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Observation of Ship Damage over the Past Quarter Century

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ABSTRACT

This paper treats with ship damages taken from surveys of the United States Salvage Association, Inc., over the past quarter century, on vessels of all flags.

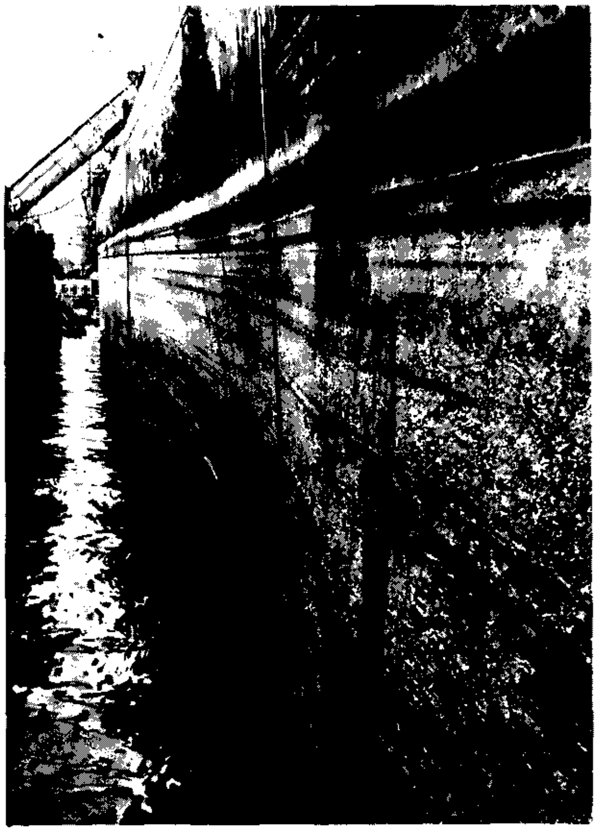
Insofar as U. S. flag vessels are concerned, the period involves the mid-life and concluding years of operation of preponderant numbers of the well-known World War II standardized design vessels. Certain of these types showed some common inadequacies; others showed propensities fortunately peculiar to themselves.

In the early 1950's the supertankers of 28-30,000 tons deadweight came into being, as did the "Mariner" class of dry cargo carriers; subsequently, in the early 1960's, many of the U. S. subsidized operators commenced laying up the World War II types, and filled out their fleets with vessels specially designed for their specific trades, with multiple units being constructed from the same design. Certain of these vessels suffered some of the weaknesses peculiar to the World War II designs.

No sooner had the specialized dry cargo vessels been put together than the container revolution came upon us, which created considerable conversion in existing ships and thinking. Also, the huge tanker revolution commenced after the mid-1950's.

With all of the changes, how much relay of operating experience was transferred from one growth pattern to the next concerning the faults of the various types? What has been the contribution of research and technology?

This paper sets forth and treats with, and in certain instances illustrates, specific inadequacies; it includes observations on what has appeared to have been inadequate communications in the past among the disciplines involved, makes reference to today's circumstances, and makes some suggestions for the future relating to technology.



.. the sea rose up and smote the ship ..

CASUALTIES OF U. S. FLAG WORLD WAR II BUILT VESSELS

The United States merchant marine following World War II was comprised of large numbers of a relatively small number of types of vessels, mostly built during the war, in the general cargo and tank-ship categories.

From this circumstance common disorders were easily ascertainable, and very definitely oft-repeated failures showed patterns not only for each type but across the board for all types in similar trades, i.e., all general cargo ships, or all tankers.

The types treated herein embrace the C1, C2, C3, C4, Liberty, Victory, and T2 Tanker. Certain of these types were designed prior to the U. S. entry into World War II, and were a part of the general rebuilding of the U. S. merchant marine beginning in 1936.

Some of the problems peculiar to the vessels considered here, and the necessary repairs and/or corrective steps taken (where applicable to preclude repetitive failure), are presented in the following, which by no means should be considered to be a complete summary.

Failure of Longitudinal Strength Members

A common disorder was fracturing of structural members contributing to

Fig. 1. Attempts by the crew to prevent complete hull fracture

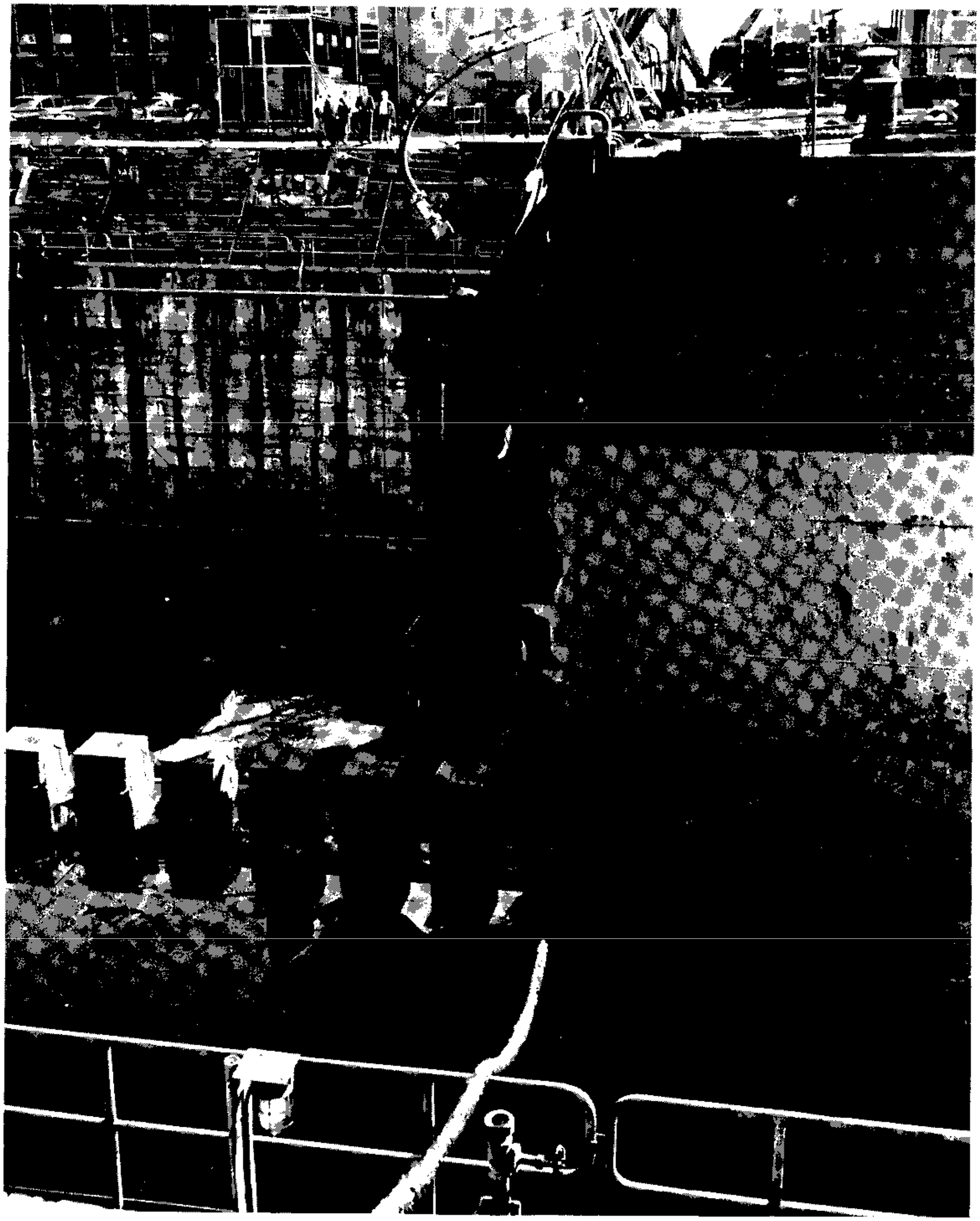


Fig. 2. A complete longitudinal failure of a "T2" tanker.

longitudinal strength due to structural arrangement which caused local areas of high stress.

Figure 1 shows emergency measures taken by the crew of a "C3" type vessel to prevent complete girth propagation of a shell fracture, and Figure 2 shows the complete failure of a "T2" tanker.

Structural arrangements such as square hatch cutouts in deck plating were eliminated by inserting radial shaped plates in the hatch corners (1). Doublers were installed in way of square house corners. Discontinuities in longitudinal members, such as resulted from the cutout for the accommodation ladder in the bulwarks of the "Liberty" type, were eliminated.

"Crack arrestor" straps were installed on deck, gunwale, side shell, bilge shell, bottom shell, etc., to preclude complete girth propagation of fractures in deck and shell.

Probably more than any other type of damage the fracturing of structure contributing to longitudinal strength influenced the formation of the working groups, panels, and committees of the interagency Ship Structure Committee, and the SNAME Hull Structure Committee. Doubtless the theatrical impact of the types of failures involved, particularly where complete failure of the hull girder occurred, often with loss of life, had much to do with the emphasis placed on seeking solutions to the problems, which, fortunately, were found. Pertinent are (1) through (6) which are but a few of the pursuits stemming from individual efforts under the auspices of SNAME, classification societies, etc., and in addition to which must be added the staggering quantity of reports under the auspices of the Ship Structure Committee on works of unique quality relating to establishment of longitudinal and transverse forces, fast fracture arrest, computer programs, full scale measurement programs, thermoelastic model studies, temperature influence studies, etc. References (7) and (8) provide indices which include such works embracing 1946 to 1969.

Relating to compressive stresses in the bottom shell, and restricted to the transversely framed vessels, was the upward buckling of the bottom shell between transverse floors, largely within the midships half length, the phenomenon commonly called "hinging", which was a direct result of hogging bending moments. (In (1) the phenomenon is treated with respect to the "Liberty" type.)

The bottom shell in way of the "hinging" experienced a significant thinning in way of the unsupported span nominally midway between the transverse floors, as contrasted with the thickness of the shell immediately adjacent to the floors. (Invariably this factor was not taken into consideration in presenting records of audigaugings or drillings to establish bottom shell thicknesses.) Figure 3 illustrates the "hinging" phenomenon.

Fig. 3. Typical hinging damage

The bottom shell plating required renewal in the worst affected areas, and often the new plating showed the typical upward indentation between floors, without significant thinning, after only a short period in service, perhaps because of the loss of resistance to compression from the neighboring plates which showed some hinging, but not considered sufficient to require renewal when the new plating was installed.

In a few instances intercostal longitudinal flat bar or inverted angle stringers were installed between transverse floors, breaking by perhaps one-third the transverse span between existing longitudinal girders, in an effort to put a stop to the phenomenon. The longitudinal stiffeners intercostal to the floors were of two varieties: one had ends fixed to the floors, the other was cut short of the floors, being wholly supported by the shell immediately adjacent to the floors. In a few rare instances the bottom of the intercostal members was scribed and cut to fit the upset of the affected plates.

It is noteworthy that as might be expected longitudinally framed vessels, such as tankers, did not suffer the sickness.

If a system of transverse framing is to be utilized in the bottom of a vessel it is obvious that the number of longitudinals, and/or the thickness of the bottom shell, within the midships half length, must be given more consideration than was the case with the World War II types.

It is also rather obvious that longitudinal framing in the bottom and deck of a vessel (with transverse framing for the sides to reduce docking damage) is a more efficient structural arrangement than complete transverse framing.

Slamming Damage

All the general cargo types except the "Liberty" type suffered indentation of forward bottom shell and buckling of internals, and in some cases secondary damage to kingposts, piping, machinery, etc., from slamming. Figure 4 illustrates typical slamming damage to forward bottom shell plating.

Fig. 4. Slamming Damage

Little structural addition was made to reduce the frequency of this type of damage.

In one instance of damage, to a "C2" type vessel, high strength steel was used to replace damaged shell plating on one side and the keel plating, while ordinary mild steel was utilized to replace damaged shell plating on the opposite side. After one year's operation the high strength steel was unaffected while the mild steel plating showed severe damage; however, the area of the vessel in way of the slamming damage was bodily set up 1¼" above the base line. No repairs were made then, but a year later, after two years operation subsequent to the installation of the high strength steel, again no damage was found to the high strength steel plating, but the damage to the mild steel plating had been aggravated, and the bodily set-up had increased to 2¼" above the base line.

For reasons unknown to the author this striking experiment was not made known to the technical fraternity, which is unfortunate, for some extremely interesting aspects were a part and a result of the pursuit, not the least of which was proof that to prevent indentation of shell plating from the influence of slamming either the unsupported span should be reduced, or high strength shell plating can be utilized with the existing spans, keeping in mind that the internals failed when the high strength steel plating was used for the bottom shell with original internal spacing.

As a matter of interest the records of the United States Salvage Association show practically no slamming damage on the "Liberty" type (often forward-located hinging damage was confused with slamming damage on the type).

Additionally, tankers, including the "T2" type, did not suffer from slamming damage, doubtless due to the fact that tankers can be ballasted down.

An indication of the frequency, the location, and the cost of repairs of slamming damage for the vessel types afflicted is covered in (9). The damage invariably affected the keel strake, and strakes A, B, C, and sometimes D, the damage by no means being limited to the flat of the bottom. Local indentations as much as 4" were observed. Damage to internals usually was not too severe, and where same occurred it generally related to buckling of the lower part of the transverse floors and the center vertical keel. Figure 5 illustrates the internals of the vessel with the shell damage shown in Figure 4.

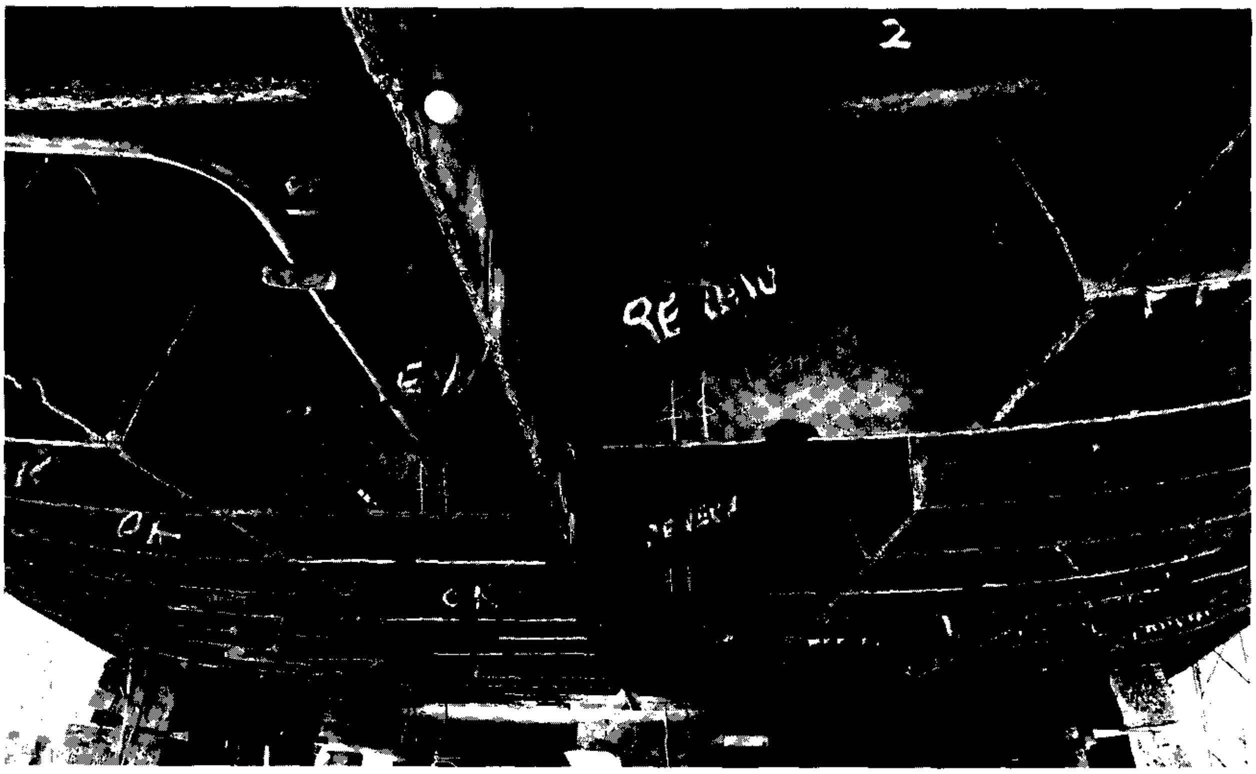


Fig. 5. Slamming damage (same ship as Fig. 4) showing minimal damage to internals

SNAME's Slamming Panel was formed in the latter 1950's, and under its auspices (10) was produced, in which a series of hull forms was presented as hopefully representative of forms which would develop relatively low slamming impact pressures, this being achieved with the one fullness so far investigated (11).

In (12) there are presented values to predict slamming impact forces for various vessel forebody transverse section shapes.

References (13), (14), and (15) are significant contributions of the Ship Structure Committee to the pursuit of the subject of slamming.

A currently proposed pursuit under Ship Structure Committee auspices is directed to the development of instruments to measure, simultaneously, impact and relative velocity of ship and wave. The program is aimed at correlating forward bottom and bow flare impact pressures measured on ship and model, and is fundamental to a better understanding of the problems.

Tanker Internal Structural Fractures

The fracturing of the internal structural members of tankers was common. Such structure rapidly reveals configurations and arrangements which lead to fractures since corrosive attack is so standard in the trade. Corrosion is accelerated in areas of high stress, and such "hard spots" were common in many of the internal structural arrangements of World War II vintage tankers. Hard spots were found in web frames, brackets joining transverse bulkheads to longitudinal structure, connections between transverse bulkheads and longitudinal bulkheads, shell longitudinal stiffener penetrations through transverse bulkheads, tripping brackets, etc.

Fluted transverse and longitudinal bulkheads showed a consistent propensity to fracture in way of where the metal had been originally stressed beyond the elastic limit to form the corrugations. The circumstance became particularly evident where advanced corrosion obtained.

Figures 6 and 7 present the structural arrangement of the "T2" tanker. The fluted bulkheads and hard cornered configurations will be noted.

Short of completely replacing the bulk of the internal arrangement which led to fractures, the owners followed the only course open to them, which was to chip out and weld the fractures (often also installing doublers in way), or to replace affected material with sound metal. Access staging costs were always a significant part of the repair costs.

In efforts to minimize recurrence of fractures, where structure of similar disposition and arrangement was reinstalled, replacing failed structure, some owners specially coated the structural internals in an attempt to prevent thinning; however, except in a few isolated cases the internal coating of tankers did not really catch on until the new middlebodies were fitted to World War II tankers.

By the time the "Jumboizing" craze hit the U. S. merchant marine enough had been learned, and fortunately passed on to most of the design fraternity, to incorporate structural arrangements other than those which had led to failures in the first place. One has only to look at current practice in the design and construction of transverse and longitudinal bulkhead arrangement, web frame arrangement, the methods of easement where flanges and bulkheads make up to associated structure, etc., and compare it with the standard World War II tanker structural arrangement, to achieve an understanding of the reasons why fractures were so commonplace in World War II tanker tonnage. See (16), (17), and (18).

Figure 8 shows the marked change in structural arrangement for a "Jumbo" "T2" from original "T2" arrangement.

Tanker internal fractures are still with us, but not at the rate of the 1940's and 1950's.

Side Shell Damage

Side shell damage, consisting of the setting in of shell plating and/or internals, afflicted all types, primarily from docking and from collision with lighters alongside. Little or nothing was done to design or rebuild against it. Structure was replaced as before. In many cases the damage was in way of refrigerated spaces and required most costly removals and replacements to perform the repairs.

Figures 9 and 10 are representative of typical side shell docking/undocking damage.

Damage to Castings

Castings, employed on all of the types, presented an unpredictable service performance. This pronouncement stems from observation of the use of steel castings in service for stern frames, shaft bossings and sleeves,

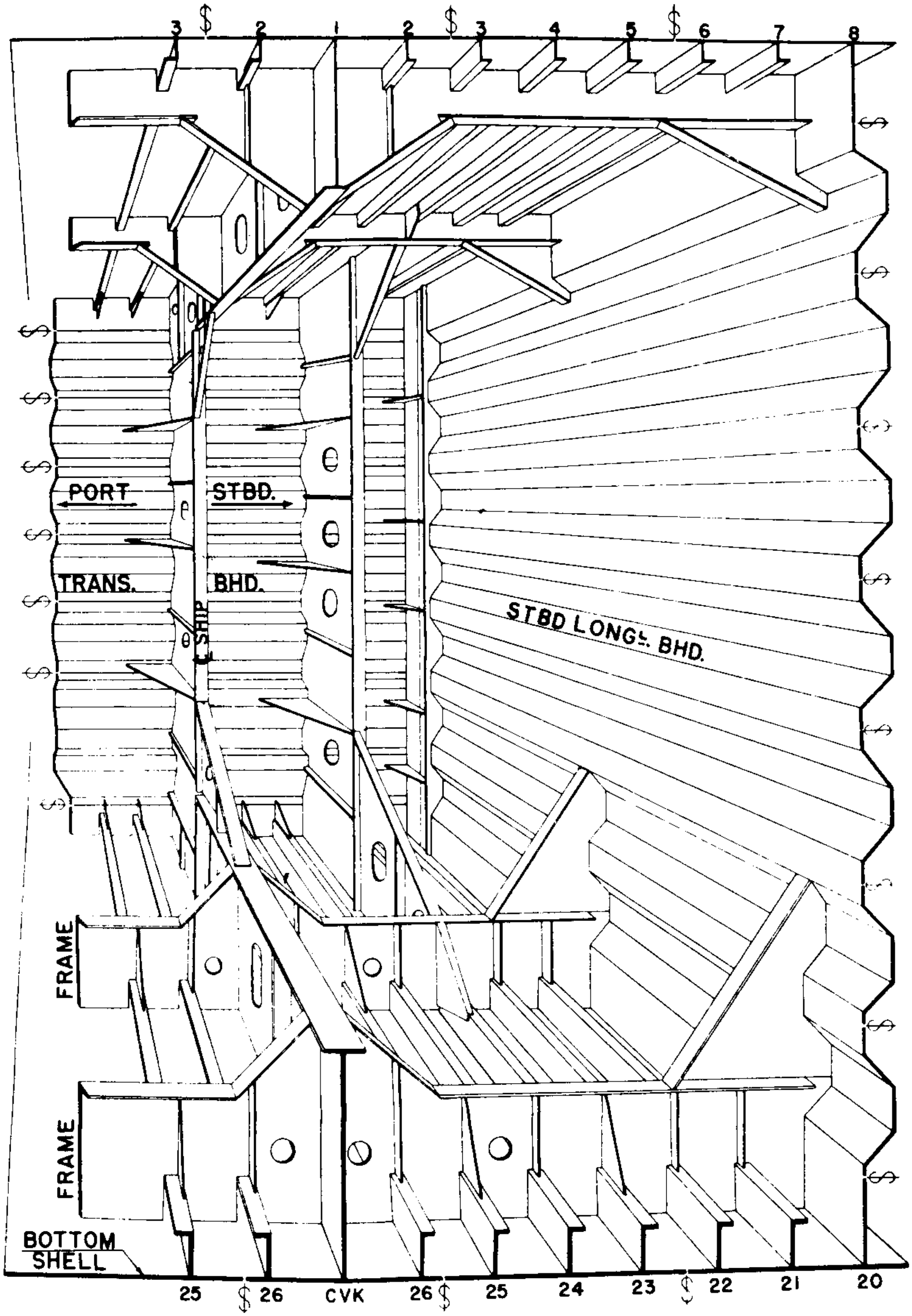


Fig. 6. "T2" structure (center tank)

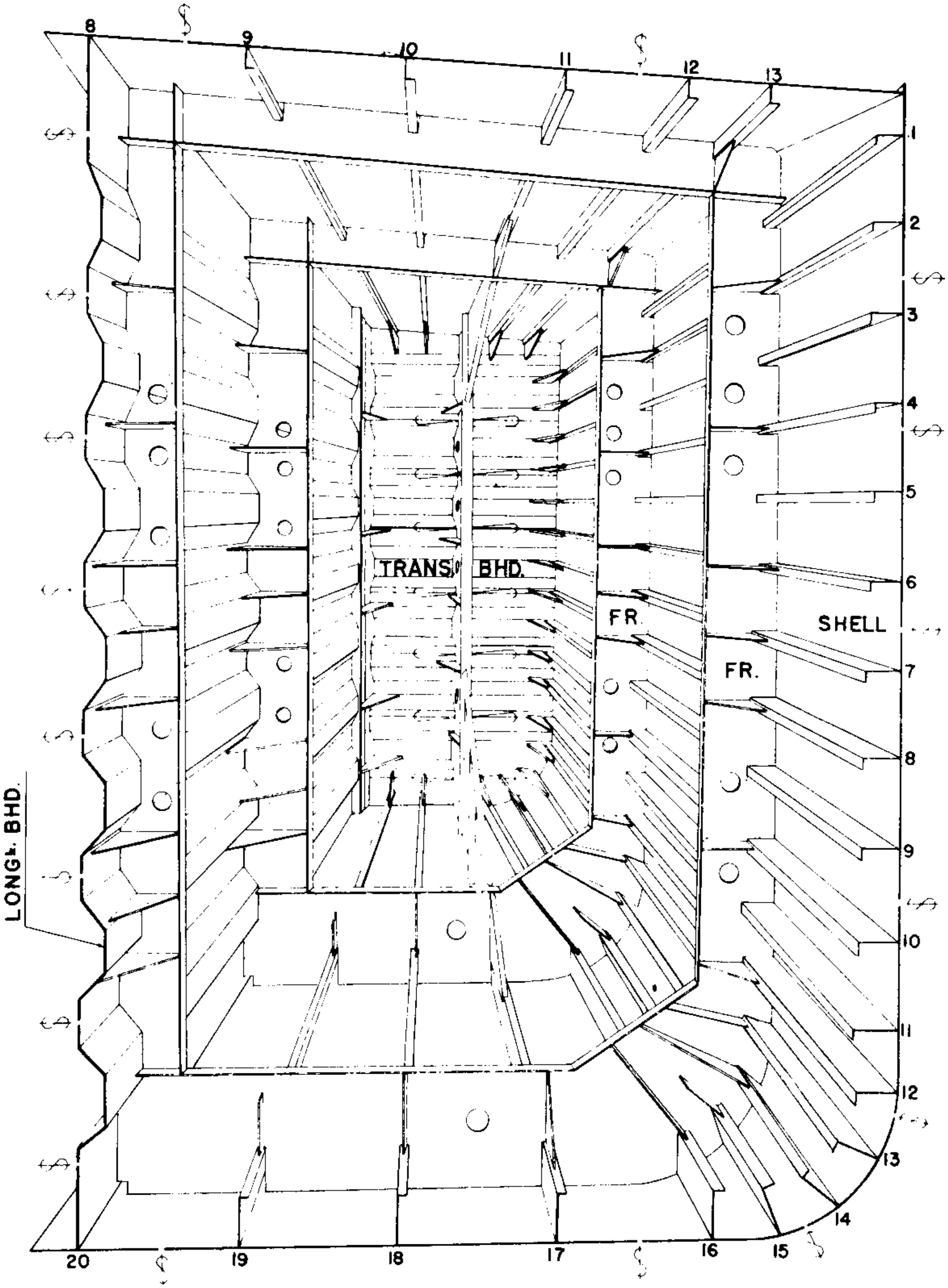


Fig. 7. "T2" structure (wing tank; web tie beams not shown)

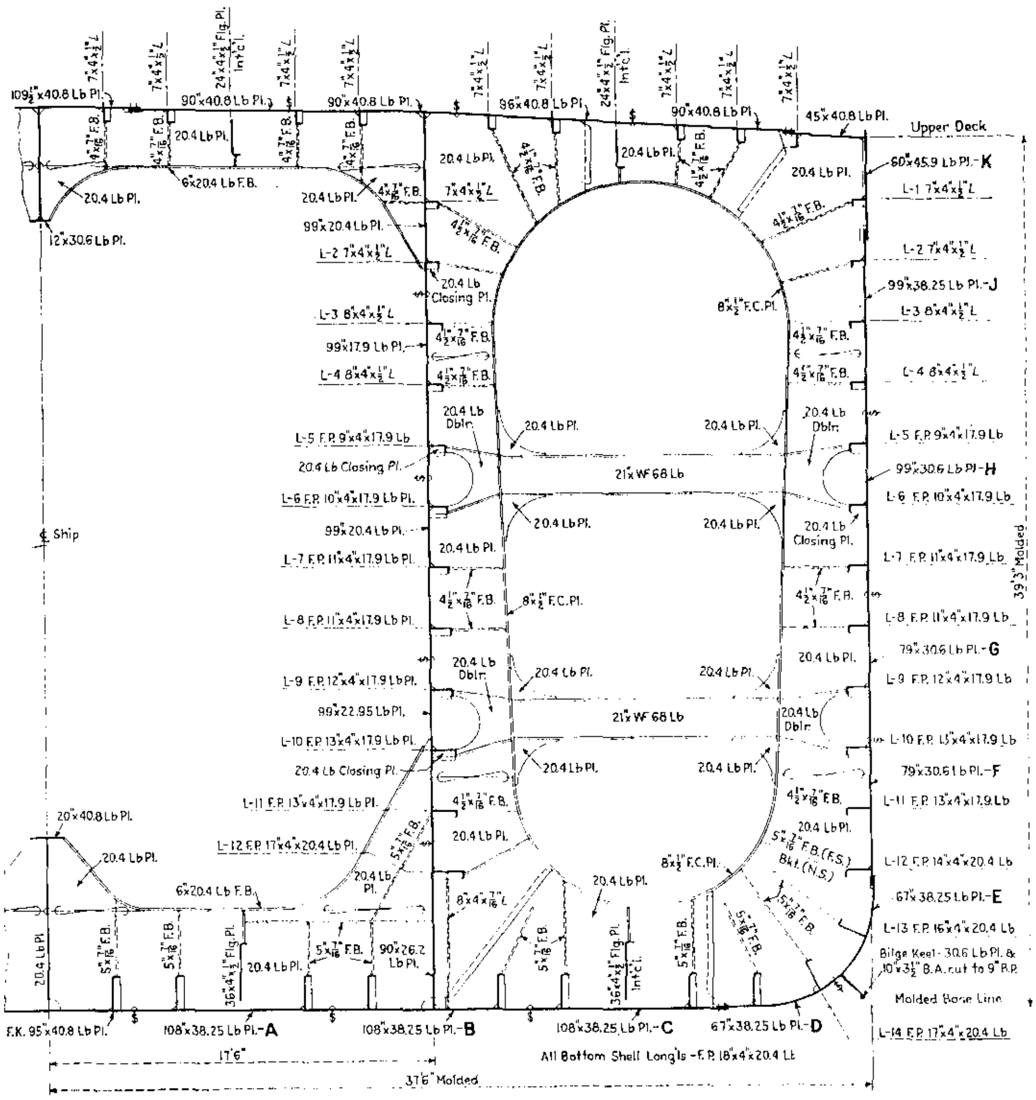


Fig. 8. Typical structure proposed for Jumbo "T2" (Ref. 16)

and a myriad of uses in the machinery category.

Few World War II vessel stern frames survived without showing fractures which required chipping out to sound metal, which often disclosed further imperfections such as shrinkage fractures, porosity, inclusions, etc. See Figure 11.

When a major damage occurred (see Figure 12) which required the replacement of even a section of a cast steel stern frame, the repair cost was enormous. One would ask then, why were castings utilized in the ends of ships, where the shell plating draws together and presents of itself massive strength? Perhaps it was inertia, stemming from wooden and riveted steel construction, or at least a throwback to an era of preweldment construction, when castings were the easiest method in iron or steel riveted ship construction to achieve the compound shape forms for efficient hydrodynamic flow.

"Thermit" welding, and "Metalock" were, and still are, means of joining fractured pieces of castings, and many repairs using these methods were made to avoid the expense of the replacement of an entire casting.

Obviously the disadvantage of a casting is that it does not lend itself to the cropping feature of welded ship construction.

"Liberty" Rudder Problems

The "Liberty" contraguide rudders showed vulnerability to excess wear of the wood bearing above the rudder, fracture of the rudder tube (stock), and fracturing of the rudder plating and welds in way of the division plate.

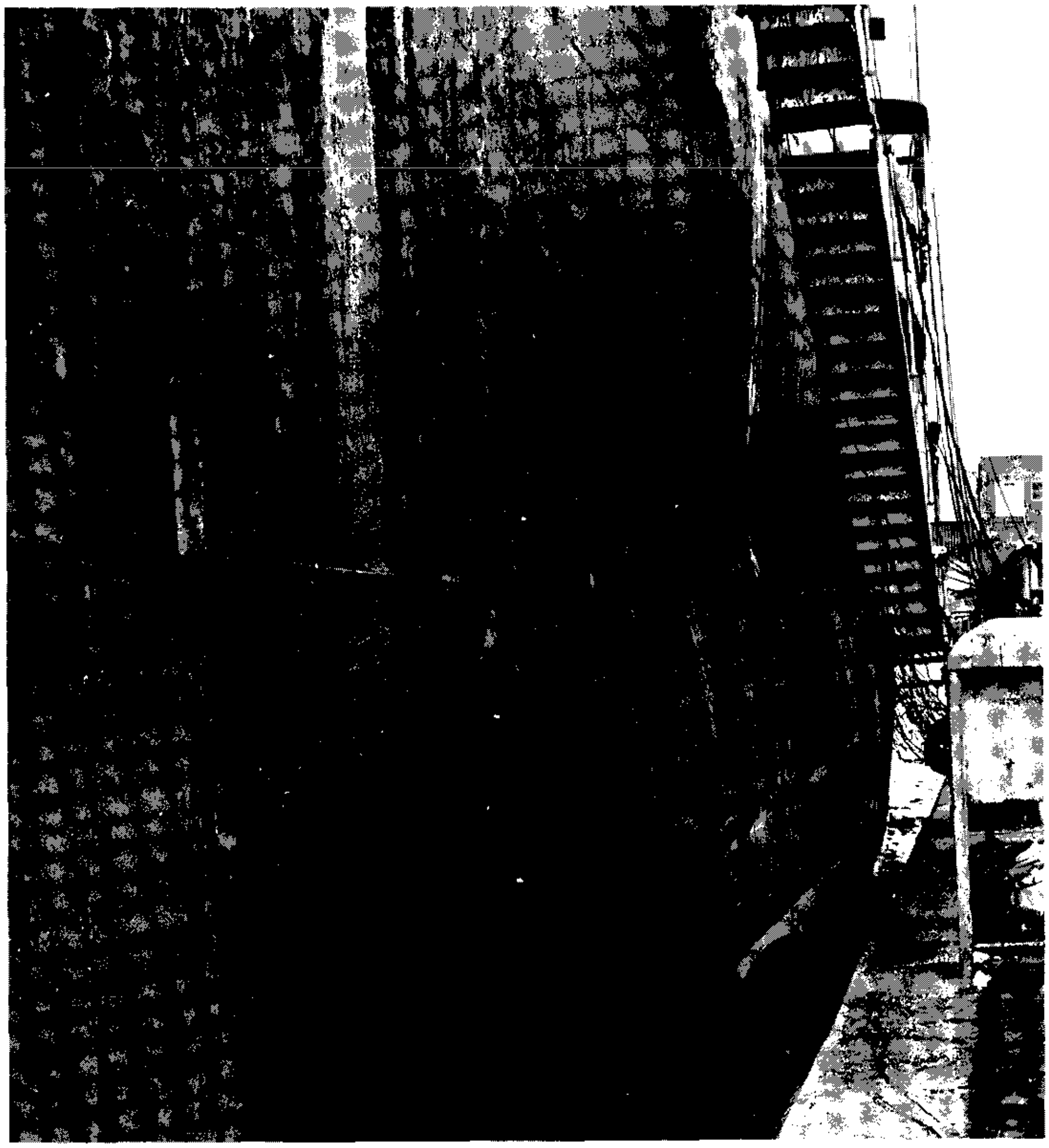


Fig. 9. Typical side shell damage

Repairs consisted of replacing the wooden bearing with a bronze bearing arranged for lubrication from the steering flat, welding up or replacement of the tube, and reinforcing the rudder in way of the division plate with angles and straps.

Tailshaft Failures

The incidence of fracturing of tailshafts, either circumferentially just aft of the liner, or in way of keyways was alarmingly high for all types of vessels. See Figure 13.

Where there was propeller damage it was invariably alleged that a striking caused the fracturing.

Literally hundreds of metallurgical examinations were made on behalf of underwriters on specimens of tailshafts taken from in way of the fractures, and many varying conclusions were reached relating to the causes of the fractures. Some concluded that propeller impact led to the failures; however, many concluded that fatigue was the prime causation, particularly in the case of circumferential fractures just ahead of the propeller, indicative of failure in cantilevered bending. In some relatively rare cases the tailshaft material was found to be at fault.

In an attempt to reduce the recurrence of fractures in way of keys the keyway configuration was altered by "spooning" out and generously radiusing the shaft material at the forward end of the keyway (Figure 14).

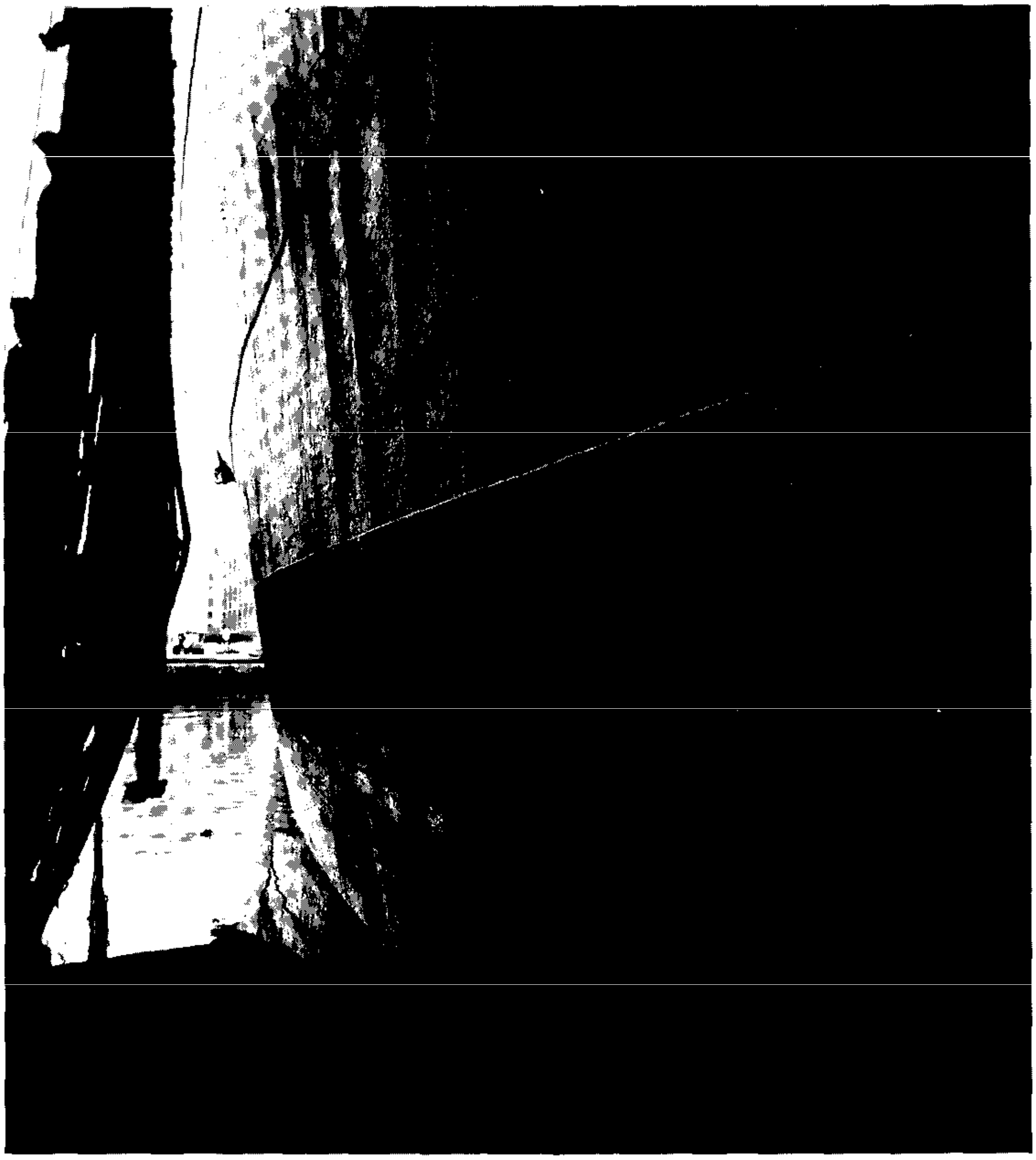


Fig. 10. Typical side shell damage

Numerous repairs to shafts were made by chipping or grinding away the shaft in way of fractures, and replacing the removed metal with weld metal.

Where the tailshaft was condemned for further service, this invariably led to the rewooding of the top and bottom halves of the stern bearing to accommodate the diameter of the bronze liner on the newly installed tailshaft.

The "Liberty" tailshaft problem, which in many cases involved the complete fracture of the tailshaft just aft of the liner, and loss of propeller, was found to be related to a third order torsional vibration, critical at about 78 RPM when the vessels were light, and at about 74 RPM when loaded. The usual cure was to install a propeller capable of absorbing normal full power at reduced RPM.

Unfortunately, for all of the types considered here, in order to remove the propeller for even the simple examination of the tapered end of the tailshaft, it was necessary to withdraw the tailshaft into the vessel, a most laborous and expensive procedure, and further, if it was necessary to remove the tailshaft from the vessel, it was generally found less expensive to make an opening in either the shaft alley or the shell to accommodate this removal rather than to attempt to move the tailshaft into the engine room spaces and out through the fidley. See Figures 15 and 16.

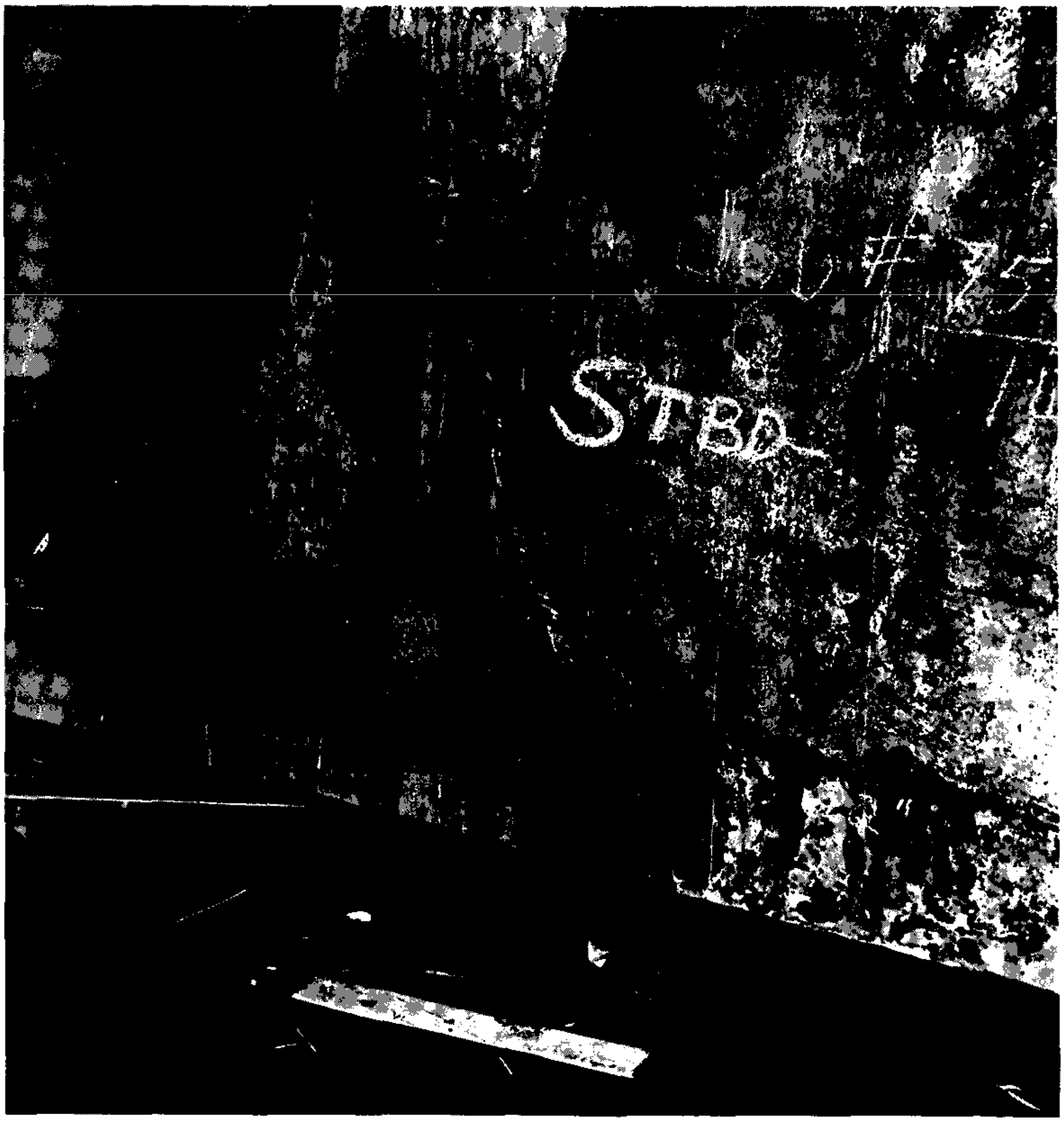


Fig. 11. Typical fracture in cast steel stern frame

Had the designers of these vessels been aware of the tailshaft problems which arose they most certainly would have arranged the vessels such that at least the propellers could have been removed without drawing the tailshaft inboard.

Today we find many vessels which can accomplish the immediate above, and also we are blessed with the development of a satisfactory seal allowing for oil lubricated stern bearings which void the necessity of a bronze liner; some of the arrangements even allow for inspection of the tailshaft forward of the propeller, afloat.

We are also blessed with the development of the "Pilgrim" nut and other hydraulic arrangements which avoid the time consuming and difficult procedures which were a part of the propeller and tailshaft problems of World War II stern gear arrangement.

Stern gear arrangement is as much a part of the naval architecture/strength of materials discipline as the marine engineering discipline, and it is mentioned here for obvious reasons.

Tailshaft Liner Erosion

A phenomenon which showed up with no regularity, and appeared to affect only a few of the vessels here treated, of all types, was the appearance of longitudinal bands of erosion on tailshaft liners, radially located nominally between propeller blades.

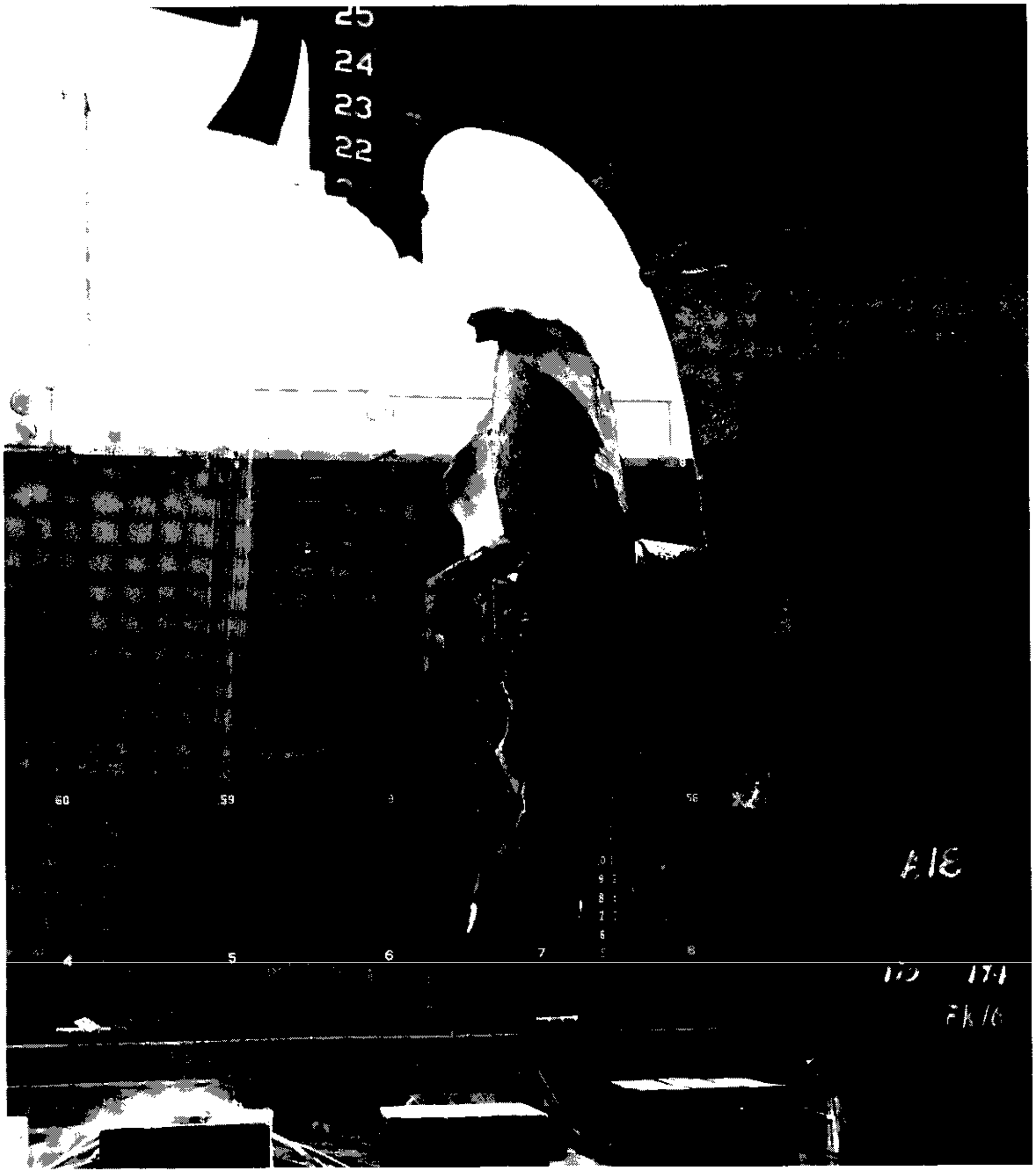


Fig. 12. Major damage requiring replacement of much of a cast steel stern frame

Many theses were advanced to rationalize the existence of these bands of erosion, ranging from water pulsations through the bearing, electrolysis taking place from generated static electricity or galvanic action, etc. In one instance it was even alleged that the damage was caused by the vessel lying in contaminated waters.

It is believed that to this day no positive knowledge is at hand as to why the phenomenon occurred; however, the need to establish the true cause has been obliterated by the development of the sealed, oil lubricated stern bearing, which fortunately shows no vulnerability to such damage.

COMMUNICATIONS BEFORE, DURING, AND AFTER WORLD WAR II

Surely neither the designers nor the builders of the World War II types were aware that they were building in weaknesses.

Further to the foregoing, and on the subjects of slamming damage and hinging damage, both types of damage usually lent themselves to long periods of deferment of repairs, and also the damage was not of a theatrical nature and invariably was not accompanied by

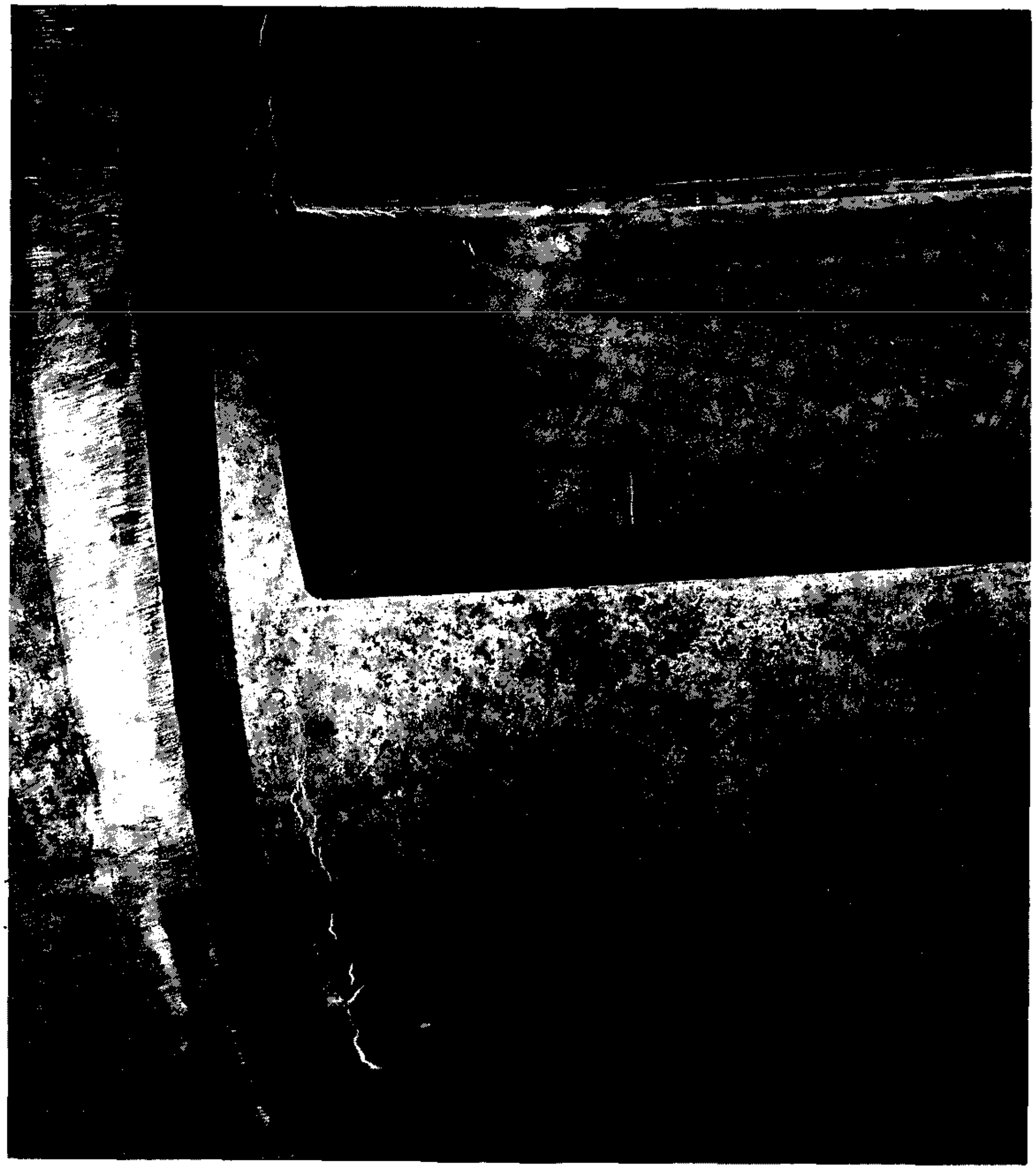


Fig. 13. Typical tailshaft fractures, both circumferentially and in way of keyway

loss of life, all of which simply did not lead to a broad awareness of the frequency of the damage among the design fraternity. Further, the standard bamboo curtain which seems to exist between field personnel and design personnel was apparent.

In large measure the owners did nothing about the types of damage which occurred except to make repairs in kind, or at best respond to classification recommendations. The very nature of owning one of a vast group of similar ships simply did not lend itself to unique or individual thinking. Even though few owners were making plans for new construction, most owners considered the World War II vessels as obsolete and not worthy of grandiose, expensive schemes to reduce recurrences of the types of diseases that the owners knew they were susceptible to. Under the circumstances it is perhaps remarkable that certain owners, who made it their business to maintain a rapport with SNAME, caused pursuits to come into being which in the long term did lead to solutions; however, it is clear that segments of the ship designing fraternity had no feedback concerning certain of the experience even after years of operation and failures, and it was evident that there was a gap in the flow

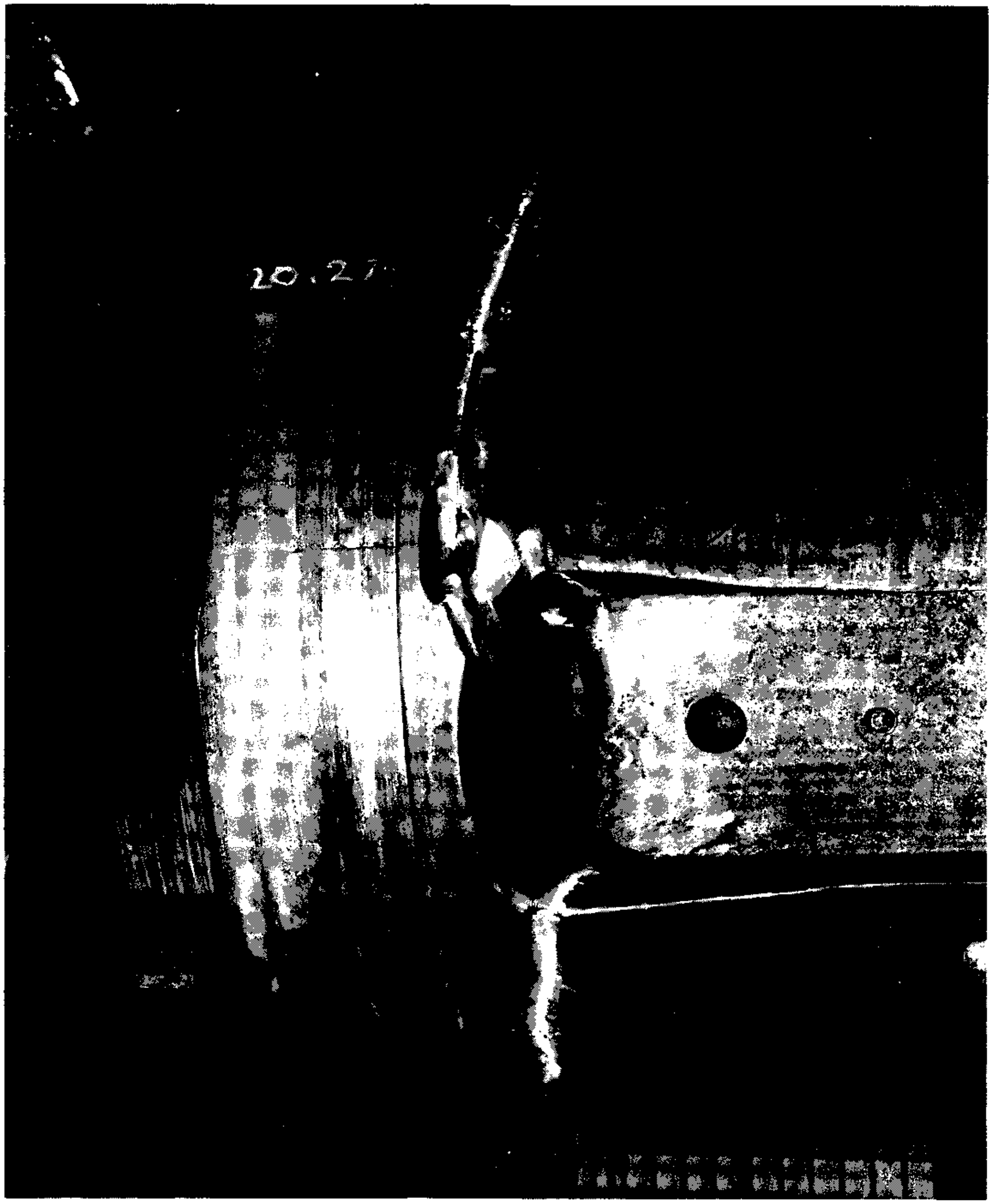


Fig. 14. Typical tailshaft fractures (shows "spooned" keyway)

of communications between the repair divisions and the design divisions of most shipyards. It was also apparent that a means was missing to create a flow of information between seagoing people and their owners, and a continuation of this flow from owners to those in the shipbuilding and ship design fraternity.

One might be curious as to how much of the oft-repeated standard weaknesses, shown across the board by so many of the World War II built/designed vessels, could have been avoided by better communication; however, in pursuing this we should keep in mind that the U. S. merchant marine jumped from World War I to World War II largely without any new construction or design, and it is remarkable that the flaws were as few as they were. Additionally, the state of the art of the welded ship was in its infancy just prior to 1940.

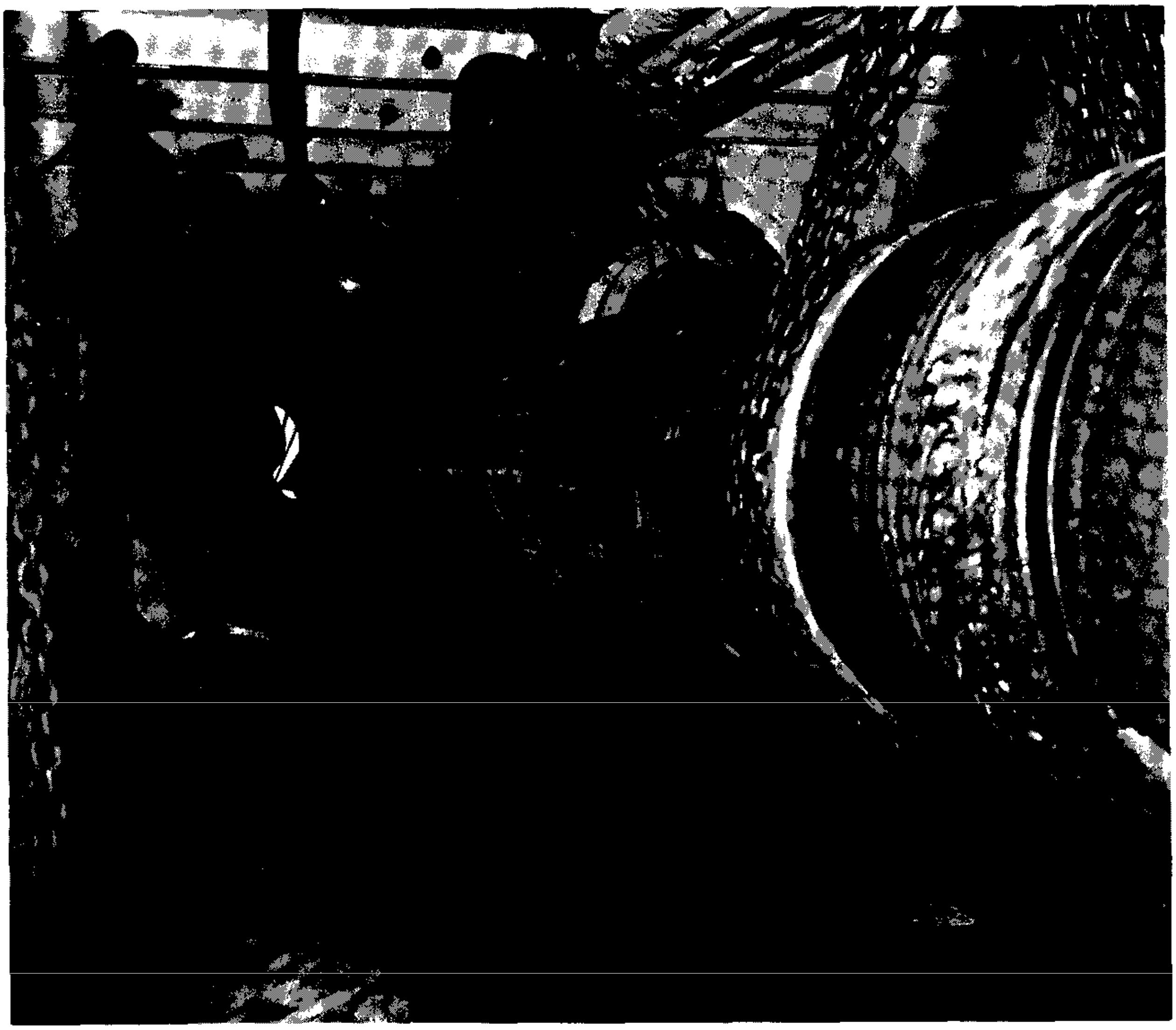


Fig. 15. The disturbance attendant to pulling in the tailshaft

CASUALTIES OF POST WORLD WAR II VESSELS

Nominally in the order of their construction to date, U. S. flag post World War II large ocean-going vessels comprised high density ore carriers; 28-30,000 tons deadweight ("Super") tankers; the "Mariner" class (as general cargo vessels); various classes of general cargo vessels, many of which were converted either during construction or subsequent to construction to container vessels; initial design container vessels; special bulk carriers; large tankers and ore/oil carriers; large bulk cargo barges; integrated tug/barge units; barge carrying vessels; and LNG vessels.

Abroad, not only were all the foregoing types constructed, but also very much larger tank vessels began to show up in the mid 1950's.

The earlier U. S. flag general cargo vessels, when operated in the North Atlantic at least, showed as severe a propensity to suffer from slamming damage as their World War II predecessors. See Figures 17 and 18. One class of these vessels, when the unsupported span of the forward bottom shell was halved, showed no further damage. The balance of the affected vessels have almost all been converted from general cargo service to container service, and are operating at a more nearly constant, relatively great forward draft, and have not shown the propensity to damage which was evident when they were purely in the general cargo trade.

Certain arrangements of internal structure of the early "Super" tankers, after only a few years of service showed

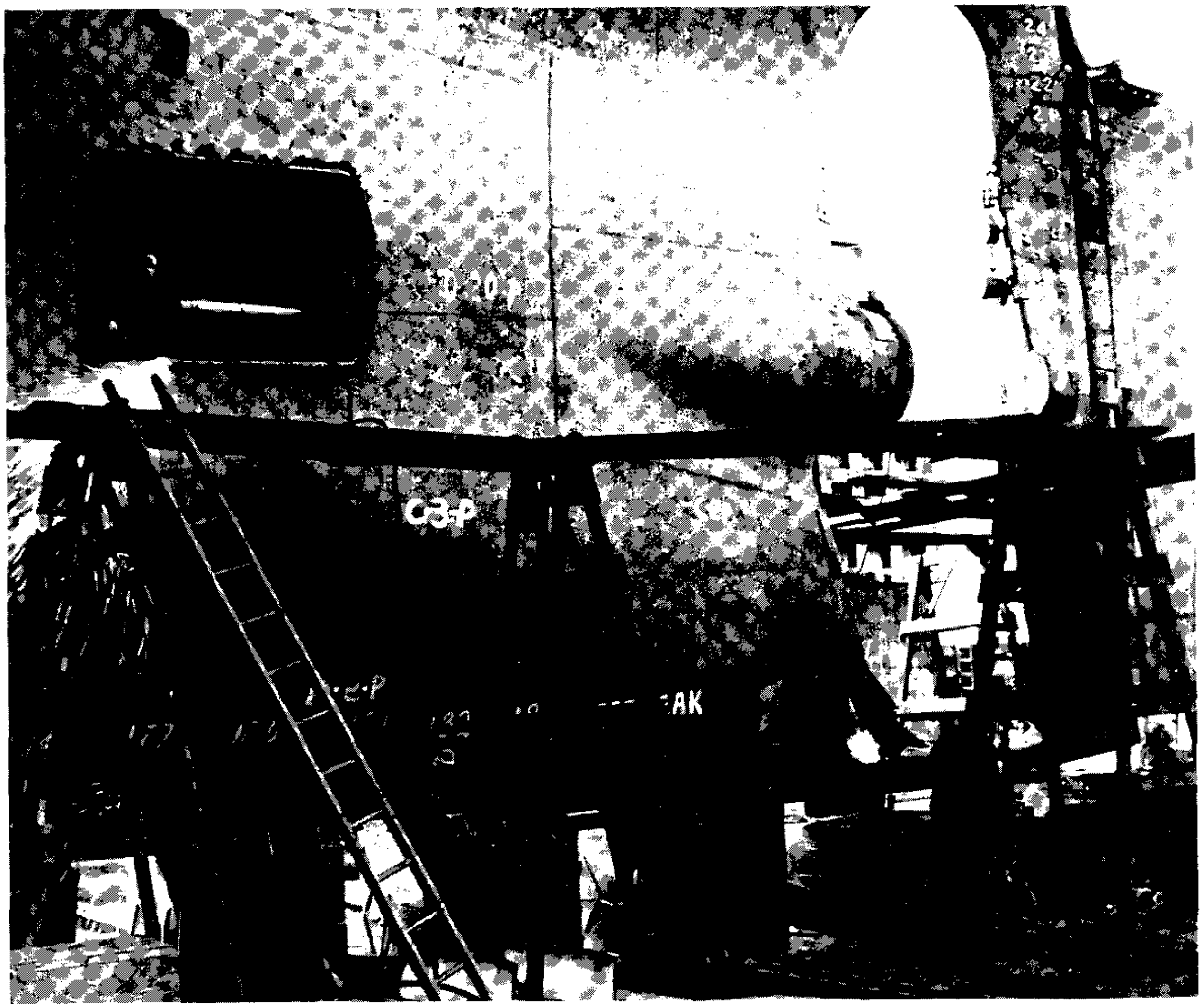


Fig. 16. Shell plate opening made in order to remove tailshaft

a propensity to fracture, raising questions as to whether or not there had existed a proper rapport between shipyard repair and design divisions. Some of these fractures related to the continued use of corrugated bulkheads in lieu of flat plate stiffened with welded structural shapes.

Ship designers and builders worldwide were feeling their way with tanker internal structural configurations which would not fracture in service, and it is understandable that certain of the configurations simply did not stand up. One such configuration, once again proving that stretched metal such as results from corrugations or joggles does not stand up, related to horizontal tie beams (struts) supporting the inboard and outboard portions of the web frames, and the webs of horizontal bulkhead stiffeners in the wing tanks of a class of tankers. Figure 19 illustrates the location of fractures, and also the method of altering the structure to avoid fractures in the future, which was applied in each wing tank of every vessel built with the original construction.

Another circumstance concerning tanker structural configuration very vulnerable to fracture, and related to the fairly recent concept of segregated clean salt water ballast spaces, is illustrated in Figure 20, which is a sketch of a transverse web frame in way of the cutouts accommodating the longitudinal stiffeners of the longitudinal bulkheads in the clean salt water ballast tanks, the structure being uncoated. Thinning of the structure in way of the fractures shown was down to almost zero thickness after less than two years service, from original nominal 1/2" thickness, which thickness still nominally obtained in areas of low stress.

The failure was a direct result of stress set up by fluids on one side of a bulkhead only, and resultant accelerated

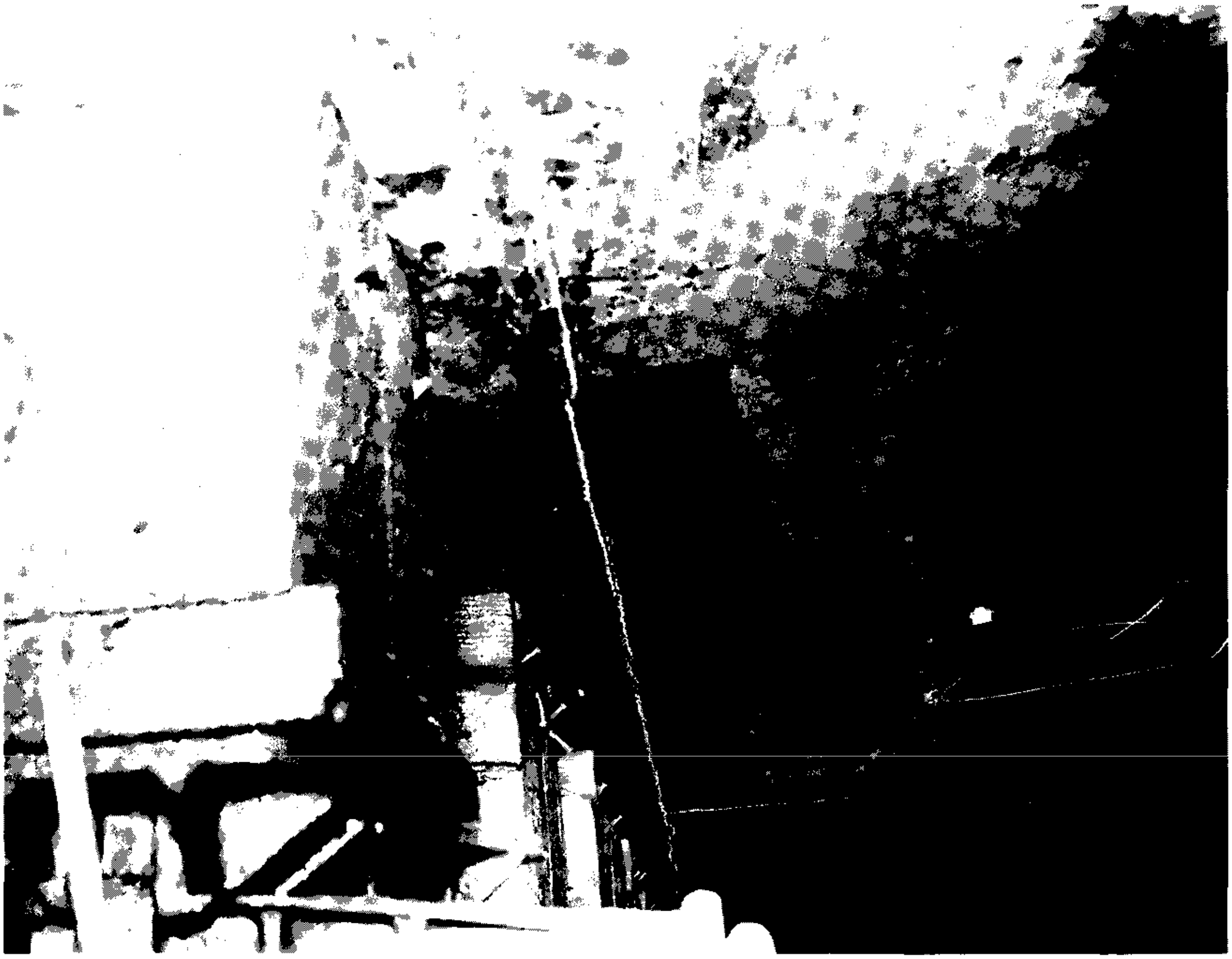


Fig. 17. Slamming damage to a post World War II U.S. flag vessel

corrosion and loss of strength in areas of high stress, causing the metal to fail in shear in way of the cutouts. While the cutout configuration for the bulkhead longitudinals was the same in the cargo wing tanks, and the web frames in those tanks were also uncoated, the massively accelerated thinning had not occurred, and no fractures as yet obtained, obviously due to the protection against corrosion by the cargo oil.

In the segregated clean salt water ballast tanks there was no recourse but to crop out and replace affected metal, installing closure pieces in way of the cutouts to help absorb the shear, and clean the webs from top to bottom, and coat same.

The performance of the huge tankers bore out the fact that great emphasis had been laid on longitudinal strength, for there were little or no longitudinal strength problems in their operation, but this was not the case with transverse structure. Crippling of huge webs occurred in the early VLCC's, which required that greater attention be given to vertical stiffeners and their spacing (19).

Problems relating to damage to the forecastle head and forward upper shell plating of the larger tankers, from the effects of the sea, began to show up even on the 28-30,000 tons deadweight tankers which appeared in the early 1950's. The damage related to the setting down of forecastle deck plating (see Figure 21), crippling of webs and stanchions (see Figure 22), generally accompanied with the setting in of the upper flared section of the vessel at the sides of the forecastle head, and upon occasion the indentation of the upper stem and forward side shell plating and supporting structure (see Figure 23). The damage as a type led to a revamping of classification structural criteria for forecastle head design; currently the affliction appears less frequently. The fact that the navigating bridge was moved all the way aft probably had some influence on the frequency of occurrence of this type of damage, since those in the wheelhouse were so remote from the

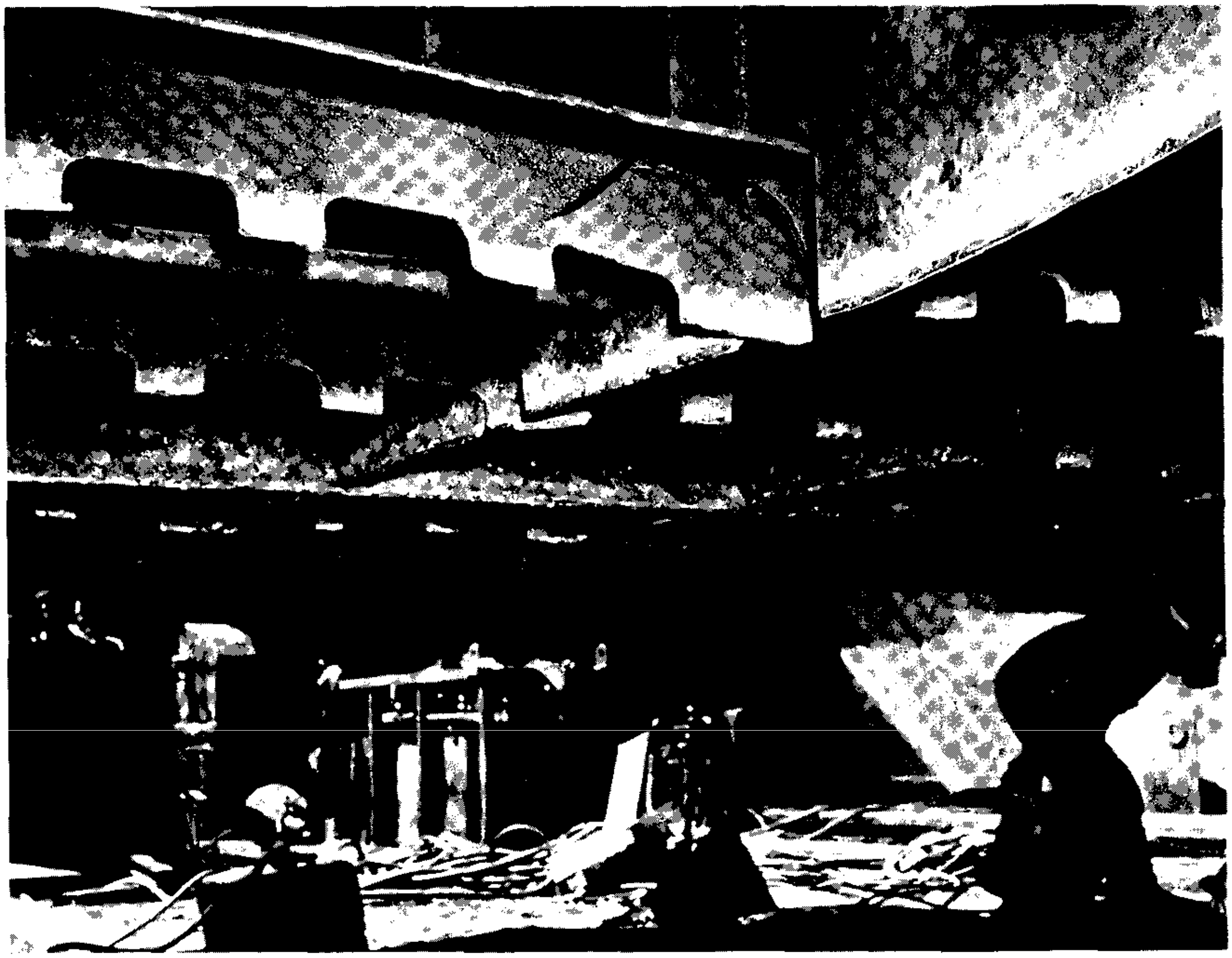


Fig. 18. Slamming damage (same ship shown in Fig. 17) showing damage to internals

area of damage, and inadvertently they may have driven the vessels of this very large displacement type too hard into the seaways.

A type of damage which seems to consistently carry on, and which afflicts all types of vessels (which can be disastrous when it occurs to tanks formed by the vessel's hull, such as is the case with bulk liquid carriers), is the rupturing of tanks of vessels during the filling of these tanks with fluids. The fact that the damage occurs so often would indicate that few people are aware of how important it is to arrange tank venting/overflow systems to prevent the damage, which is invariably laid at the door of crew negligence. In some cases blanks or valves have been installed in an otherwise adequate venting system, to prevent overflow of oil or other contaminating substance into the water surrounding the vessel. In some cases flame screens in vents have been painted nearly shut. In some cases the height of the vent head is such that from static forces alone there is sufficient hydrostatic pressure built up to severely damage a vessel's tanks. Reference (20) indicates that it is not always sufficient to provide a cross-sectional overflow pipe area 1.25 times the filling pipe cross-sectional area, it sometimes being necessary to make the ratio as high as 1:4 to allow for constraints in the overflow pipe.

Concerning steel castings, a remarkable circumstance occurred, from the standpoint of timing, for during a four months period, approximately five years after delivery of the vessels, four cast steel "Mariner" rudder horns evidenced surface fractures which required massive chipping out and welding up of fractures, and in some cases the renewal of the entire rudder horn casting. The disease seemed to be on one side of the castings, and was in large measure laid to the rising to the surface of slag and inclusions on the affected side of these large castings which were poured on their side. See Figure 24.

Propellers of nonferrous cast materials were not without their problems, particularly those of special alloys of

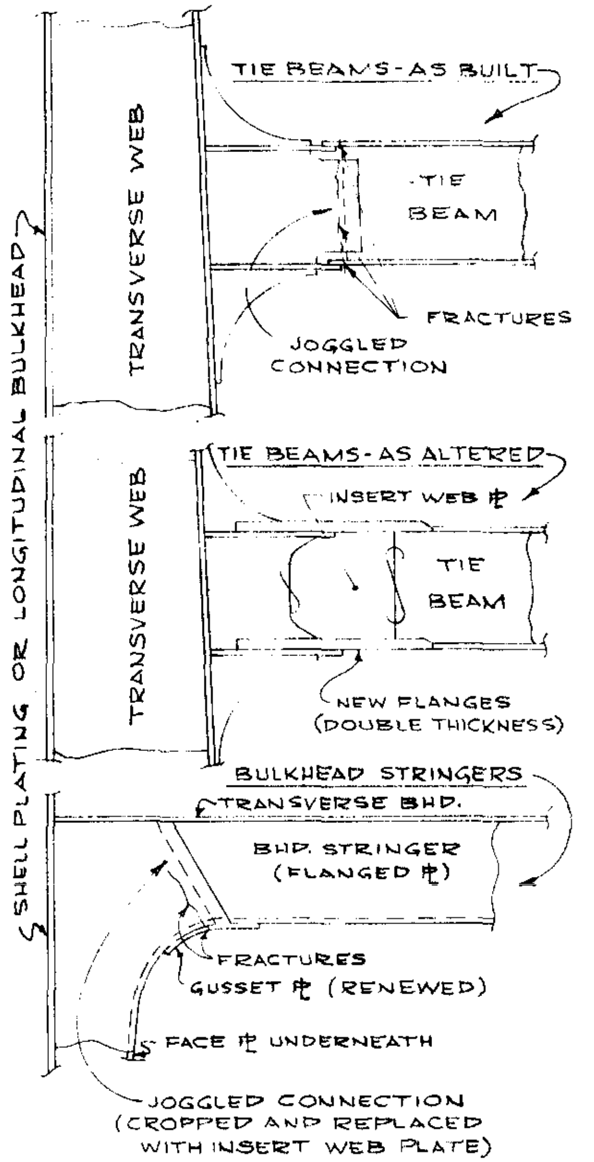


Fig. 19.
Fractures in way of joggles of tanker web frame tie beams and bulkhead stringers, and alterations to avoid future failures

alleged high strength. While a coupon of the original parent material may have shown an ultimate strength of, say, 98,000 pounds per square inch, and the propeller blade thickness was determined on this basis, after failure of the blade in bending, in service, a coupon taken in way of the failure submitted for metallurgical examination in many instances showed an ultimate strength of approximately 40,000 pounds per square inch; clearly a case of a change in the physical characteristics of an alloy perhaps resulting during the heating or the pour of the propeller casting from the original billet(s). See Figure 25.

In another area, side shell damage went marching forward, particularly for those vessels laid out in the tradition-al fashion to accommodate mooring. The results in the St. Lawrence/Great Lakes Seaway were disastrous, and caused certain salt water U. S. flag operators to vow they would abandon such service forever. This was a direct result of the lack of rapport between the salt water and Great Lakes segments of the U. S. merchant marine. The missing equipment on the salt water vessels was wire mooring winches, universal chocks, stern anchors, and the lack of tumble home and rubbing strakes on the sides. The resulting side shell damage during lock transiting was enormous, as was bottom and stern gear damage from grounding aft when anchored by one anchor at the bow in narrow estuaries (the docks being engaged by other vessels waiting to transit the locks). The lack of the proper ship handling equipment literally drove the salt water vessels of the day out of the Seaway, and while most of the U. S. vessels never returned to the Seaway (certainly for many reasons), ironically the Great Lakes wire mooring arrangement has caught on, largely stemming from the necessity of such equipment on the larger seagoing bulk carriers which could not be handled properly with a multitude of fiber lines, revolving gypsy heads, line stoppers, and the quantity of personnel required to operate such archaic equipment.

SAFETY, COMMUNICATIONS, AND RESEARCH

What is safety worth? Who benefits from a safe ship? Who is in a position to promote safety the most?

If everything rotates around low cost of transportation, which taken to its extremes means that each vessel will incorporate only minimum requirements, how can damage-conscious operating personnel prevail? Must an owner be forced by monetary reasons to limit his ship purchases to standard production items which can be produced with the minimum dollar?

Taking the example of LNG vessels, current predominant fashion is to place one-fifth or one-sixth of the total cargo in tanks of one shape or another. It is apparently left to chance to determine whether or not the product should be carried in many more containers. In this case design agents are currently in no position whatever to sustain an argument to depart from what is accepted as conventional arrangement, from the standpoint of added safety (and its cost), versus what is saved in the end through that added safety.

The public, shipowners, financiers, and underwriters of every category all can benefit from extra safety arrange-

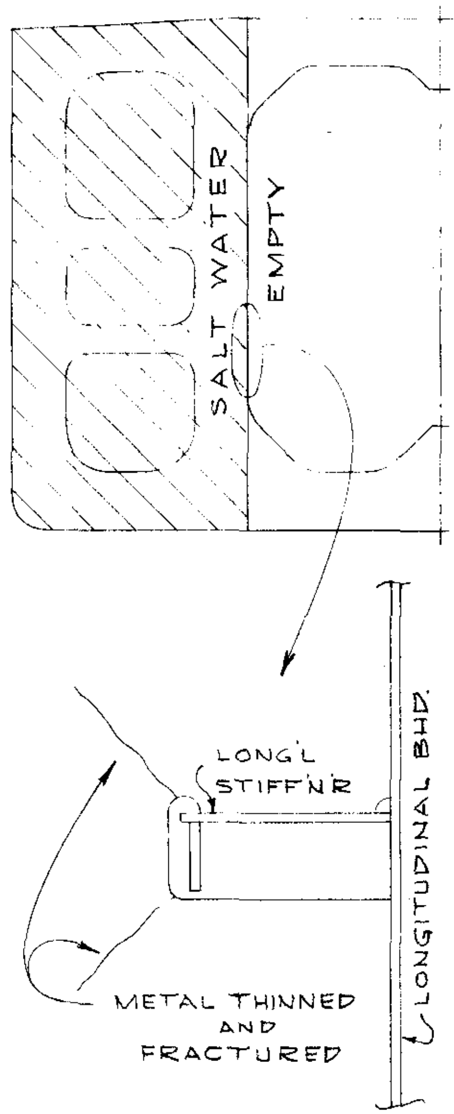


Fig. 20.
Fractures in way of web frame cutouts in segregated clean salt water ballast tanks

ments, particularly with vessels carrying a product which has huge potential to damage life and property, yet there is currently no way of placing a dollar value, at the time of ship design or construction, on the incorporation of safer arrangements in a vessel to carry such cargoes. It is unfortunate that the basis for safety always seems to be regulation after the fact.

In treating with less dramatic casualties that probably will never lead to regulation, it becomes obvious that ship designers are in no position to develop improvements, or suggest the incorporation of features which cost money, where they have no statistics on damage experience relating to what might be avoided if the improvements or features were installed. For example, without statistics relating to the prevalence and cost of side shell damage from mooring, one is in a poor position to recommend the installation of a bow thruster.

As another example, it is submitted that design agents are not in a position to place more emphasis on vent arrangements of tanks than has been customary in the past. How much information on the bursting of tanks through alleged crew negligence has been processed through design offices? The damage is prevalent, and can cost hundreds of thousands of dollars to repair.

It is submitted that the design department of a shipyard is in a very poor position to determine whether or not a raised forecastle should be installed on a "ULCC", with the attendant additional cost of same, versus a flush deck arrangement, when there is little or no feedback from seagoing personnel, or operators, condoning or condemning the flush deck arrangement on a typical vessel of the type.

Traditionally ships have not been laid out to make it easy for others to record damage; for example, it is seldom specified that frame numbers be located on vessels. Whose fault is this? How many owners require that a casualty book be maintained on each ship, to avoid wading through log books to find instances of casualties or records of same?

Some vessel operators are in a position to frequently add new vessels of their own design to their fleet. Such fortunate operators can be guided by the faults of vessels which they built a year or so previously. Presuming good in-house communications, a very high level of operating efficiency, by selectivity, can result with such an arrangement. Such an organization is in a position to contribute much to research carried out under public auspices, and importantly, is in a position to know what needs to be researched.

Where an owner operates with ships developed by others, whether they be standard designs of shipyards, or government sponsored designs, the liklihood of that operator contributing to research, via the experience of his own personnel, would seem to be low, for his personnel simply will not have the keenness of pursuit in establishing how their design can be made better, for it was not their design in the first place.

Whatever the cause, where an operator's personnel more or less take a back seat to the subject of research, research is forced into the academic theater.

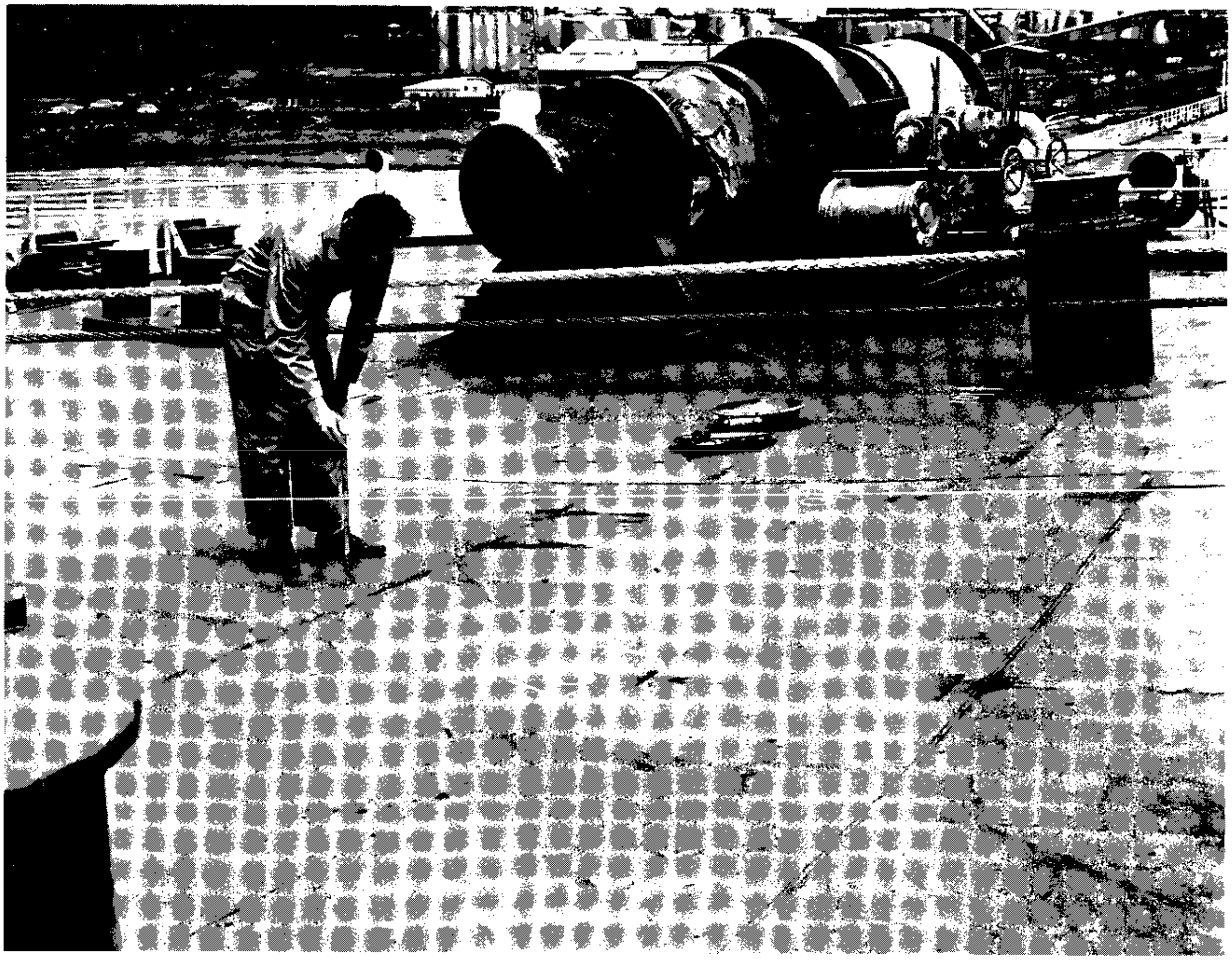


Fig. 21. Large tanker forecastle head damage showing set-down of deck

Reference (21) provides a summary of sources of personnel and ship casualty data, and it can be concluded from that work that very little organized emphasis has been placed on the gathering of such data. Full ship damage data requires knowledge of not only what was damaged, how often it was damaged, and how it was damaged, but also the cost of repairs. The cost input certainly should be a prime catalyst to look into various failures, but how often is research based on such input? References (22) and (23) are two of the few efforts existent in the casualty gathering theater.

Certainly a significant part of research relates to the establishment and maintenance of a system to gather damage statistics, for without a specific indication of the trends and patterns of damages the leads to research are of a haphazard nature. When flaws or failures are given a specific dollar value, research will trend more to be on a practical basis, as opposed to a theoretical exercise perhaps dedicated to long-term results.

When one considers the willingness of owners to jump into areas having little or no operating history, one must concede that the owners have shown either massive fortitude in being willing to take what most cautious people would consider prohibitive risks, or have moved forward in blessed ignorance. In all but a very few instances things have worked out pretty well for such risk takers. Undoubtedly research in metallurgy, structural analysis, and welding has made the record possible.

SUGGESTIONS FOR THE FUTURE

Quite apart from the specific instances mentioned earlier herein of apparent communications problems between the disciplines involved, there is a demonstrated current need for operational damage statistics, and the possible sources of same. Time and again, to justify (or even establish) programs, agencies and contractors (particularly those representing disciplines peripheral to the marine theater) demonstrate their need for statistics. Time consuming education best describes the circum-

Fig. 22. Large tanker (same ship as Fig. 21) showing structure inside forecastle

stances as each group separately spends the time to interview organizations reported to them as possible sources of statistics (which organizations repeatedly have to describe what they do or do not collect).

Obviously there should be a central damage statistics information agency to direct such groups to. Such an agency undoubtedly cannot come into being nor exist on a voluntary (gratis) basis. It must be funded; either the funds must come from industry or the government.

Further to the above, it is suggested that the recommendations set forth in (21) be followed, i.e., damage data should be generated by those in a position to develop it, and made available to a central collecting agency, and from this data trends and patterns should be distilled which should be distributed to:

- Shipowners and operators
- Governmental agencies and research centers
- Classification societies
- Design agents
- Shipbuilding and ship repair yards
- Technical societies such as SNAME
- IMCO
- The financial fraternity
- Maritime oriented schools and colleges
- Underwriters
- Maritime labor unions and trade organizations

A formal distribution of damage trends and patterns among the above-listed segments of the maritime industry would go a long way toward creating a

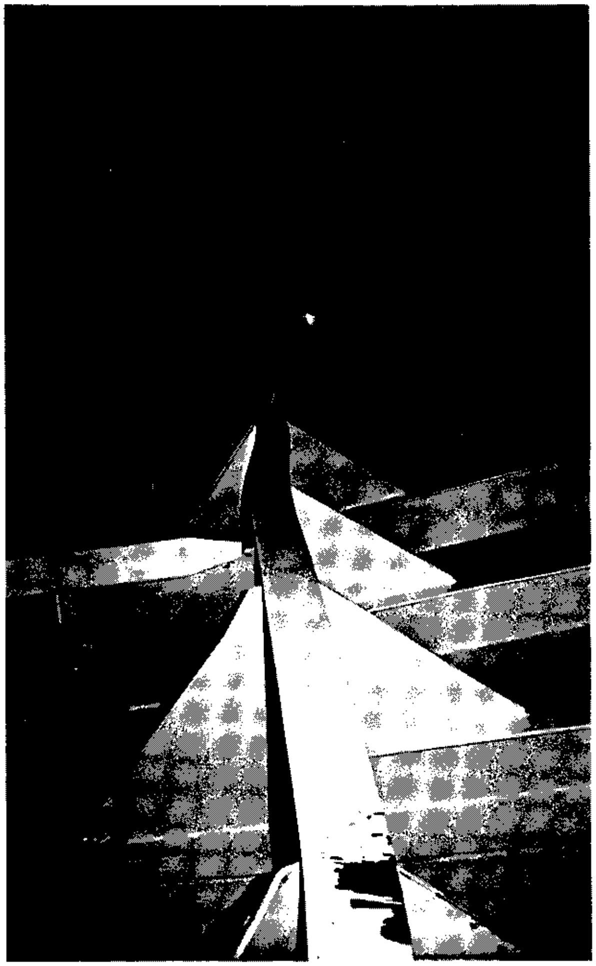


Fig. 23.
Huge tanker, showing buckling of internal structure underdeck forward

rapport which, among certain of the disciplines, is now totally missing, and hopefully, remedies for the ills would grow out of such distribution.

More candor is needed from all sides, and more cooperation. Classification societies are in a unique position to accumulate information on those parts of vessels which are repetitively adversely affected either by the forces of nature or by people; their standards will not be changed where they need change without a candid disclosure of faults.

Where research programs are put together and funded, which include instrumentation of vessels, largely to provide long-term benefits, and the programs relate to new and unusual vessels, it is obvious that a part of the funding could well be dedicated to the solution of problems that were not anticipated but which when they occur require immediate solution. In this fashion an owner would achieve a measure of immediate compensation for making his vessel available for instrumentation.

Stern gear vibration problems, including bearing/shaft failures and loss of propellers, have appeared in the relatively high speed, very high powered fine lined vessels of this modern age. On the other end of the fullness spectrum, vibration has plagued full ships for years, and it will be of immense importance to assess its probability in the proposed low L/B, high B/H very full vessels currently being considered. References (24) through (31) lay emphasis on the importance of the vibration problem.

The traditional handling of propulsion systems leads to fractionalization of disciplines. Many of the problems are of a vibratory origin stemming from propeller-induced vibration (hydrodynamics) and the reaction of the hull (structures and mechanics). Obviously there is a whole missing link treating totally with the hydrodynamics of the waterflow into the propeller, the propeller-induced pulsations, and the response of the hull girder. To date, vibration analyses seem to be made by mechanically and structurally oriented people, both of whom come into the picture after hydrodynamically oriented persons have finished their pursuits. In many cases this leads to disastrous results.

Systems must be put together to predict vibration problems with models. This may require accommodation for motion in the model's propulsion system, including shafting, struts, bearings, etc., with instrumentation to measure whipping or movement in shafting and shaft bearings, and possibly actual structure simulation in the models, perhaps using halographic methods as described in References (32) and (33).

In the area of wave forces the world awaits the development of a blanket, for model scale use, and full size use, which can be placed upon a ship's shell that will record not only pressures, but the envelopes of pressures from wave slap and slamming.

There is an interagency Ship Structure Committee. Where are the interagency Ship Machinery Committee and Ship Operations Committee, the latter treating with the human error aspect of hull and machinery problems?

While there may be currently some moves to the contrary, traditionally, would-be naval architects, when they go to sea, end up in the engine room. Accordingly, they do not personally experience the problems of deck operation. They are in no position to treat with the layout of cargo handling equipment, mooring equipment, anchoring equipment,

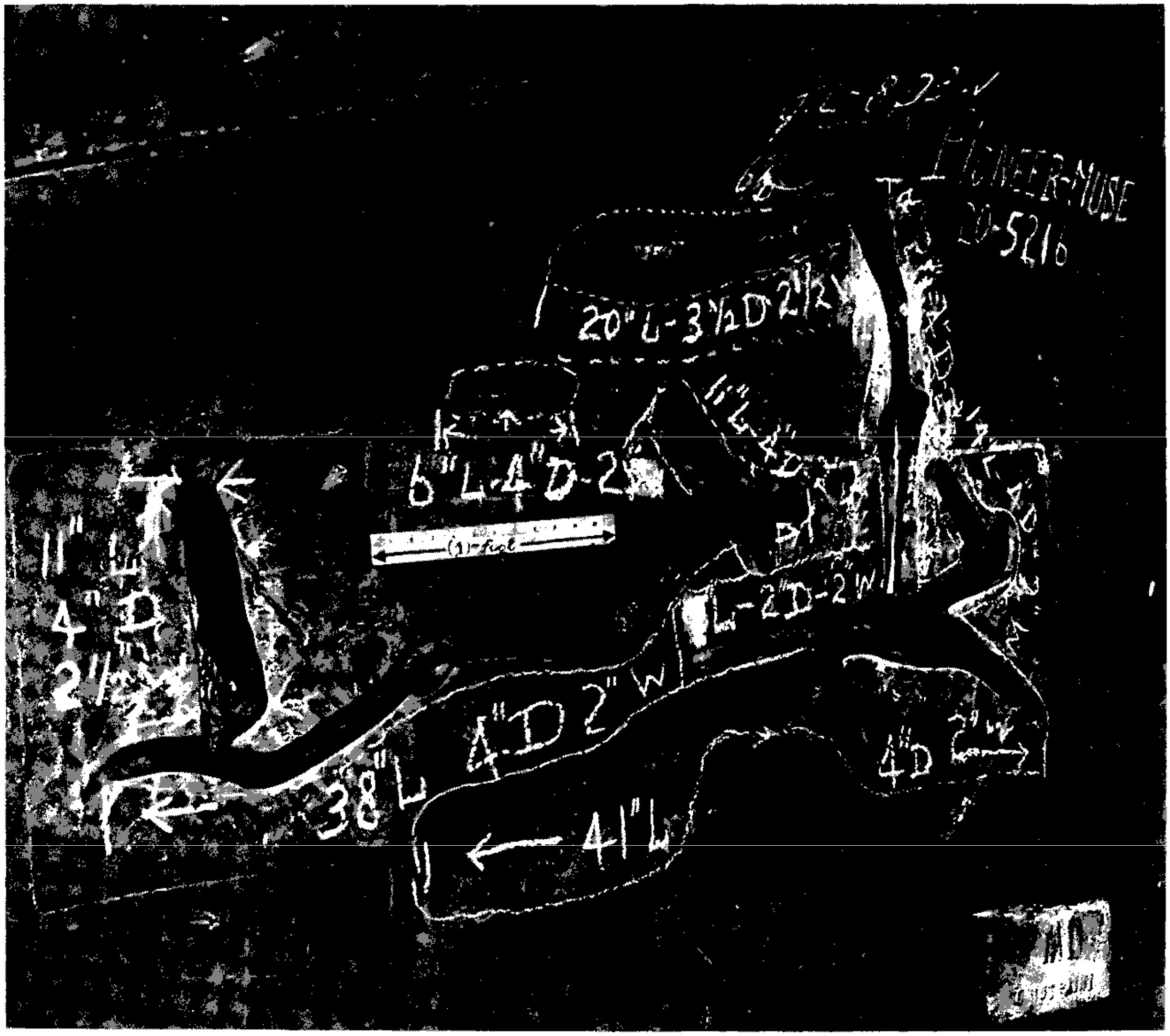


Fig. 24. Cast steel "Mariner" rudder horn showing metal removal in way of fractures

etc. Undoubtedly this was one of the reasons why up to the end of World War II deck personnel were topping cargo booms with a cargo winch and stopping off topping lift wires with chain stoppers. Perhaps this is also the reason why salt water vessels are even today fitted with the outlandish arrangement for mooring which is obtained with fiber lines, in lieu of wire mooring winches (34). The placing of expensive machinery such as an anchor windlass above the deck, exposed to the weather, is a direct result of people in one discipline either not paying attention to the problems of another discipline, or not giving thought as to how circumstances can be bettered.

CONCLUSIONS

1. There were inherent weaknesses designed and built into the multiple units of a relatively few types of vessels making up the U. S. merchant marine, immediately prior to and during World War II.

2. In some areas attention was given to the weaknesses and cures were found. Generally there was a demonstrated lack of communications between those who knew of the weaknesses and/or vulnerabilities, and those designing new vessels.

3. Certain of the inherent weaknesses appeared in post World War II vessels of the U. S. merchant marine.

4. Ship damage history should lead to research - currently this is seldom the fact in the United States.

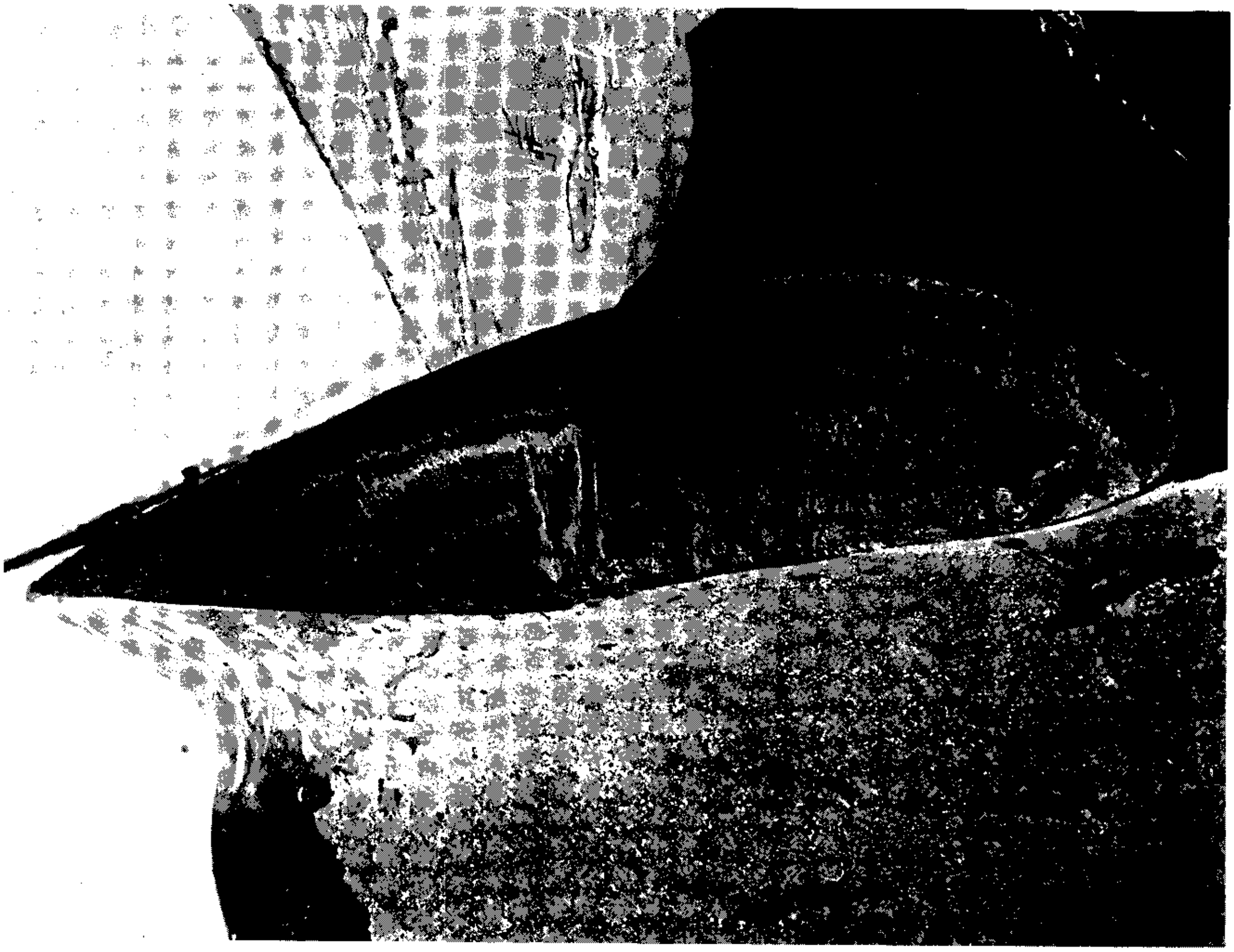


Fig. 25. Section of propeller blade in way of fracture

5. The development of a system for the gathering of vessel casualty data, definitely including the non-theatrical but often-repeated types of damages, lies dormant. There is a need for the results, and the effort should be pursued vigorously.

6. All pertinent disciplines should receive the results of 5, and should occasionally meet to better align the solution of problems as they are determined.

7. Means to predict vibration problems in the model stage must be implemented, and the need cannot be too strongly emphasized.

8. An interagency Ship Machinery Committee and Ship Operations Committee should be brought into existence.

9. Emphasis should be placed on the necessity of deck department service as a part of naval architectural training.

ACKNOWLEDGMENT

The type of damage information included herein is representative of the daily effort of the United States Salvage Association which organization has never failed to generously release its findings to those interested in bettering vessel operational efficiency.

Special appreciation is also extended to Mrs. Muriel Fox who so patiently and carefully committed to paper the many words making up this effort.

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