

TITANIC LECTURE NOTES

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BACKGROUND - PERCEPTIONS OF ICEBERGS IN 1912

MARITIME SAFETY INCIDENTS INVOLVING ICEBERGS OR WHITE STAR LINE

1873 - April 1, 1873 the White Star Liner *ATLANTIC* (3,700 tons) ran aground 15 nautical miles (nm) SW of Halifax, Nova Scotia, having diverted there in deference to New York, because of heavy seas and low fuel state. She eventually capsized to starboard, and inrushing seawater caused boilers to explode. 400 survivors, mostly crewmen, all but 1 of the 200 children died. 547 deaths resulted, making it the worst maritime catastrophe on the high seas up until that time (1,700 people were lost when the steamer *SULTANA* sank on the Mississippi River about seven miles north of Memphis on April 27, 1865).

1879 Guion steamer *ARIZONA* (at 5,750 tons, second largest ship in the world) left New York bound for Liverpool in November 1879, with 509 people aboard. While crossing Newfoundland's Grand Banks 250 nautical miles (nm) east of St. Johns, the ship hit an iceberg just after midnight while steaming at a speed of 18 knots (kts). She limped into St. Johns 36 hours later, under her own power. She was later repaired in England.

1904 - On June 15th, an excursion steamboat, the *GENERAL SLOCUM*, caught fire going through Hell Gate on New York's East River, more than 1000 lives lost (worst maritime disaster prior to the *TITANIC*'s loss).

1907 - The White Star steamer *SUEVIC* (12,500 tons) was one of the first steamers fitted with watertight bulkheads. She ran aground near Land's End in Cornwall in March 1907. The forward end of the ship was left on the rocks and the after 2/3 salvaged and towed back to Southampton! A new 212 feet long bow section is constructed in Belfast and floated down to Southampton, where it was fitted to the remains of the ship. This was seen as a triumph for technology. The *SUEVIC* grounding and salvage leads most mariners to believe that modern steel steamers fitted with watertight bulkheads are virtually unsinkable.

1907 - The Canadian Ship *LAKE CHAMPLAIN* strikes an iceberg, and damages bow. Other accounts say that she sank, actual outcome unknown.

1909 - On January 22, the Steamer *REPUBLIC* (15,378 tons) collides with liner *FLORIDA* in fog about 170 miles off the Massachusetts coast. The *REPUBLIC* sinks on the 24th while being towed, but thanks to wireless sets, White Star Liner *BALTIC* comes to her rescue, and only 6 of the 1,650 passengers and crew are lost at sea. This incident serves to reinforce the idea that wireless radio receivers can provide an acceptable margin of safety for even the most precarious maritime emergencies.

SHIPS PRESUMED LOST TO ICEBERGS OFF NEWFOUNDLAND'S GRAND BANKS

March 1841 - The steamer *PRESIDENT* crossing between New York and Liverpool, lost with 120 aboard.

March 1854 - The *CITY OF GLASGOW* left Liverpool bound for Philadelphia with 480 aboard, vanishes.

February 1856 - Ship *PACIFIC* bound for New York from Liverpool with 185 aboard.

May 1870 - The *CITY OF BOSTON* left Boston bound for Liverpool, with 191 aboard.

February 1892 - White Star liner *NARONIC* from Liverpool bound for New York

February 1896 - The steamer *STATE OF GEORGIA*, from Aberdeen for Boston

February 1899 - The steamer *ALLEGHENY*, from New York bound for Dover

February 1902 - the steamer *HURONIAN*, from Liverpool bound for St. Johns

All of these ships were presumed lost with all hands, and none of them were equipped with wireless communication. Between February and May the Grand Banks are most infested with icebergs, and prior to 1901 no ships were fitted with wireless communications. The ships that disappeared were assumed to have struck icebergs and sank. Up until the time the *TITANIC* was lost (April 1912) avoidance of icebergs was dependent on visual watches from the vessel's themselves, and darkness or foul weather could prove extremely dangerous. The common sighting distance was one nautical mile, which usually afforded time to take evasive maneuvering. It was standard practice for ships to halt when encountering ice fields at night and wait for daybreak before attempting any navigation through such obstacles.

WHITE STAR LINE

White Star Line was formed in Liverpool in 1845, and established itself in the Australian trade by 1852, with one ship. Went bankrupt in 1866-67; but assets and name purchased by Thomas Henry Ismay of Ismay, Imrie & Co. for £1000, who forms the Oceanic Steam Navigation Co. (OSNC) in 1869. OSNC contracted with Harland & Wolff shipbuilders of Belfast to construct two new steamers for the transatlantic trade, the *OCEANIC* and *ATLANTIC*, of 3,700 tons each. These become the largest steamers then plying the seas. They began service to New York in 1871. With six ships White Star Line plied the Atlantic and Asiatic routes. Harland & Wolff partners bought shares of White Star and took seats on their board of directors, and vice versa.

White Star was absorbed by the International Mercantile Marine of J. P. Morgan in 1902-03. Morgan dies in 1913. Thomas Ismay' son J. Bruce Ismay served as President of IMM between 1904-1912. He is forced to resign from his post in 1912 because of public humiliation concerning his surviving the *TITANIC* sinking. He lived in seclusion until 1937. White Star was sold to Royal Mail Line in 1926, which was then absorbed by Cunard Line in 1935, and all White Star Line records were lost.

DESIGN OF TITANIC

The design team was originally headed up by Alexander Carlisle, Lord Pirie's brother-in-law. He had designed the *OCEANIC* in 1899, the first ship to surpass the massive *GREAT EASTERN* in size. He retired in June 1910, and leadership of the design team was assumed by Thomas Andrews, Pirie's nephew. Prior to this Andrews had served as Harland & Wolff's Chief Draughtsman. Edward Wilding was Harland & Wolff's Senior Naval Architect. After

TITANIC sank, it was Wilding who performed the admirable calculations concerning the net size of the opening that sank the ship, about 12 square feet. After completing these remarkable studies Lord Pirie fired him.

TITANIC's design size was 852.5 feet long by 92.5 feet wide. Height from keel to C Deck was 64'-9" (top to top). C Deck was the highest which extended along the entire length of the ship. Design waterline was 34'-7" at amidships. The upper three decks (superstructure) were fitted with two expansion joints, immediately abaft Funnels 1 and 3. These joints could accommodate two feet of expansion/contraction.

TITANIC'S POWER PLANT

The *TITANIC* was powered by two sets of four-crank triple expansion reciprocating steam engines drove the wing propellers (outboard shafts). Each engine had four inverted pistons with direct acting cylinders, fed by 215 psi input steam pressure from the boilers. The high-pressure cylinder was 54 inches in diameter; the intermediate 84 inches across, and the low pressure cylinder being 97 inches in diameter, with a piston stroke of 6 feet 3 inches. The wing propellers were made of magnesium bronze, with 3 blades each and were 23-1/2 feet in diameter. The design shaft horsepower (shp) was 15,000 at 75 rpm, and 17,000 shp at maximum turn (80 rpm).

The center shaft was powered by a Parsons Low Pressure Turbine, which ran off the exhaust steam from the reciprocating engines. It propelled a four-bladed magnesium bronze propeller, 16-1/2 feet in diameter. No reversing mechanism was accommodated in the early Parson's Turbines. The maximum shaft horsepower (shp) was 16,000 at 175 rpm. Total shp for all three engines was 50,000 for a design speed of 21 kts, but she was capable of developing 55,000 shp if operating all her boilers.

BOILERS

Steam was provided by 24 double-ended and five single-ended boilers, arraigned to deliver a working pressure of 215 pounds per square inch (psi). The 29 boilers were distributed within 6 boiler rooms, separated by watertight bulkheads between adjacent coal bunkers. The boiler rooms were numbered aft to front (1 to 6). The 159 furnaces were hand stoked, from either end on the double-ended boilers, fed from coal bunkers forward and aft of each boiler room. The five single-ended boilers were confined to Boiler Room 1 and were intended to provide auxiliary power. The two port boilers in Boiler Room 2 were intended to provide steam for the electric light engines. During typical operations about 1/5 of the boilers would be shut down for underway maintenance or fuel conservation. On *TITANIC*'s maiden voyage all of the boilers were gradually brought on line and the shaft horsepower and ship speed increased accordingly.

BILGE PUMP CAPACITY

Five ballast and bilge pumps were fitted to the ship's amidships area, each capable of delivering 250 tons of water per hour (or 2.23 cubic feet per second), and three bilge pumps were capable of sustaining 150 tons per hour. These made for an aggregate capacity of 1,700 tons per hour of pump capacity, or 407,564 gallons per hour, sufficient to keep pace with an maximum inflow rate of 15 cubic feet per second (which should theoretically have kept her afloat for a week). However, three bilge pumps were distributed in the boiler rooms, two in the reciprocating engine room and the other in the turbine engine room. There were no sluice valves incorporated into the bilge system, so no means of joining the pumps in series to allow water to be pumped from one compartment to another. The enormity of this oversight was appreciated in *TITANIC*'s post-failure assessments, which suggested that it took the ship 2 hrs 20 min to take on 16,000 tons of sea water. This back-calculates to approximately 12 ft² of hull opening allowing sea water to infiltrate the hull.

HULL DESIGN

TITANIC utilized a 5'-3" double bottom throughout most of the hull, increasing to 6'-6" below the reciprocating engine spaces. The annular space contained the water tanks for trimming the ship. This cellular structure was referred to as "The Tank Top", and it provided a greater degree of structural integrity and stiffness for the overall structure of the hull. Water in this bilge keel was also used to stabilize the ship in rolling seas. A 300 feet long and 25-inch deep external bilge keel was also utilized amidships to reduce rolling (one of the first liners to employ this advance).

Construction of the Tank Top utilized 500,000 steel rivets, alone weighing 270 tons. This represented 1/6 of the more than 3,000,000 rivets used to construct the ship. The tank top also utilized three longitudinal divisions to create four longitudinal watertight compartments. The centerline division was 670 ft long, while those on either side of the keel were 447 ft long.

The remainder of the ship was constructed using conventional frames with riveted hull plates. The **FRAMES** were spaced 3 feet apart, tapering to 2 feet in the bow and stern areas. The steel **HULL PLATES** were 6' x 30' x 1" thick, each weighing 3 tons.

The *TITANIC* employed an old fashioned kingpost **RUDDER**, similar to a Spanish Galleon. It was of an elliptical shape, made of cast steel in 6 pieces. The rudder was 78'-8" high and weighed 101 tons. It was woefully undersized for a ship of this displacement.

SIZE AND DISPLACEMENT

The *TITANIC* was 852-1/2 feet long and up to 92.5 feet wide. At launching (May 31, 1911), she already displaced 24,000 tons. Her gross registry tonnage was 46,328 tons, with 21,831 net register tons (how much load she could carry in addition to her dead weight displacement). She displaced 52,310 tons when her draught was 34'-7", and up to 66,000 tons if fully loaded. Long tons (2240 pounds) were used to calculate displacements by Harland & Wolff (in contrast to our American system).

LIFEBOATS

English legal requirements for lifeboats were set by the 1894 Merchant Shipping Act, which only envisioned ships up to 10,000 tons. The Regulations of the British Board of Trade were actually being reformulated in early 1912 to consider the much larger vessels then plying the seas. White Star Line was legally bound to have sufficient lifeboats for 960 people, but they actually provided space for 1,178. 3,560 cork life belts also supplied.

Harland & Wolff designer Alexander Carlisle originally envisioned 64 lifeboats, but the White Star management (Bruce Ismay) objected to the seemingly cluttered appearance of doubling up the lifeboats next to the Welin davits. The purpose of using Welin Davits was to accommodate extra boats at each launch position. The number of boats was downgraded to 40, then 32, and finally down to 20. The patented Welin Davits were supplied with sufficient rope to lower three boats each. The ship's forward davits were always swung outboard with the lighter 40-man cutters, used for harbor pilot liaison and man-overboard emergencies (referred as the "*emergency cutters*" by the vessel's officers in post-failure testimony).

The ship carried 14 regular lifeboats. These main lifeboats were intended to have a passenger capacity of 65 each (910 people); the two crew cutters with 40 each (80 people) and the four Englehardt collapsible boats were designed for 47 each (188 people); giving *TITANIC* a theoretical lifeboat capacity of 1,178 persons. Collapsibles A and B were stowed on the roof of Officer's Quarters while C and D rested on forward end of Officer's Promenade.

TITANIC'S SISTER SHIPS

R.M.S. OLYMPIC preceded *TITANIC* by about 9 months, having been launched on October 20, 1910, and commissioned in June 1911. *OLYMPIC*'s initial year of operation was dismal from a financial perspective, with costly delays afforded by the September 1911 collision with *HMS HAWKE* and the February 1912 loss of her port propeller, both incidents requiring major refit work in Belfast, causing her to miss 7 transatlantic trips. When she departed New York on March 23, 1912 she was carrying 4,800 tons of additional coal for *TITANIC* (the English coal strike was settled on April 6, 1912, but many weeks passed until recovery actually occurred). *OLYMPIC* began her 7th transatlantic trip from Southampton on April 3, 1912, 12 hours before *TITANIC* arrived at Southampton coming down from Belfast.. *OLYMPIC* departed New York City on her return leg on Saturday morning April 13, 1912. She was steaming 750 nautical miles (nm) from New York when she received *TITANIC*'s CQD in early morning hours of April 15th.

The *OLYMPIC* served as a troop transport during World War I and was converted to an oil burner in 1919-20. She served on until 1935, and was sold and broken up for scrap in 1937. She was known throughout her career as “*Old Reliable*”, and her remarkable safety record after 1912 gave rise to legends about curses and good luck charms aboard ships.

White Star announced their intent to construct a third ship of the *OLYMPIC* Class on Sept 1, 1911, to be named the *GIGANTIC*. After *TITANIC* sank, White Star changed the name from *GIGANTIC* to *BRITANNIC*. Due to financial difficulties associated with the *TITANIC* disaster, the *BRITANNIC* was not launched until two years later, in February 1914. She was 889 ft long and 94 ft wide, with 48,158 [long] tons displacement. The First World War erupted in August 1914 and *BRITANNIC* was completed in November 1915 as a hospital ship and commissioned in the Royal Naval Reserve in December 1915. She made five voyages to the Mediterranean bringing back 15,000 wounded and sick. She struck mine in the Aegean Sea off Kea Island on November 21, 1916. The explosion caused a secondary explosion of coal dust in several of her coal bunkers, hastening her demise. She took 50 minutes to sink by the head, but with only 21 killed. 10 of the 35 White Star Line steamers were lost in combat during First World War. White Star was given several German liners after the war as reparations.

COLLISION BETWEEN THE HAWKE AND THE OLYMPIC

This incident was a important in the *TITANIC* legacy because the damage required cannibalization of parts from the incomplete *TITANIC* and the *OLYMPIC* missed three transatlantic voyages, costing the firm more than half the enormous liner’s original cost. The collision occurred on September 20, 1911, right at the beginning of *OLYMPIC*’s fifth trans-Atlantic voyage to New York. She was sailing down the Southampton Channel towards some shoals called “The Bramble”, where she had to execute an inverted “S turn” to cut southeasterly, down the Spithead Channel towards Portsmouth, thence across the English Channel to Cherbourg. *OLYMPIC* was under pilotage traveling 18 kts down Southampton Channel and slowed to 11 kts to *execute the reverse turn at The Bramble*. She made a sweeping turn to starboard, showing her port side to *HMS HAWKE* (coming up the channel); then *OLYMPIC*’s pilot rang two blasts of her horn and reversed his turn, coming to port to bring her onto a southeasterly heading, accelerating in the port-hand turn. By bringing her starboard side against the *HAWKE*’s port side, she was rendered to give way to the *HAWKE*, as priority was always to be given to the starboard ship (*HAWKE* now located to starboard of *OLYMPIC*).

Believing they had right-of-way priority, and misunderstanding that *OLYMPIC* was turning to proceed parallel to their track, *HAWKE* waited too long before taking evasive action, and her rudder jammed when she attempted a sharp port turn to clear *OLYMPIC*’s stern. The force of suction pulled the *HAWKE* into the *OLYMPIC*’s starboard side near her stern. The British Admiralty hired renowned American naval architect Rear Admiral Donald W. Taylor to be their expert witness on the effects of suction created by large displacement ships and prevailed in the succeeding litigation.

DAMAGE TO OLYMPIC

OLYMPIC spent two weeks in Southampton having temporary repairs effected to make her seaworthy. She left Southampton on October 4, 1911, and proceeded at 12.5 kts. *HAWKE*’s bow rammed *OLYMPIC* about 86 feet forward of her stern post, inverted triangular hole 14 feet wide at top, extending down from D Deck 15 feet, and 8 feet into the *OLYMPIC*. *HAWKE*’s ram was beneath water and shaped like an inverted pear, it punctured hull between G and Orlop Decks. 18 feet of the starboard propeller bossing was damaged and all three blades of the starboard propeller. *Hawke*’s concrete-filled ram was recovered from inside the *OLYMPIC* in the drydock at Belfast.

REPAIR OF OLYMPIC

Placing the *OLYMPIC* in drydock meant displacing the *TITANIC*, and redirecting the yard’s work force to making repairs to *OLYMPIC* as soon as practicable. Repair work entailed part of *OLYMPIC*’s starboard crank shaft, which was strained and out-of-true. Two of the four shaft sections serving the starboard propeller were damaged. The

aftermost section was externally accessible, but remainder not, so her hull plates had to be removed. In order to restore her in a timely fashion, they cannibalized the *TITANIC*'s starboard propeller blades and propeller shaft. The repairs took 6-1/2 weeks to complete, pushing back *TITANIC*'s scheduled completion 3 weeks, to April 10, 1912. But the collision cost White Star dearly, as *OLYMPIC* was unable to return to service until November 29, 1911, having missed three round-trip transatlantic voyages, and the revenue generated thereby. White Star lost £250,000 pounds Sterling, half the original building cost, and the ship was only insured for 2/3 of the building cost.

Postscript: The British cruiser *HMS HAWKE* sunk by U-9 three years later in North Sea on Oct 15, 1914, with loss of 550 souls.

OLYMPIC LOSES HER PORT WING PROPELLER BLADES

OLYMPIC subsequently lost her port propeller blades on a submerged wreck on the Grand Banks off Newfoundland, about 750 nautical miles (nm) from New York, on February 24, 1912. This repair took a week, and caused her to cancel her scheduled transatlantic trip of March 6, 1912. Once again, Harland & Wolff had to haul *TITANIC* out of the Thompson Graving Dock in Belfast to scavenge a new prop for the *OLYMPIC*. The last photo of the two sister ships taken together was on March 6, 1912 next to Thompson Graving Dock in Belfast.

DIFFERENCES IN APPEARANCE BETWEEN OLYMPIC AND TITANIC

Near the last moment of fitting out (in mid-March 1912) IMM Chairman J. Bruce Ismay asked that the forward portion of the A Deck promenade be fitted with screened sliding windows. This section was 192 feet long. In addition, the enclosed B Deck of *TITANIC* was also longer than *OLYMPIC*, with a less uniform pattern of windows. Front names on both ships were in burnished gold on black hulls, hard to see in photographs. Virtually all interior photos of the *TITANIC* were actually imaged aboard the *OLYMPIC*.

DESIGNATION AS R.M.S. TITANIC

Because of her superior speed, *TITANIC* was designated by the British government as one of 13 transatlantic steamers which carried the Royal Mail. She was, therefore, afforded the prestigious preamble R.M.S., for "Royal Mailer Steamer". This designation meant she was under contract to transport mail from the European continent across the Atlantic Ocean, to the United States and Canada. During her maiden voyage she was carrying over 3500 bags, containing more than 500,000 pieces of mail.

TITANIC'S SEA TRIALS

Performed in Belfast Lough on Tuesday April 2, 1912, over a period of 12 hours. The ship averaged 18 kts for a 2 hour run, with bursts up to 21 kts. Her **Turning Circle** was determined to be 3,850 feet with a forward motion of 2,100 feet. **Emergency stop** from 20 kts took 850 yards (unloaded). Emergency stop from 22.5 kts would require a little over 1,000 yards (half-mile). During her 570 nautical miles (nm) run to Southampton, she briefly reached 23.5 kts (but, was not loaded) By comparison, *OLYMPIC* reached 22.75 kts at 78 rpm of her outboard screws.

TITANIC'S SAILING SCHEDULE

White Star wanted to run a 3-week rhythm with their two leviathans, *OLYMPIC* and *TITANIC*. Each ship was to depart Southampton every 3rd Wednesday (picking up passengers in Cherbourg, France and emigrants in Queenstown, Ireland), and reaching New York the following Wednesday morning early. The ships were then coaled up in New York during a 3-1/2 day layover, departing New York early Saturday morning. The return leg made landfall at Plymouth, crossing to Cherbourg, then back to Southampton, where they were coaled for the next trip. Queenstown [called Cobb today] was an emigrant loading point, only frequented on outbound legs.

CREW OF TITANIC

Edward John Smith, b. 1850 at Hanley in Staffordshire. He left school at age 13 in 1863 to go to sea, joining White Star Line as a 6th Officer in 1880 at age 30. He rose rapidly to Captain by 1887. He was given command of *TITANIC* on April 1, 1912, coming from her sister ship, the *OLYMPIC*. He had received the Admiralty's Transport Medal for captaining troop ships during the Boer War and the Royal Navy Reserve Decoration. He was also a Commander in the Royal Naval Reserve (RNR), and therefore allowed to fly the blue RNR ensign from the vessels he commanded. A very visual status symbol, this added to his status as "the millionaire's captain". In 1904 **Smith** became Commodore of the White Star fleet (their most senior steamer captain). In 1907 he was given command of *S.S. ADRIATIC*, the first turbine-powered ship in the White Star fleet. The *ADRIATIC* ran aground in New York's Ambrose Channel on November 4, 1909. He was also given command of the *OLYMPIC* when she was commissioned on May 31, 1911.

Smith was commanding *OLYMPIC* when she collided with *HMS Hawke* in September 1911. At the time of *TITANIC*'s sailing he was the world's highest paid seaman, at £1,250 per year, with £200 annual bonus for avoiding any collisions, half of which was customarily divided between the senior officers (the three senior officers rotated the con of the ship's bridge in 4 hour shifts). He was quoted in the New York TIMES in May 1907, while commanding the *SS ADRIATIC*:

Quote: "I will say that I cannot imagine any condition that would cause a ship to founder....Modern shipbuilding has gone beyond that.

Henry Wilde signed on as Chief Officer of *TITANIC* at 6 AM on sailing day, Wed April 10th. He had been detached from the *OLYMPIC* on April 3rd, and granted leave until the 10th, by request of Captain **Smith**. His acquisition bumped **Murdoch** down to First Officer and **Lightoller** to Second Officer. Second Officer **Blair** left the ship on Tuesday April 9th, but not before stowing the lookout's binoculars in his cabin without having informed **Lightoller** of their whereabouts, in the Second Officer's cabin. This oversight was to have enormous repercussions.

Only **Wilde**, **Murdoch** or **Lightoller** could command the watch. Their sailing schedule was 4 hrs on the con with an intervening 8 hrs off. Of the senior officers, only Captain **Smith** and **Charles Lightoller** held Extra Master's Certificates, while **Wilde** and **Murdoch** held Ordinary Master's Certificates. An Ordinary Master's certificate was required to have active command of the ship.

SHIP'S OFFICERS

Captain E.J. Smith	Chief Officer H.T. Wilde	First Officer W.M. Murdoch
Second Officer C.H. Lightoller*	Third Officer H.J. Pitman	Fourth Officer J.G. Boxall*
Fifth Officer H.G. Lowe*	Sixth Officer J.P. Moody	* indicates survived sinking

CREW

The White Star crew for *TITANIC* numbered 799. 500 of these looked after the passengers, 325 cared for the engines and power plants, while only 66 were actually responsible for sailing the ship. The remaining 8 were the band members, assigned to the second class passenger list.

PASSENGERS

The *OLYMPIC* and *TITANIC* were designed to accommodate 735 First Class, 674 Second Class and 1,026 Third Class (or steerage) passengers, for a total of 2,435. With her crew of 900, the ship was certified to sail with 3,300 people. During her maiden voyage *TITANIC* was carrying 329 First Class, 285 Second Class and 710 Third Class passengers, for a total count of 1,324 passengers. This was about 54% of *TITANIC*'s maximum capacity. Total passengers and crew embarked for the Maiden Voyage was 2,223 people.

Meals were served: Breakfast 8:30 to 10:30 AM
 Dinner (lunch) 1:00 to 2:30 PM
 Tea (dinner) 6:00 to 7:30 PM

NAVIGATION DURING LAST VOYAGE

Like other westbound liners, *TITANIC* took the OUTWARD SOUTHERN TRACK across the north Atlantic Ocean, an established sea lane which had been used by westbound ships between January 15th and August 14th of each year, since 1899. Exceptions were 1903, 1904, and 1905, when westbound vessels crossed the 47th meridian about 60 nautical miles (nm) further south, because of sea ice. This was a great circle route emanating from FASTNET ROCK on the southwest tip of Ireland to the TURNING POINT, along a compass track of S 62° W, or 242° true. The TURNING POINT was located at 42° N latitude and 47° W longitude. From this point, the route shifted westward, towards the Nantucket Shoal light vessel off New York, on a track of S 86° W, or 266° true.

Before leaving the bridge for dinner with the George Wideners and John Thayers on Sunday evening April 14th, Captain **Smith** left instructions in the Night Order Book for the turn to be made at 5:50 PM, 30 minutes later than when due. This delay was because of the ice sightings *TITANIC* had received from other vessels taking the same track during the previous 24 hours. At a speed of 22 kts, this would have taken *TITANIC* about 11 nautical miles (nm) further along the 242° course, resulting in a westward track towards New York about 4 miles further south of the standard track. According to Fourth Officer **Boxall**, this turn was made at 5:50 PM, as ordered. Plotting the described track lines assuming a turning point 11 nm pass the traditional turning point brings the ship's track to the collision and sinking positions established in 1985 by the Woods Hole expedition that eventually discovered the wreckage.

Most investigators have assumed the delayed turn was ascribable to the ice warnings received that afternoon, which lay across their proposed course. The new course would have taken them somewhat southward and to the west of the ice reported by White Star's *BALTIC* and south of that reported by Cunard's *CARONIA*, earlier in the day. Plotting their respective reports would suggest an ice field up to 78 miles across had been reported directly in their path. A major omission in Captain Smith's thought processes may have been forgetting to account for the ice pack's southward drift, which was about 1 mph. That could have brought the ice pack 20+ miles further south-southeast than the positions reported by *BALTIC* and *CARONIA* and likely plotted on *TITANIC*'s navigational charts.

TITANIC'S INCREASING SPEED

The *TITANIC* increased speed each day, bringing more and more boilers online, and extinguishing the fire that broke out in Coal Bunker 10. By Sunday April 14th the last three main boilers of 24 were brought online. *TITANIC*'s speed increased to about 22.5 kts on PM run April 14th. The last five boilers were usually reserved for auxiliary power, but it is believed Bruce Ismay ordered that these be brought online the following day (Monday) for a high speed run into New York. This would have brought *TITANIC* into New York Harbor early Tuesday evening instead of Wednesday morning, and likely made something of a splash in the New York newspapers, gaining publicity for the faltering White Star line, which was in deep financial distress.

From Noon Thursday April 11th to Noon Friday April 12th included 2 hr layover at Queenstown, Ireland. The ship ran 464 nautical miles (nm), with her wing screws turning at 70 rpm. From Noon Friday to Noon Saturday the ship covered 519 nautical miles (nm) with her wing screws turning 72 rpm. From Noon Saturday to Noon Sunday the ship covered 546 nautical miles (nm) at 75 rpm (only 2 nautical miles short of *OLYMPIC*'s record 24 hr run). Remember, going west, the ship's clocks were turned backward each day, so the average speeds are not quite as fast as the figures suggest.

On her last day, the *TITANIC* supposedly gained 260 nautical miles (nm) between 12 Noon and 11:40 PM collision, for an average speed of 21.75 kts; but the clock would have been turned back 1 hour at Midnight, so actual speed was closer to 22.25 kts. On Monday April 15th the remaining five auxiliary boilers were to have been brought online, because the ship had precious little coal to spare on her maiden voyage to New York.

COAL SITUATION

The capacity of *TITANIC*'s 11 coal bunkers was 8,000 tons. The bunkers ran from the Tank Top to the underside of F Deck. The bunkers were numbered from amidships forward. With the exception of the area forward of Bunker 11, these bunkers were arranged in back-to-back pairs. Watertight bulkheads split all of the coal bunkers.

TITANIC left Belfast with 1,880 tons of coal, enough for 3 days steaming. It was intended to collect another 5,500 tons of coal left in Portsmouth by the *OLYMPIC* (she actually contributed 4,427 tons). Coaling was done by hand labor from small coalers, or lighters, rowed up against the ship's sides. This was a holdover from older days with smaller ships. More sophisticated coaling procedures were developed soon thereafter.

FIRE IN COAL BUNKER 10

Shortly after completing her April 2nd sea trials off Belfast, *TITANIC* developed a spontaneous combustion fire of the coal stored in the starboard side of Bunker 10. Bunker 10 was situated at the after end of Boiler Room 6, and just ahead of Bulkhead No. 5. The fire began in Belfast, and was extinguished by gradually emptying the contents and stoking the adjacent boilers with this material (which was standard procedure). By Saturday morning April 13th, the bunker was excavated of its cargo, and the fire thereby extinguished. The fire may have made the hull plates more brittle in this area, but these plates have never been recovered for testing. Critical buckling of hull plate laps extending 2 feet into this bunker allowed seawater to infiltrate Boiler Room 5, sealing *TITANIC*'s ultimate fate. That two feet made all the difference.

UNUSUAL WEATHER CONDITIONS

1911-12 was the mildest winter in the north area for over 30 years. More icebergs, ice floes and field ice drifted further south than reported in previous 30 years. The icebergs were brought southward along COLD LABRADOR CURRENT, and then swept NORTHEASTWARD along the GULF STREAM. The source of the ice floes encountered by *TITANIC* was in Disko Bay, GREENLAND. Bergs cleaving off from this locale can take three years to reach the Grand Banks off Newfoundland.

Six separate ice warnings were received by the *TITANIC* on Sunday April 14th. The descriptors used in the wireless reports included: Icebergs; large masses, more than 200 feet across; Growlers: smaller icebergs; Ice Floes: sea ice broken up but moving together as one broken patch; Sea Ice: one uninterrupted mass of ice. Ice packs and floes normally drift southward between ¼ and 1-¾ nautical miles per hour (knots).

TITANIC entered the cold water of the Labrador Current beginning around 5:30 PM Sunday. By 7:30 PM the sea water temperature had dropped 10 degrees F, and was measured to be about 33° F, falling to 32°. At 9 PM the officers on watch became concerned about freezing of the fresh water supply in the ship's tank top and amidships bilges, the ocean temperature had dropped to 28° F (which is an unusual circumstance). The iceberg *TITANIC* struck was described as a twin-peaked mass, more than 200 feet high, with a red-ochre scratch line at the water level, from scrapping the *TITANIC*'s anti-fouling paint. She was also described as being "black ice", suggestive of having turned and rotated in the water as she melted. Icebergs containing "black ice" can be very stinky, due to rotting organic inclusions.

Sunday evening saw flat calm seas, such as had never been seen in the North Atlantic. It was also a moonless night (new moon). A slight breeze began to blow during the hour just before dawn on Monday April 15th. Breezes and wave swells are acutely common on the high seas. The absence of waves against the iceberg accounted for the failure to spot it inside of 2,000 yards (one nautical mile), which was the normal sighting distance on a moonless sea. Waves lapping against the iceberg would be observable, even on a dark night, due to the customary phosphorescence caused by turbulence and wave splash. In this respect, the lookouts would have been greatly aided by binoculars, so as to keep their eyes from watering. But, without waves splashing against the bergs, they would have been virtually invisible until a very close distance. Steaming at 22+ kts in such an area with such a large unwieldy ship was somewhat reckless in retrospect, especially when compared to the other steamers in the area, who exercised considerably increased caution.

LOOKOUTS WITHOUT BINOCULARS

Second Officer **David Blair** came aboard at Belfast, and sailed with *TITANIC* to Southampton. He was charged with stowage of the binoculars for the ship's lookouts. The binoculars were labeled "*Second Officer, Titanic*". Blair locked all five pairs of binoculars in his cabin on Tuesday April 9th, which was inherited by **Charles Lightoller the following morning**. Blair was dismissed at Southampton and reassigned a berth on another ship to accommodate **Henry Wilde** as the new Chief Officer (which bumped **William Murdoch** and **Charles Lightoller**

down one rank). The ship was steaming at a speed between 22.25 and 22.5 kts during last evening with considerable wind chill. The lookout's eyes would have to have watered up pretty quickly. The wind chill factor would have been approximately -27° F, bringing the ambient air temperature down from 35° F to about 8° F. This would have caused the lookout's eyes to water after only a few painful seconds. Binoculars would have helped protect their eyes from watering, as well as made their vigilance more effective.

SIGHTING OF ICEBERG

The iceberg which *TITANIC* struck was initially sighted by lookout **Frederick Fleet** from the forward Crows Nest, situated 95 feet above the water line. He sounded three strokes on the Crow's Nest bell, signifying an object was dead ahead of the ship, at 11:39 PM (ship's time) at distance of about 500 yards. At a speed of 22.5 kts, this gave the ship about 40 seconds to react. Other icebergs had previously been reported during the watch, but not directly in ship's path. **Murdoch** should have taken these sightings more seriously. Fleet rang the bridge on his phone: *Are you there?* **Moody**: *Yes, what do you see?* **Fleet**: *Iceberg right ahead!* **Moody**: *Thank you.* [to First Officer **Murdoch**] *Iceberg right ahead!* **Murdoch** to helmsman: *Hard a-starboard!*

ATTEMPTED EVASIVE ACTION

First Officer **Murdoch** commanded the watch, assisted by 6th Officer **Moody**. Quartermaster **Robert Hitchens** was at the ship's helm. **Murdoch** ordered "**hard a-starboard**", meaning turning the ship's wheel to the right, in order to turn the ship to the left. It was a hold over command from sailing days, and the use of these terms were discarded in 1928. Today we would say "left full rudder". The rear of the ship would swing outward in opposite direction, like driving a forklift with rear steerage. The rudder is the one control apparatus on the ship's bridge that was directly connected to the maneuvering room, and there should have been no lag in response. It was a power assisted rudder. **Murdoch's** intention was to swerve around the iceberg by going hard-a-starboard followed by hard-a-port. The ship needed 850 yards to stop from 20 kts, and about 1000+ yards to stop from 22.5 kts (she was now almost fully loaded). Murdoch found himself without adequate separation to effect the prescribed evasive maneuver.

Murdoch then ordered "*FULL ASTERN*", taking the bridge telegraph through "*ALL AHEAD STOP*" first. He then rang the bell button warning of watertight door shut-down for 10 seconds, then pulled the switch to close the watertight bulkhead doors electrically. The doors were closed just AFTER striking the iceberg. All of these actions were standard specified procedures for avoiding an imminent collision.

WHY THE SHIP DID NOT RESPOND QUICKLY

Unlike the rudder, control of the ship's engines was via the telegraph, connected to the engine rooms. An engine room telegraph works like the actual engine controls, and in order to switch power from FLANK to FULL ASTERN, the operator would first have to go through ALL AHEAD STOP, a time consuming process, as described below.

On the outboard reciprocating engines, the engineers would have to close off the main steam valves to each engine, by bleeding off the steam feed down to zero pressure, which would then back up steam in the boilers. In order to avoid shock wave in the boilers, this steam has to be blown up the funnels. The entire time *TITANIC* was loading her lifeboats, there was so much excess steam it was being blown up the funnels. Although choking off the steam feed shuts down the mechanical driving force to the engines, the props would continue to spin with forward rotation because of the ship's forward momentum.

On the triple expansion reciprocating engines connected to the ship's wing props the engineers would have been forced to bring these shafts to a stop, or have a clutch. Once the shaft has stopped turning forward, the shaft is reversed by opening the steam valve to the reverse side of the engines. In those days manual adjustments were required to reverse motion of the steam cylinders that move the valving between the pistons (two valves, one pushes down and the other pushes up). Nevertheless, one big advantage of reciprocating engines is that they offer full horsepower in reverse.

The centerline turbine is completely different. Today's turbines include separate blades for reverse motion attached to the same prop shaft, using a different steam inlet (modern turbines generally allow for about 15% of the power in reverse). The *TITANIC's* central propeller was turbine powered, but **without any ability to reverse**. Unfortunately, it was this screw which also had the greatest influence on the rudder, and hence, maneuvering.

In modern turbine-powered shafts, a brake must be applied to slow down the forward spin of the shaft. After shutting down forward power, the engineers in the engine room would then turn on the reverse valves to serve as a brake, slowing down the forward motion of the screws. The screws would have to come to a complete stop before reversing, and then begin turning in the opposite direction before actual deceleration would commence.

“FULL ASTERN” WAS THE WRONG CALL

The force on the rudder is proportional to the volume of water pushing against it. The rudder serves to flare the stern in one direction or the other; using rearward steering like a forklift. In order to turn the ship to port, the port outboard shaft would be shifted to ALL AHEAD ASTERN while the starboard outboard prop would be advanced to ALL AHEAD FULL, with the central shaft ALL AHEAD FULL, to push as much water against the rudder as possible, so as to pull the ship's stern to the right. **The rear end of the ship would move in the direction opposite the turn.** The bow doesn't move per se, just the stern. This is a difficult concept for lay people to grasp who have not actually steered large ships.

WHAT ACTUALLY HAPPENED

Robert Hitchens later testified that he pulled the ship's wheel full to starboard, turning the rudder full tilt to port, but the centerline (turbine powered) propeller pushing against the rudder was being shut down. The ship did not seem to respond to the rudder correction. 30 seconds passed before the ship even appeared to move, veering 2 compass points, or about 22.5 degrees to port when she struck the iceberg with a glancing blow. Contact began about 50 feet behind the bow on the starboard side, extending about 180 feet, to Boiler Room 5's forward coal bunker (Bunker No. 9). Contact with the berg lasted about 6 to 10 seconds. The time was 11:40 PM (ship's time).

The maneuver was later reenacted with the *OLYMPIC* and it was determined that 37 seconds were required for the ship's bow to move 2 compass points to port at a speed of 22 kts, which would equate to 466 yards of forward travel. This agrees with the testimony of Quartermaster **Hitchens**. This was how the estimate of “500 yards distance” to the iceberg was deduced, after the fact.

The ship eventually stopped and began moving astern, then came again to a complete stop, then half speed ahead (to reduce the forward momentum) before shutting down to appraise their damage. The men in Boiler Room 6 were able to scramble to safety as sea water rushed into the compartment.

TITANIC was designed to withstand flooding of its first 4 compartments, because these forward-most compartments were small, having been designed to isolate damage in a bow collision. She actually had an additional bow compartment fitted as compared to her sister ship *OLYMPIC*. Had *TITANIC* rammed straight into the iceberg she would have easily survived, but this would have killed about 56 firemen berthed in the forward block of F Deck and it was not the prescribed avoidance procedure. Extreme maneuvering measures were always to be taken to avoid collisions because it was hoped such measures would save the most lives.

WATER ENTRY

The worst hull plate buckling appears to have occurred at a position about 10 feet above the keel, or about 4-2/3 feet above the tank top in Boiler Room 6. The hull plates were buckled at the rivet laps where the iceberg rubbed against the segmented steel hull. Inspection revealed that seawater was observed entering the fore peak, No. 1 hold, No. 2 hold, No. 3 hold, Boiler Room 6, and Coal Bunker 9, just abaft Watertight Bulkhead 5, allowing water into Boiler Room 5 approximately 25 minutes later. The damage extended over a length of approximately 180 feet, not the 300 feet commonly reported. Water entered Boiler Room 6 about 2 feet above the stokehold plates, but only at the after end of the compartment. In Boiler Room 5 the separation only extended two feet into the forward coal bunker, with water pouring in at the rate of “an ordinary fire hose”. At the time of the collision this bunker had no coal in it. There was no indication of hull damage or leakage abaft of Boiler Room 5. Boiler Room 6 was evacuated almost immediately. Within 10 minutes (11:50 PM local time) water had risen 8 feet in Boiler Room 6 and as much as 14 feet above the forward keel in the forward holds.

Around Midnight Captain **Smith** and Harland & Wolff Chief Engineer **Thomas Andrews** (who made the maiden voyage to observe the ship's performance) made a joint inspection of the damage. They observed mail bags (they were carrying close to 5,000) floating 24 feet above keel level, indicating a leak of sizable proportion. **Andrews** gave Captain **Smith** 1 to 1-1/2 hours, possibly two hours to go before the ship would founder. **Smith** seemed completely shocked by this information and became increasingly distant as the night wore on. Such detachment is a common manifestation of emotional shock.

By 12:05 AM the floor of the squash court forward on F Deck was awash, 32 feet above keel level, and water began entering Boiler Room 5, from Coal Bunker 9. By 12:40 AM the accumulating water likely built up to the height of the watertight bulkhead at the level of E Deck. Then it would have begun to spill over, into the next adjacent compartment (this spillage could have been delayed by proper counter flooding, discussed next).

FAILURE TO APPRECIATE COUNTER-FLOODING

If the watertight bulkheads between the boiler rooms had been carried upward to the Main, or Shelter Deck (officially referred to as "C Deck" on the ship's plans), instead of the top of F Deck, the ship would have remained floating. This oversight became apparent during Edward Wilding's forensic assessment in the late spring of 1912. The *OLYMPIC* was immediately retrofitted to correct this shortcoming and humanity witnessed the birth of the watertight compartment, as opposed to the older watertight bulkheads employed up to that time.

This spilling over of intruding sea water over the forward bulkheads was exacerbated by the deepening head-ward list of the ship, which increased the volume of water that could pour over each bulkhead. In this respect they would have been better off leaving the watertight doors open and allowing sea water to enter the boiler rooms and engine room. By spreading the water aft, the head-ward tilt would have been reduced, and the intake of water thereby reduced, keeping the bow as high as possible. This would not have saved the ship, but could have prolonged its sinking by as much as 2 to 4 hours. That may not seem significant, but keep in mind that the *S.S. CARPATHIA* arrived on scene at 4 AM, just 1 hour and 40 minutes after the *TITANIC* sank.

The practice of counter-flooding for damage control was not appreciated or taught prior to the *TITANIC*'s untimely demise. It became commonplace practice among the world's navies immediately thereafter, especially during the First World War (1914-18). When the American battleships were attacked at Pearl Harbor in December 1941, all of the junior officers standing watch that morning correctly applied counter-flooding to prevent their ships from capsizing, after receiving enormous damage from Japanese torpedoes. The only ships which capsized were the *OKLAHOMA* and the *UTAH*. The *OKLAHOMA* was unable to counter-flood because the inspection ports on her bilges had been opened for an inspection expected the following day. The *UTAH* was an old battleship that had been converted to a target ship. She carried a skeleton crew and lacked modern damage control systems. She was hit almost simultaneously by two torpedoes amidships on her port side. She quickly lost electrical power so could not employ pumps to counter-flood. Lessons learned in the loss of *TITANIC* saved thousands of lives in the years that followed.

WIRELESS COMMUNICATIONS

The wireless (radio) communications transmitter and receiver was invented by Italian Guglielmo Marconi shortly before the turn of the 20th Century. Steamers began carrying wireless sets in July 1901, beginning with Cunard's *LUCIANA*. The Allen Line followed in 1902, and by 1904 most transatlantic ships were fitted with wireless sets, operated under license by employees of the Marconi Company. This included the steamers of the White Star Line. The guaranteed range of the Marconi set was 350 miles, but this increased greatly at night. The Marconi system used aerials strung between the *TITANIC*'s two mainmasts, about 205 feet above the waterline. The wireless shack was located at the after end of the officer's house, behind the navigation bridge (on the Boat Deck level).

The bulk of a Marconi wireless operator's earnings came from tips, provided by wealthy travelers. The minimum cost of any message was \$3 for 10 words. Sending wireless messages from a steamer at sea became a mark of prestige and wealthy passengers fell over themselves to send messages. Messages could not be sent to the United States until the vessels came within range of the Cape Race, Newfoundland transmitter. That range was about 350 nautical miles (nm) during daylight and something close to 600 nautical miles (nm) at night. In the interim, messages could be routed across the ocean from one transiting ship to another, and this is how weather and

navigational advisories were routinely passed between vessels. Most of the ship's masters working the north Atlantic sea lanes knew one another by name, and virtually everyone knew *TITANIC*'s Captain **E.J. Smith**, who had commanded ships on the North Atlantic sea lanes since 1887.

The *TITANIC*'s wireless transmitter broke down at 11 PM Friday evening April 12th, and was restored to operation around 5 AM Saturday April 13th.

ICE WARNINGS RECEIVED BY TITANIC ON SUNDAY April 14, 1912

9:00 AM	Cunard steamer <i>CARONIA</i> reports ice field
11:40 AM	Dutch liner <i>NOORDAM</i> reports "much ice", same position as the <i>CARONIA</i>
1:30 PM	White Star steamer <i>BALTIC</i> reports message from Greek steamer <i>ATHINAI</i> , who reports passing icebergs and large quantities of field ice at 41° 5' N and 49° 52' W (plots about 250 miles ahead)
1:45 PM	Same sort of message intercepted from steamer <i>AMERIKA</i> (but not sent to bridge)
2:00 PM	Captain alters course of ship slightly to south
7:30 PM	Captain Smith goes to formal dinner with the Wideners and the Thayers
8:10 PM	Leyland Liner <i>CALIFORNIAN</i> radios ice warning, on same course as <i>TITANIC</i> , slightly north. Reports passing 3 large icebergs, 3 miles to south (this message was not given to Capt Smith). When he came on watch at 10 PM First Officer Murdoch ordered the forecstle hatch closed to enhance visibility for his forward lookouts
9:00 PM	Capt Smith returns to the bridge, discusses the situation with the 6-10 PM watch commanded by Second Officer Lightoller ; concerns expressed over drop in air and sea temperatures, which threatened to freeze ship's fresh water supply (stored in tanks against the hull below waterline).
9:20 PM	Captain Smith retires to his sea cabin
9:30 PM	Lookouts told by First Officer Murdoch to keep a sharp lookout for icebergs
9:40 PM	Wireless message from <i>MESABA</i> to <i>TITANIC</i> : In Latitude 42° N to 41° 25' N and Longitude 49° W to 50° W saw large icebergs, also field ice, weather good, clear". This was directly ahead of <i>TITANIC</i> 's position. This message was not taken to the bridge from the wireless room because of commercial wireless activity. <i>TITANIC</i> had just come within wireless range of Cape Race, Newfoundland (about 450 miles distant). Private messages that had piled up all day that could now be sent.
10 PM	Watch change, First Officer Murdoch relieves Second Officer Lightoller as Officer-of-the-deck on <i>TITANIC</i> 's bridge.
10:50 PM	<i>CALIFORNIAN</i> , dead in water at eastern edge of ice field, can see lights of <i>TITANIC</i> on horizon, approaching from the southeast at range of 19 miles. Her wireless operator attempts to send another warning to the <i>TITANIC</i> . This message "blasts" <i>TITANIC</i> wireless operator Phillips, because of close range. Phillips brushes off this communication by telling the <i>CALIFORNIAN</i> : "Shut up. Shut up. I am busy. I am working Cape Race."
11:40 PM	<i>TITANIC</i> strikes iceberg 380 miles southeast of Newfoundland, in 12,400 feet of water
11:47 PM	<i>TITANIC</i> stopped in water, begins head-down list, first to starboard, later to port.

CQD/SOS MESSAGES SENT BY TITANIC

Fourth Officer **Boxall** was ordered to fix the ship's position after the collision with the iceberg, using dead reckoning based on Second Officer **Lightoller**'s last fix at 7:30 PM. Unfortunately, **Lightoller** had made a navigational error the previous day, which was carried over into Sunday. **Boxall** calculated 41° 46' N and 50° 14' W. The actual position appears to have been 49° 55' W. In this area each minute of latitude equates to about 1,520 yards, so an error of 19 minutes longitude equaled 14.4 nautical miles. This was the erroneous position they reported in all of their distress calls. The times referred to here are the *TITANIC*'s local ship time, which at this position (50°W longitude) was 1 hour, 50 minutes ahead of Eastern Standard Time in New York and Boston.

At 12:15 AM on Monday April 15th the first CQD message was broadcast from the wireless room, giving coordinates 41° 44' or 41° 46' N and 50° 24' W. *TITANIC*'s call sign was MGY. CQ meant "All Stations", and D meant "Danger". Later they also broadcast "SOS", a simple distress code which meant "Save Our Souls". It had

been introduced in 1908. **Boxall's** amended position was received at Cape Race, Newfoundland at 12:25 PM. The French ship *LA PROVINCE* and the Canadian ship *MOUNT TEMPLE* acknowledge *TITANIC's* first transmissions.

The ship *RAPPAHANNOCK* had just passed the *TITANIC* heading in the opposite direction and was only 15 miles east of accident, but she was nursing a damaged rudder and had no wireless set.

An unidentified schooner was reportedly seen by the *TITANIC* lifeboats, the *CALIFORNIAN* and the *MT TEMPLE*. This is now believed to have been the Norwegian *SAMPSON*, 506 Gross Registry Tons, 148 feet long, reported to be about 8 to 13 miles distant during *TITANIC's* sinking; according to a deathbed confession of its first officer in 1962 (described later).

Wireless operator on the *CALIFORNIAN* (**Cyril Evans**) turned off his wireless set at 11:20 PM *TITANIC* time (11:30 PM on *CALIFORNIAN*), 35 minutes before the first distress call.

SIGNAL SOCKET FLARES

Fourth Officer **Boxall** was ordered by **Captain Smith** to fire the socket flares. He was assisted by Quartermaster **George Rowe** and begin firing SIGNAL SOCKETS from the starboard side of the navigation bridge. They could see the *CALIFORNIAN's* red and green navigation lights; later switching to a red light with two white masthead lights (indicating a turn away, to starboard). **Rowe** and **Boxall** also tried to raise the mystery ship with a hand held Morse signal lamp. The officers standing watch aboard the *CALIFORNIAN* simultaneously attempted to signal *TITANIC* with a Morse Lamp. The effective range of a hand-held Morse Lamp was only 4 to 5 miles, so this was ineffective.

The socket signals flares were launched from mortars on the bridge wings. They fired white missiles 800 feet into the air, exploding into 12 slowly falling white stars. **Boxall** launched 8 rockets at 5-minute intervals, beginning at 12:45 AM, as the first lifeboat was launched, and finishing at 1:20 AM, as Boats 9 and 10 took to the water.

There were no uniform international procedures for distress signals, however, there was an established custom and practice of firing rockets at regular intervals to indicate an emergency. White rockets were recommended. This became a contentious issue for the **Captain Lord** of the *CALIFORNIAN* the rest of his life, though he was asleep during most of this period.

The *CALIFORNIAN* placed her original stop position at 42° 5' N 50° 7' W, which would have initially been about 13.5 miles NW of *TITANIC's* impact with the iceberg. With a SSE drift of 1 nautical miles (nm)/hr, she should have moved about 1.7 nautical miles (nm) closer, making her about 11.8 miles distant when the *TITANIC* stopped (if **Captain Lord's** position was absolutely accurate). Considerable testimony from watch standers on *TITANIC*, *CALIFORNIAN* and *MT TEMPLE* suggest *CALIFORNIAN* was drifting within 8 to 15 miles of *TITANIC* when she sank. *TITANIC* struck the iceberg at 41° 47'N and 49° 55' W, but both vessels appear to have initially drifted SSE with clockwise rotation, then SSW, with the prevailing current. Neither ship dropped anchors.

LOADING OF TITANIC'S LIFEBOATS

45 minutes after colliding with the iceberg, Captain **Smith** gives the order to load the lifeboats with "women and children" [first], at 12:25 AM. *TITANIC* had 14 special purpose lifeboats, designed to hold 65 people each. These had been load tested by Harland & Wolff, but the successful operation not recounted to the ship's officers. These lifeboats were 30 feet long, much larger than standard lifeboats of that period. She also carried two emergency cutters, capable of holding 40 people each, and 4 Englehardt collapsible lifeboats.

First Officer **Murdoch** and Fifth Officer **Lowe** were assigned to supervise loading of lifeboats on the starboard side; while Second Officer **Lightoller** and Sixth Officer **Moody** were ordered to supervise loading on the port side. They both began at amidships and worked their way forward.

It took 20 minutes to get the first boat loaded and into the water, **Boat 7** was lowered away on the starboard amidships at 12:45 AM. The first lifeboat launched from the Port side was Boat 6 at 12:55 AM, with 28 aboard. **Boat 5** lowered away at 12:55 from starboard side with 41 people and Third Officer **Harold Pitman**. Boats 5 and 7

later joined together. **Pitman** was ordered by Captain **Smith** to row towards the mast light on the north horizon [thought to be the *CALIFORNIAN*], which appeared to be about 5 miles distant, 2 points (22.5 degrees off the starboard bow (it is more likely that she was about 11 miles distant).

Cutter **Boat 1** launches from forward starboard at 1:10 AM with only 12 people (capacity of 40). **Boat 8** was lowered from the port side around the same time (1:10 AM) under Chief Officer **Wilde's** supervision, aided by **Lightoller**. 39 aboard, including 35 females. By 1:10 PM, 10 lifeboats had been lowered and 10 remained aboard. Starboard **Boat 9** was next lowered at 1:20 AM with 56 aboard, including 42 women. Port **Boat 10** lowered at 1:20 AM with 41 women and 7 children aboard.

Those gathered topside could see the masthead lights of the *CALIFORNIAN* and most were confident this nearby ship would be summoned to come to their aid. This knowledge and the seemingly slow descent of the bow persuaded many first and second class passengers to refrain from being loaded aboard the lifeboats.

At 1:25 AM **Boat 11** lowered from starboard side with 63 aboard. The ship's bilge pumps discharged into the lifeboat as it was being loaded, drenching its occupants. At 1:25 AM portside **Boat 12** lowered with 42 aboard. At 1:30 AM Chief Officer **Wilde** orders Fifth Officer **Lowe** to take command of **Boat 14**, with 63 aboard. At 1:35 AM the last of the regular lifeboats on starboard side was lowered. **Boat 13** carried 59 women and 9 men (including 5 crewmen), while **Boat 15** carried almost 70, including 13 crewmen, but only 4 women and 3 children. **Murdoch** was less zealous in packing the lifeboats with women and children, whereas on the port side, **Mr. Lightoller** was most strict in this regard and, therefore, took much longer in getting his boats off.

Collapsible **Boat C** was situated on the forward starboard side. It was attached to Boat 1's davits and lowered away with 39 souls aboard. First Officer **Murdoch** had to fire his pistol to maintain order during loading. Quartermaster George Rowe was appointed by Captain **Smith** to command her (he was the man who helped Fourth Officer **Boxall** fire the distress rockets). She picked up 4 more (for a total of 43). Rowe steered towards a sailing vessel, but could not catch her (probably the *SAMPSON*).

Emergency cutter **Boat 2** on the port side was launched by **Lightoller** around 1:45 AM. Fourth Officer **Boxall** was given command along with a supply of green signal rockets. The boat carried 26 people, of which 21 were women. All but 1 of the starboard boats had been launched by 1:40 AM, followed by the port side, 25 minutes later.

1:55 AM **Boat 4**, last of the conventional lifeboats was launched from the port side, 70 minutes after the order to load was given. **Boat 4** was carrying 46 people. She was originally let down to A Deck, but nobody could board because of **Ismay's** windows, so brought back up to the Boat Deck, then re-lowered to A Deck after a seaman was dispatched with the proper tool to open the window covers. This boat contained 36 women and children, and only descended 25 feet to the water, because of *TITANIC's* list. **John J. Astor** asked to board with his pregnant wife, but was refused. **Boat 4** remained nearby, and picked up 7 men from the water, but it leaked badly and required constant bailing. **Astor** appears to have died when Funnel No. 1 toppled onto the submerged bridge, where a group of men were clinging to the overturned hull of Collapsible Lifeboat B.

At 2:05 AM Collapsible **Boat D** lowered from the Boat 2 davits, forward on the port side. By this time the sea was level with B Deck, so only lowered 2 decks. Her loading was supervised by **Wilde** and **Lightoller**, contained 40 to 46 people.

Collapsibles A and B were stowed on the roof of the officer's deckhouse, behind the navigation bridge. B went into the water upside down. **Lightoller** had given up on launching A, but men sitting on it went into the water with it when the ship's bridge dipped under, around 2:10 AM. **Wilde** and **Murdoch** were last seen trying to free up Boat A on the starboard side. Neither officer survived.

At 2:21 AM the stern section of the *TITANIC* sank

On overturned collapsible **Boat B**: Wireless operator **Harold Bride** ended up beneath Collapsible B, he was later picked up by Boat 12. The first group which reached it appears to have been crushed by Funnel No.1 when it toppled forward. After this wireless operator **Jack Phillips** made it to Collapsible B, but died of exposure. 30 or so men clambered aboard overturned Boat B, balancing on the upturned bottom. They stood upright back-to-back for

over 2 hours, reciting the Lord's Prayer in unison. This group included **Lightoller, Archibald Gracie**, the ship's cook and many others. They were taken aboard Boat 12 under Fifth Officer **Lowe** just after dawn, after being summoned by **Lightoller's** whistle. **Lightoller** then took command of Boat 12, which had also relieved Collapsible D of some of her survivors, around 6:30 AM.

Unfurled collapsible **Boat A**: Men were attempting to slide her down off the deckhouse when the bridge dipped under the waves, and the boat floated away right side up, but with her side screens down. Four men managed to stay aboard as the boat was swept off *TITANIC*. She was commanded by First Class Steward **Edward Brown**, who served as an excellent witness in the British inquiry. 16 men eventually clambered aboard, out of the water, but only between 11 and 14 survived, due to hypothermia. The survivors were removed by Collapsible D and Boat 14, commanded by Fifth Officer **Lowe** shortly after dawn. Three dead were left in the boat.

25-year old Fifth Officer **Harold Lowe** was the officer who purposefully waited "*for the people to thin out*" (or until the cries died down) to go back in and try to recover survivors from the icy water. He only managed to recover three people, one of whom died, thereby saving 2 out of the 1,517 who were left to the frigid waters. Boat 10 joined Collapsible D and Boats 4, 12, and 14 to form a small flotilla linked by ropes and commanded by Fifth Officer **Lowe**.

Collapsible Boat C, with **Bruce Ismay** aboard, was picked up by *CARPATHIA* around 6:15 AM. Collapsible D arrived in tow by Boat 14, flagship of **Lowe's** flotilla, around 7 AM. Boat 12 was the last to transfer her more than 70 people to the *CARPATHIA*, between 8:15 and 8:30 AM. Second Officer **Lightoller**, the senior surviving officer, was last to come aboard *CARPATHIA*.

THE SHIP ON THE HORIZON

The *S. S. CALIFORNIAN* was a 6,223 ton Leyland Liner out of Liverpool, bound for Boston with a cargo of cotton. She was built in 1901-02 in Dundee, Scotland; 447 feet long with beam of 54 feet and accommodations for 47 passengers (none carried on this trip). The *CALIFORNIAN* was carrying a crew of 55 and her design speed was just 13 kts. She was commanded by **Stanley Lord**, b. 1877 in Bolton, England, his 4th command in 6 years.

The *CALIFORNIAN* left Liverpool on April 5, 1912 bound for Boston, MA Her wireless received several ice warnings on Saturday April 13th. She sighted icebergs to south near dusk on Sunday April 14th, while traveling westbound. She notified *ANTILLIAN* at 6:30 PM that icebergs sighted, this message overheard by *TITANIC*.

At 10:09 PM (*TITANIC* time) Captain **Lord** ordered FULL ASTERN, then STOP, swinging helm hard-to-port to bring the ship around onto a northeast heading, an emergency stop. Although isolated icebergs had been sighted, Captain **Lord** correctly deduced he had stumbled upon the edge of a large ice field. This was 1-1/2 hours before *TITANIC's* collision. He calculated their position by dead reckoning as being 42° 5' N and 50° 7' W. If his calculations were correct, he was initially located about 13-1/2 nm NW of where *TITANIC* struck the iceberg at 11:40 PM. He should have drifted to within about 11-1/2 to 12-1/2 miles of *TITANIC* by the time she arrived, 1-1/2 hours later.

At 10:40 PM, the *CALIFORNIAN's* bridge watch observed a large ship approaching from the southeast. At 11:20 PM Captain **Lord** observed this vessel's green starboard navigation light, indicating westbound travel, and her white masthead light, as well as numerous deck lights. This could only have been *TITANIC*. Captain **Lord** estimated the ship appeared to be about 5 nautical miles (nm) south of their position, and they were drifting SSE. The maximum visibility from **Lord's** bridge [49 feet above ocean level] would have been about 8 miles. Taller objects, such as the *TITANIC's* bridge could be seen from further away.

CALIFORNIAN's Marconi wireless operator was 20 year old **Cyril Evans**, who had just 6 months experience. Captain **Lord** ordered **Evans** to notify *TITANIC* he was stopped and surrounded by ice. Evans began to do so, but was rudely cut off by *TITANIC* wireless operator **Jack Phillips**. Unfortunately, Evans did not leave his emergency bell switched on when he turned off his set at 11:20 PM and *TITANIC* did not broadcast her first distress call until 35 minutes after striking the iceberg, around 12:15 AM.

Third Officer **Charles Groves** tried to raise the ship with his Morse [signal] Lamp, but received no response. Just after midnight, Second Officer **Herbert Stone** took over the watch. He saw a ship about 5 nautical miles (nm) south and a little west, with one white masthead light and a portside red navigation light. This was probably due to some drifting of the *TITANIC*, which was dead-in-the-water. All the while, *CALIFORNIA* was also drifting, swinging slowly clockwise, from ENE to WNW, through 225°. If *TITANIC* also drifted clockwise a similar amount, her red portside navigation light should have been facing the *CALIFORNIAN*.

Around 12:30 AM bridge watch on the *CALIFORNIAN* began noticing *TITANIC*'s socket signal rockets being fired off. In the exceptional weather conditions of that evening the rockets may have been visible from 20 miles away, if not very far above the horizon. However, several of the officer's also testified that they could see the lighting of the rockets as well as the launch, suggesting that they were 8 to 10 miles distant at most.

Captain **Lord** left the *CALIFORNIAN*'s bridge around 12:45 AM. At 1:15 AM Second Officer **Stone** reported that the ship on horizon is steaming away to the southwest, also reporting seeing white rockets low in sky and thought to be from another ship, further to the south. For unknown reasons, the *CALIFORNIAN*'s officers did not associate any sort of distress by the firing of the white socket flares. The headward list of *TITANIC* would have appeared identical to a ship sailing away to the south, over the horizon.

At 2:05 AM Cadet **Gibson** on *CALIFORNIAN* reports to the Chart Room he has observed 8 white rocket firings, and thought he saw a tramp steamer steam away (actually the lights of the *TITANIC* fading as she goes down by the head). **Gibson** is told by Second Officer **Stone** to inform the Captain **Lord**, which he does, but does not respond to Captain's inquiries about having been awoken. Second Officer **Stone** and Cadet **Gibson** were clearly afraid of Captain **Lord**, who was known as a stern disciplinarian. Second Officer **Stone** should have awoken the Captain.

Captain **Lord** awakes around dawn, 4:40 AM (local time), and notes a steamer is visible about 14 miles off, with one yellow funnel and 4 masts, but not on the bearing of rockets observed during the midwatch. This appears to have been the *SATURNIA*, south of the *MT TEMPLE* (the *MT TEMPLE* had extinguished her lights while DIW).

At 5:15 AM **Stewart** informs Captain **Lord** that his wireless has reported a ship sunk the previous night at 41° 46' N and 50° 14' W. Message is taken from the *MOUNT TEMPLE*, situated on the opposite side of the offending ice field.

At 5:40 AM the *MT TEMPLE* informs them that the sunken ship was the *TITANIC*. At 6:05 AM Captain **Lord** sets sail for the indicated [**Boxall's**] position, which is WEST of the ice field. *CALIFORNIAN* picks her way carefully across the ice field in the early morning light. At 7:35 AM *CALIFORNIAN* arrives at the indicated position, but sees nothing.

During the 1912 American and British inquiries, Captain **Lord** comes across as very defensive and self-serving, causing few to believe him. The public outcry following the *TITANIC* disaster caused Leyland Lines to discharge Captain **Lord**. The British re-opened inquest into the *CALIFORNIAN* in 1920, 8 years later. **Lord** spent the later years of his life fighting to have the Merchant Marine Board reopen his case and reconsider all the facts, retaining a lawyer. He became very agitated at the manner of his portrayal in the 1958 film *A Night to Remember*. He died a few years later, in January 1962, almost 50 years after the *TITANIC* sank.

THE OTHER SHIP NEARBY

The *MT TEMPLE* had left Antwerp, Belgium on April 3, 1912. She had received the same ice warnings as *TITANIC* via wireless on Saturday April 13th, plotted these, and decided to steer south, around them. She stopped around midnight April 14th (New York time, would have been about 2 AM local time) because of *TITANIC*'s CQD (distress) signal, notifying her that *TITANIC* had struck an iceberg and to please render aid and assistance. *MT TEMPLE* changed course and headed for *TITANIC*'s original position, then changed course to **Boxall's** corrected position. Around 2 AM she believes she has sighted the *TITANIC*. She encounters the ice field around 3 AM and doubled her lookouts. They see a small schooner showing a green starboard light about 1-1/2 miles ahead (this must have been the Norwegian *SAMPSON*). She turned sharply to port (northward) to pass the schooner starboard to starboard, but the light went out (*SAMPSON* had been engaged in an illegal seal hunting expedition to the Grand Banks, so shut her navigation lights when approached).

Captain **Moore** of the *MT TEMPLE* stated that he shut down at 3:25 AM, about 14 nautical miles (nm) from *TITANIC*'s reported position, and let his ship drift (some accounts say 2 hours, the captain stated 3 hours, between 3:25 and 6:30 AM), before attempting to cross the ice field (everyone was a bit nervous about hitting an iceberg by this point). He estimated the ice field as being 20 miles long and 5 to 6 miles wide. He came to **Boxall**'s corrected position around 4:30 AM, and circled, seeing nothing. He did note the steamer *SATURNIA* ahead and south of his position. Captain **Moore** estimated that **Boxall**'s position was actually 8 miles east of that broadcast, based on *CARPATHIA*'s position (drift was about 1 knot per hour SSE that evening). *MT TEMPLE* then sighted the German steamer *FRANKFURT* to the northwest and Russian steamer *BIRMA* to the south (which came up from a position about 70 nautical miles away). She communicated with both via her wireless set.

At 6 AM *MT TEMPLE* sighted the *CARPATHIA* across 6 miles of ice field, on the east side of the field. At 8:30 AM *CARPATHIA* sends her a message regarding her pick-up of *TITANIC* survivors, and advises *MT. TEMPLE* there is no need for her to stand by. They searched until 9 AM.

NORWEGIAN SCHOONER SAMPSON

The *SAMPSON* was a 506 ton Norwegian schooner, 148 feet long, commanded by Captain **C.J. Ring**. First Officer named **Hendrick Naess**. **Naess** makes a deathbed confession in Norway in 1962, stating that he observed the *TITANIC*'s white socket flares from close aboard on evening of April 14-15, 1912, but would not render assistance, thinking these to be signals from a revenue cutter, aiming to apprehend the *SAMPSON*, because she had been engaged in illegal hunting of seals off the SE Canadian coast and the Grand Banks. She was owned by a sealing company in Trondheim, Norway. **Naess** said they observed the rocket firings, then doused their lights, being fearful that these might be a signal for them to heave to.

Some have discounted the **Naess** report because the *SAMPSON* was logged in an Icelandic port on April 6th and April 20th. However, if they were engaged in illegal sealing activities, such an entry could have been purchased and served as a convenient alibi should the authorities probe her whereabouts.

THE DOROTHY BAIRD

A fishing schooner from Gloucester, Massachusetts was also reported to be in the general vicinity when the *TITANIC* foundered. This ship has been offered up as an alternative for the *SAMPSON*, but little corroborating evidence exists.

S.S. CARPATHIA COMES TO THE RESCUE

S.S. *CARPATHIA* was a Cunard liner of 13,600 tons, built on the River Tyne in 1902-03 for transatlantic emigrant service. She was 540 feet long and 65 feet wide, with a single funnel, capable of 14.5 kts. She was upgraded in 1905 to carry 100 first class, 200 second class and 750 third class passengers. Commanded by Captain **Arthur Henry Rostron**, born in Bolton, Lancashire in 1869, he joined Cunard in 1895. Promoted to Steamer Captain in 1907. *CARPATHIA* had 740 passengers embarked when she sailed from New York on Thursday April 11th, bound for Gibraltar and the Mediterranean.

Her only wireless operator was **Thomas Cottam**, age 21. He had a busy day Sunday April 14th, beginning at 7 AM, unable to turn in till midnight. But as fate would have it, he did not turn his set off because he had not received an acknowledgment of a message he had sent to the liner *PARISIAN* earlier that evening. Idly scanning the airwaves he tuned into the Cape Cod transmitting station (call sign MCC) and overheard transmissions to the new liner *TITANIC*. He wondered if *TITANIC* was receiving these, so he addressed a wireless inquiry to *TITANIC*'s call sign MGY:

I say, OM [old man], do you know there is a batch of messages coming through for you from MCC?

Before he could finish the transmission, he was interrupted by the reply from *TITANIC*'s **Jack Phillips**:

Come at once. We have struck an iceberg. It's CQD OM [old man]. Position 41° N, 50° 14' W

Cottam replies: Shall I tell my Captain? Do you require assistance?

Phillips replies: *To MPA [CARPATHIA], yes, come quick.* This was received by *CARPATHIA* at 12:25 AM local time (12:35 AM on the *CARPATHIA*, about 58 nautical miles (nm) southeast)

CARPATHIA was only designed for a flank speed of 14.5 kts, but Captain **Rostron** diverted all steam to the ship's engines, locking down all auxiliary power, and achieved 17.5 kts for the run-in to *TITANIC*'s reported position, 58 miles distant.

Last message received from the *TITANIC* was at 1:45 AM, which stated "*Engine room filled up to boilers*".

CARPATHIA steers a course of 308° true, or N 52° W. At 2:30 AM she sights green flares fired from Fourth Officer **Boxall**'s lifeboat, but *TITANIC* survivors don't see *CARPATHIA*'s responding white rockets till 3:30 AM.

CARPATHIA arrives at the scene at 4:00 AM, about 20 minutes before dawn, not quite 3-1/2 hours since picking up the distress call. She has come from the southeast, across relatively clear seas. She sets sight on **Boxall**'s green light, and records the pick-up position at 41° 40' N, 50° W, 7 to 8 nautical miles (nm) southeast of Fourth Officer **Boxall**'s "corrected position". *CARPATHIA* secures **Boxall**'s lifeboat to her starboard side at 4:10 AM.

When the sun rose *CARPATHIA* counted two dozen large icebergs (over 200 feet showing) in the vicinity. Captain **Rostron** noted that while picking up survivors, he noted "hardly a bit of wreckage floated, just a deck chair or two, a few lifebelts, good deal of cork, no unusual amount of flotsam. Only saw one body

TITANIC Lifeboats D, 14, 4 and 15 were cast adrift after pick-up. The other 13 lifeboats (1,2,3,5,6,7,8,9,10,11,12,13 and 16) were hoisted aboard *CARPATHIA* between 4:10 and 8:30 AM. **Rostron** reports these as: 13 lifeboats, two emergency cutters and 2 collapsible, 2 overturned [collapsible] boats sighted. One regular lifeboat noted to be capsized.

TITANIC SURVIVORS

1,517 people lost their lives on *TITANIC*, including the Captain, Chief Officer, First Officer and Third Officer; the entire engineering staff of 32 officers and men (who stayed below to keep the lights going); both Ship's doctors; the 8-man ship's band; **Thomas Andrews** and his 8-man guarantee party sent by Harland & Wolff; and all 5 postal clerks.

706 people survived, accounting for 31.8% aboard. Breakdowns by group were: 199/329 of the first class passengers (60%), including 93 % of the women and children; 119/285 of the second class passengers (42%), including 81% of the women and children; 174/710 of the third class passengers (25%), including 47% of the women and children; and 214/899 of the ships crew (24%), including 87% of the women (20 of 23). 27% of the boys and 45% of the girls in Third Class (steerage) survived.

The loss of life on the *TITANIC* was the worst civilian maritime disaster until April 1980, when a Philippine passenger ferry collided with a tanker and 4,375 drown.

FORENSIC ENGINEERING IN 1912

Edward Wilding, Harland & Wolff's senior naval architect, subsequently testified at the British Inquiry, which commenced in London on May 2, 1912. In the report dated July 30, 1912 **Wilding** stated that *TITANIC* would most certainly have survived a head-on collision with the iceberg, crushing the bow section back to the second watertight bulkhead. This would have killed 56 off-duty firemen berthed in the forecabin of the ship.

Wilding also calculated buoyancy loss, using reports of observations by the survivors, in particular the officers. *TITANIC* remained afloat for 2 hours and 41 minutes. **Wilding** calculated that the iceberg-induced hull damage extending back to Coal Bunker 10/Boiler Room 5 was likely a series of discontinuous cracks, irregularly distributed along the first 200 to 300 feet of hull, with an average area of breach of only 12 square feet. The average width of

such a crack would have been only 3/4 inch, which caused him to speculate that buckling of the hull plates at rivet laps was most likely responsible mechanism.

Wilding also calculated that 16,000 tons of seawater taken into the bow section would have been required to bring the bow down 40 feet, where it dipped beneath the surface around 2 AM.

CREDIBLE FORENSIC EVALUATIONS SELDOM REPORTED IN THE MEDIA

Wilding's statements came months later, after careful scrutiny of the evidence and a great number of engineering calculations. In addition, White Star was obliged to take *TITANIC's* sister ship *OLYMPIC* on forensic sea trials to measure response times, turning radii and ability to take evasive action under flank speed when fully loaded. The results of these tests were of extreme import in estimating what occurred when First Officer **Murdoch** attempted to make an evasive reverse turn around the iceberg.

These credible evaluations were largely overlooked by the media coverage of the day, similar to reporting today. When the news arrives months later it was considered "cold". **Wilding's** estimate of 12 square feet of opening has recently been corroborated by the French team who used geophysical techniques to evaluate the character and extent of damage to *TITANIC's* forward starboard side. This team also discerned that the damage was discontinuous, as **Wilding** also alleged. The separations appear to have occurred at laps between adjacent hull plates, where rivets had been sheared off. This discontinuous tearing appears to have been fostered by blunt indentation of one of the plates, as would be expected from the hull scrapping against a dense hard object.

ACTUAL POSITIONS BASED ON FORENSIC ANALYSES

The *TITANIC* wreckage was discovered in 1985, some 13 miles from Fourth Officer **Boxall's** reported position. It would appear that *TITANIC* was steaming at **41° 47' N and 49° 55' W** when she struck the iceberg. The hull sank at **41° 43.6' N and 49° 56.9' W**. During the post-failure inquiries in 1912, the *CALIFORNIAN's* position was represented to have been 19 nm from *TITANIC*, which implies that officers standing watch on here elevated bridge would not have been capable of making any direct observations of the *TITANIC*, but were observing a "mystery ship" supposedly situated between *TITANIC* and *CALIFORNIAN*. This seems incredulous, given the sheer volume of corroborating testimony from the surviving officer's on both vessels' navigation bridges. But, the events observed and described by *CALIFORNIAN's* officers, including observation of **Boxall's** rocket firings, suggests they were within direct line-of-sight of *TITANIC*; not to mention the mutual observation of bridge navigation lights, from both ships. If Captain **Lord's** dead reckon position was accurate, he would have been about 10.5 to 12.5 miles from *TITANIC* when she struck the iceberg, and 1 to 2 miles closer when she foundered. A sinking ship would not drift as fast as a trimmed ship.

PROBABILITY OF OCCURENCE

The winter of 1911-12 was unusually warm. The warmth increased iceberg calving at Disco Bay, Greenland and brought the cold Labrador Current further south into warm north Atlantic Gulf stream than in previous 40 years. *TITANIC's* Captain **Edward J. Smith** was the most experienced ship's captain on the North Atlantic, having commanded ships along those sea lanes for 25 years. He was also the highest paid mariner in the world at the time. He didn't take iceberg warnings as seriously as he should have and forgot to account for the southward drift of those sightings when these were plotted on the *TITANIC's* navigation bridge.

The environmental conditions surrounding the *TITANIC's* untimely demise were extremely rare: the night was moonless; the sea temperature was 29 degrees Fahrenheit and the *TITANIC's* fresh water bilges were freezing up. There were no waves, the ocean was at Sea State 1, unusually calm, described as "*being like a millpond*". These windless and waveless conditions prevented phosphorescent wave wash against the icebergs, which was how they were normally identified at night by watchmen stationed in the crow's nest, about 120 feet above the water. With binoculars the watchmen were usually able to identify icebergs at ranges of between 6,000 and 2,000 yards. The watchmen were without binoculars that evening because they had unknowingly been stowed in the Second Officer's cabin. The speed of the ship was about 22.5 kts and the wind chill factor on the watchmen would have been about -27° F, bring the ambient air temperature from 35° down to just 8° F. The iceberg that sank the Titanic was not identified until the ship was within about 500 yards, an extremely close range to enable effective evasive maneuvers.

At the time the environmental conditions fostering the April 1912 tragedy were universally judged to have been unusual, referred to as “*the mildest winter in some 30 or 40 years*”. There had not been any rational attempt to maintain records of sea surface temperature and iceberg migration until the *TITANIC* sank. An International North Atlantic Iceberg Patrol was established in 1912 and that body has quietly recorded environmental conditions ever since. The next time icebergs emanating from Greenland drifted into the North Atlantic sea lanes to the same latitude as in April 1912 was in March-April 1957, necessitating shifting of Trans-Atlantic steamers 100 nautical miles southward. It was exactly 45 years later and it was also the **ONLY** time such an advisory has been issued since 1912. Most oceanographers and climatologists disagree on the recurrence frequency of the southerly shift, but would agree that it’s likely on the order of one-in 50 years or thereabouts.

IMPACTS ON MARTIME DESIGN

The impacts of the *TITANIC* sinking on maritime safety legislation and naval architecture are legion. Needless to say, sufficient floatation and lifeboat space for each passenger, mandatory lifeboat drills and provisioning of lifeboats was immediately instituted.

On the design front, we have the *TITANIC* tragedy to thank for the rapid development of watertight compartmentalization (as opposed to watertight bulkheads); sluice valves between bulkheads for bilge pumps, so these could be connected in unison; damage control training which emphasized pumping and counter-flooding measures; increased maneuverability (larger rudders and voluminous hull skegs forward of the propulsion screws); reversible Parson’s turbines; double hulls; and a host of other technical innovations, which saved thousands of lives during the First and Second World Wars. Damage control training became routine in the world’s modern navies. During the surprise attack on Pearl Harbor in December 1941 junior officers standing watch on a quiet Sunday morning ordered watertight doors closed and initiated counter-flooding to prevent capsizing of a half dozen heavily damaged battleships and cruisers, saving thousands.

A most descriptive quote would be: **The terrible “ifs” tend to accumulate** - Winston Churchill, 1915