that designed the ship using a series of hand drawn blueprints. The official order was placed September 17, 1908 for both Olympic and Titanic.

Construction of the Titanic began on March 31, 1909 in Belfast, Ireland at the Harland & Wolff shipyard when Thomas Andrews laid the first keel plate. Construction on the Titanic's sister ship, the Olympic had begun three months earlier. Harland & Wolff had a long relationship with White Star Line, dating back to 1867. Ismay's father had worked closely with William Pirrie for years. White Star Line had an exclusive contract with Harland & Wolff. Harland & Wolff had approximately 15,000 employees working on the construction of the Titanic, which sometimes led to injuries and fatalities. There were two new shipyards constructed to build the Titanic and her sister ships.

There were injuries involved in the construction of the ship, as safety in construction at the time was not what it is today. There were 246 injuries reported and 28 of these injuries were classified as "severe". These involved arms severed by machines and legs crushed under falling steel. There were also several deaths during the construction of the Titanic. Six of these were on the ship, and another two in the sheds and workshops in the shipyard, and one from a falling wood support just before launch.

The Titanic's hull was launched on May 31, 1911 in the River Lagan, six months after the Olympic. She was then towed to a fitting out dock for the next phase of construction. The construction of the interior, decks and installation of the 29 boilers took nearly a year. The Titanic's sea trials took place on April 2, 1912. This was done over a twelve hour period with various maneuvers to determine the capabilities and limitations of the new ship.

When it was completed, the Titanic was 882 feet 9 inches long and had a maximum breadth of 92 feet 6 inches. The height of the Titanic from the base of the keel to the top of the bridge was 104 feet. The Titanic had a gross weight of nearly 45,000 tons. The Titanic had eleven decks, eight of these for passenger use. The upper three decks were fitted with two expansion joints that allowed two feet of expansion or contraction.

J. Bruce Ismay

Joseph Bruce Ismay was born December 12, 1862 near Liverpool, England. He was the chairman of White Star Line and was a businessman, not an engineer. He was the son of Thomas Henry Ismay, who owned White Star Line and he became chairman after his father's death in 1899. It was under his direction that White Star became noted for luxury liners. He continued as the chairman of White Star Line even after the company was acquired by J.P. Morgan's International Mercantile Marine Company (IMM) in 1902. In 1904, he also became president of IMM.

It was in 1907, when Ismay attended an event in London with William Pirrie, who was the Chairman of Harland & Wolff. Pirrie and Ismay developed a plan to build large luxury ships to compete with Cunard. Ismay was aboard the Titanic during her maiden voyage. Harland & Wolff had a relationship with White Star Line that dated back to 1867, when White Star Line was under Ismay's father. They had a "cost-plus" arrangement and this was the arrangement used on Titanic and Olympic.

Thomas Andrews and the Lifeboats

The Titanic's designer was Thomas Andrews, who took over after the sudden retirement of Alexander Carlisle. He had way into Harland & Wolff, being the nephew of the owner, William Pirrie. He became an apprentice in 1889 at the age of 16 and worked his way up in the company. He became Managing Director of Harland & Wolff in 1907. Andrews had recommended 64 lifeboats and that the watertight bulkheads extend to B deck. His recommendations were overridden by his uncle and Mr. Ismay.

Thomas Andrews made it a practice to go on the maiden voyage of White Star Line ships. This was to see how they would operate under real world conditions. After the ship hit the iceberg, Captain Smith consulted with Mr. Andrews, who predicted it would sink in less than two hours and informed the Captain the extent of the damage.

The Crew

While it would be impossible to discuss every member of the crew, there must be a discussion of some of the key people involved in the design and key members of the crew. There were six watch officers and 39 seamen. The rest of the crew was composed of engineers, firemen, stokers, stewards, and galley staff. The total number of crew was 799, where 500 served passengers and 325 cared for the ship, and 66 were responsible for sailing the ship. That left only the band members.
The majority of the crew members were casual workers that came aboard the ship a few hours before departure. Lack of a permanent crew was significant as they had little time to become familiar with the structure and procedures of the ship.

There were eight officers. These included the Captain, Chief Officer, and First through Sixth Officers. Half of them died in the disaster. Of these officers, the only ones that could command the watch were, Murdoch (First Officer), Wilde (Chief Officer), and Charles Lightoller (Second Officer). These were the only officers that held at least an Ordinary Master's Certificate, which was the minimum required to have active command of the ship.

Captain Edward John Smith and the Olympic

The Titanic was commanded by Captain Edward John Smith, who was the most senior of the White Star Line's captains. He was 62 years old and had four decades of sea experience, including 27 years in command. He joined White Star Line in 1880 at the age of 30 as a 6th Officer and became Captain by 1887. He was a Commander in the Royal Naval Reserve. He was also the world's highest paid seaman. The Titanic maiden voyage was to be his last voyage before retiring. It is always said that the Captain goes down with the ship, he died when the Titanic sank.

Captain Smith had been transferred to the Titanic from the RMS Olympic on April 1, 1912. Before he was Captain of the Olympic he became Commodore (most senior steamer captain) of the White Star fleet in 1904. In 1907 he was given command of the RMS Adriatic. He was in command of the RMS Adriatic when it ran aground in New York's Ambrose Channel on November 4, 1909. He was given command of the Olympic when it was commissioned on May 31, 1911, before her maiden voyage departing on June 14, 1911.

Captain Smith was interestingly the Captain of the Olympic, the Titanic's sisters ship, when it collided with the HMS Hawk on September 20, 1911 off of the Isle of Wight. The two ships were running parallel to each other when the Olympic took a sudden turn to Starboard and was broadsided by the Hawke, who believed they had the right-of-way. The Hawke had waited too long to make evasive action and the Hawke's rudder jammed when attempting a sharp port turn.

This caused the Hawke to nearly capsize and put a couple of large holes in the Olympic's hull that flooded two of the watertight compartments. The Olympic was able to return to Southampton under her own power.

The incident was blamed on the Olympic by the Royal Navy. It was claimed at an inquiry that the Olympic's abrupt turn and massive displacement combined to pull the Hawke into her side. White Star Line maintained that the Olympic was under the direct control of the harbor pilot at the time of the accident. The accident cost White Star Line a lot of money in legal fees, costs to repair the Olympic, and lost earnings with Olympic out of service.

The Olympic had temporary repairs done in Southampton to make her seaworthy. Olympic left Southampton on October 4, 1911 and proceeded to Belfast for repairs. The concrete filled ram of the Hawke was recovered from inside the Olympic during drydock repairs. When the Olympic was put into drydock for repairs, it meant redirecting some of the yard's work to the repair of the Olympic from building the Titanic. They took Titanic's starboard propeller blades and propeller shaft. This delayed completion of the Titanic by three weeks. Olympic was unable to return to service until November 29, 1911. This meant the lost revenue from three round-trip voyages.

Other Titanic Officers

Henry Wilde was the Chief Officer of the Titanic. He signed on at 6 AM the day the Titanic set out on her maiden voyage. Wilde was transferred from the Olympic where he worked with Captain Smith. In fact, it was Captain Smith's request for Wilde to be transferred. This transfer in effect demoted Murdoch to First Officer and Lightoller to Second Officer. The Second Officer that Lightoller was replacing, David Blair, left the ship on April 9, 1912 without informing his replacement of the location of the lookout's binoculars that were locked in the Second Officer's cabin.

Design and Safety Features/Flaws of the Titanic

Hull Steel

A 1991 expedition to investigate the disaster discovered pieces of the hull steel on the ocean floor. The pieces were sharp and looked like broken glass, indicating the plates shattered. Most steel today would bend instead of shatter under impacts that an iceberg would yield. The Olympic and Titanic were both built with steel using the Siemens-Martin formula. This type of steel was first used on the armed merchant cruisers Teutonic and Majestic.

The first piece of hull material was recovered in 1991 by the submersible Nautile of the French Oceanographic Institute. The material came into the possession of the Maritime Museum of the Atlantic, who asked the Defense Research Establishment–Atlantic (DREA) and CANMET to test the mechanical properties of the steel. Charpy impact tests showed the steel fractured in a 100

percent brittle fashion at ice brine temperatures. This result caused speculation that the brittle character of the hull steel in ice water (brine) could have been a major factor in the sinking of the Titanic. It was considered possible that the impact with the iceberg was sufficient to shatter the brittle hull steel plates in the bow of the ship.

A 1996 salvage trip recovered a section of the Titanic's hull plating as well as several hull and bulkhead rivets. The purpose was to determine the physical properties, microstructure, and chemistry of the hull steel. The other purpose was to consider the possibility of rivet failure by analysis of the rivet samples. These samples were analyzed using modern methods.

In 1996, a study was headed by Dr. Phil Leighly, a professor of Metallurgical Engineering at the University of Missouri-Rolla, on the steel used for the Titanic, to characterize mechanically. Chemical analysis and impact tests were conducted on sample steel. He had received more than 400 pounds of the steel plate from the hull in September 1996. The steel was determined to be very inferior compared to modern steel used to build the ships of today. Leighly stated that the steel could shatter easily in the cold waters of the North Atlantic, but also that is was the best available at the time. The steel was determined to be 10 times more brittle than steel used in modern times. The microstructure showed a large a large amount of banding in the rolling direction. Manganese Sulfide (MnS) and oxide particles were present throughout the material and were quite large. The MnS particles were deformed into lenticular shapes, not melted into stringers. A low rolling temperature is indicated by the lack of rare earth element additions that would increase the sulfide melting point. A large grain size and a course pearlite indicate air cooling of the rolled plate with no evidence of or quenching or normalization heat treatments.

Dr. Leighly also noted that survivors had reported hearing loud cracking noises as the Titanic sank. He noted that when steel breaks "you expect a groaning, not a cracking sound . . . unless the steel is brittle." Brittle steel is more prone to fracture. The tests on the steel revealed a profile that matched semi-killed steel manufactured in the early 1900s.

The steel structure was evident of the plate being produced in a low speed rolling mill. This was consistent with early 20th century Ireland. The closest modern grade of steel is AISI 1018 with a similar chemistry and not possessing a specialized microstructure. Figure 1 shows comparative photographs of AISI 1018 steel plate and the Titanic hull plate. The modern 1018 shows a finer grain size, finer pearlite, and fewer rare earth elements doped MnS particles. The 1018 microstructure is typical of that produced in a high speed mill followed by quench and normalizing treatments.

Tensile tests performed on steel recovered in 1996 and in 1991 are shown in Table 1. The values in the table are consistent with the design requirements specified by Harland & Wolff. There were two groups of Charpy impact specimens, longitudinal and transverse.

Tensile Tests Results		
Plate recovered in:	1996 [7]	1991 [2]
Yield Stress	38 ksi (262 MPa)	41 ksi (280 MPa)
Ultimate Tensile Stress	62.5 ksi (430 MPa)	62.6 ksi (432 MPa)
% Elongation (50 mm gage length)	29%	30.9%

Table 1. Tensile tests on recovered steel.

The conclusions of testing on the plate material was that material had adequate strength, but extremely low fracture toughness at ice water temperatures. The measured fracture toughness was determined to be unacceptably low for use as a structural material at these temperatures. The low toughness was attributed to low manganese (Mn) content, low Mn/C ratio, large ferrite grain size, and large and course pearlite colonies. There was also a wide variation in properties across the 2000 plates that made up the Titanic's hull. The plate samples indicated this variation. The variation makes it difficult to determine the effect of the Manganese Sulfide particles and micro cracks in the sinking of the ship without examination of the plates. It was determined to be possible the brittle steel contributed to the damage to the bow, due to the impact with the iceberg. It was more likely that the brittle steel was a factor in the breakup of the ship at the surface. Heat treatment could have improved fracture properties, but this knowledge was not available at the time.

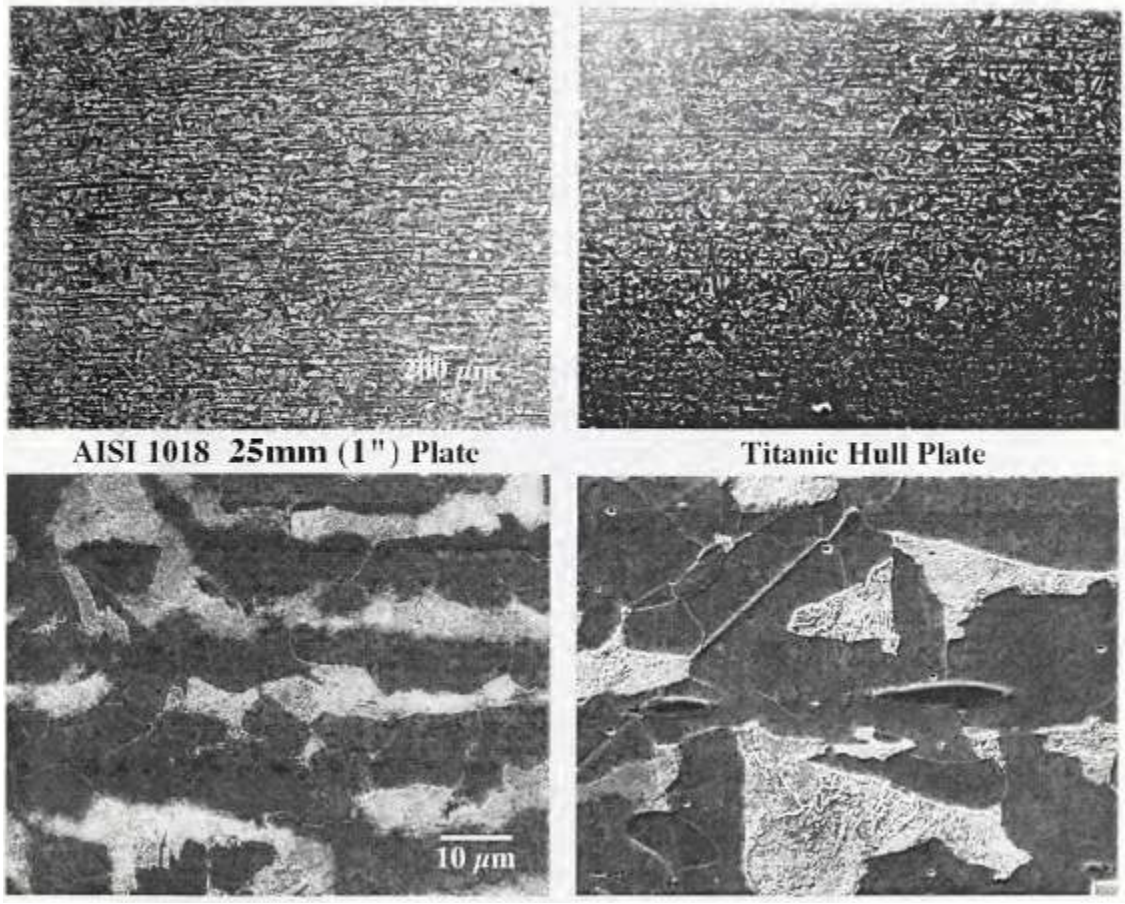

Figure 1. NIST images of scanning electron microscope sections of the steel hull and AISI 1018 steel plate.

The welding of steel was new at the time the Titanic was built and had not developed into the methods that we know today. The steel structure of the Titanic was held together with 3,000,000 hydraulically driven rivets made of iron and steel. Samples of the rivets were analyzed like the plate samples were. Failure of the rivets may have played a role in the sinking of the Titanic. This is indicated by a parting of the seams and not a gash in the bottom of the hull.

The microstructure of the rivets that evolved during the driving may have had an effect on the type and distribution of the damage to the hull of the Titanic. The slag stringers were oriented perpendicular to the tensile axis. The rivets were brittle and easily broke in the below freezing water of the North Atlantic.

A piece of the hull from the stern side is on display in the Luxor in Las Vegas, Nevada. This piece is known as the Big Piece and was recovered in 1998. It was from a location between the third and fourth stack. The Big Piece is 12 feet tall by 26 feet long and weighs approximately 15 tons. This piece likely tore free during the decent to the bottom of the Atlantic.

Watertight Compartments

The Titanic had sixteen watertight compartments in the hull created by fifteen bulkheads. These extended well above the waterline. These compartments are the reason that the media dubbed the ship "unsinkable". This may have started from a special issue of Shipbuilder magazine, where the Olympic class liners were deemed "practically unsinkable". White Star Lines capitalized on this and used it as a marketing tool for ticket sales. There were eleven electric doors that could seal off the compartments in an emergency. They could be operated from the bridge. In theory, the ship should not have sunk, especially at the speed it did. The watertight compartments were a genius engineering idea that was cancelled out by poor budgeting and design execution. Looking back, it was learned that the compartments were only watertight below the waterline. Water, however, could pour from one compartment into another. As the water rushed in, the ship was weighed down since the compartments were not sealed off, and began to list. As the ship began to list, other compartments filled.

The Titanic was designed to stay afloat with as many as four of the watertight compartments flooded. The structural integrity of the ship was compromised with the fifth compartment being flooded. The Titanic only had a single sump pump that was unable to pump the water out fast enough.

Lifeboats

The Titanic was thought of as unsinkable and this line of thought was reflected in the lack of lifeboats. There were only sixteen lifeboats and four Engelhardt collapsibles. The lifeboats were

intended to transfer passengers to nearby vessels coming to the rescue in an emergency. The Titanic had only enough lifeboat space for half of the people on board the ship. The boats at full capacity could only carry only 1,178 people even though the Titanic could carry 3,300 people as designed. This actually exceeded the British Board of Trade's requirements of 960 for the Titanic, but those requirements were outdated and did not figure a ship the size of the Titanic. The English requirements were set by the Merchant Shipping Act of 1894, which only conceived of ships weighing up to 10,000 tons. The gross registry tonnage on the on the Titanic was 46,328 and the net register tons was 21,831.

The ship's original designer, Alexander Carlisle, proposed 64 lifeboats. J. Bruce Ismay objected to this proposition, as he did not want a cluttered appearance next to the Welin davits. The Titanic's next designer, Thomas Andrews, originally proposed 64 lifeboats. His uncle, J. Bruce Ismay, talked him down to 32, and they finally end up with 20.

The Titanic carried 14 regular lifeboats each with a capacity of 65 people, for a total capacity of 910 people. There were also 2 crew cutters that had a capacity of 40 for each (80 total). The four collapsibles could carry 47 each (total 188). These totals assumed they were filled to capacity, which was not done.

The crew had insufficient training to evacuate the ship properly. Even the officers on the crew did not know how many people each lifeboat could carry. This led to many lifeboats being launched half full during a disorganized evacuation. For example, the first lifeboat had 28 aboard and it was designed to carry 65. Nearly every lifeboat was loaded in this disorganized manner, not utilizing the full capability of the lifeboats.

Propellers

The Titanic ran slower than it could have, and this was intentional. The propellers were pitched to give a smoother ride and less vibration. The center propeller on the Titanic was turbine powered, but did not have the ability to reverse. This screw had the most influence on the rudder and maneuverability of the ship.

Coal Fire

A coal fire developed in one of the coal bunkers shortly after Titanic completed her sea trials on April 2, 1912. This was on the starboard side of Bunker 10. Bunker 10 was located at the tail end of Boiler Room 6, forward of Bulkhead Number 5. The fire had begun in Belfast. To extinguish the fire, the contents were gradually emptied and the coal was used to stoke the adjacent boilers. The fire was extinguished by the morning of April 13, 1912. Theories have been advanced that the fire may have made the hull places in this area more brittle. These have not been able to be recovered for testing, so it stays a theory. Buckling of hull plate laps extending two feet into this bunker allowed seawater to penetrate Boiler Room 5. Sources indicate that the two feet made all of the difference in sealing the fate of the Titanic.

An Irish journalist, Senan Molony, spent 30 years investigating the sinking of the Titanic. His belief is that the fire played a role in the sinking of the Titanic. His investigation indicated that

the ship would have been weakened by the smoldering fire. Mr. Molony gained possession of a photo album, that was created by John Kempster, who was an engineer. He had photographed all stages of the construction of the Titanic in Belfast. When he was looking at the pictures, Mr. Molony discovered a spot, approximately 30 feet, on the starboard side of the ship where the iceberg struck the hull.

Mr. Molony showed the images to experts. They determined that the spot in question may have been caused by the smoldering fire in the coal bunker. A smoldering fire burns slowly and will not be stopped until the fuel is exhausted. During their U.S. Senate testimony, the individuals that were asked about the fire did not claim to have much knowledge.

The captain and the chief engineer determined that it was not likely that the fire caused any damage to the hull structure. The stokers were ordered to continue attempting to control the fire while at sea.

Mr. Molony asserts that the entire crew knew about the fire when it left the Belfast shipyards and that may sailors were reluctant to continue to New York. Their concerns were dismissed by White Star Line management, who did not want to further delay the maiden voyage. J. Bruce Ismay further gave instructions to conceal the fire from the passengers.

Mr. Molony further claims that the ship was docked on the port side on purpose to insure the passengers did not see the damage from the fire. It is practice to dock a ship on the starboard side. Passenger complaints of smells and smoke were explained by the crew as normal.

The heat given off by the fire was estimated to be approximately 1,000 degrees Celsius. At that temperature, steel becomes extremely brittle and its resistance to impact and deformation is reduced by 75 percent. Mr. Molony further cites Dr. Leighly's studies of the hull steel, stating that the steel, that was rich in phosphorus, sulfur, and oxygen, and poor in nitrogen and silicon, was fragile at low temperatures. A low temperatures, it breaks instead of deforming.

The temperature of the water in the North Atlantic was slightly negative (Celcius) on the night of the disaster. Wrought iron was used at the stern (back) and the bow (front) of the ship. This was due a shortage of steel parts, mainly rivets holding the plates. The slag in the wrought iron is what made them fragile. The rivet heads likely came off, and created an opening between the plates while under the pressure created by contact with the iceberg.

When the coal was emptied from the bunker and put into the boilers, the ship had picked up speed by pushing the engines and lightening the coal load. The ship should have slowed down because the captain had been warned of many icebergs on its course. The increased speed at 22 knots made the ship less maneuverable in case evasive action of the iceberg was needed. The ship did not have enough coal after this to slow down or change course.

One of the theories put forth was that after the ship left Southampton the fire became uncontrollable. This forced the crew to attempt a full speed crossing of the Atlantic. The high speed could have made a collision unavoidable.

It is also believed that Bruce Ismay ordered boilers to be brought on-line Monday for a high-speed final run into New York to arrive early. This would gain publicity for White Star Line, that was having financial troubles.

The Voyage and Collision

The Titanic got under way on April 10, 1912 at noon from Southampton. The First Class passengers included wealthy industrialists, dignitaries, and celebrities of the time. Also on board was a troubleshooting team known as the "guarantee group", J. Bruce Ismay (Managing Director of White Star Line, who had boarded at 9:30 AM), and Thomas Andrews (the ship's designer from Harland & Wolff). The financier J.P. Morgan (his IMM Shipping Trust controlled White Star Line) was supposed to be on the voyage, but cancelled at the last minute due to business matters. The wealthiest passenger was John Jacob Astor IV, who was the heir to the Astor family fortune. Also aboard was Isador Straus (owner of Macy's) with his wife, industrialist Benjamin Guggenheim, and widow and heiress Margaret Brown. The largest group of passengers were the Third Class, totaling more than 700. It was the Third Class that was a large source of profits for lines like White Star Line.

As she left the dock at Southampton, the Titanic narrowly escaped colliding with the SS New York of American Line. One of the coal bunkers of the Titanic also had a smoldering coal fire that took several days to put out.

The Titanic took a well established westward route across the North Atlantic. It varied farther south some years due to sea ice. She left Queenstown, Ireland on April 12, 1912 at Noon, after a 24-hour layover, before starting across the Atlantic Ocean.

On April 14, 1912, the Titanic received reports of ice from other ships. These reports started at 9 AM when the Cunard steamer Caronia reported an ice field. At 11:40 AM, the Dutch liner Noordam reported ice in the same position the Caronia had earlier. At 1:30 PM the White Star steamer Baltic reported a message from the Greek steamer Athinai of passing an ice field 250 miles ahead of her (Baltic). At 1:45 PM the same type of message is received from the steamer Amerika. Captain Smith cancelled a morning lifeboat drill that was scheduled.

Ice sightings were the reason that Captain Smith delayed a westward turn from a southerly turn made at 2:00 PM. On April 14th, before going to dinner, Captain Smith left instructions in the Night Order Book for the turn to be made at 5:50 PM, 30 minutes later than when usually due. This was 20 minutes after the Titanic entered the cold water of the Labrador current at 5:30 PM. This order was carried out, according to Fourth Officer Boxall. Captain Smith's thought process failed to account for a reported ice field also drifting south.

After Captain Smith had gone to dinner, there were more ice warnings. At approximately 8:10 PM, the Leyland liner Californian radioed an ice warning on the same course as Titanic, but slightly north. This message was not given to Captain Smith. At 9:30 PM, First Officer Murdoch told the lookouts to be vigilant in looking for icebergs, during his watch that began at

10 PM. At 9:40 PM, Mesaba sent a warning to Titanic about an ice field and the message was never passed to Captain Smith.

It was at approximately 11:39 PM that night that lookout Frederick Fleet saw the iceberg from the forward crow's nest. It was coming out of a haze and was directly ahead 95 feet above the water line at 500 yards. He rang a warning bell with three strokes at 11:40 PM and then telephoned the bridge. Fleet spoke to 6th Officer Moody and warned of the iceberg, and Moody then told First Officer Murdoch.

The officer in charge on the bridge at the time of the collision was William Murdoch, who was the first officer if the Titanic. He was assisted by 6th Officer Moody and Quartermaster Robert Hitchens, who was at the helm (wheel). The engines were ordered reversed and the ship made a sharp turn to try to avoid a direct collision with the iceberg. At 22.5 knots, the ship was travelling too fast and would have required over 1000 yards to stop. The Titanic grazed along the side of the iceberg at 11:40 PM. This sent ice fragments onto the forward deck. Contact with the iceberg lasted between 6 and 10 seconds.

Robert Hitchens testified later that he pulled the ships wheel full to the starboard, turning the rudder full to port. The centerline propeller (turbine powered) was pushing against the rudder and the ship did not seem to respond to the rudder correction. He stated it took 30 seconds to respond. The ship eventually was stopped and moved astern (backwards) before coming to a complete stop. They then moved ahead and shut down to inspect for damage.

The lookouts sensed that there was no collision, but did not know that the iceberg had a jagged underwater spur that left a 300 foot gash in the hull of the ship, below the waterline on the starboard side. Most of an iceberg is unseen and below the water line. This is what makes what you don't see the most dangerous part of the iceberg.

Fourth Officer Boxall was ordered to calculate the ships position after the collision. This was based on Lightoller's last fixed point, that was at 7 PM. Lightoller had made a navigational error the previous day, so dead reckoning was used based on an erroneous point. This erroneous position was reported in Titanic's distress calls.

The men working in Boiler Room 6 rushed to safety as water came pouring in and it had risen 8 feet by 11:50 PM. Five compartments were already filling with seawater and the bow (front) tipped downward by the time the captain toured the damaged area. He toured the area with Thomas Andrews of Harland & Wolff. The downward pitch of the bow allowed water to pour from one bulkhead into a neighboring compartment, further weighing down the ship.

As they toured the ship, Mr. Andrews made a calculation and estimated that the ship would stay afloat for approximately an hour and a half. This prompted the captain to order the lifeboats to be loaded and launched. He had already instructed the wireless operator to make a distress call. The Titanic exceeded Mr. Andrew's expectations and stayed afloat nearly three hours.

It was 45 minutes after the collision with the iceberg that Captain Smith ordered the lifeboats to be loaded. The first of the lifeboats were lowered a little over an hour after contact with the

iceberg. The lifeboats were to be loaded women and children first per the Captain's order. Men were permitted only when no women or children were close by. The first CQD message was broadcast at 12:15 AM giving the erroneous coordinates. The first distress signal was received by La Provence and Frankfurt, and heard by Mount Temple and Cape Race station. At 12:18 AM, the German steamer Ypiranga heard Titanic's CQD call. Later they broadcast an SOS signal, which had just become the new standard distress signal in 1908, chosen to be easily recognizable in Morse Code. Boxall's amended position was received at Cape Race at 12:25 AM. Carpathia calls Titanic at 12:25 and advises that Cape Cod was messaging Titanic. Titanic advised Carpathia that immediate assistance was required after striking an iceberg. At this time engineers also begin releasing steam to lower the risk of a boiler explosion.

An SOS signal was sent to Olympic at 12:45 AM. At 12:50 AM, another CQD signal was sent that was received by Celtic.

First Officer Murdoch and Fifth Officer Lowe were assigned to supervise the loading of the lifeboats on the starboard side of the ship. Second Officer Lightoller and Sixth Officer Moody were assigned to supervise the loading of the lifeboats on the port side of the ship. The first lifeboat (boat 7) took 20 minutes to load and it was lowered into the water on the starboard side at 12:45 AM. The first lifeboat lowered on the port side (boat 6) was launched at 12:55 AM with 28 on board. Third Officer Pitman, who was in charge of boat 5, was ordered to row towards the mast light on the north horizon. This was thought to be the Californian that was likely 11 miles away.

At 1:10 AM, boat 1 launched from the starboard side with only 12 people aboard and boat 8 was lowered from the port side. Boat 8 was supervised by Chief Officer Wilde, who was aided by Second Officer Lightoller. By that time, ten lifeboats had been launched and ten remained. At 1:27 AM, Titanic told Olympic that they were putting women in lifeboats, then three minutes later told Olympic women and children.

Several gathered and watched the lights of the Californian, which was traveling from Liverpool to Boston, Massachusetts. They were confident that this ship would come to their rescue. This may have played a role in some passengers' decision to refrain from being loaded onto the lifeboats. Captain Stanley Lord, of the Californian had made an emergency stop at approximately 10:09 PM, on the edge of a large ice field approximately 1.5 hours before the Titanic collided with the iceberg.

The Californian could have saved the Titanic or prevented the disaster altogether. At approximately 10:40 PM Californian crewmembers observed a vessel approaching from the southeast that Captain Lord saw at 11:20 PM. He determined that this could only have been the Titanic based on the visible lights and the direction of travel (west). Captain Lord ordered the Marconi wireless operator, Cyril Evans, to notify Titanic that Californian was stopped and surrounded by ice. This was at 10:55 PM. Evan's was rudely cut off by the Titanic wireless operator, Jack Phillips. Evans switched off his set at 11:20 PM (11:35 PM in some sources). He

did not leave his emergency bell switched on. Third Officer Charles Groves, aboard the Californian tried to signal the Titanic with his Morse Lamp, but did not receive a response.

At approximately 12:30 AM, the bridge watch on the Californian noticed Titanic's signal rockets being fired off. Later testimony did not agree on how far away these signals were from the Californian. At approximately 12:45 AM, Captain Lord left the bridge of the Californian. At 1:15 AM, Second Officer Stone reported that the ship was steaming away to the southwest which is how the headward list of the Titanic would have appeared. The reason that the officers of the Californian did not associate the rockets with a distress call is unknown.

At approximately 2:05 AM, a cadet named Gibson aboard the Californian reported to the chart room that he had observed eight rockets being fired. Cadet Gibson was told by Second Officer Lord to inform Captain Lord. Both were afraid of Captain Lord, who was known as a stern disciplinarian. Cadet Gibson informs Captain Lord. Captain Lord obviously took it to be of no importance as he went back to sleep and did not wake until 4:40 AM.

Also at 2:05 AM, Captain Smith entered the wireless room for the last time. He released the wireless operators. Phillips continued sending after the Captain left. At approximately 2:17 AM, Virginian picked up Titanic's unreadable call to all ships. The signal then suddenly stops, indicating a loss of power on the Titanic.

During and after the evacuation of the Titanic there were actions of the crew and passengers to note. Mr. Andrews was last seen in the First Class smoking room by a steward as he was staring blankly at a painting of a ship on the wall called "Plymouth Harbour". He had discarded his life preserver. It was Mr. Andrews that advised passengers after the accident to get into heavy clothes and prepare to abandon the ship. During the evacuation he had been see throwing deck chairs and other floatable objects to people in the water.

Mr. Ismay got into one of the collapsibles (as stated earlier). He apparently took advantage of the chaos to secure one of the valuable seats. He was publically branded a coward.

Astor put his wife in a lifeboat, but was refused a seat himself. It appears that he died when funnel number 1 collapsed onto the submerged bridge, where there was a group of men clinging to an overturned lifeboat. Isador Straus refused to accept any special consideration due to his age. His wife, Ida, would not leave without him. They then retired to their cabin and went down with the ship.

Benjamin Guggenheim changed into formal evening dress, along with his valet. He then came onto the deck and declared "We are dressed in our finest and prepared to go down like gentlemen."

Molly Brown helped load the lifeboats. She was forced into one of the last boats to depart. She begged the crewmen to turn back to help survivors. They refused, stating that they feared they would be swamped by desperate people.

The lights went out at 2:18 AM and the ship broke into two pieces between the third and fourth funnels. The Titanic finally sank at approximately 2:20 AM on April 15, 1912. The Carpathia, operated by Cunard, had received the Titanic's distress call at about Midnight, while enroute from New York to Gibraltar. The Captain of the Carpathia, Arthur Rostron was informed of Titanic's urgent distress call at 12:35 AM. Carpathia was immediately ordered towards the Titanic, and proceeded at 17 knots, which was 3 knots more than her rated maximum. The Carpathia also had 740 passengers on board. The Carpathia arrived at the site of the Titanic disaster at approximately 4:00 AM, an hour and forty minutes after the Titanic sank. The first lifeboat (boat 2) reached the Carpathia at 4:10 AM. At 4:10 AM, Ismay wrote a message to be transmitted to White Star Line offices, "Deeply regret advise you Titanic sank this morning fifteenth after collision iceberg, resulting serious loss life; further particulars later."

After the Californian Captain Lord awoke, he was informed at approximately 5:15 AM by Chief Officer Stewart that his wireless operator had reported a ship sunk the night before. The report had come from the Mount Temple, located on the other side of the ice field. At 5:40 AM they were informed by Mount Temple that the ship that sank was the RMS Titanic. At 6:05 AM, the Californian started for the position given by Boxall the night before, but saw nothing upon arrival at 7:35 AM.

The Carpathia rescued the survivors aboard the lifeboats, containing a total of 705 survivors, according to Senate testimony. Upon boarding the Carpathia, J. Bruce Ismay refused to come out of his room until the Carpathia arrived in New York. The Carpathia started toward New York City at 8:50 AM. The Carpathia sailed into New York Harbor, April 18, 1912, three days after rescuing the survivors. The ship was met at Pier 54 by the media.

It took several hours after the accident to get an accurate accounting of what had happened. The initial accounts carried by the newspapers were that the ship collided with an iceberg but had remained afloat, and was being towed to port with all on board.

Forensic Engineering

A forensic engineering analysis was conducted by Edward Wilding, who was Harland & Wolff's senior naval architect. He testified at the British Inquiry that began on May 2, 1912 in London, England. He made a forensic report that was dated July 30, 1912. His report stated that the Titanic would have survived a head-on collision with the iceberg. It stated that it would have crushed the bow section back to the second watertight bulkhead, and would have killed 56 off duty firemen housed in the part of the ship known as the forecastle.

Wilding made calculations of the buoyancy loss in the ship based on reports from survivors. The Titanic remained afloat for two hours and forty-one minutes after the collision. He calculated that the hull damage from the iceberg extended back to Coal Bunker 10 adjacent to boiler room 5. He hypothesized that the damage was a series of discontinuous cracks that were irregularly distributed along 200 to 300 foot of the forward hull. He calculated the average crack to be

approximately 12 square feet and the average width to be only three quarters of an inch. This caused Wilding to hypothesize that buckling of hull plates at the rivet laps was the likely mechanism.

Wilding calculated that 16,000 tons of seawater went into the bow section of the ship to bring it down by forty feet. That is the point it dipped beneath the surface of the Atlantic at approximately 2 AM.

White Star took the Olympic on forensic sea trials. This was done to measure response times, turning radii, and the ability to take evasive action at true maximum speed while being fully loaded. This was an important test to estimate what occurred in First Officer Murdoch's attempt to make an evasive maneuver (reverse turn) to avoid the iceberg.

The maneuver by Quartermaster Hitchens was reenacted with the Olympic. It was determined that 37 seconds were required to make the maneuver of 2 compass points to port at 22 knots. This equaled 466 yards forward travel. This was consistent with Hitchens testimony and was how the 500 yards distance were deduced.

The Investigation and Aftermath

The investigation into the disaster led to recommendations from British and US Boards of inquiry in 1912. A United States inquiry was in the United States Senate from April 19 through May 25, 1912. Senate testimony began with J. Bruce Ismay. Recommendations in government inquiries usually end up becoming laws and/or mandates. There were a total of five boards of inquiry conducted on the sinking of the Titanic.

During both the U.S. and British inquiries, Captain Lord of the Californian was perceived as self-serving and defensive. This caused a public outcry and he was fired by Leyland Lines.

The United States passed the Radio Act of 1912. A portion of this legislation required for radio communications on passenger ships to be operated 24 hours a day. It also required a secondary power supply to not miss distress calls. In addition, it required ships to maintain contact with other vessels in their vicinity and coastal radio stations

The First International Conference for Safety of Life at Sea (SOLAS) was held in London in 1913. Rules were drawn up and the text was signed on January 20, 1014. One of the recommendations was concerning lifeboats. The recommendation was for all ships to carry enough lifeboats for everyone on the ship. It was also to mandate lifeboat drills and conducting inspections. Moderation of speed or changing course around ice was another SOLAS requirement. SOLAS has changed over the years, but is still in use.

Another entity coming out of the Titanic disaster is the formation of the International Ice Patrol as part of SOLAS. It is a part of the United States Coast Guard that monitors the location of icebergs in the North Atlantic since 1913. It has also recorded environmental conditions. There has been no loss due to an iceberg collision since it was created.

SOLAS also mandated that all passenger ships have a public address system. There was no public address system on the Titanic. Information filtered down to the passengers slowly from person to person.

Ship design was also changed by the Titanic disaster. It led to the development of watertight compartmentalization, instead of watertight bulkheads. It also led to installation of gate valves between bulkheads for bilge pumps. Damage control training was also introduced. These damage control techniques included pumping and counter flooding measures, which turned out to be valuable in the attack on Pearl Harbor in 1941. Maneuverability of vessels was increased by larger rudders and voluminous hull skegs forward of the propulsion screws (propellers). Reversible Parson's turbines were also introduced as well as double hulls.

On the front of ethics, there was an issue that was apparent then and still comes up today. Mr. Andrews design incorporated safety and emergency preparedness, as he assured enough lifeboats for everyone aboard. He was overruled by the businessman, Ismay, who was more concerned about how the lifeboats would look. The same lifeboat issue had evidently caused Alexander Carlisle to retire. Both were related to Lord Pirrie, but Alexander Carlisle retired where Thomas Andrews seems to have caved on the lifeboat issue.

Mr. Andrews did try to warn as many as he could to get off the ship once he was convinced that it would sink. Despite caving on the issue of lifeboats during the design and building, he did do the right thing and attempt to assist after the accident. J. Bruce Ismay on the other hand had the number of lifeboats reduced and then during the chaos jumped into one if the lifeboats. He took one of the valuable seats that he made sure were as few as he could get away with.

Ismay also likely ordered a high-speed final leg for publicity. Ismay was asked specifically about this in the United States Senate hearing when he testified. Senator Smith asked Ismay if he had "any talk with the captain with reference to the speed of the ship?" Ismay replied "Never, Sir." People that are being deceptive often substitute the word "never" for "no". They do not mean the same thing.

Both Carlisle and Andrews were related to Lord Pirrie. Nepotism is often frowned upon today. Pirrie may have hired a relative because it was someone he could trust. On the other hand, he could have hired a relative because it was someone he could control.

The sinking of the Titanic was one of the worst disasters in history. There have been countless studies, articles, and movies about the disaster. It is a story that had its heroes that did the right thing in the face of death. It also had its villains who did the wrong thing at every stage. It was also a marvel of engineering that was cancelled out by cutting corners.

Date	**Time**	**Event**
3/1841		The steamer President crossing from New York to Liverpool is lost with 120 on board. Assumed to be an iceberg off Grand Banks.

1845		White Star Line formed in Liverpool
3/1854		City of Glasgow leaves Liverpool for Philadelphia with 480 on board. Vanishes and iceberg off Grand Banks is assumed.
2/1856		The Pacific leaves Liverpool for New York with 185 aboard. Assumed lost due to iceberg off Grand Banks.
12 Dec 1862		Joseph Bruce Ismay is born near Liverpool, England
1867-1868		White Star Lines goes bankrupt and the name and assets purchased by Thomas Henry Ismay
1869		Thomas Ismay forms Oceanic Steam Navigation Company (ONSC)
1870		Alexander Carlisle begins as an apprentice at Harland & Wolff
5/1870		The City of Boston leaves Boston for Liverpool with 191 aboard. Assumed lost due to iceberg off Grand Banks.
1871		OSNC / White Star begins service in the Atlantic
4/1/1873		White Star Line Atlantic ran aground 15 nautical miles Southwest of Halifax, Nova Scotia. Diverted there instead of New York due to low fuel and heavy seas. Capsized with 547 deaths.
11/1879		Guion steamer Arizona leaves New York for Liverpool with 509 aboard. While crossing the Grand Banks, the ship hits and iceberg at 18 knots. Makes it to St. Johns 36 hours later under her own power.
1880		John Smith joins White Star Line at age 30 as a Sixth Officer
1887		John Smith becomes a Captain with White Star Line
1889		Thomas Andrews joins Harland & Wolff as an apprentice
1890		Alexander Carlisle becomes General Manager at Harland &Wolff
1891		Edward Wilding becomes a naval cadet in the Royal Navy at the age of 15
2/1892		White Star Naronic leaves Liverpool for New York. Assumed lost due to iceberg off Grand Banks.
1894		Britain passed the Merchant Shipping Act, establishing legal requirements for lifeboats on ships weighing up to 10,000 tons
2/1896		The steamer State of Georgia leaves Aberdeen for Boston. Assumed lost due to iceberg off Grand Banks.
1899		Alexander Carlisle is designer the Oceanic
2/1899		The steamer Allegheny from New York to Dover is lost. Assumed due to iceberg off Grand Banks.
2/1902		The steamer Huronian leaves Liverpool for St. Johns. Assumed lost due to iceberg near Grand Banks.
1902-1903		White Star Line is absorbed by JP Morgan's International Mechantile Marine (IMM)
1904		Joseph Bruce Ismay becomes President of IMM

15-Jun-1904		General Slocum, an excursion steamboat catches fire going through Hell Gate on the East River in New York. More than 1,000 died.
1-Mar-1907		White Star Line Suevic runs aground near Land's End in Cornwall. Part of the ship was salvaged
1907		Captain Smith is given command of the RMS Adriatic
1907		Joseph Bruce Ismay attends an event in London with William Pirrie
1907		Thomas Carlisle becomes Chairman of the Board of Directors of Harland & Wolff
1907		Thomas Andrews becomes Managing Director of Harland & Wolff
1908		SOS becomes the new standard distress signal
29-Jul-1908		Representatives of White Star Lines arrive in Belfast, Ireland to give formal agreement to the plans for Olympic and Titanic
17-Sep-1908		Ships are ordered, Titanic and Olympic
22-Jan-1909		The steamer Republic collides with the liner Florida off of the Massachusetts coast. Only 6 dead of 1,650 due to wireless sets, and the White Star Baltic comes to rescue.
31-Mar-1909		Constructions begins on Titanic in Belfast, Ireland
6-May-1909		Canadian steamer Lake Champlain strikes an iceberg near Grand Banks with damage to the bow. Injuries unknown.
4-Nov-1909		Adriatic, commanded by Captain Smith, runs aground
30-Jun-1910		Alexander Carlisle retires and leadership and design team is taken over by Thomas Andrews
20-Oct-1910		Olympic is launched
31-May-1911		Titanic's hull is launched in the River Lagen
31-May-1911		Olympic is commissioned
14-Jun-1911		Titanic's sister ship, Olympic departs on her maiden voyage
20-Sep-1911		Olympic under the command of Captain Smith collides with HMS Hawke
4-Oct-1911		Olympic leaves Southampton for repairs in Belfast
29-Nov-1911		Olympic returns to service
12-Feb-1912		Olympic loses her port propeller blades in a wreck near Grand Banks
1-Apr-1912		Captain Smith is transferred from RMS Olympic to RMS Titanic
2-Apr-1912		Titanic sea trials are conducted
2-Apr-1912		Coal fire develops in one of the coal bunkers
9-Apr-1912		David Blair leaves the Titanic after being replaced by Lightoller
10-Apr-1912	6:00 AM	Henry Wilde signs on as Chief Officer on Titanic
10-Apr-1912	9:30 AM	Mr. Ismay boards the Titanic at Southampton
10-Apr-1912	12:00 PM	Titanic sets sail from Southampton

11-Apr-1912	12:00 PM	Layover in Queenstown, Ireland
12-Apr-1912	12:00 PM	Titanic leaves Queenstown, Ireland
13-Apr-1912		Coal fire extinguished by morning
14-Apr-1912		Captain Smith cancels scheduled lifeboat drill
14-Apr-1912	9:00 AM	The Cunard steamer Caronia reports an ice field
14-Apr-1912	11:40 AM	Dutch liner Noordam reports ice at Caronia's earlier position
14-Apr-1912	1:30 PM	White Star steamer Baltic reports message from Greek steamer Athinai of passing an ice field 250 miles ahead of Baltic
14-Apr-1912	1:45 PM	Same type of message is received from Amerika as received from Baltic
14-Apr-1912	2:00 PM	Titanic makes southerly turn
14-Apr-1912	5:30 PM	Titanic enters the cold water of the Labrador current
14-Apr-1912	5:50 PM	Titanic makes westward turn as ordered by Captain Smith
14-Apr-1912	7:00 PM	Lightoller takes last fixed point before accident (erroneous point)
14-Apr-1912	8:10 PM	Leyland liner Californian on same course as Titanic radios ice warning
14-Apr-1912	9:30 PM	First Officer Murdoch speaks to the lookouts about icebergs
14-Apr-1912	9:40 PM	Mesaba sends a warning to the Titanic about an ice field and message is never passed on the Captain Smith
14-Apr-1912	10:00 PM	First Officer Murdoch begins his watch on the bridge
14-Apr-1912	10:09 PM	Californian makes an emergency stop at the edge of a large ice field
14-Apr-1912	10:40 PM	Californian observes a large ship approaching from the Southeast that could only have been the Titanic
14-Apr-1912	10:55 PM	Californian radios the Titanic that they are stopped and surrounded by ice, but Phillips replies to shut up because he is working Cape Race
14-Apr-1912	11:35 PM	The wireless operator on the Californian turns off radio
14-Apr-1912	11:39 PM	Lookout Fleet sees the iceberg directly ahead of the Titanic
14-Apr-1912	11:40 PM	Lookout Fleet rings the warning bell with three strikes and phones the bridge
14-Apr-1912	11:40 PM	Titanic strikes an iceberg that scrapes along the starboard side
14-Apr-1912	11:50 PM	Water had risen by 8 feet in Boiler Room 6
15 Apr 1912	12:00 AM	Lifeboats are beginning to be readied for launch
15-Apr-1912	12:15 AM	Titanic broadcasts first CQD distress call
15 Apr 1912	12:18 AM	German steamer Ypiranga hears CQD message from Titanic
15-Apr-1912	12:25 AM	Captain Smith gives the order to load the lifeboats, women and children first
15-Apr-1912	12:25 AM	Cape Race hears corrected position from Titanic (given by Boxall)

15 Apr 1912	12:25 AM	Carpathia calls Titanic advising that Cape Cod sending messages to Titanic. Titanic advises Carpathia to come immediately, requiring assistance after striking an iceberg
15-Apr-1912	12:30 AM	Bridge watch on the Californian noticed Titanic's signal rockets being fired off
15 Apr 1912	12:35 AM	Captain Rostron of the Carpathia is informed of the urgent distress signal from Titanic by his First Officer and Wireless Operator
15 Apr 1912	12:45 AM	Titanic sends SOS signal to Olympic
15-Apr-1912	12:45 AM	Boat 7 lowered from starboard side (first lifeboat)
15-Apr-1912	12:45 AM	Captain Lord leaves the bridge of the Californian
15 Apr 1912	12:50 AM	Titanic broadcasts CQD signal that was received by RMS Celtic
15-Apr-1912	12:55 AM	Boat 6 lowered from port side (first lifeboat)
15-Apr-1912	1:10 AM	Boat 1 launches from starboard side with only 12 people and boat 8 lowered from the port side
15-Apr-1912	1:15 AM	Second Officer Stone of the Californian reported that the ship was steaming away to the southwest
15-Apr-1912	1:20 AM	Starboard boat 9 lowered with 56 aboard, 42 of which were women
15-Apr-1912	1:20 AM	Port boat 10 lowered with 41 women and 7 children
15 Apr 1912	1:27 AM	Titanic tells Olympic that they are putting women into lifeboats
15 Apr 1912	1:30 AM	Titanic tells Olympic that they are putting passengers into the lifeboats women and children first
15-Apr-1912	2:05 AM	Cadet Gibson aboard the Californian reports to the chart room that he had observed eight rockets being fired
15 Apr 1912	2:05 AM	Captain Smith goes to the wireless room and releases the wireless operators. Phillips continues sending after the Captain leaves
15 Apr 1912	2:17 AM	Virginian hears Titanic's unreadable call to all ships and signal ends suddenly
15-Apr-1912	2:18 AM	The lights go out on the Titanic and she breaks into two pieces between the third and fourth funnels
15-Apr-1912	2:20 AM	Titanic finally sinks, stern portion first
15-Apr-1912	4:00 AM	Carpathia arrives at the site of the Titanic disaster
15-Apr-1912	4:10 AM	First lifeboat (boat 2) reaches Carpathia
15-Apr-1912	4:10 AM	Ismay writes message to be transmitted to White Star Line offices, "Deeply regret advise you Titanic sank this morning fifteenth after collision iceberg, resulting serious loss life; further particulars later."
15-Apr-1912	4:40 AM	Captain Lord of the Californian finally wakes
15-Apr-1912	5:15 AM	Captain Lord is informed by Chief Officer Stewart that his wireless operator had reported that a ship sank the night before
15-Apr-1912	5:40 AM	Mount Temple informs Californian that the ship that sank was the RMS Titanic

15-Apr-1912	6:05 AM	Californian starts for the position given by Boxall the night before
15-Apr-1912	7:35 AM	Californian arrives at position given by Boxall and sees nothing upon arrival
15-Apr-1912	8:50 AM	Carpathia starts toward New York City
18-Apr-1912		Carpathia arrives in New York City
2-May-1912		British inquiry begins in London
30-Jul-1912		Wilding's forensic report is published
13-Aug-1912		Radio Act of 1912 is signed by the President
1926		White Star Line is sold to Royal Mail Line
1935		Cunard Line absorbs Royal Mail Line
1991		Expedition to investigate the disaster discovers pieces of hull steel on the ocean floor
1991		First piece of hull material is recovered
1996		Salvage trip recovers a section of the Titanic's hull plating and several hull and bulkhead rivets
1996		Study on the recovered steel by Dr. Leighly
1998		Big Piece recovered

References

1. (no date) Azose, Molly, Sarah Hanan, and Henry Vallee. The Titanic: How and Why it Became One of the Most Influential Disasters in the Twentieth Century. Retrieved November 18, 2022 from: http://titanichms.weebly.com/index.html.

2. Careaga, Andrew (2012 April 10). In 1990s, S&T researchers studied secrets of Titanic steel. Missouri S&T. Retrieved December 12 2022 from: https://news.mst.edu/2012/04/in_1990s_st_researchers_studie/.

3. Cleverlysmart.com (2021 November 2). Titanic was on fire: A drama written in advance? Mysterious investigation! Cleverlysmart.com. Retrieved January 9, 2023 from: https://www.cleverlysmart.com/titanic-was-on-fire-a-drama-written-in-advance-mysterious-investigation/.

4. Edwards, John (2020 September 20). *Olympic Survives Collision*. Ocean Liners Magazine. Retrieved December 29, 2022 from: https://oceanlinersmagazine.com/2020/09/20/olympic-1911-collides-hms-hawke/.

5. Edwards, John (2021 February 6). *Thomas Andrews – Titanic Designer*. Ocean Liners Magazine. Retrieved December 29, 2022 from: https://oceanlinersmagazine.com/2021/02/06/thomas-andrews-titanic-designer-2/.

6. Edwards, John (2020 April 15). Carpathia's Perilous Journey. Ocean Liners Magazine. Retrieved December 29, 2022 from: https://oceanlinersmagazine.com/2020/04/15/carpathias-perilous-journey/.

7. Encyclopedia Titania (2007). Alexander Carlisle Obituary. The Times 6 March 1926. Retrieved December 28, 2022 from: https://www.encyclopedia-titanica.org/alexander-carlisle-obituary.html.

8. Fowler, David (2022). Titanic Facts: The Life & Loss of the RMS Titanic in Numbers. Retrieved November 7, 2022 from: https://titanicfacts.net/who-designed-the-titanic/.

9. Eschner, Kat (2017 February 7). *The Chief Designer of the 'Titanic' Saved Everyone He Could as His Ship Went Down*. Smithsonian Magazine. Retrieved November 7, 2022 from: https://www.smithsonianmag.com/smart-news/chief-designer-titanic-saved-everyone-he-could-his-ship-went-down-180962008/.

10. History.com Editors (09 April 2021). The Titanic: Sinking & Facts. Retrieved October 19, 2022 from: https://www.history.com/topics/early-20th-century-us/titanic.

11. The Manufacturer (2012 April 12). *The engineering feat behind the tragedy.* The Manufacturer. Retrieved November 8, 2022 from: https://www.themanufacturer.com/articles/titanic-the-engineering-feat-behind-the-tragedy/.

12. Maritime Knowledge (2021 April 12). Remembering Titanic: The Tragedy behind SOLAS. Maritime Knowledge. Retrieved March 9, 2023 from: https://safety4sea.com/cm-remembering-titanic-the-tragedy-behind-solas/.

13. (no date) McClish, Mark. Unique Words: "Never" Detecting Deception Using Statement Analysis. Blifaloo. Retrieved March 28, 2023 from: https://www.blifaloo.com/never-statement-analysis/.

14. (no date) Parkes, Dan. *Titanic Officers*. Retrieved November 22, 2022 from: https://titanicofficers.com/index.html.

15. (no date) Rogers, J. David. *Titanic Lecture Notes*. University of Missouri-Rolla. Retrieved Janiary 5, 2023 from: https://web.mst.edu/~rogersda/american&military_history/TITANIC%20LECTURE%20NOTES.pdf.

16. (no date) Ultimate Titanic. Retrieved November 4, 2022 from: https://ultimatetitanic.com/titanic-construction/.

17. (no date) Tikkanen, A. *J. Bruce Ismay*. *Encyclopedia Britannica*. Retrieved December 15, 2022 from: https://www.britannica.com/biography/J-Bruce-Ismay.

18. (no date) Tikkanen, A. *Timeline of the Titanic's Final Hours*. *Encyclopedia Britannica*. Retrieved February 21, 2023 from: https://www.britannica.com/story/timeline-of-the-titanics-final-hours.

19. (no date) Titanic Museum. *RMS Titanic Hull Fragment*. Retrieved December 27, 2022 from: https://www.titanicmuseum.org/artefacts/titanic-hull-fragment/.

20. (no date) Titanic Museum. *Titanic: Timeline of Artefacts*. Retrieved December 27, 2022 from: https://www.titanicmuseum.org/a-timeline-of-titanic-artefacts/.

21. Tyrell, William. (2016, August 30). *Engineering Disasters: RMS Titanic.* Engineeringclicks. Retrieved November 8, 2022 from: https://www.engineeringclicks.com/titanic/.

22. (no date) United States Coast Guard. International Ice Patrol History. Retrieved November 21, 2022 from: https://www.navcen.uscg.gov/international-ice-patrol-history.

23. Foecke, Tim (1998 February 4). Metallurgy of the RMS Titanic. National Institute of Standards and Technology (NIST-IR 6118).

24. San Diego Natural History Museum (2012). *Titanic: The Artifact Exhibition*. Timeline of Distressed Messages.

25. United States Senate (1912). Titanic Disaster: Official Transcript of the United States Senate Hearings.

26. Lyons, William and Neil McKay (2005). Titanic – Birth of a Legend. Documentary.