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ment should see to it that the new Chief is such a man, chosen from the only organization whose members are fitted by training and association to carry on the work and to whom the Department is under a very practical, as well as a moral, obligation.

Only by such an appointment can the Department do justice to itself, to the Navy and to the country at large.

The Strength of Large Ships

IN a recent editorial in these columns it was suggested that the structural damage occasionally sustained by very large vessels as the result of being driven into heavy seas might be attributed to the relatively lighter scantlings of these ships as compared with smaller ones as well as to the possibility of a sudden combination and concentration of the rather obscure stresses arising from violent rolling and pitching.

Elsewhere in this issue there is given a description of structural damage sustained last year by the *Majestic* and it is interesting as well as most assuring to note that in this particular instance, at least, there is no evidence whatever of general structural weakness or any indication of extreme and unusual combination of stress.

On the other hand, it seems clear that the designers of the ship, after having carefully determined the scantlings of the principal strength members, did not exercise an equal amount of care in seeing to it that the detail design of these members was worked out in such a way as to ensure the best possible distribution of material and continuity of strength.

While the plans indicate clearly a line of relative structural weakness at the point where the damage took place, it appears that the determining factors in producing fracture were the square and apparently unreenforced corners of the uptake openings and neighboring ventilating trunk, and not an overstressing of the original structure as a whole.

It is a cardinal principle of machine design, and should also be of ship design, to avoid sharp corners and sudden variations of effective area in all strength members. In a ship, as well as in a casting, a corner may start a crack which becomes progressive and continues to extend until the stress resisting area of material falls below the point of safety and rupture eventually takes place.

Apparently this is just what occurred on the *Majestic*, and while the damage was serious insofar as the interruption of the ship's schedule and the considerable cost involved in repairing it were concerned, it is a satisfaction to feel the assurance that there was nothing inherently wrong with the structure of the vessel as a whole, and that repairs of a relatively simple character have amply insured against the possibility of a recurrence of the trouble.

The *Majestic* has now been back in active service for a considerable period and there is no doubt but that the thorough manner in which the repairs were carried out has made her stronger than ever before. The experience with her is, however, of the greatest importance and value as giving a practical and illuminating demonstration of the necessity of the utmost care in the design of important structural details. Particularly is this true when changes are under consideration for existing vessels. The writer has in mind the case of a large and heavily built cargo steamer which came under his personal observation. This vessel, as originally designed, was of ample strength, but in altering her to a transport, early in the war, certain damage was done to the hull structure, which, while it did not actually cause trouble, would almost inevitably have done so had the ship been forced into a heavy sea when deeply loaded.

What was done to the structure of this vessel in carrying out alterations of quarters seems worthy of description. Two large ventilating openings (about 42 inches in diameter) were cut close to each after corner of No. 3 hatch, just forward of amidships, practically entirely destroying the effectiveness of the hatch corner doublings. As if this were not enough, a booby hatch was cut athwartships directly abreast of these ventilators, extending outboard into the deck stringer plate for nearly one-half its width and completely severing the strake of plating immediately inboard of the stringer, the effective longitudinal strength of the deck being altogether reduced by nearly 50 percent. Such treatment appears to a naval architect as quite unthinkable but it was actually carried out and necessitated the expenditure of a considerable amount of money in repairs when the ship was returned to private operation after the war was over.

There is much concerning the strength of ships which is not positively known and conclusions can be arrived at only by comparison. Such cases as are here mentioned do not belong in that category. Their effective and satisfactory handling is thoroughly understood and there appears to be little or no excuse for defects of like character ever being allowed to exist, particularly in the design of a new vessel.

Marine Power Plants

IT is a rather curious fact that while, up to a comparatively recent date, many, if not most, of the developments in steam engineering tending to increased economy have originated or at least been first put to practical use by marine engineers; during the past decade the shore steam plant has far outdistanced its seagoing counterpart in fuel economy.

The modern power plant engineer regards the average marine propelling equipment as hopelessly antiquated and inefficient, and is at a loss to understand the hesitancy shown by his marine brother in not more generally adopting the methods which have brought about the present high efficiency of stationary steam power equipment.

The cause of the apparent lack of progressiveness in marine engineering is, however, not far to seek and from the point of view of the ship operator is entirely reasonable. The whole training of the marine engineer, particularly one who has had extended seagoing experience, tends to conservatism—and rightly. The very first essential in a seagoing ship as regards hull, machinery or equipment is reliability. However desirable economy may be, and no one will deny its importance, it is outranked in the scale of essential characteristics which a commercially successful ship must possess by reliability and the certainty of continued and uninterrupted operation over long periods and under varying and trying conditions. Economy which is obtained

Structural Damage Sustained by S. S. Majestic

Failure of deck plating indicates importance of careful design and arrangement of strength members of hull structure

By Edward Ellsberg*

IT is an unfortunate truth that no shipowners will publish the facts concerning structural failures of their vessels. As a consequence, the naval architect is usually enabled to learn little or nothing from the defects found in operation on ships other than those belonging to his own company. A few rumors get about, conjectures are made (usually erroneous) but the actual facts ordinarily remain a secret and the designer can only guess at the faults.

A shining example of this nature was the accident to the *Majestic* last winter. This vessel was so damaged as to necessitate her withdrawal from service from late December until nearly May for repair. Her condition was extensively commented on in the British press at the time and her cancelled passages were briefly noted in the American papers. What caused the damage, the extent of the trouble and the adequacy of the means taken to remedy it were not made public. It was noted that even in the British shipbuilding press there was considerable criticism of this policy.

A knowledge of the facts in the case will lead to the conclusion that the damage, instead of being the result of general structural weakness or of any unusual strains peculiar to large ships, was due only to a local strain arising from a detail error in design which was in no way connected with the size of the ship.

What Happened to the Majestic

Chronologically, the following was the sequence of events:

During the summer of 1924, it was discovered that the *C* deck of the *Majestic* was fractured at the midship section in way of the inboard lobby. The *C* deck is the strength deck of the vessel, forming the top flange of the ship girder. This deck at the sides is formed of two courses of plating, which doubling is carried inboard on each side for several strakes, but these doubled stringers are pierced both port and starboard by the uptakes which on this vessel come through near the sides instead of on the centerline as in the ordinary ship. Just inboard of these uptake openings the deck is still further cut away by an elevator shaft on each side. This construction results in leaving only about 25 percent of the beam of the ship intact inboard of the elevators and uptakes. However, this inboard section of the deck was not intended to take any strain, and was made only ⅝ inch thick as compared with the deck stringer plating which is about 2 inches thick at the side and about 1½ inches thick in the strakes next inboard.

It was the section of ⅝-inch plating between the elevators which was first discovered to have parted. The failure in this location was verified by taking down the ceiling underneath. At the time, little importance was attached officially to the fracture. As the light plating here was not the strength plating, the vessel was not considered weakened and, as it was then in the midst of the tourist rush, nothing was done to remedy the damage. It was apparently intended to defer repairs to some slacker period in the future. However, a little reflection, and a further investigation at this time as to how a light strake could ever get sufficient strain to let go when there were outboard of it heavy strakes intended to take all the strain, would have proved both illuminating and profitable.

There can be no doubt that such an investigation would have shown the deck stringers on both sides already fractured through a considerable portion of their width, so that the strains in working had been partly thrown on the light strakes inboard, with the consequences noted. But the *C* deck at the sides was a weather deck covered with wood planking; underneath, the stateroom ceilings sheathed it. If anyone connected with the ship had any doubts, they were not strong enough to cause the laying open to inspection of the deck stringers, and no examination of them was made.

Matters continued in this status until the westbound trip in December. Very rough weather was the rule on this trip. While still over a day out from New York, a loud report, likened by many to "a cannon shot," was heard. An investigation showed that the *C* deck had now cracked open all the way from the starboard to the port side, and that the port sheer strake had also let go, the crack in it extending down the side to the top of a circular porthole, where the crack stopped. The starboard sheer strake held.

The *Majestic* made her way to New York, and sailed as per schedule on her return voyage to Southampton. The crack in the *C* deck on the port side opened as the vessel worked, about ½ inch, but the damage did not extend further. On this eastbound trip the weather was apparently not bad. On arrival at Southampton, all future trips were cancelled, and the ship laid up for an indefinite period for repairs by Harland and Wolff.

Structural Conditions of the Deck Revealed

The wood decking was removed from the *C* deck and the staterooms underneath torn out. Structural conditions of the deck were revealed as follows:

At the forward outboard corner of each uptake hatch, the plating of the deck was cut out on a right angle. There was no compensation fitted around the corners of the opening. Just outboard of the uptake corner, and about 8 inches from it, another rectangular hole about 12 inches by 20 inches was cut through the deck stringer for a ventilator trunk. Just outboard of this ventilator was a butt in the adjoining strake of the deck plating, with its consequent close rivet spacing. About 18 inches forward of the uptake was an expansion joint in the superstructure, which commenced just above the *C* deck. Underneath the *C* deck, and in line with the edge of the uptake, was a girder which ended with a small bracketed connection to the uptake plating. Inboard of the uptake openings were the elevator shafts as already pointed out.

All the above factors produced a most obvious line of weakness, which happened to come right on the midship section. In addition, failure to compensate the heavy deck for the openings cut in it, especially at the forward outboard corners, resulted in concentrating at these sharp corners all the strain carried from forward by a much wider strake of heavy plating.

Due to this local strain, it is evident that the cracking first started at the square corners. From this point, the cracks ran outboard a short distance into the ventilator hole. From here the cracks continued outboard, along the line of closely spaced rivets in the buttstrap, to the 2-inch deck stringer, through which they ran to the sheer strakes and

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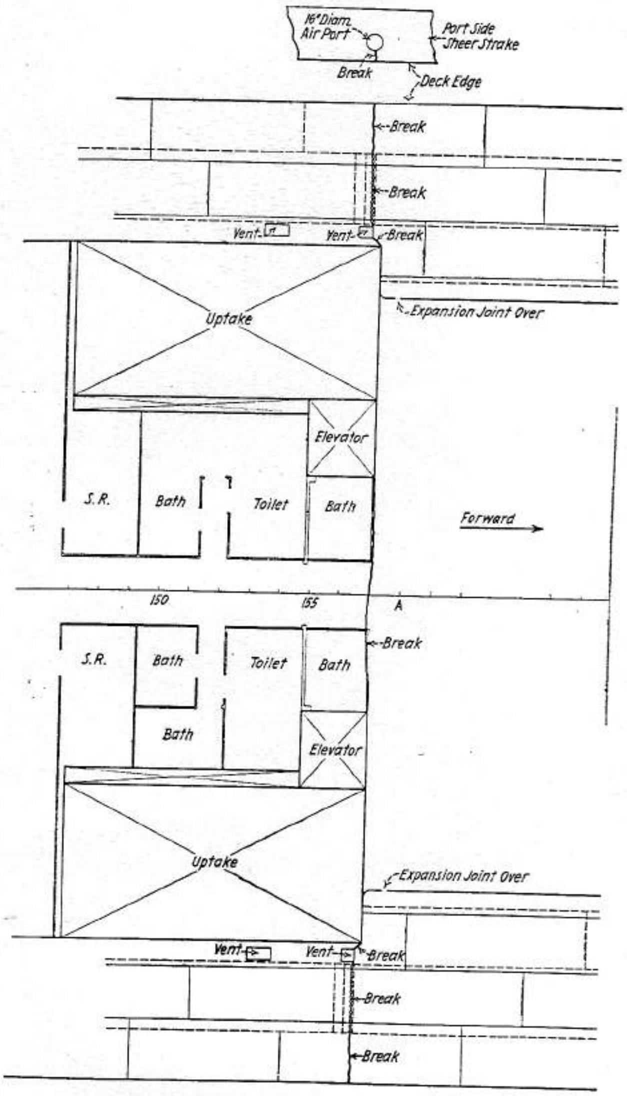
down the port sheer strake at its weakest section into a porthole.

Fracture Gradually Extended Along Weakest Section

It will be seen that in this case, the damage followed the weakest section. Considering the structure and the nature of the fracture, it is clear that the fracture was progressive. From the port and starboard uptake corners the cracks



Plan of section of C deck, showing location of break

worked their way outboard rivet by rivet until enough of the deck was gone on both sides to make the light inboard plating take part of the strain. This light plating then let go, which damage was soon discovered, as in this location there is a central passage over this spot and the interior deck covering would crack with the deck. This was the condition in the summer of 1924.

The progressive rupture of the *C* deck continued through the fall, and when in December the vessel was finally exposed to heavy weather, there was so little of the top flange left that, under a real strain, the remaining metal let go with a bang. It is safe to assume that at this instant the vessel was rolled to the starboard side, so that the port sheer strake was also acting as part of the top flange and consequently was partly torn through when the deck parted.

There have been numerous instances previously in ships, buildings and machines where cracks have started in structures that were adequately strong generally but where a local stress was excessive due to an error in detail design. A crack once started is bound to extend itself, especially in a structure subjected to alternating stresses, regardless of the strength of the section through which it is working. Recognizing this, the designer usually tries to prevent the start by making all points subject to excessive local strain considerably stronger than the remainder of the structure, and by making all changes in shape take place gradually. To these ends, the machine designer fillets his corners and thickens up his shoulders; the ship designer endeavors to avoid sharp corners and compensates all openings by thickening up his plating. Both Lloyds and the American Bureau rules require compensating plates around openings cut in strength members.

Just why the German designer of the *Majestic* failed to compensate his strength deck when he cut out an oblong section of it on each side with the uptakes is not known. It can only be assumed that the stresses were so low in the sections of the deck stringers left that the chance of local concentrations of stress at the corners was overlooked.

How Repairs Were Made

In repairing the damage, care was taken to insure its nonrecurrence. All fractured plates were of course replaced. The initial error was corrected by making the new plating around the uptake corners half an inch thicker than the adjacent deck plating. In addition, the ventilator opening near the corner was eliminated, the buttstrap outboard of the corner was moved several frames away and the girder underneath the deck was more securely fastened to the uptake bulkhead. The effect of all this was to eliminate the line of relative weakness and to reinforce the corner against local strain. Finally, in renewing the fractured deck plate inboard between the elevator shafts, the thickness was increased from ⅝ inch by laying a new doubling, several hundred feet long, over this section. This, however, appears a useless precaution. As there are no inboard longitudinal bulkheads to connect this plating to, it can never take a strain until the outboard sections of the deck, which, due to their connections to the shell, act as the flanges, give way. As means to prevent such a mishap to the outboard plating have been provided, the strengthening of the deck inboard was unnecessary, resulting only in needless expense and addition of weight.

As this structural failure on the *Majestic* was not one peculiar to large ships, it is hoped that a knowledge of the trouble in this instance will prove useful to naval architects in the future, in designing anything from yachts to liners.

Survey of Tank Ships.—A recent survey of the tank ships engaged in, or available for, handling the world trade in petroleum and other oils, and molasses, made by the Bureau of Research, United States Shipping Board, indicates that on June 1, 1925, the United States ranked first in ownership of this class of vessels, with 45 percent of the gross tonnage and 39 percent of the total ships. Great Britain was a close second, however, with 36 percent of the gross tonnage and 38 percent of the ships. The next countries in point of ownership were Holland and Norway with about 4 percent each of the total number of tankers, followed by France and Italy with 3 percent each, while Argentine, Germany and Japan each own approximately 1 percent of these ships. Ownership of the remaining 6 percent of the tank ships was participated in by sixteen other countries. In all there are 1,039 tankers in the world with a gross tonnage of 5,578,036.