

**BULK CARRIER LOSSES**  
**A NAVAL ARCHITECTS VIEWPOINT**

BY

**B.J. CORLETT AND J.C. COLMAN**

## Bulk Carrier Losses - A Naval Architect's Viewpoint

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This Paper discusses some of the background to bulk carrier losses, and in particular the role of structural failure. The principal failures likely to contribute to a total loss and the significance of heavy ore cargoes are considered from a Naval Architect's viewpoint.

### 1. Introduction

Conceptual designs for bulk carriers reached maturity in the early sixties. Examination of casualty records since then reveals that losses of this type of vessel, large and small, have always accounted for a large proportion of total ship losses and that older vessels operated by second, third or subsequent owners account for most of this. The situation was highlighted by the unexplained loss of the DERBYSHIRE and several other ships in the early eighties.

It was against this background that in the late eighties it was claimed that bulk carrier losses were not 'atypical'. Between 1989 and 1991, however, this standpoint became impossible to maintain in the face of mounting loss rates especially of ships carrying ore cargoes and increasing concern about the numbers of crew lost.

Some Classification Societies acknowledged that there was a particular problem with these vessels and that systematic investigations were required. These investigations have not resulted in any major changes in the design rules, but they have generally resulted in post construction surveys being made tougher and more frequent, with attention focused on particular problem areas.

Burness Corlett & Partners (BCP) have investigated in depth the losses of several bulk carriers, including the DERBYSHIRE, and believe that we have direct experience of most of the causes of loss for these vessels. It will come as no surprise that matters such as corrosion, fatigue cracking, heavy weather flexing, hatch cover collapse, light scantlings and cargo damage feature frequently in the list of technical causes alongside other more general causes such as fire and explosion, collision, grounding and scuttling.

We have also come across a wide variety of claimed causes. These include collision with an unknown object at night, sudden and catastrophic emergence of a long hidden latent defect (perhaps a crack that has been growing for many years within a shell plate weld), a late night encounter with a mine leading to the sinking of the vessel, usually in a deep part of the ocean, and the freak wave whose force no vessel could endure.

In a great many incidents structural problems have been identified as the actual or probable cause of loss. This is not surprising in view of the size and complexity of the hull structure of a bulk carrier, the extremes of load to which it can be subjected and the harsh environment to which much of it is exposed.

This paper will concentrate on outlining some of the structural problems which arise with bulkcarriers, their causes and how they can contribute to the loss of this type of ship.

## 2. Basic Concepts

The basic design of a bulkcarrier features large, clear holds and wide hatch openings and is intended to enable it to carry a variety of homogenous, dry bulk cargoes with maximum efficiency. This means that the ships are easy to load and discharge, and should be cheap to run and cheap to build. The resulting basic arrangement of the ship is the main factor in the structural problems which arise.

Fig.1, a section through the hold of an average single skin bulk carrier, throws some light on to the structural design problems. The section consists of three very stiff and strong groups of structural elements joined by three relatively flexible and weak groups. The strong areas are the double bottom and lower hopper tanks, which form a single group, and the topside tanks on each side which form the other two strong groups. These groups are strong because they are fully enclosed cellular structures with substantial internal longitudinal stiffening and including transverse webs which in effect divide the structure longitudinally into boxes.

The weakest elements are the two side shell areas between the topside tanks and the lower hopper tanks, and the hatch covers and coamings, none of which are usually cellular. Normally the side shell has only transverse (i.e. vertical) stiffening and the frames are not deep in comparison with the depths of the topside and hopper tanks. The hatch coamings are normally discontinuous and stiffened only by transverse stays, although a flat bar longitudinal stiffener is often incorporated at half height, as shown in Fig.1.

The hatch covers are not rigidly connected to the ship, hence they can move about to some extent. They often consist of lightweight and lightly stiffened single plate structures designed to the minimum strength required by the Load Line convention (which governs the strength of hatch covers).

There are a variety of designs derived from the basic bulk carrier concept either to meet specialist requirements or to provide even greater economic efficiency. These include combination carriers, OBO's (ore/bulk/oil), ore strengthened bulkers, con-bulkers (container/bulk), bulk/car carriers, and others. The most common and the most important are:

- a) Ore Strengthened Bulkcarrier - The conventional bulk carrier is designed to carry cargo distributed in all holds and substantially filling them. Some ore cargoes, the most common being iron ore, are very dense and a full deadweight cargo only part fills some of the holds leaving the others empty. (See Fig.2(a)). This alternate loading of holds means that the bending moments and shear forces applied to the hull vary sharply along its length and the structure has to be strengthened accordingly. Dedicated ore carriers are very different, having holds which are sized so that they are filled up when the ship is fully loaded (see Fig.2(b)).
- b) OBO (Ore/Bulk/Oil) Carrier - The OBO is designed to be able to carry oil cargoes as well as dry bulk (including ore) giving the operator even greater flexibility and efficiency. The holds are designed to serve as cargo tanks and cargo pumps and piping are also fitted. With all the other facilities necessary, including inert gas, tank washing, handling of slops, etc., these become very complicated ships with many additional operational problems and potential hazards. This paper concentrates on structural problems but it should be acknowledged that explosions in OBO's, caused by ignition of hydrocarbon residues in spaces such as duct keels are known to have caused losses and that the leakages can be a consequence of structural problems.

Since the basic bulk carrier concept was defined, approximately 30 years ago, over 6000 ships have been built which embody it. It is in this context that losses must be examined.

### 3. Structural Problems and Bulk Carrier Losses

An examination of the statistics of bulk carrier losses helps to put the significance of structural failure into context. For the period 1980 to 1991, Lloyd's Register have published data illustrating the loss of dry bulk carrying ships, where such losses can be attributed to structural failure, i.e. ships which have had reported hull leakages or have simply gone missing. The ship types include single hull and double hull bulk carriers as well as ore carriers. Over this time period the average rate is about six ships per year with the highest level being 12 ships during the year 1990. Fig.3 illustrates this and Fig.4 shows how the figures are related to size and age of vessels.

Based on analysis of the casualties listed in Appendix I, covering the period 1980 to August 1991, there are three common factors:-

- a) About 70% of losses were vessels over 15 years old.
- b) About 75% of losses were loaded vessels carrying heavy cargo - i.e. ore.
- c) Over 70% of losses occurred in heavy weather.

It should also be noted that only 18% of losses had one factor present, while 58% had two factors present and 24% had all three.

There have been numerous articles recently where underwriters, operators, Classification Societies, etc., have put forward their views on possible causes, some likely, some not so likely. Last year, Lloyd's Register (LR) issued an interim report on their investigation into bulk carrier losses, which identified some commonly recurring problems with bulk carriers:- (see fig.5).

1. Cracking of hatch corners.
2. Cracking of hatch coamings.
3. Plate panel buckling of cross deck strips and stiffening structure.
4. Cracking at fore and aft extremities of topside tank structures.
5. Corrosion within topside tanks and double skin.
6. Grab and bulldozer damage to the main frame/lower brackets.
7. Cracking at main frame bracket toes.
8. Both general and localised corrosion of side shell, side frames and frame end brackets.

9. Cracking at the connection of the inner bottom and hopper plating.
10. Grab damage to the tank top plating, hopper and lower stool platings.

While the damages listed above are typical of those found on bulk carriers, they are not inevitable. Evidence would seem to indicate that even with sister ships significant differences in occurrence and extent do exist. It is also clear that some of the defects listed above, whilst undesirable, are unlikely to lead to the sudden and rapid loss of the ship. This indicates that, additional factors related to structural strength are involved and other factors, such as the trade in which the vessel is employed, loading sequences, inspection, maintenance and seamanship come into play.

A particular difficulty in identifying problems which lead to total loss is that there is rarely more than patchy evidence of what happened. Problems leading to catastrophic structural failure may not be adequately recognised as such during the general inspection and maintenance of ships in service and so do not feature in class records. Investigation of actual accidents where the ship was lost or nearly lost may provide a better indicator.

#### 4. Particular Problem Areas

In the course of accident investigations BCP has seen structural failure as a possible or probable factor in the loss of bulk carriers in the following main areas:

##### 4.1 Side shell cracking

Flexing of the side shell close to the stiffer topside tanks due to rolling in moderate to heavy weather, causes horizontal fatigue damage in the side shell at the connection of the frames to the lower hoppers and just below the bottom of the topside tanks. Inertial effects on the top side tanks when rolling, particularly when the tanks are full, may also be an important factor in aggravating fatigue damage. The side shell frames are exposed to cargo and to cargo handling equipment and are therefore prone to mechanical damage and sometimes to aggravated corrosion if the cargo is potentially aggressive, as with coal or sulphur. This was identified by Lloyds as one of the biggest problems on bulkers.

In some respects the side shell should be less prone to fracturing at the joint with the lower hopper side tank, as the frame brackets are larger and so flexing here is not so severe. However, this area is more prone to corrosion and mechanical damage and so is equally at risk.

Resistance to flexure is provided by the frames. If these are corroded, the risk of cracking increases and cracking of the side shell is then likely to occur. The area subject to the largest stress range and hence the greatest fatigue damage is at the forward end, where rolling, pitching and wave impacts all contribute to the damage. This is why the forward hold often fails first in casualties involving side shell cracking.

For non-dedicated ore carriers, cargoes present particular problems because of the part filled holds which result. When the hold is full of cargo, the cargo helps to support the side shell against the pressure of seawater on the outside. With an ore cargo this does not happen and so the side shell can flex more, increasing the risk of cracking and failure. (Fig.6).

#### 4.2 Topside Tanks

The topside tanks provide a cargo self trimming capability for the vessel, limiting the possible amount of bulk cargo shift when the hold is full or nearly full. They also provide a large ballast capacity high in the ship to reduce the GM (stability) to a comfortable level. This means that these tanks are continuously subjected to a salt atmosphere and it is well known that they are particularly prone to corrosion with two major consequences:-

- (a) the tanks start to leak (sometimes causing cargo damage claims) and ultimately become unuseable as ballast tanks;
- (b) the reduction in the thickness of plating reduces the longitudinal strength of the ship.

The second effect is clearly much more serious.

The greatest field stresses applied to bulk carriers are the hull bending stresses caused by the loading pattern and by the seastate (Still Water Bending plus Wave Bending stresses). Loaded bulkers generally have a sagging Still Water Bending Moment so the greatest deck loads occur where this combines with the vessel on a sagging wave, i.e. with a crest near each end of the ship and the trough amidships (Fig.7). This produces compressive stresses in the topside tank structure. With the exception of continuous hatch coamings which anyway are unusual, the topside tank structure (including the deck, top sides and sheerstrake and the sloping internal bulkhead) is the only piece of structure resisting the compressive bending load. If this fails, the ship will fold up and probably sink.

Under compression, the most likely failure mode for stiffened plating is by buckling. Corrosion reduces the thickness of the plating and this has the dual effect of increasing field stresses, because the load has to be carried by less steel, and decreasing the buckling strength which reduces with the thickness of the plating. In tension corrosion increases the stresses, in compression it increases the stresses and reduces the strength.

The highest bending stresses usually occur amidships but the tapering of the new steel thicknesses towards each end of the ship, as permitted by the Rules, can mean that almost any area of the ship away from the bow or stern could be prone to catastrophic buckling, especially in the region of a peak in the still water loading curve.

#### 4.3 Double Bottoms

A number of specific problems apply to double bottom structures, especially in ore or similar heavy cargo carriers. From the structural loading point of view, it is important to realise that most of the largest loads affecting the ship run directly through the double bottom structure.

The double bottom obviously holds the cargo up, sometimes supporting the weight of many thousands of tonnes of ore above empty or part filled tanks below it. It also absorbs the vertical water pressure which provides the vessel's buoyancy. With ore cargoes in large holds, it is often the case that ore is piled up in a cone, a pattern that greatly increases the stresses in the bottom under the centre of the cone; this tends to bend the double bottom locally rather more than would be the case with more even loading. Dropping the cargo from a significant height can provide a dynamic addition to this effect during loading. Double bottoms are very heavily built to cope with this sort of still water loading, which is additional to the dynamic loads applied by the seastate.

The effect of alternate loading of holds is to induce large shear stresses in the longitudinal double bottom girders and transverse floors, which support, on one side of a bulkhead, a cargo weight much greater than the water pressure over the bottom area, and on the other side, a very large water pressure which is unresisted by weight of cargo. (See Fig.8). The stress regime is complex so careful and accurate analysis is required to determine the likely levels of stress in any given component.

The response of the double bottom structure to these loads depends upon its design, construction, maintenance and contents. Class rules have developed to a stage where new scantlings for double bottoms are adequate, and proper

supervision of construction should result in a structure that fulfills the requirements, although quality is not always as high as would be expected. The major problems arise with deterioration of structures where access is difficult and therefore thorough inspection is rare, and particularly when exposed to high levels of corrosion in ballast tanks. Most surveyors will be aware that the very freshly painted appearance of a double bottom ballast tank does not guarantee adequate scantlings.

Corrosion can cause rapid degradation of strength and lead to collapse failures, although it is unusual for such incidents to lead to the loss of the ship. Perhaps the biggest risk is that the progressive loss of longitudinal strength could result in failure of the hull girder and the ship breaking in two.

#### 4.4 Hatch Covers

The strength of hatch covers is one of the few structural criteria set directly by Statute rather than by Class. Under the 1965 Loadline Convention it was decided somewhat arbitrarily that hatch covers should be designed for a head of water of 1.71m with a factor of safety of 4.25 to ultimate stress, thereby implying a failure head of 7.25 metres (23ft. 9ins.). Unfortunately, this type of design philosophy is very misleading, plastic analysis shows that failure occurs at yield not ultimate stress. For hatches in new, as designed condition, total failure may occur at about 4.0 meters of water over the hatch. The effect of corrosion is to bring this figure down very rapidly.

It is possible for loads of this magnitude to occur on the forward hatch in storm conditions when a deeply laden ore carrier is hove to (Fig.9). In these conditions and on vessels with low freeboard, no foc'sle and virtually no foredeck, the forward hatch is likely to be more or less permanently awash, and if it loses watertight closure, the forward hold will fairly quickly fill up. For a dedicated ore carrier this is not too dangerous as the hold will already be full of ore and so the vessel is unlikely to trim much more by the bow. On an OBO or bulk carrier, however, the ore may occupy only 1/6 or even 1/10 of the hold, so a very large amount of water

can get in. This trims the bow down, allows green seas to roll up the main deck and places all the hatch covers at risk. This could conceivably happen at night on a large ore carrier without anyone on board realising what has happened. The additional trim due to flooding of the forward hold would only be about 1 degree on a large vessel, almost imperceptible in heavy seas with the vessel pitching. Once the second and possibly third holds have flooded, the vessel will nosedive and sink very rapidly.

Many Classification Societies now require higher scantlings for hatch covers than the Loadline minimum. However on older vessels this remains a major potential problem, particularly where there is significant corrosion.

#### 4.5 Bulkheads

The transverse bulkheads dividing the holds of bulk carriers carry loads associated both with cargo pressures and with the general transverse strength requirements of the hull. In OBO's and similar vessels with liquid cargo or tanks adjacent to holds, the bulkheads must also provide liquid or gas tight divisions between compartments. Transverse bulkheads are often designed using a vertically corrugated configuration which combines adequate stiffness and strength with minimum steelweight and simplicity of construction. If the steel corrodes, then this structure can lose strength rapidly and penetrations or cracks at welds become more likely.

With vessels carrying dry cargo, collapse of a bulkhead should not of itself cause the loss of the ship. It may however allow sufficient flexing of the side steel, bottom and/or deck to induce cracking and loss of watertight integrity. Once the hold or holds start flooding then other problems can arise.

Even in an OBO the bulkhead will be designed to resist the pressure of water on one side to a small head above the deck. With a "dry" cargo which has become saturated with water, the combined density can be much greater than water alone and the pressure can exceed the design load by a considerable margin. This can lead to bulkhead collapse aggravated by sloshing of the liquid.

If a bulkhead fails under pressure from a liquid, whether cargo, ballast or due to flooding, a 'domino effect' can occur where several bulkheads all in the same condition fail progressively, allowing a large amount of cargo space to flood. In cases where the source of liquid is the sea, as with flooding through side shell cracks or hatch covers, the loss of the vessel must become a possibility. (See Fig.10).

#### 4.6 Loading Operations

Much criticism has been directed at the very high loading rates at ore terminals. It has been suggested that dynamic effects of such rapidly changing loads can affect the ship's structure. This is not realistic. The rates of loading required to induce dynamic hull flexing are of the order of one thousand tonnes per second. Such rates happen generally only during events such as collision, groundings, slamming and explosions. Even at very high loading rates the behaviour of the ship is quasi-static in structural terms.

There are however four areas where fast loading is of particular concern.

Firstly, it is possible that although the calculated start and end conditions for a loading operation are within the allowable limits, the stresses at intermediate condition during loading might exceed them. The situation could be aggravated if several holds are being loaded simultaneously. If stresses exceed harbour limits by more than about 25 to 30%, permanent structural damage to the main hull may occur even in a new vessel, and obviously a corroded, weaker vessel could be damaged more easily.

Secondly, it is possible that the vessel's de-ballasting capability is inadequate to keep up with the loading. This can lead to a situation similar to that described above, conceivably resulting in overloading of the vessel. This is undoubtedly a major operational problem for older and less well maintained tonnage.

Thirdly, there is the problem of local impact damage being caused to the inner bottom and its stiffeners by dropping heavy cargo on to it from a

great height. Problems with grabs, bulldozers and pneumatic hammer damage also fall into this category. If holds are in good condition, cargo is properly graded and then loaded and unloaded with due care and consideration, problems should not arise. Notes of protest about loading practices for pig iron or the like are however seen from time to time and loading officers should be alert for possible damage. It is unusual for such problems to be directly connected to a total loss, but unseen damage to the inner bottom structure could contribute to collapse of the double bottom and leakage into the hold.

The fourth problem is that of trimming. A well trimmed cargo has two safety advantages over a peaked cargo with slopes at the angle of repose. The stresses imposed on the bottom structure are reduced and more evenly spread, and the cargo is less likely to shift.

The stressing aspect of trimming has been mentioned in 4.3 above. With untrimmed heavy cargo subjected to large vertical accelerations, as might occur in the forward hold of a bulker head to sea in a storm, severe damage can be caused to the double bottom structures. Cargo shifting is not common with ore cargo and although liquefaction of ore cargoes has been the subject of much debate, especially since the loss of the Derbyshire, we are not aware of any firm evidence that it has ever happened to such a cargo in service.

#### 4.7 Cracking and corrosion of Welded Joints

In theory, a vessel is designed so that, with proper maintenance, cracking of the steel structure should not occur until a fatigue life in the region of 20 years of operation has been used up. Fatigue is a process whereby cumulative damage is done by cyclic loading on the structure and which eventually results in the initiation and propagation of cracks at points where stresses are locally high (stress concentrations), e.g. hatch corners. The fatigue life is the time required in service for the structure to experience enough stress cycles for a fatigue crack to initiate.

Fatigue or cracking in steel ship structures invariably starts at welded joints, of which there are several miles on an average bulkcarrier.

Classification societies divide these connections into several categories reflecting the loads they carry and their importance to ships' safety. Broadly speaking, the system is intended to ensure that vital joints such as shell plating seams have a negligible chance of fatigue failure. Less vital joints, such as the fillet welds connecting frames to the shell plating, have a lower rating but are not so highly stressed. Nevertheless, the expected life of all joints should exceed twenty years.

It is important to realise that fatigue life, once used up, cannot be regained except by complete replacement of the welded joint. Thus the so-called life extension programmes carried out on bulkers and tankers nowadays do not extend the fatigue lives of welded joints that have not been replaced. The Owner and Classification Society of such a life-extended ship over twenty years old should still expect a high incidence of cracking in original welded joints. Many take the view that there will be little difference between a well maintained ship and a life extended ship.

The use of substantial amounts of high tensile steel in the hull structure allows reduced scantlings and therefore reduced lightship weight but aggravates some of the problems. First, it increases general stress levels which increases the risk of fatigue damage and second, with lower scantlings the structure is more flexible which can often increase the cyclic stresses and consequent risk of fatigue damage at "hard" points in the structure. Third, corrosion allowances are a percentage of thickness and so in a structure with a substantial amount of high strength steel the allowances are used up more quickly. The benefits of increased deadweight and revenue potential should be traded off against higher maintenance costs and reduced life, but this is not always so.

Returning to fatigue cracking, the consequences can range from the completely benign crack which relieves a stress concentration without overloading or endangering any other detail, to side shell cracks allowing water ingress or even to a crack capable of starting a major brittle fracture which could break the hull in two. Fortunately, the quality of modern steel, welding techniques and detailed designs is such that catastrophic brittle failures are extremely rare, although the loss of the tanker KURDISTAN showed that they are not impossible.

Turning to corrosion at welded joints, it has become apparent that welded seams in some internal stiffening members, such as the deep webs in the topside and hopper ballast tanks, are prone to accelerated corrosion, as are unprotected fillet welds joining stiffeners to shell or deck plating in similar compartments. This can be dealt with by good inspection, repair and maintenance (IRM) systems. The rate at which this accelerated corrosion can degrade a structure is such that it is not safe for an owner to rely on annual class surveys to detect the problem before it becomes acute, particularly on older ships and where paint coatings have broken down. The disconnection of longitudinal stiffeners from the deck over a significant area is particularly dangerous as this massively reduces the buckling strength of the deck plating, referred to in 4.2 above.

## 5.0 The Particular Problems of Ore Carriers

The significance of ore cargoes as a factor in bulkcarrier loss figures can be understood from any reasonably regular reading of the marine press and is only emphasised by the statistics quoted in Section 3. It is worth summarising some of the particular features of the transport of ore cargoes which differentiate them from lighter bulk cargoes.

- a) High alternating shear forces and bending moments on the hull girder due to alternate loading of holds.
- b) No support to side shell in empty or part filled holds allowing increased flexing of side shell in the loaded condition.
- c) Non-uniform loading of the double bottom in loaded holds due to inadequate trimming of the cargo, leading to increased local loads in the double bottom structure.
- d) High differential loads in double bottom structure due to alternate loading of holds, leading to large shear stresses in the double bottom longitudinal girders.
- e) Large floodable volume even in loaded holds, leading to greater changes in draft and trim on flooding of holds.
- f) Dense slurry formed in flooded holds may be more likely to cause bulkhead collapse.
- g) High bulk density of ore allows high loading rates by weight resulting in greater risk of vessel passing through unacceptable conditions during loading process.
- h) Poor loading and discharge practice more likely to cause local impact damage.

All the above particular problems are a consequence of the high density of most ore cargoes. When combined with the more general structural problems of bulkcarriers such as side shell cracking or hatch cover leakage and an elderly, part corroded hull, it is easy to see why ore strengthened bulkcarriers and OBO's are particularly at risk. Related cargoes of even higher density such as pig iron or iron ore concentrates present even greater risks and also feature in the loss statistics.

## 6.0 Addressing the Problem

Many would say that the best way to address the problems of safety and continuing losses in the world bulkcarrier fleet would be to improve the trading climate allowing owners to build new tonnage and pay for it. Unfortunately good trading conditions also provide an incentive for continuing to operate older vessels. The commercial problems involved are beyond the scope of this paper, however we can address design and technical operation issues which could have a significant impact.

### 6.1 Design Solutions - Existing Ships

There are a number of technical design solutions to some of the problems with existing vessels outlined above. One fairly obvious 'fix' is substantially beefing up the side frames between the topside and lower ballast tanks, either when renewing side frames because of deterioration or by welding additional steel onto the existing frames. Similarly, problems with weakness of hatch covers can be dealt with by adding stiffeners. Such solutions however have at least one and sometimes two or more fatal flaws. The major problem is that they cost a considerable amount both in terms of steelwork and loss of hire. A further problem, particularly with oversized frames which would significantly reduce bale capacity, is loss of payload through deadweight and capacity reductions. In the present economic climate for bulker owners, such actions could only be contemplated if everybody had to execute them, and there seems to be no realistic prospect of Class or statutory powers being taken to force such a situation upon owners.

Design solutions for existing ships for the moment will therefore be limited to rectification or modification of detail design defects when the time comes to repair or replace degraded structures. In general, replacements tend to the original design because of the cost of major improvements.

### 6.2 Design Solutions - New Ships

Again, economics dictate the position that prospective owners have to take. While minor improvements in design can be made in the normal evolutionary manner, a substantial commitment to increased scantlings and reduction of

higher tensile steel content is difficult to justify in a market where a new bulker built right to the rule minima can only raise about half the daily rate required to make a profit. Orders for high quality vessels have been cancelled in recent months because of the impact of higher capital cost on required freight rate and the poor state of the market.

Some of the design features required to make new bulk carriers safer have of course already been incorporated into general practice, often under new Class and Statutory Regulations. Detail design was improved from the point of view of avoidance of stress concentration, hatch covers tend to be designed a little over Rule requirement and the economic penalty for some further strengthening is very marginal.

Required scantlings are in general slightly higher than those of a decade ago and designs are more accurately assessed for compliance using direct calculation techniques. Production methods and quality control have improved, reducing the likelihood of substantial welding, material or other production defects. Coatings for ballast tanks are much improved and more widely applied. For the vast majority of the bulk carriers being built, however, avoidance of the problems mentioned will not be achieved simply by relying on these design improvements.

### 6.3 Inspection, Repair and Maintenance

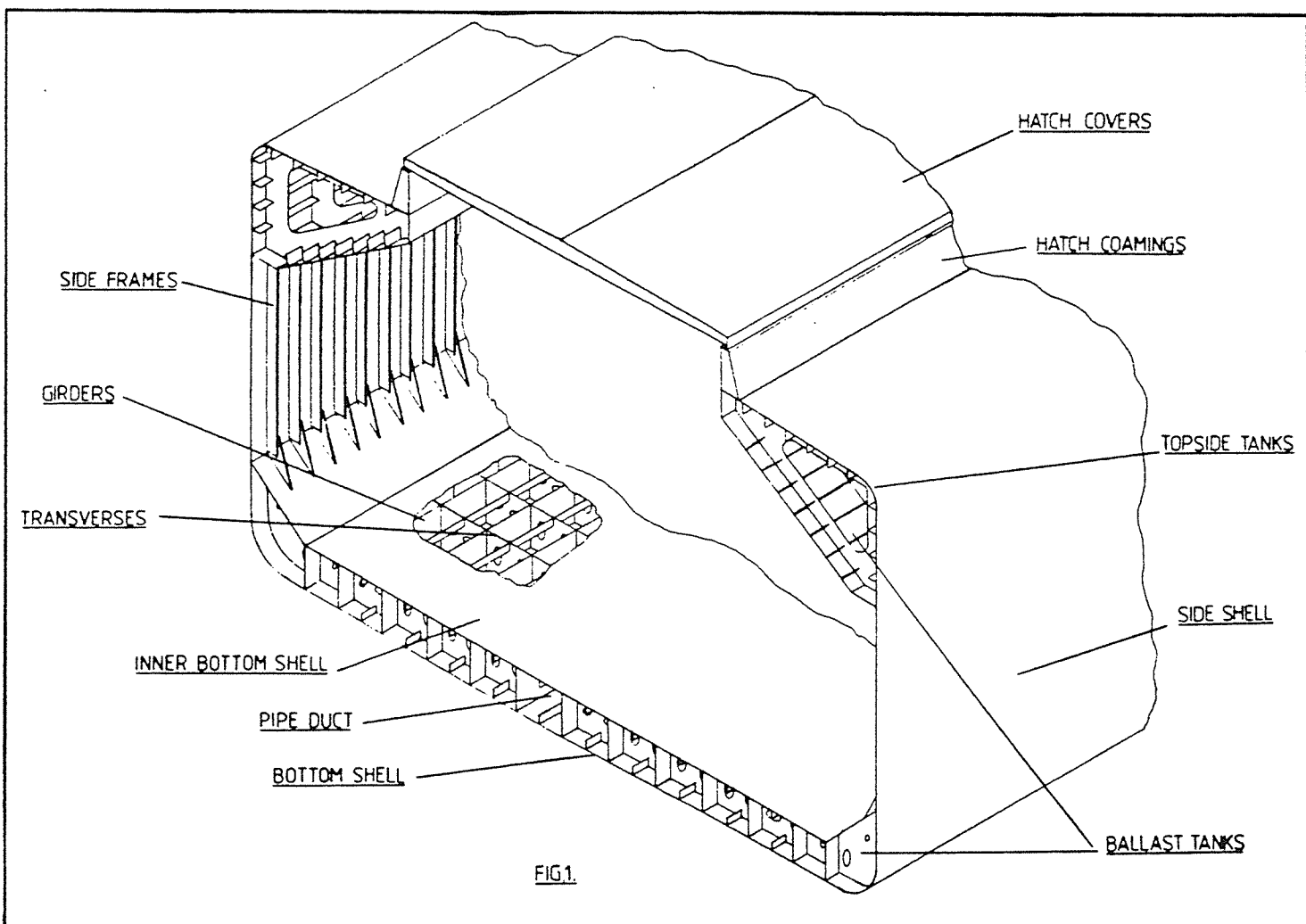
There is no doubt that the established way of life of the bulk carrier will remain much the same in the 90's and for at least the first decade of the next century. Corrosion will reduce structural capability, storms will overload weakened components and fatigue life will continue to be used up. In the absence of an operating climate in which older vessels can be upgraded or retired and newer more reliable vessels built, the marine community as a whole has to find ways of identifying problems before disasters occur. Perhaps the two main factors forcing the issue have been increased political sensitivity to the scale of losses, particularly of human life, and the scale of insurance claims making Underwriters aware of the unacceptable level of risk involved in some of these vessels. Both of these have resulted in an increase in survey activity, the first with more extensive port state inspections and the second with structural warranty surveys carried out by the Salvage Association on behalf of hull

underwriters. This is coupled with more intensive inspection by some Classification Societies and greater scrutiny from P & I Clubs and some flag authorities.

The profusion of surveys to which older vessels in particular are being subjected points the way for reducing bulk carrier losses, though the increase in numbers does not always mean better or more comprehensive inspection. Some rationalisation must happen.

Nevertheless, the increased levels of inspection will identify problems and force owners to rectify them or, if uneconomic, take vessels out of service. To minimise the economic impact, owners will have to take action on their own initiative. If owners follow a firm IRM policy, involving flag or Class on the appropriate occasions, the majority of the problems described in this paper can be avoided or solved at reasonable cost.

It is to be hoped that this practice, will become a key part of the legal concept of 'due diligence', and will spread beyond the 'quality' owners and managers who already use it. Ultimately it should become impossible to operate a ship anywhere in the world where such systems are not applied and perhaps their application will become at least partially incorporated into the definition of seaworthiness.



### Age Structure of the World Bulk Carrier Fleet.

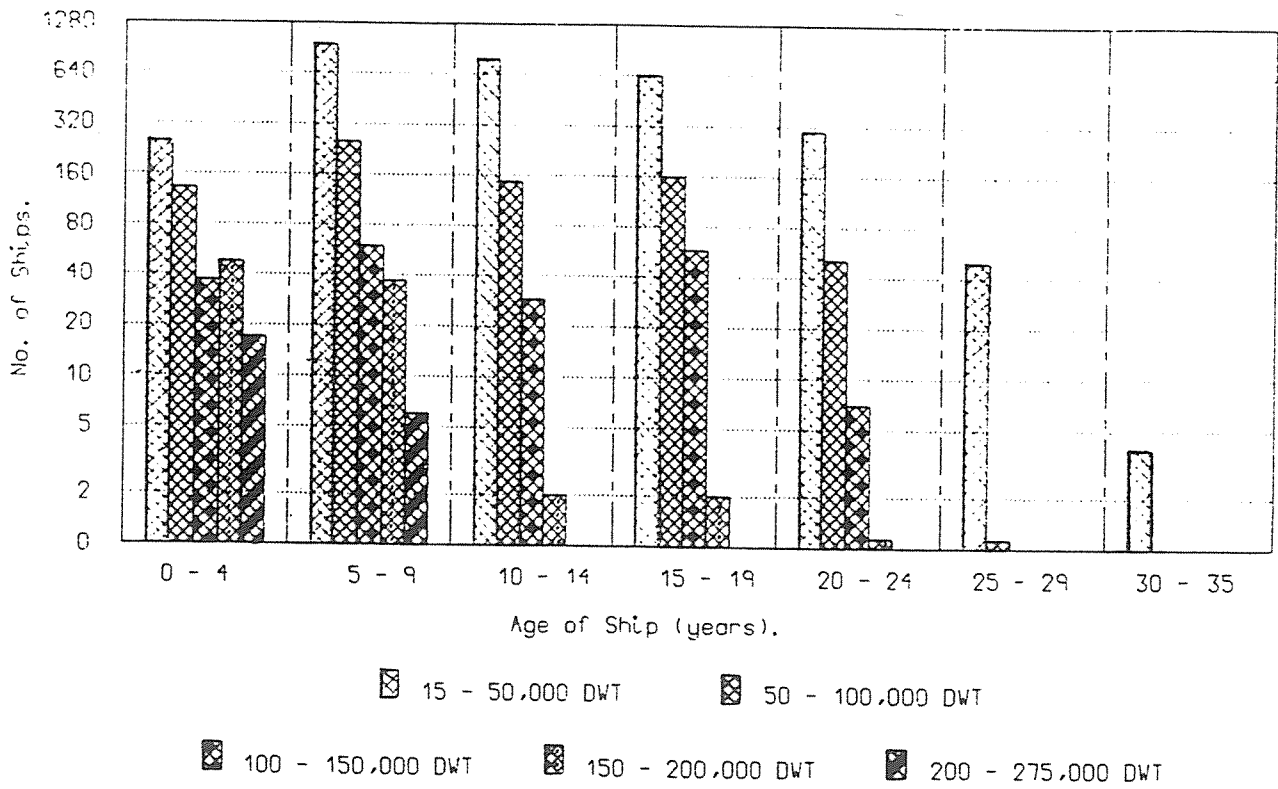
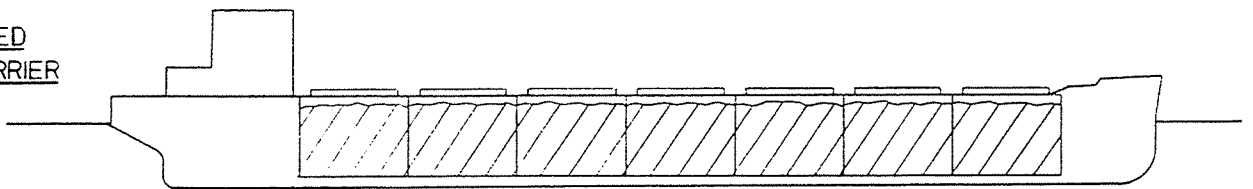


Fig. 2.

LOADED  
BULKCARRIER



LOADED  
ORE STRENGTHENED  
BULKCARRIER

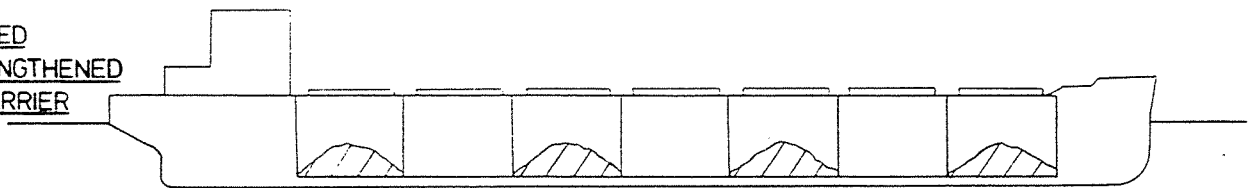
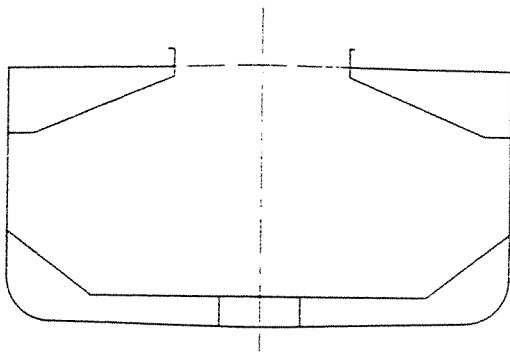
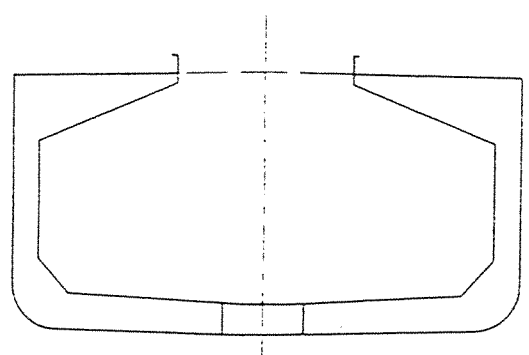


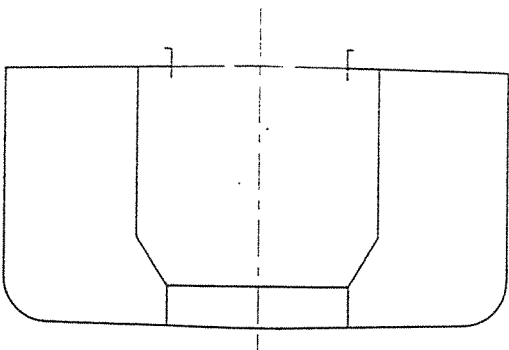
FIG.2.(a)



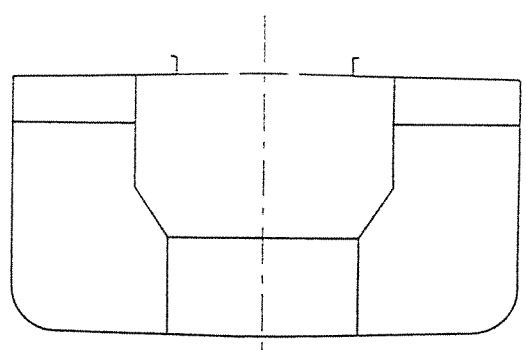
Bulk Carrier/OBO  
Single Skin.



Bulk Carrier/OBO  
Double Skin.



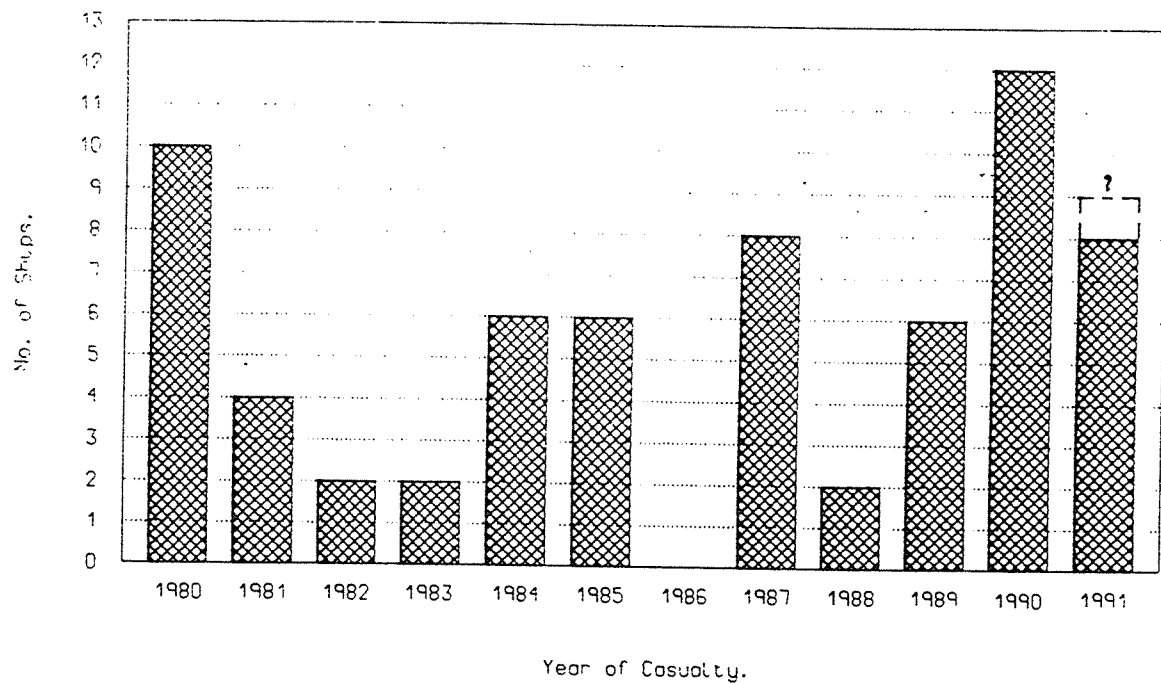
Oil/Ore Carrier.



Ore Carrier.

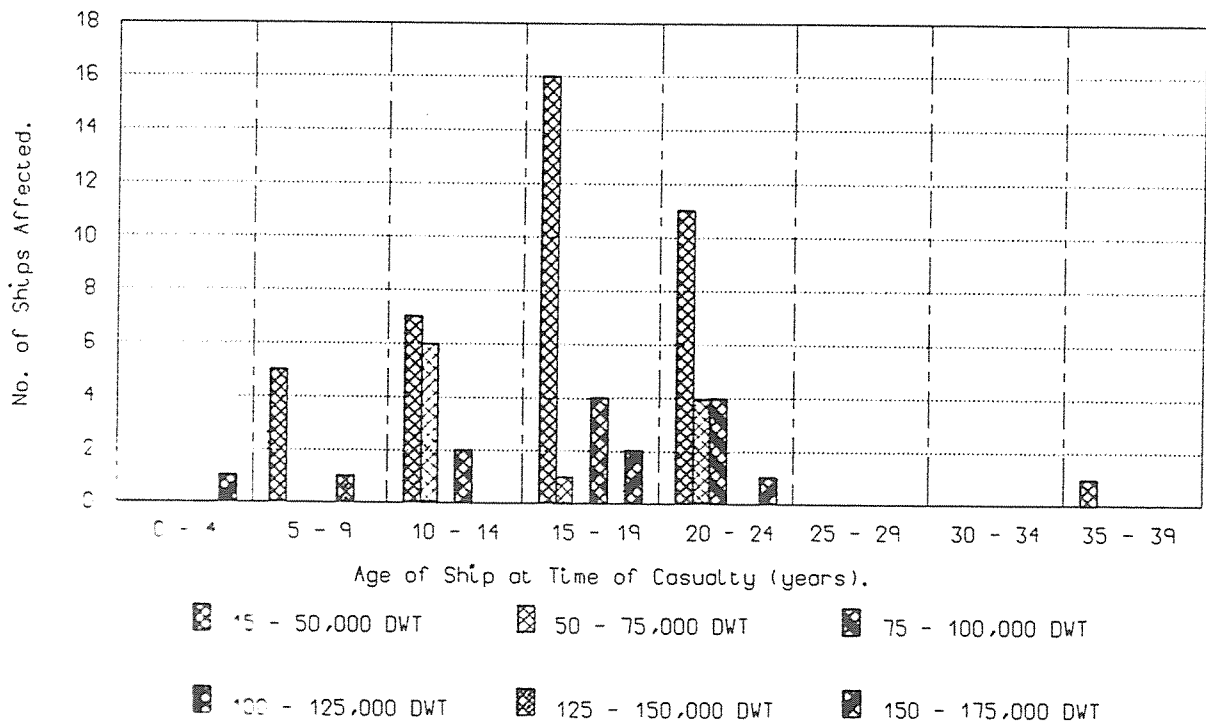
Fig. 2(b)

**Bulk Carrier Total Losses Where Structural Failure May Have Been A Factor  
(1980 - 1991) 15,000 T. DWT Upwards.**

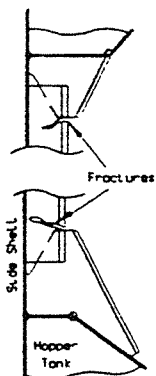


**Fig. 3.**

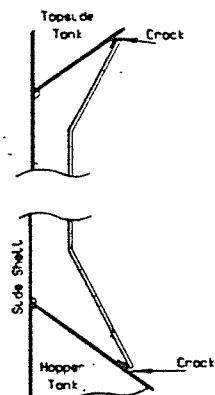
**Bulk Carrier Total Losses Where Structural Failure May Have Been A Factor.  
on Basis of Deadweight and Age. (1980 - August 1991).**



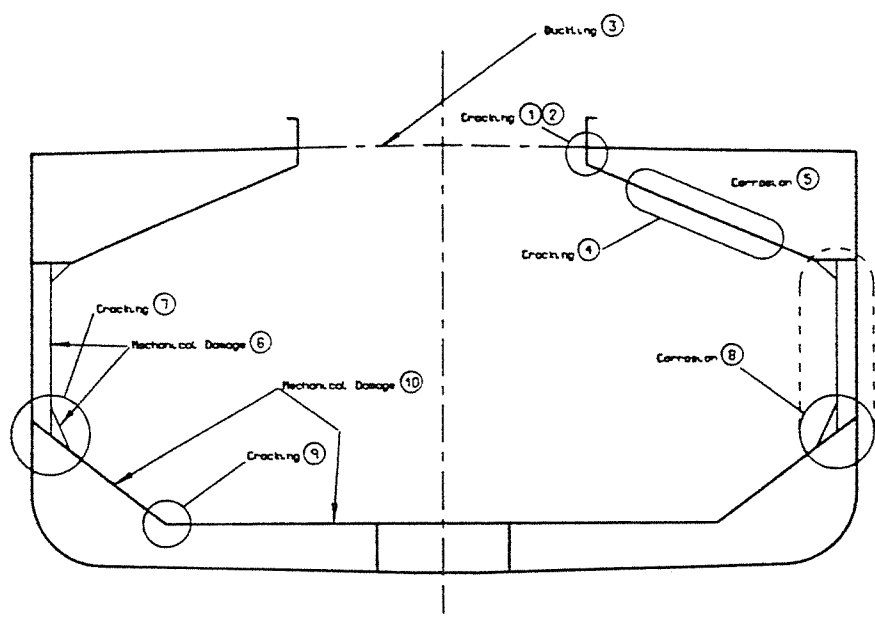
**Fig. 4.**



**Typical Cracking of Side Frame.**



**Typical Cracking of Side Framing.**



**Single Skin Section.**

**Fig. 5.**

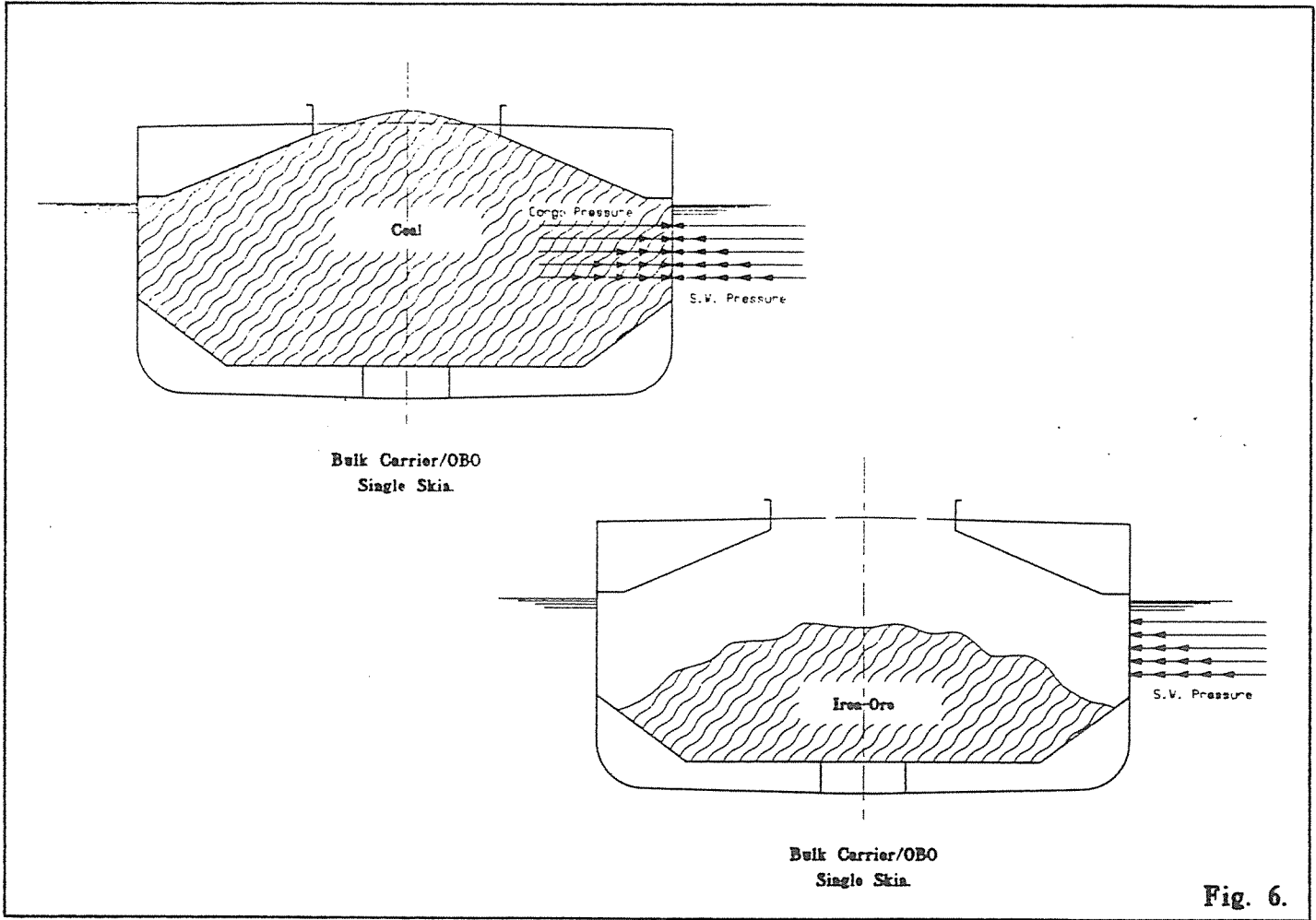
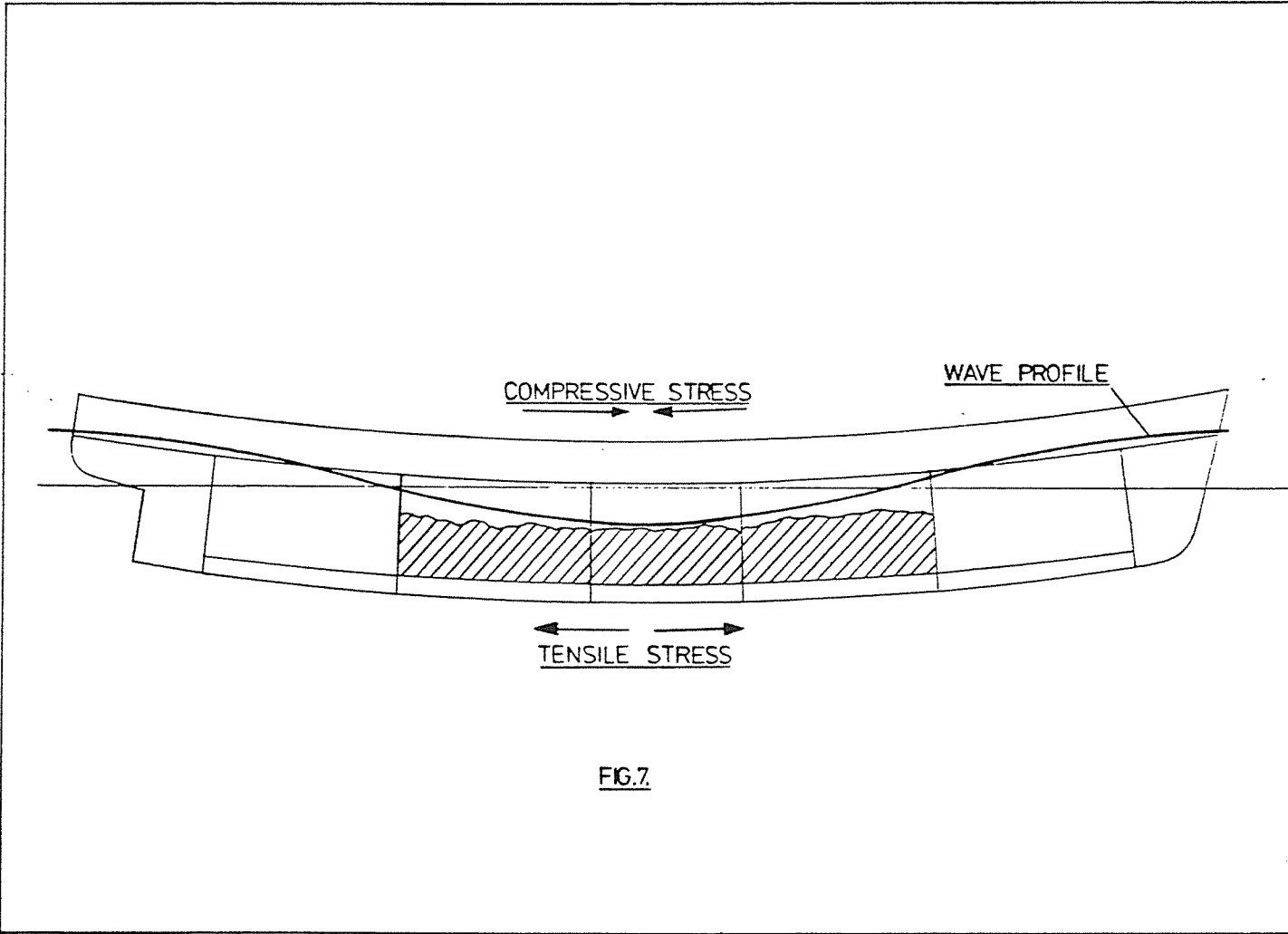


Fig. 6.



**FIG.7.**

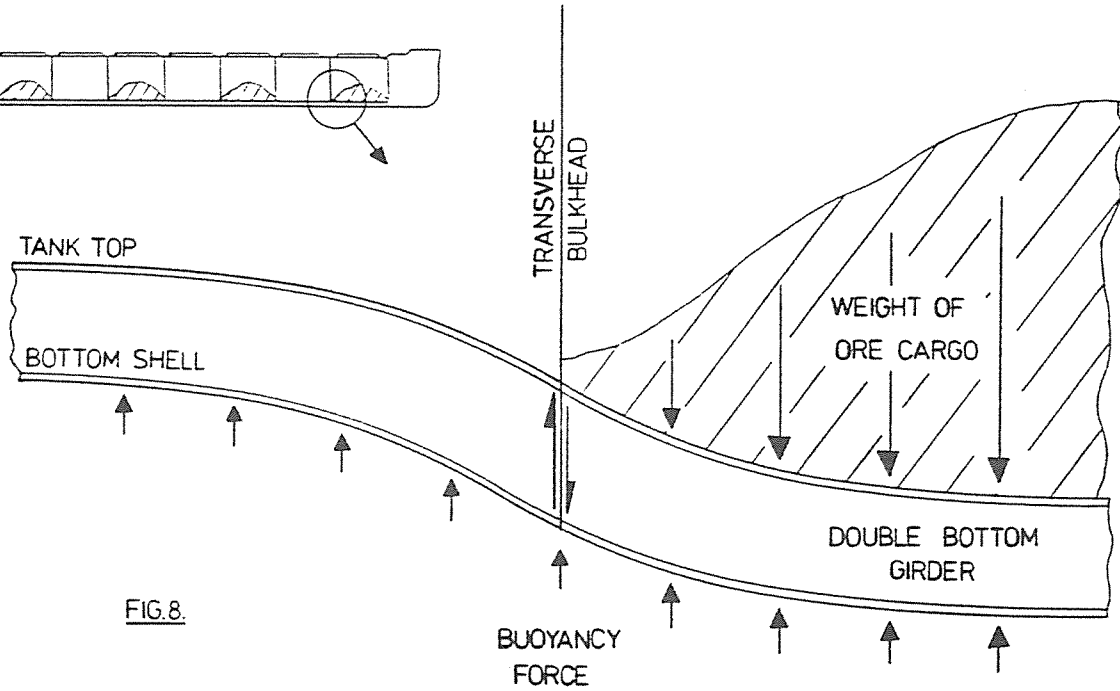
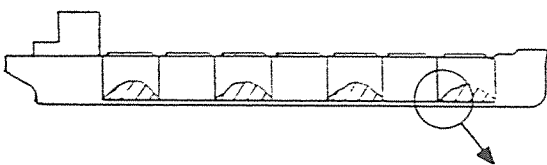


FIG.8.



fig. 9 / KOVLOOM BRIDGE / following probable landing forward

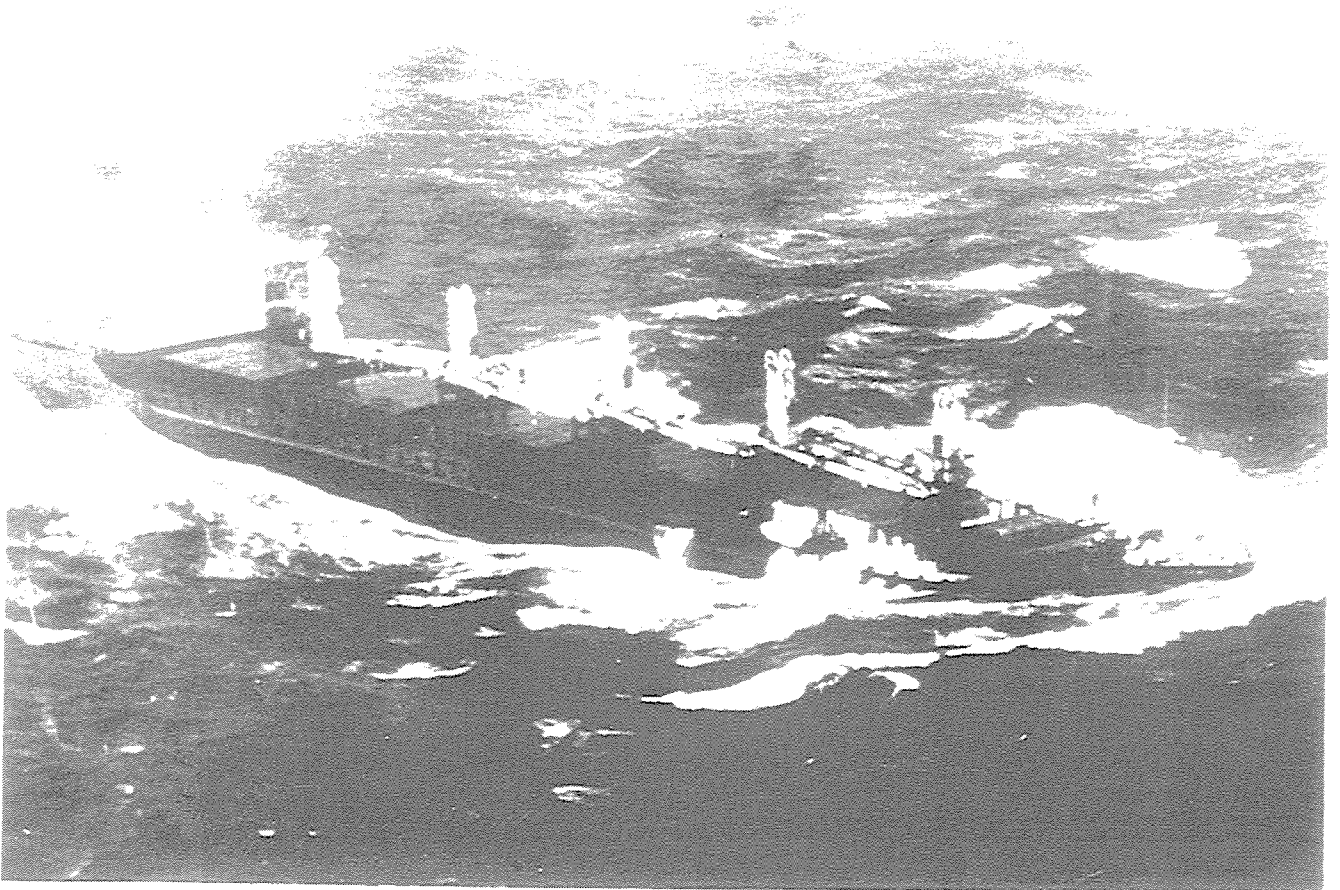


Fig.10 - Marina di Equa

