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MARINE DISASTERS AND MERCHANT SHIP DESIGN

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THIS ARTICLE will illustrate the real laboratory of the sea proving ship designs by testing them to the ultimate limit of their endurance. This limit we call marine disaster. Fire will be touched upon in the historical data to be presented, but it is considered outside the scope of this work. We will analyze the various actions and reactions which these disasters cause and try to assign them their true weights in the evolution of ship design. One specific example will be examined to see how, at this very time, these factors are affecting present and future ship design. We shall also attempt to project present trends into the future.

The need for safer ships seems to have been recognized from most ancient times. There was, however, little organized action toward safer ships or even recognition of what constituted a safe ship until 1760. In that year the first Lloyd's Register giving data as to tonnage, date built, materials used in construction, and name of master and owner was published. Lloyd's was the first of the classification societies which compile data to enable underwriters to better estimate the risk in insuring a vessel and her cargo.

By 1832 steam propulsion was becoming popular and so too were explosions of steam plants, for in that year 14% of the steamboats in operation were destroyed by explosions and fires. A direct result in the United States was the passage of a law in 1838 which created the Steamboat Inspection Service.

Though classification societies might examine and classify the ship herself and Steamboat Inspectors might check her boilers and hull, the owners were still free to burden her as carelessly and heavily as they saw fit. Naturally many ships foundered under test in the ocean's laboratory. England led the way in reform when Mr. Samuel Plimsoll secured the passage of the Load Line Act in 1870. This required the now familiar "Plimsoll Markings" to be painted on a ship's side to mark the intended draft.

In 1912 the "Unsinkable *Titanic*" struck an iceberg in the North Atlantic, opened six watertight compartments, and sank after several hours, with great loss of life. This was the disaster which brought reward to hopes and efforts for the first real international action toward safety at sea. The 1914 International Conference on Safety of Life at Sea, at London, was attended by thirteen nations. Agreements were reached in such things as subdivision, boats and lifesaving equipment, and the use of radio.

During World War I much more was learned of a ship's ability to withstand the forces of the sea, especially in damaged condition. This, coupled with a continuing chain of marine disasters and the prece-

dent of the 1914 Conference, helped bring about the 1929 International Conference at London. Eighteen nations attended and continued much on the same lines as had the 1914 Conference, but with special emphasis on watertight subdivision and the use of radio as a safety device. In 1930 an International Convention was held in London to standardize freeboard and load lines.

Unfortunately, due to the wording of the 1929 Conference and certain opposition at home, this country did not immediately ratify the Conference. In 1934 the *Morro Castle* caught fire and was beached on the New Jersey coast with considerable loss of life. This was followed in 1935 by the collision of the *Mohawk and Talisman*, which caused the *Mohawk* to sink in 70 minutes. These two disasters influenced Congress to hold hearings and investigations which produced the well known Senate Report No. 184 in 1937. This report was the result of much investigation and experimentation in all fields of safety at sea, and proposed standards generally far in advance of those used throughout the world. Many of these proposals were enacted into law despite the fact that, in 1936, the United States found that its existing laws were often less stringent than the standards of the 1929 Conference which it had just ratified as a result of committee recommendations and great foreign and domestic pressure.

During World War II a great deal more was learned in our ultimate laboratory, especially about the many merchantmen of welded construction which were being launched on rigid schedules. The high incidence of cracking at stress concentrations (technically called "notch sensitivity") caused the U S. Government to devote considerable study to the matter and to modify and abandon previous techniques of construction. Recognizing these advances in technology and the fact that marine disasters were still occurring when safer construction and navigation could prevent them, thirty nations met in London for the 1948 International Conference on Safety of Life at Sea. One definite innovation was a regulation requiring signatories to investigate their own major marine casualties and to submit reports to an Intergovernmental Marine Consultative Organization (IMCO), which was to meet every two years, starting in 1951, to recommend amendments to the regulations. As yet, not enough nations have ratified the Conference to allow IMCO to come into being.

From the standpoint of construction, the safety of ships may be divided into the following categories which we shall consider in turn:

The Freeboard of Ships
Subdivision of Ships
Strength of Ships
Reliability of Shipboard Machinery
Safety Equipment and Radio

THE FREEBOARD OF SHIPS

Though the Plimsoll Act of 1870 did not prevent the owner from changing the draft marking at will, it did indicate his practice which could be compared with the ever-influential Lloyd's recommendation that the freeboard be equal to at least ¼ the depth of the hold. Led by the classification societies and the British Board of Trade, there was, during the period up to 1930, a gradual decrease in the amount of freeboard thought necessary, but little special consideration for ships such as tankers or those deck-loaded with buoyant cargo such as timber. On the other hand, it had been American practice to load coastal tankers to 3″ of freeboard and trust to the buoyancy of their subdivision. In 1930 the International Load Line Convention generally reduced the freeboard for most types of ships and compromised British and American practice by giving a 500 foot tanker 15″ less freeboard than a similar cargo ship. In general, freeboard standards have changed little since then.

SUBDIVISION OF SHIPS

Subdivision will be considered here to also embrace stability, since the two factors are often intricately interrelated in marine disasters. In subdivision, it was again classification societies and British Law of the 1850's which led the way. At that time there were but four transverse watertight bulkheads recommended or required. These were what would now be called the forepeak and afterpeak bulkheads, to combat bow damage of collision and leakage from the shaft packing respectively, and two bulkheads to isolate the machinery spaces from the cargo spaces. Despite numerous investigations by government and private societies of disasters ranging from collision at sea to capsizing at the dock, there was little legislative action for many years. The classification societies began to write more exacting requirements on subdivision and stability in the last quarter of the 19th century; their aim was to make all ships "one compartment ships," that is, able to sustain flooding in any one compartment.

Another matter which was brought to attention at that time was the advisability of having longitudinal centerline bulkheads. It was found that these had often caused off-center flooding and capsizing. A trend then started to either eliminate these bulkheads or pierce them to allow transverse flow and symmetrical flooding. In 1912 the shock of the *Titanic* disaster moved around the world and propagated the 1914 International Conference. Many experts are of the opinion that, with a clamor from their people in their ears, the delegates rather overshot the mark in regard to subdivision. These subdivision rules were very strict on vessels carrying a great many passengers and though less stringent for cargo ships, required an overall increase in cost of ships of about 3 to 4 per cent. Although the greater part of the Conference rules were not fully put into law by most nations, they did have a great influence on classification societies and the British Board of Trade.

The 1929 International Conference was greatly influenced by World War I experience with merchant

ships. The effect of centerline watertight bulkheads was clearly shown by the fact that, of the ships not fitted with them which were lost during the war, none capsized before sinking. It was also felt that the previous Conference's rules as to subdivision and floodable length were burdensome and these were eased considerably with the more exacting being applied to vessels with greater numbers of passengers. The 1929 Conference also took a new step forward in stability by requiring that new passenger ships be inclined and the data given to the ship's officers. Civil cooperation was evidenced by action of the U. S. Shipping Board which furnished two ships which were actually flooded in tests to reevaluate permeability factors used in subdivision and stability calculations.

After the *Mohawk* and *Morro Castle* disasters, U. S. public opinion demanded investigation and action. The Senate appointed committee which brought out Report 184 had a membership which represented well the Maritime and Marine Engineering organizations. Again civil interest and cooperation were displayed in the Merchant Fleet Corporation's donation of a steel ship and $10,000 for actual experimentation in fire prevention and fighting. Report 184 recommended that all older ships be made at least one compartment ships and that all new ships be at least two compartment ships. It also recommended requirements to prevent change of trim, listing, or sinking to an unsafe condition or to a degree which might prevent the lowering of lifeboats. Though not all their proposals were enacted into law they still had considerable effect, for by that time the U. S. Merchant Marine was being highly subsidized to keep it in a competitive position and thus with federal aid in ship construction also went federal approval of the standards of construction. These standards usually parallelled first the 1929 Conference and later Report 184.

Once again, a World War supplied invaluable experience with merchant ships and showed the world that ships were not as safe as they might be. It also showed that the 1929 Conference rules on subdivision and stability had been generally sound. The 1948 International Conference made generally small extensions of the subdivision and stability requirements, but extended the requirement for inclining experiments on new ships to all those above 500 gross tons. By this time, the U. S. requirements had become so high that virtually no changes in our laws were required to comply with the 1948 Conference.

STRENGTH OF SHIPS

This part of the evolution of ships, more than others, truly did employ full scale experimentation in our extensive marine laboratory. Iron was first used as plating for wooden hulls and gradually replaced the wood until we had fully iron ships. Thus it was very natural that the early iron ships should be built on the same patterns as wooden ships which used transverse framing to support the longitudinal hull planking. Recognizing the iron's greater strength, the builders were quick to save material and weight by slimming the scantlings and increasing frame spacing for a new ship. If a new hull should fail the tests at sea due to weakness, the builder was forced to restore some of the metal saved to the next hull he designed. With an increase in size and number of tankers and bulk ore and grain carriers, a major strength problem arose, with many experimental failures in the form of marine disasters. Early in the 20th century, a new method of construction in the form of the patented Isherwood System was tried with marked success. This is basically longitudinal framing with transverses attached, all of which is directly joined to the shell plating. In this way, considerable improvement in longitudinal strength of ships is provided directly and also the strength of the shell and deck plating is utilized. This basic system has been so successful that it is still in wide use today, especially in tankers. The International Conferences and classification societies helped to standardize criteria for hull strength and spell out the lessons learned through marine disasters.

An increase in seaworthiness, mainly through increase of hull strength, can be seen by the steady decline in the annual percentage of vessels reported foundered, missing, or abandoned relative to the total tonnage owned in the world, excepting the years of the World Wars. In the period 1899-1903 it was 0.26 percent and has declined to 0.07 percent in the 1946-1948 period. It is interesting to note that figures for U. S. ships have been consistently below the world averages. One very notable reverse in our successes has been the World War II type ships, especially T-2 tankers, with welded hulls. After considerable study and experimentation, we relearned to "round our corners" to avoid stress concentrations and the value of first class workmanship in our yards to prevent localized stresses and cracks. Even after modification, the *Fort Mercer* and *Pendelton* broke in two in the winter of 1952, and the *World Concord* was lost in November 1954 due to lack of ultimate hull strength. To gain a more complete understanding of the forces and problems involved, some of the most modern methods of scientific testing and analysis are being employed.

RELIABILITY OF SHIPBOARD MACHINERY

As we have seen, the first real government inspections of ships were brought about because of unreliable steam plants when the Steamboat Inspection Service was founded in 1838. Certainly public opinion required some such action, but this is not the full substance of the matter. As the laws and classification society rules on steam plants and other machinery, especially steering gear, grew in size and detail a great many were pointed toward reliability as well as immediate safety. It is a fact, well recognized by seamen and marine engineers, that a ship

at sea without power or steering is in peril from the elements and other ships. The 1914 and 1929 International Conferences considered the matter of machinery reliability, but not in any great detail. In this country the boiler rules continued to expand but, until Public Act 40 of 1933 was passed, were so inflexible as to inhibit technical progress.

Investigations subsequent to the *Mohawk* and *Morro Castle* disasters showed that "pressure vessels" of all types were commonly failing by explosion because of weakening by corrosion, or faulty valves, regulators, etc. Combustible gas explosions were also far too common. Since these failures could, and often did leave the ship without power, they added to the dangers in a seafarer's life. These findings, and others such as the vibrational failure data from World War II merchant ships, made for more interest in machinery reliability in the 1948 Conference and a great many new and detailed rules in this country.

SAFETY EQUIPMENT AND RADIO

Prior to the 1912 *Titanic* disaster, very little had actually been done to develop any special types of safety equipment. Radio was carried aboard most large ships, especially passenger ships, but there was no coordinated plan for its use as a safety device. The 1914 Conference made its use mandatory and set up a basic system for its employment. That conference also recognized the fact that the *Titanic* had lifeboats for only a fraction of her passengers and that most of them were never put into use; it therefore attempted to improve lifeboat capacity, accessability, and launching. By 1929 the value of radio in sounding the alarm in the event of marine disaster was well recognized and its mandatory use was extended to smaller ships.

In the 1930's some general safety goals had come to be: (a) Lifeboats or rafts for all. (b) Davits and falls to be simple, rugged and able to swing boats clear with the ship listing to a reasonable angle. (c) Some sort of public address system, if necessary, to insure that passengers will be informed and can be instructed during times of distress. (d) Some type of alarm to arouse sleeping passengers. Through Senate Report 184, the 1948 Conference, and an occasional disaster to hasten the process, these goals have been largely met in the U. S. and much progress has been made internationally.

Aside from disasters resulting from negligent navigation, we find that the majority of today's ships having major casualties are those below 4,000 tons. Three-fourths of the casualties accrue to ships 100 to 300 feet long and the percentage of casualties to ships less than 200 feet is actually increasing. Thus it would seem that, though ships have been getting larger and thus able to sustain greater damage and incorporate more safety in their design, we may be neglecting the smaller ships and their particular problems.

To gain a feeling of the relative safety of ships, consider some figures from the British Ministry of Transport for the nine years prior to 1948. These are the yearly averages of lives lost in ship casualties and in miscellaneous injuries on board ships:

	Crew	*Passengers*
Ship Casualties	177	13
Miscellaneous Injuries ...	269	29

These figures might make us wonder if perhaps there is a greater need for better handrails than for bigger reserve buoyancy in present ships.

It is also significant to note that while marine disasters usually trigger action toward safety, they are not always the sole objects of the investigations which follow. In more recent times there has been a pronounced trend to go to specific experimentation and study of theories of shipbuilding when a marine disaster has brought a deficiency to light.

Next we consider the 25 July 1956 collision of the Italian *Andrea Doria* and the Swedish *Stockholm*, to illustrate how a marine disaster is presently influencing ship design. At the time of the collision, the ships were in international waters. This puts the matter in the hands of the respective home governments, Were IMCO functioning, they would be required to submit their reports for international analysis, but neither government has yet released the results of its investigation, nor has either Sweden or Italy ratified the establishment of IMCO.

To gain more information, the House of Representatives Committee on Merchant Marine and Fisheries appointed a four man staff of technical advisers to investigate the matter from the standpoint of safety at sea. This staff, headed by Vice Admiral E. L. Cochrane, USN (Ret.), former Chief of the Bureau of Ships, reported in December 1956. The *Andrea Doria*, which had been designed to comply with the 1948 Conference, was a two compartment ship by a very narrow margin. This ship, with 697 feet length and 90 feet beam, was required to be able to withstand damage extending 29 feet fore and aft and to a depth into the ship of 18 feet. It is stated in her builder's "stability report" that the ship could meet the stability requirements of the 1948 Conference provided she was kept ballasted with substantial and specified quantities of liquids. Apparently, if the damage encountered exceeded that allowed for by the Conference rules, it was only in moderate degree. Even if we assume that all her deep tanks in way of the collision on the starboard side were initially empty but flooded immediately, this would not account for the immediate list reported as 18°. It appears that the stability at the time of collision was perhaps only one-third of the amount indicated in the "stability report." This staff report raised a number of questions in regard to the adequacy of existing standards and the methods of enforcing them.

The report was sent to various concerned agencies of our government for their study, and Department

of State, Coast Guard, Maritime Administration, Hydrographic Office, and Federal Communications Commission representatives reported on progress of their studies in July 1957 and January 1958. In October 1957, the Coast Guard assembled a "Committee to Evaluate Certain Safety Standards for Vessels." This committee is not confining itself to the *Andrea Doria* disaster but is considering marine safety in a broader sense. It is headed by Admiral Cochrane and consists of thirty leading U.S. technical experts. The results of their studies and reports are to be incorporated into proposals to be submitted to an anticipated International Conference. Many members of this committee feel that far more than enough time has passed since the collision for public sentiment to die down and that the Conference should be held without delay. Our State Department has taken steps to initiate the Conference. The British propose one during 1960, and as traditional hosts will probably prevail.

We now venture to project forces and trends into the future. Public alarm over the *Andrea Doria* sinking has virtually ceased to exist and will play little part in a future International Conference. Regardless of the outcome internationally, U. S. regulations and enforcement practices will be stiffened as a result of the studies now underway. This will mean that the disparity between U. S. building and operating costs and those of our competitors in maritime transport will increase and require additional government subsidies to make up the differential. It is also probable that action will be taken in this country to check the increase of casualties to ships less than 200 feet. Barring war, there will be another International Conference within five years, but not before 1960. It is hard to foreseee any great changes in construction coming out of such a Conference, since they would almost certainly require increased building and operating costs. It is almost a certainty, however, that the subject of nuclear powered ships will be discussed and at least some small steps taken to see to the safety of their construction.

In an intensive study to develop methods of using very thin steel sheets in aircraft structural applications, the Ryan Aeronautical Company has developed a method of using miniature corrugations to stiffen sheets as low as 0.001 inches in thickness. Welded to a thin skin sheet, the resultant panel compares very favorably in specific strength with titanium, aluminum and magnesium, and is superior to these materials in high temperature performance. The smallest corrugation, designed for very thin sheets, has a repeating section of less than one-sixth inches, and about one-twelfth of an inch in thickness. A light weight jet tail pipe has been made of type 321 steel sheet 0.002 inches thick, welded to a corrugation of the same material. It is 12 feet long, 14 inches in diameter and weighs 14.7 pounds.

—from Industrial Laboratories, March 1958

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SECRETARY'S NOTES

Council Changes

Since publication of the last issue of the JOURNAL, we have experienced a more than 25 per cent change in the membership of The Council. At a meeting of the Council on 10 July 1958, losses were considered and action was taken as follows:

Incident to transfer from the Bureau of Ships to the Puget Sound Naval Shipyard as Commander, Rear Admiral P. W. Snyder, U.S.N., resigned from the Council. The Council moved Captain Jamie Adair, U.S.N., whose term expired on 31 December 1958 to fill Admiral Snyder's vacancy which expires on 31 December 1959.

The vacancy created by this action was filled by the appointment of Captain James A. Brown, U.S.N., to the Council.

Captain R. D. Schmidtman, U.S.C.G., was detached from Coast Guard Headquarters to Command the icebreaker *Eastwind*. The Council appointed Rear Admiral E. H. Thiele, U.S.C.G., to fill the vacancy resulting from Captain Schmidtman's resignation.

Captain Louis H. Roddis, U.S.N.R., who has been in Washington with the Atomic Energy Commission has resigned from that position to become President of The Pennsylvania Electric Co. of Johnstone, Pa. Since this removes him from Washington, he resigned from the Council and Lieutenant Commander Donald E. Redmon, U.S.N.R., was appointed to fill this vacancy.