LATEST DEVELOPMENTS IN THE SUBDIVISION AND CONSTRUCTION STANDARDS OF VESSELS WITH SPECIAL REGARD TO THE PREVENTION OF POLLUTION AFTER DAMAGE

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Summary
The structural integrity and subdivision of ships, particularly oil tankers, are major factors in the prevention of pollution. This paper outlines improvements made to international requirements in this area over recent years and puts these into context in relation to other areas of the maritime industry.

Introduction
The protection of the environment is a concern to all sections of society. A large tanker casualty inevitably attracts media and environmental attention, particularly as result of the immediate impact of the released oil on the local environment and industries.

However, this was not always so as the original development of subdivision standards was in response to a need to improve the survivability of vessels after *collision* damage. Later, as public awareness of the effects of oil pollution increased, standards were established to reduce the potential for pollution, both from an operational and a damage control aspect.

This paper focuses on the improvement of standards to reduce pollution from oil tankers, but the aspects outlined in this paper generally also apply to tankers carrying chemicals in bulk.

Structure
The structure of a vessel is what separates the cargo from the environment. Vessels under the Australian flag and most foreign flag vessels are built and maintained in accordance with the structural requirements of the major international classification societies. At present there is no evidence to suggest that the standards are deficient. Rather, where structural problems have arisen, it has generally been as a result of excessive wastage through poor maintenance and inadequate enforcement of standards. AMSA's port state control activities are directed towards ensuring international adherence to these standards.

There is a perception that modern structural computation methods and the extensive use of higher strength steels has reduced the scantlings of modern vessels to a point where there is now not sufficient allowance for corrosion and wastage in the structure. The maintenance schedules and survey procedures must now be increased to ensure these vessels maintain their strength. The International Maritime Organisation (IMO) is currently developing enhanced requirements in these areas, particularly in relation to tankers and bulk carriers. The economic imperative to reduce the scantlings and hence the lightship weight of the vessel may not be as essential in the tankers of the future as these vessels will in general be restricted in the volume of cargo they can carry rather than the weight of that cargo.

Sub-Division Of Tankers

When the structure is penetrated, such as in a grounding or collision, the amount of pollution that results depends very much on the designed subdivision characteristics of the vessel.

Prior to the International Load Line Convention (ILLC 66)
Prior to the ILLC 66, there were no subdivision requirements for tankers (Figure 1). The Safety Of Life At Sea Convention (SOLAS) made no provisions until the 1981 amendments to the SOLAS 74 convention called for collision bulkheads and watertight bulkheads surrounding the engine room. However, oil tankers built after W.W.II and into the 60's had good survivability characteristics through the low permeability of their cargo spaces, the number of tanks into which the cargo area was subdivided, (up to 27 cargo tanks) cofferdams and pump rooms so characteristic of these types of vessels.

The ILLC 66
ILLC 66 produced the first subdivision standard for cargo vessels carrying liquids in bulk (Figure 2). This standard required a tanker down to its load water line to have a minimum positive, residual stability after the flooding of any one **empty** compartment. In return for meeting this standard the vessel was able to sail with a reduced (type A) freeboard. The incentive for the introduction of this regulation was the increased carrying capacity and hence profitability rather than a desire to minimise pollution of the sea. If the ILLC 66 provided any contribution to pollution prevention it was that oil loss would be contained, as the vessel would survive and be salvageable.

The ILLC 66 also applied a similar standard to other ships, enabling them to operate with reduced freeboards if they met the standard. Ships taking advantage of this provision have generally been designed for carriage of iron ore and other high density bulk cargoes.

MARPOL Convention 1973 (MARPOL 73)
By the early 70's environmental concerns over the amount of oil being released into the sea by tankers both through normal operations and incidents like the *"Torrey Canyon"* disaster forced the IMO in 1973 to adopt the MARPOL Convention, with measures calling for;

- the provision of oil discharge monitoring equipment,
- the provision of segregated ballast tanks (SBT's) for new tankers above 70,000 dwt to operate on ballast voyages without the need to carry ballast in cargo tanks,
- limitations on the length and volume of individual cargo tanks,
- the monitoring of oil discharge and maintenance of the oil record book,
- substantially increased subdivision requirements (over those of the 1966 ILLC) to minimise oil pollution due to side and bottom damage resulting from collision or grounding.

These new provisions created vast changes in the design of tankers (Figure 3).

The provisions specified the extent of damage and the hypothetical outflow of oil resulting from this damage. Importantly, whereas the ILLC 66 requirements assumed that damage would occur to the side of the tanker through collision and would not damage any main subdivision bulkhead, the MARPOL requirements involved assuming damage could occur at any point on the ship's side or bottom. The size of wing tanks were now limited both longitudinally and transversely.

From a commercial view point, one of the main implications of these changes was the requirement for water ballast to be carried in dedicated tanks, which necessitated a larger ship to carry a similar quantity of oil. Through this measure, the quantity of oil that could be carried on a tanker was no longer limited by weight, but by volume.

MARPOL Protocol 1978 (MARPOL 73/78)
A number of factors, including oil pollution incidents occurring subsequent to the MARPOL Convention in 1973 forced the maritime community to review and seek to improve upon those standards. In 1978, through IMO a protocol to MARPOL 73 was introduced (MARPOL 73/78) which provided the following improvements in the design and construction of new tankers (Figure 4):

- the provision of SBT's reduced from 70,000 dwt to 20,000 and 30,000 dwt for new crude and products tankers respectively,
- cargo oil washing of all cargo tanks (COW) rather than the use of water,
- existing tankers to be converted to SBT and COW or to convert existing cargo tanks to dedicated ballast tanks as an interim measure
- provision of the inert gas systems to all cargo tank atmospheres,
- protective location of the SBT's outboard so as to protect the cargo tanks.

The intention of these amendments was to;

- minimise the quantity of oil discharged through routine tanker operations by using the COW system,
- to reduce the risk of fire and explosion by inerting the atmosphere especially during discharge and cleaning operations, and
- to protectively locate segregated ballast spaces along the sides and bottom of the cargo tank area so as to reduce the likelihood of cargo tanks being penetrated from a collision or grounding.

The provision of segregated ballast tanks removed the need to carry water ballast in cargo tanks and hence the need to routinely undertake the potentially hazardous task of cargo tank cleaning and to carry and dispose of slops. The location of the segregated ballast tanks on the outboard side also provided some protection from the spill of oil in the event of a collision. These tanks are required to cover 30 to 45% of the bottom and side shell area in way of the cargo tank length.

Initially, the new designs located the dedicated ballast tanks on the outboard sides, but by the mid 80's tanker builders began to recognise the benefit of double bottoms in prevention of pollution after groundings and began to design tankers, especially products tankers with full length double bottoms dedicated to the carriage of ballast.

It should be noted that, in developing the MARPOL 73/78 requirements, IMO did not adopt the United States' proposal for tankers to be double hulled.

As a result of the *"Exxon Valdez"* stranding in Alaska in 1989, the United States revised its 1978 proposal that the most effective way of protecting all cargo spaces was with double hull spaces (not used for cargo) and acted unilaterally by implementing the Oil Pollution Act (OPA 90) to require all new tankers (phased in for existing tankers) using US ports to be of double hull construction. It should be noted that OPA 90 also includes requirements on oil spill contingency planning and unlimited financial responsibility for clean-up from a spill.

MARPOL 73/78 and Regulation 13F and 13G
The United States sought IMO endorsement of its double hull requirements by proposing further amendments to MARPOL 73/78. This submission was made to the Marine Environment Protection Committee (MEPC). The United States supported its proposals with an extensive research study conducted by the National Academy of Sciences to investigate methods to prevent the outflow of oil from cargo tanks following damage to a tanker.

In considering the United States proposal and the alternative mid-height deck design put forward by Japan (Figure 5), IMO conducted an exhaustive comparative evaluation of the oil outflow characteristics of the two configurations in the event of a low energy grounding or collision. The study showed the two designs to perform equally well under these conditions. Endorsement of the United States' double hull concept, in the March 1992 MARPOL amendments also accorded equivalent acceptability status to the mid-height deck design and determined that the double hull design should be used as a benchmark against which future design proposals will be evaluated by IMO. Guidelines for acceptance of other designs are currently being developed within IMO, but no strong contenders have yet emerged for acceptance alongside the double hull and mid-height deck designs.

These amendments will commence entry into force on 6 July 1993. This is the earliest of the various dates applying to different aspects of the package; it is used to apply the full double hull or equivalent requirements to any oil tanker for which the building or major conversion contract is placed on or after that date.

The package adopted by IMO also contains a set of requirements for existing oil tankers, including:

- requirements limiting the service life of such ships to 25 years unless specified modifications are completed which can permit extension to 30 years -- this can only be extended further if the ship complies with full double hull or equivalent requirements;
- enhanced survey requirements to ensure that the vessel is maintained in a safe condition throughout its service life; and
- carriage of documentation to enable the vessel's survey history to be monitored by surveyors of port states.

The United States' national requirements on double hulls generally parallel those agreed by IMO . However, the United States has not accepted that the mid-height deck or other tanker designs can be equivalent to double hulls. Should this situation continue, any new tanker which is not of double hull type would be excluded from United States ports.

At present, a tanker owner contemplating new tonnage will invariably order a tanker meeting the latest amendments to MARPOL and ILLC, and be of double hull construction, as to do otherwise would preclude the vessel from trading into US ports. The US action has, therefore prevented the arguable superiority of the mid-height deck design being recognised through building orders.

Characteristics of the double hull and mid-height deck designs
MARPOL 73/78 calls for survival from bottom raking damage of 40 to 60% of the length from the fore end depending on ship size.
The double hull configuration is designed to contain oil in cases of low energy grounding or collision. For the double hull configuration, the segregated ballast tanks (SBT) may be arranged as;

- U type with no longitudinal bulkhead separation,
- J type with centre line longitudinal bulkhead,
- L and I section ballast tanks,
- J type with upper wing tanks, or
- separate double bottoms arrangements.

Each of these arrangements affect the residual stability of the vessel after damage.

In the case of the double hull design, where the inner hull is breached, there will be a total outflow of oil from the damaged compartments. The width of the SBT space of the double hull design is much less than the transverse extent of collision damage of B/5 required by ILLC 66.

The configuration of the mid-height deck design provides a suitable alternative (Figure 6). This configuration has wider wing tanks than the double hull design and has no empty double bottoms. In groundings, the oil in lower cargo tanks is retained on board through hydrostatic pressure removing the small ullage space above the cargo.

Both designs are reported to be of similar capital cost, being about 20% more expensive to build than their predecessor MARPOL 73/78 tankers, although the mid-height deck design may be slightly cheaper to build than the double hull design.

In a double hull tanker the cargo block is subdivided transversely and often longitudinally. In the mid-height deck tanker, the cargo oil block is also subdivided vertically by the mid-height deck.

One of the ramifications of double hull and mid-height deck designs is their susceptibility to intact and damage stability problems unless special care is taken in the early design stages. Other ramifications include the arrangement of the SBT's to allow adequate inspection, maintenance and ventilation of these spaces.

Despite these changes and improvements, none of these designs will guarantee containment of oil in a high energy collision, or grounding. Such a guarantee would not appear achievable as long as oil is carried by sea, as illustrated by the break-up of the *"Braer"* by heavy seas following its grounding.

The double hull requirement has also increased the volume of hull dedicated to ballast tanks and thus extended the volume (as against weight) limitations on cargo capacity which commenced with MARPOL.

It should also be noted that the introduction of double hull tankers has given rise to concerns of an increased risk of explosion due to accumulation of petroleum vapours, particularly in double bottom ballast spaces.

Tank Size Limitations And Hypothetical Oil Outflow
The fitting of a longitudinal bulkhead serves to reduce tank size and hypothetical oil outflow. It also helps to reduce free surface effects and hence increase the residual damage stability of the vessel.

Under these regulations, the size of the mid-height deck tanker cargo tanks can be larger (if the upper and lower tank volumes are combined) and hence with a mid-height deck tanker there is the opportunity to have fewer bulkheads and tanks. The mid-height deck tanker designs show better hypothetical oil outflow characteristics from side damage which can be explained by the larger double side width.

IMO has recognised that the present formula for determining oil outflow may not be satisfactorily representing the different arrangements now being put forward and is attempting to improve the method to give more realistic results.

Other Alternatives
Other alternatives include the *"Rescue Pipe"* variant of the mid-height deck design where oil can be siphoned from damaged tanks into undamaged, intact tanks, and the *"Coulombi Egg"* design.

Other alternatives have been included in the measures applicable to existing tankers such as to restrict loading of oil into tanks to a level where the hydrostatic pressure is balanced. That is;

$$h1 * SGsw = h2 * SGoil$$

Summary
It can be seen from the foregoing that international requirements introduced over the past 20 years have substantially reduced the potential for pollution resulting from grounding or collision of an oil tanker.

Subdivision In Dry Cargo Ships

IMO recently enacted provisions in SOLAS for the damage stability of Dry Cargo Ships not covered by the damage stability requirements of other IMO instruments such as the ILLC 66 subdivision requirements for assignment of reduced freeboard. These provisions are probabilistic in nature and apply to vessels 100m and over in length. Their aim is to improve the survivability of vessels after damage rather than as a measure to prevent the potential for pollution. However, they have the indirect effect of improving the salvage ability of damaged vessels and thus reducing the potential for pollution. Prior to these provisions, there were effectively no subdivision requirements applicable to these vessels apart from the requirements for a collision bulkhead forward and a transverse, watertight bulkhead to protect the engine room compartment. Vessels covered by the new provisions include bulk carriers, container ships and ro/ro vessels.

This probabilistic concept is based on statistical data derived from approximately 250 incidents. It is not specific on damage location, but rather uses probabilistic density functions to determine the overall survivability of the vessel. Vessels with wing compartments extending well inboard and having numerous transverse, watertight bulkheads have little trouble meeting the standard. As such, bulk carriers, especially the large ones, easily meet the standard. The vessels which do have trouble meeting this standard are the smaller ro/ro vessels around 100 to 140m in length with their long vehicle decks, well below the freeboard deck, extending to the collision bulkhead.

Interestingly, the standard provides no benefits for vessels fitted with double bottoms as the vertical extent of damage is considered to extend through the bottom to the freeboard deck. There is no guarantee that a vessel meeting this standard will survive damage to one compartment.

Introduction of this standard to ships built since February 1992 has substantially increased the survivability of these vessels after damage, and IMO is currently looking at extending it application to dry cargo vessels under 100m in length.

Future - Possible Improvements
Possible improvements in the subdivision of ships has to be viewed in the context of what is feasible in the international arena. Do we need another *Exxon Valdez?* The whole international agenda is driven by vested interests. These vested interests include countries with large merchant fleets who would not wish to see legislation which made

existing ships obsolete before the economic end of their working life. It also includes countries with large ship building capacities who would benefit from the introduction of legislation requiring the building of new vessels. Australia, as a minor shipping nation would need to convince countries with large shipping and ship building interests that stronger regulations are required. This would include strong justification that stricter requirements are really necessary, in view of the recent improvements already outlined above.

Bearing in mind that the improvements outlined above relate to "hardware" whereas it has been demonstrated that about 80% of accidents are due to human error, these countries would need to be convinced that further new construction requirements did not merely compensate for an inability to adequately respond to the need to reduce the effect of human factors.

We also have to recognise the impact of strengthened regulation which could make new vessels less economic than existing vessels. Hence ship owners will retain their existing vessels and therefore defeating the purpose of the new regulation. Retrospective legislation could be enacted or Australian ports could restrict entry to the new vessels only. Such things raise the question of "Grandfather clauses" and retrospective legislation.

Normally new construction rules only apply to new ships as it is impracticable to alter the basic design of existing vessels, But this may result in the new ships having a distinct economic disadvantage. One example of where this problem has been addressed is the introduction of requirements for existing tankers (MARPOL 73/78, Reg 13G) at the same time as those for new tankers (MARPOL 73/78 Reg. 13F). These provisions will reduce the carrying capacity, but not the overall number of vessels. They would not immediately make existing vessels unemployable and hence would not lead to a shortage of vessels. On the down side, such vessels with cargo tanks only partially full would need to withstand the increased sloshing loads of the slack tanks and thus be subject of more stringent structural requirements.

On the structural side, part of the new requirements for tankers and bulk carrier's are improved and strengthened survey requirements for these ships and that involves making information available to port state authorities which originally was only available to the owner and class society. This would ensure that standards are maintained and more importantly, documented.

Conclusion

This paper has summarised recent developments in the structure and subdivision of ships as applied to the prevention of pollution.

On the structural side, existing standards are adequate so long as sufficient attention is paid to the enforcement of those standards.

With regard to subdivision, significant improvements have been made in recent years. Standards for subdivision of the larger dry ships were introduced in 1992 where previously none existed. Tanker subdivision requirements have been substantially upgraded in a series of amendments to MARPOL, to the stage where the latest tanker new buildings are truly environmentally friendly.

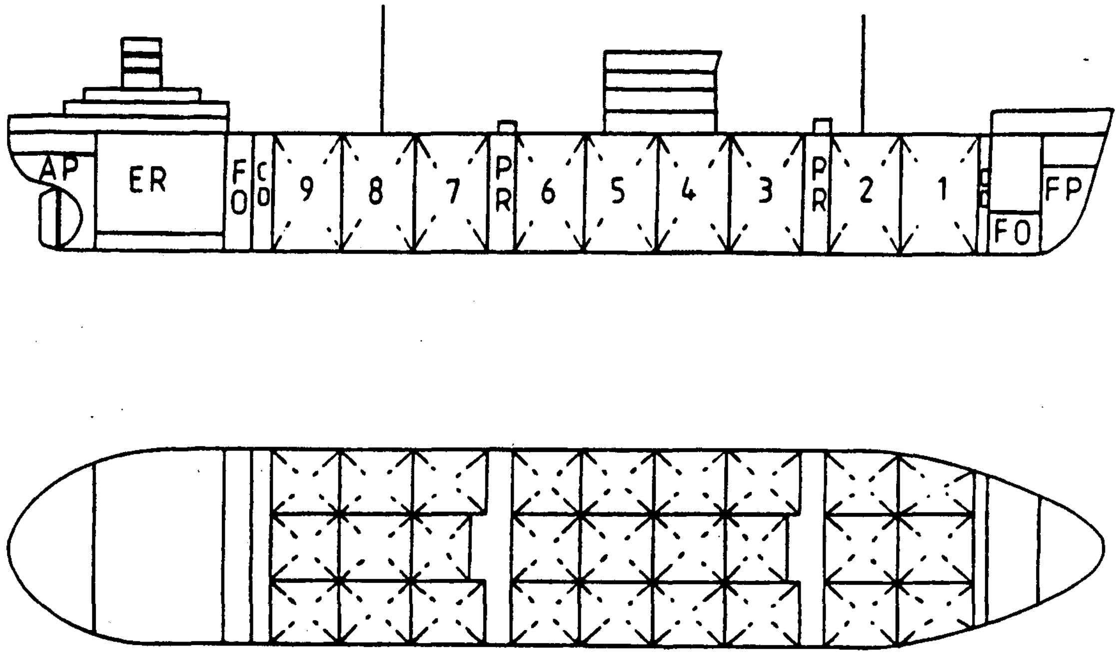

FIGURE 1. TYPICAL SUBDIVISION OF A POST WAR TANKER

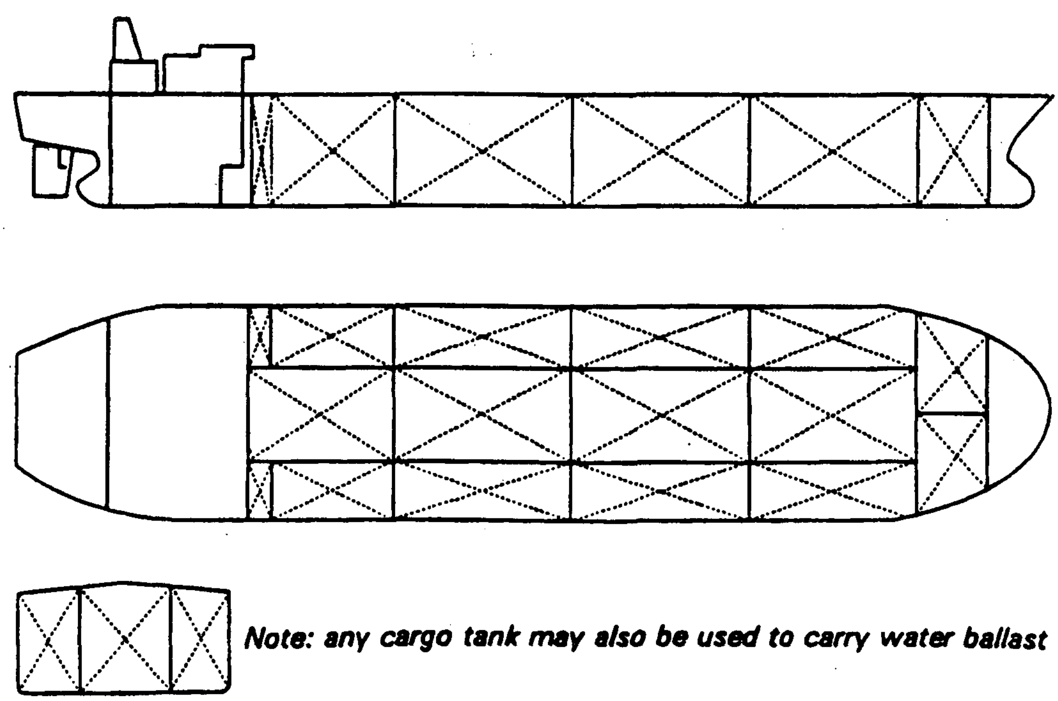

FIGURE 2: PRE-MARPOL TANKER

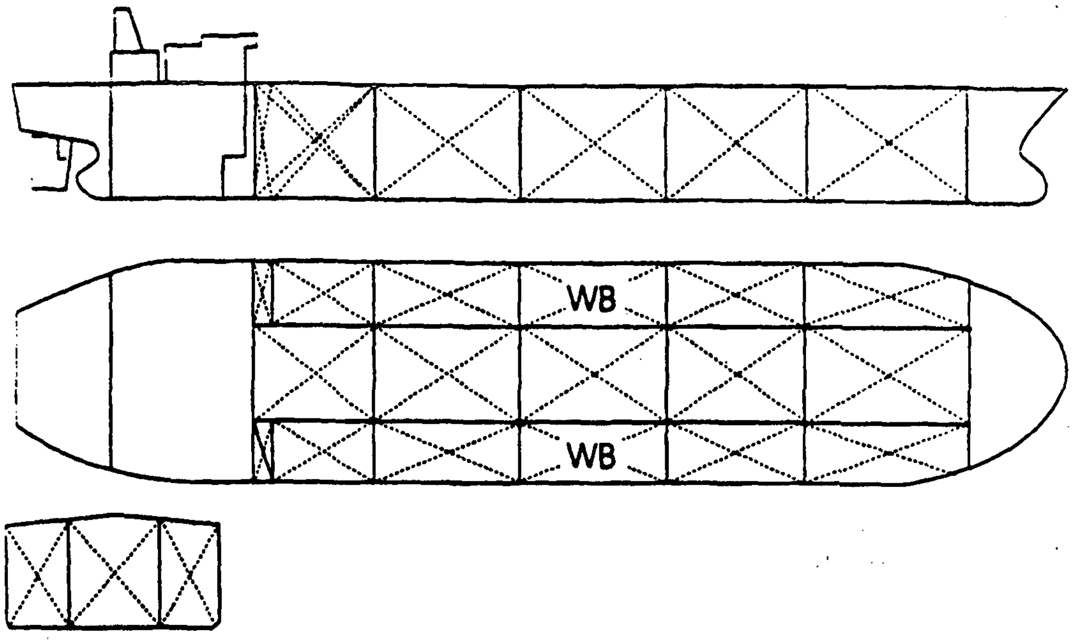

FIGURE 3. MARPOL '73 TANKER
Note: segregated ballast tanks marked WB

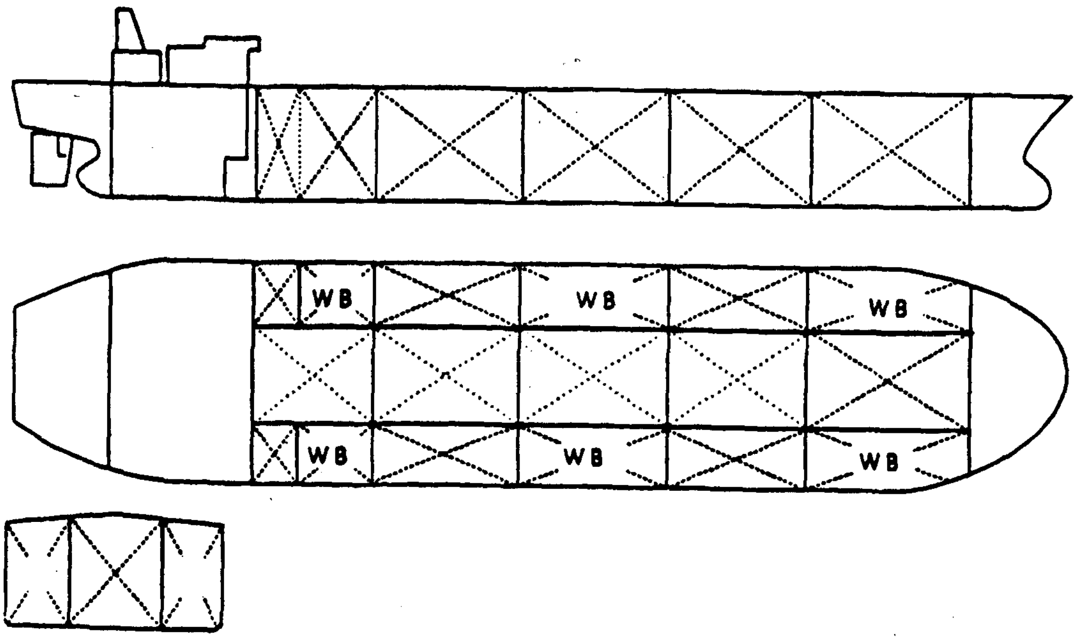

FIGURE 4. MARPOL 73/78 TANKER
Note: segregated ballast tanks marked WB.

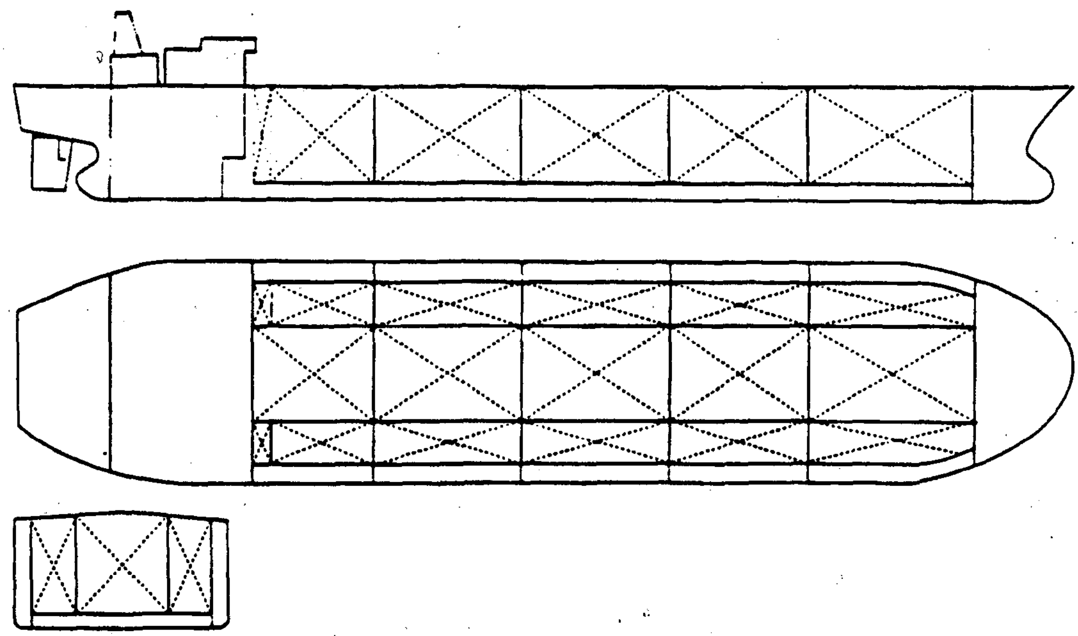

FIGURE 5: DOUBLE HULL TANKER

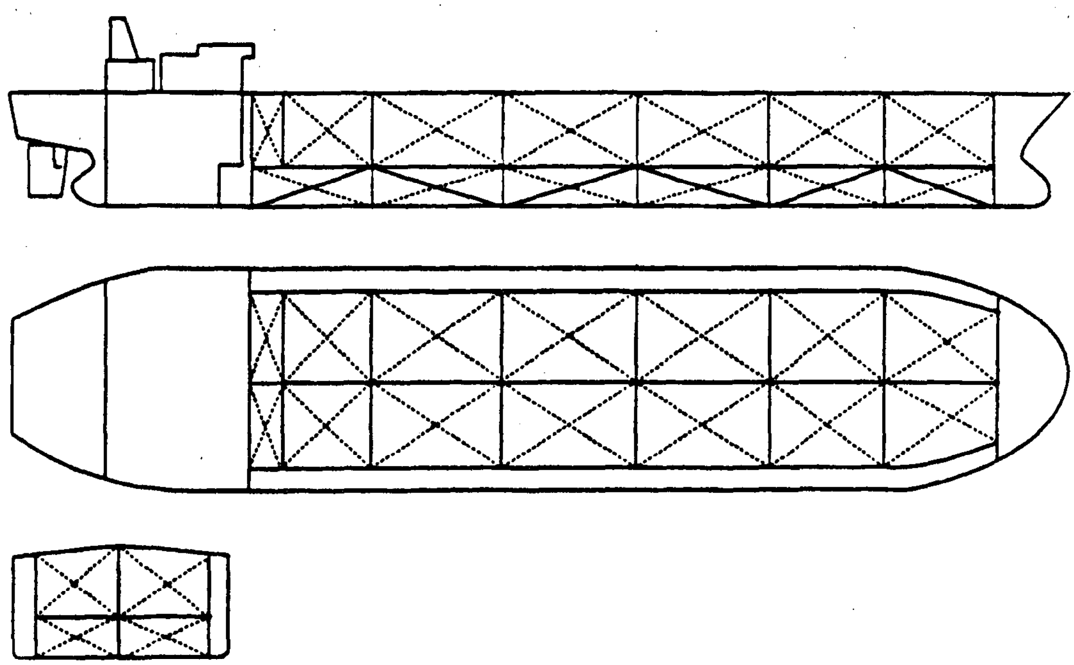

FIGURE 6. MID-HEIGHT DECK TANKER

QUESTIONS AND ANSWERS*

Robin Gehling's presentation

Question
I think that it is important to stress that the whole objective of designing a double hull or mid-deck tanker is to reduce oil outflow in the event of a grounding or collision, and the design has been made specifically to cover low impact grounding and low impact collisions, and in the case of the *Exxon Valdez,* probably a double hull would not have made any difference. So it's not the "be all and end all" of preventing oil pollution at sea, but certainly a mechanism which is designed to reduce or minimise.

Answer
Yes, that's a point in my paper that I didn't get around to making. I would also add that as well as the *Exxon Valdez,* if you've seen the TV footage of the *Braer* grounding onto the rocks in the Shetlands, a double hull would have made absolutely no difference.

Question
When you're talking about low impact, how do you define it? It was clear that the *Braer* was high impact collision, but the *Exxon Valdez* grounding was a reasonably calm day, so was that high or low impact?

Answer
Generally speaking, it's not defined. If there is likely to be penetration into the vessel by more than about two metres then it is a high impact incident, because double hulls won't make any difference.

Question
You said there's a danger in a double hull tanker of explosive mixtures in the ballast tanks. Are they taking any steps to make "inert" those ballast tanks?

Answer
It's still being talked about to my knowledge. It's still being considered as a safety issue by the Maritime Safety Committee.

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* Note: This text is not a verbatim record of the questions and answers. To assist with comprehension, the Editor has deleted some text and made modifications to highlight key points. Speakers are not identified.