



European Maritime Safety Agency

**Double Hull Tankers:  
High Level Panel of Experts  
REPORT**

3<sup>rd</sup> June 2005



# Double Hull Tankers:

## High Level Panel of Experts REPORT

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## **1. The High Level Panel**

The Panel was comprised of senior representatives from:

Baltic and International Maritime Council (BIMCO);  
The Community of European Shipyards' Associations (CESA);  
European Commission (DG TREN);  
European Maritime Safety Agency (EMSA);  
International Association of Classification Societies (IACS);  
International Chamber of Shipping (ICS);  
International Maritime Organization (IMO);  
International Association of Independent Tanker Owners (INTERTANKO);  
Oil Companies International Marine Forum (OCIMF).

Terms of reference for the work of the Panel were developed during the Panel's initial meetings. For details of the agreed terms of reference for the Panel and for participating Panel members see **Attachments 1 & 2.**

Meetings in Brussels:

1. Kick off meeting: 30 April 2004
2. 9 July 2004
3. 1 October 2004
4. 30 November 2004
5. 1 February 2005
6. Concluding meeting 31 March 2005
7. *Benchmark meeting October 2005 to assess progress made towards implementation of the Panel's recommendations and to review the status of the TSCF Double hull tanker structures maintenance manual.*

## **2. Executive summary**

The Double Hull Tanker Panel was established in April 2004 as an EMSA initiative following the 'Maritime Safety Seminar on Double Hull Tankers' that was hosted by the European Commission in November 2003.

One of the major issues that was discussed at this seminar, was the understanding that the introduction of the double hulled tanker would not be the panacea for prevention of future pollution from tankers at sea. In this respect, it was agreed that whilst the introduction of the double hulled tanker would undoubtedly lead to a reduction in pollution, further refinements to the stringent safety regime were still possible, and that this should be explored by Industry and regulators.

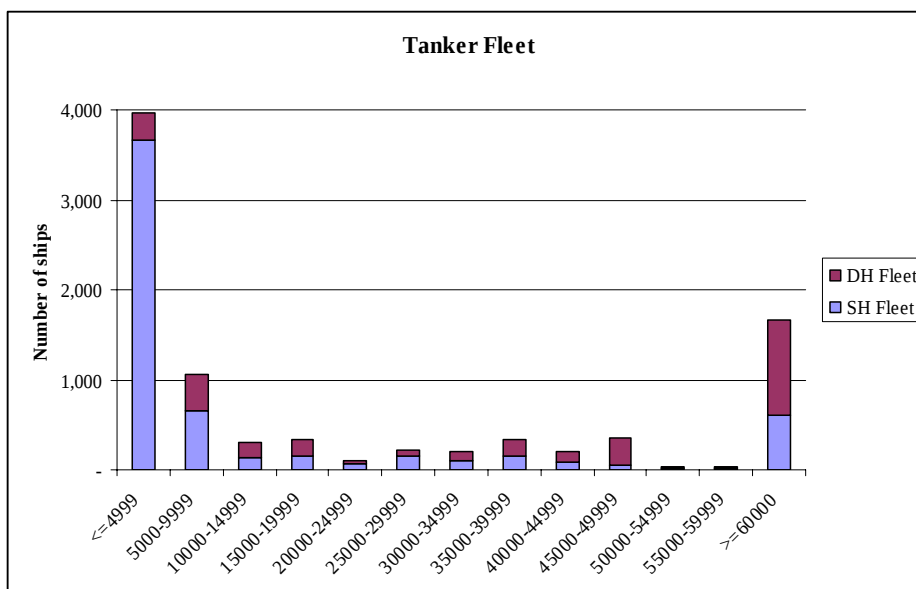
The primary goals of the Panel were therefore to stimulate an informed debate between Industry and regulators and to initiate pro-active measures for Double Hull Tankers that would lead to further improvements in tanker safety and protection of the marine environment.

The Panel met six times in the period April 2004 to April 2005 and during the course of its work, took note of the concerns of the Maritime Community that, following the phase out of single hulled tankers, there would be additional and/or different challenges associated with the new double hulled vessels that MARPOL required. These concerns were raised following the limited amount of feedback that had been received from Double Hull Tankers in service.

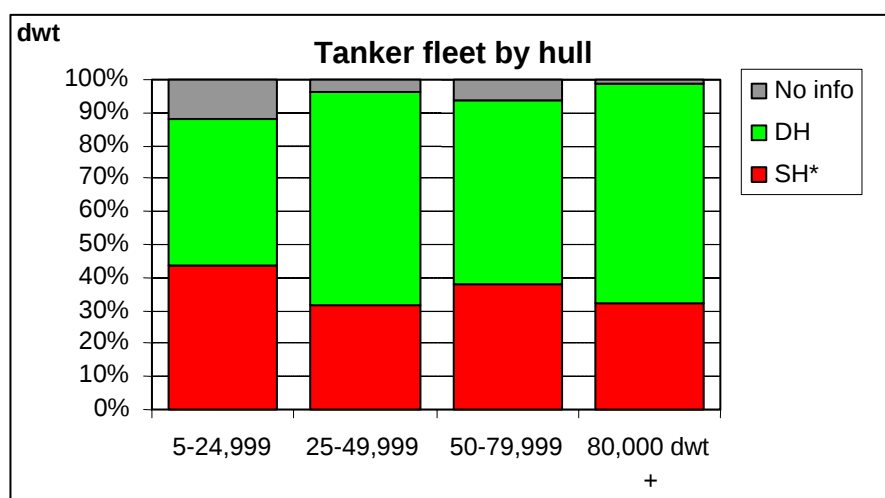
### Statistics:

At the end of 2004, some 65% by tonnage and 56% by number of existing tankers above 5,000 dwt, were double hulled.<sup>1</sup>

*Current breakdown of the single and double hull world tanker fleet by numbers and Deadweight (DWT):*



Source: CESA based on Lloyd's Register/Fairplay



Source: INTERTANKO

### Note:

Data on single hull tankers includes Double Bottom and Double Side Tankers (7% by number and 2% by Tonnage) There are also tankers, for which there is no detailed information in the data bases that were used, particularly for the smaller sized tankers.

<sup>1</sup> Tankers of more than 5 000 DWT. Tankers less than 5.000 DWT are excluded from phase out regulations and out of 8771 tankers in total (global fleet end of 2004, comprising pure chemical tankers, oil-chemical tankers and oil or product tankers), 3302 tankers are < 5.000 DWT, and of these - 1071 tankers (32%) are older than 30 years and 977 tankers (30%) are 20-30 years old. (information provided by CESA)

#### *Approach:*

Although the Panel's terms of reference did not exclude the consideration of any significant double hull tanker issue, the Panel recognized that the principal concerns brought about by the change from single to double hull geometry, related in the main, to factors that could adversely influence a vessel's hull structural integrity throughout its service life.

Following on from this, the Panel reviewed a number of possible control measures, with a view to minimizing or mitigating the concerns that they had identified.

The principal areas of concern identified by the Panel were:

- Accelerated structural corrosion in cargo and ballast tanks;
- Coating performance in tanks, including premature breakdown;
- Fatigue;
- Hull inspection and maintenance practices;
- Variations in workmanship and in construction standards during new building and during repairs;
- Variations in the content of Classification surveys (during new building and during repairs on ships in service).

Additionally the Panel considered the possibilities of loss of integrity to the cargo oil tank boundaries with hydrocarbon seepage into the double hull and double bottom spaces.

The Panel has made eight recommendations that are designed to minimize or mitigate potential problems related to these areas of concern. The Panel intends to promote these recommendations by means of the following mechanisms:

- Amendments to International regulations through IMO;
- Amendments to Classification requirements and procedures;
- Improved guidelines and self regulation by Industry.

For details of the measures that are proposed by the Panel see 'Recommendations' in paragraph 6 below.

The Panel noted that a number of the concerns that were identified were not 'new' and that some had been raised in other fora. In this context the Recommendations of the Panel may be viewed as supportive of the initiatives that are currently being progressed elsewhere.

Taking into consideration the imminent phase out of single skin tonnage and the increase in double hull new building that is now underway, the Panel suggests that some degree of urgency should be attached to a number of the report's formal recommendations, to enable their effective and timely implementation.

### **3. Background**

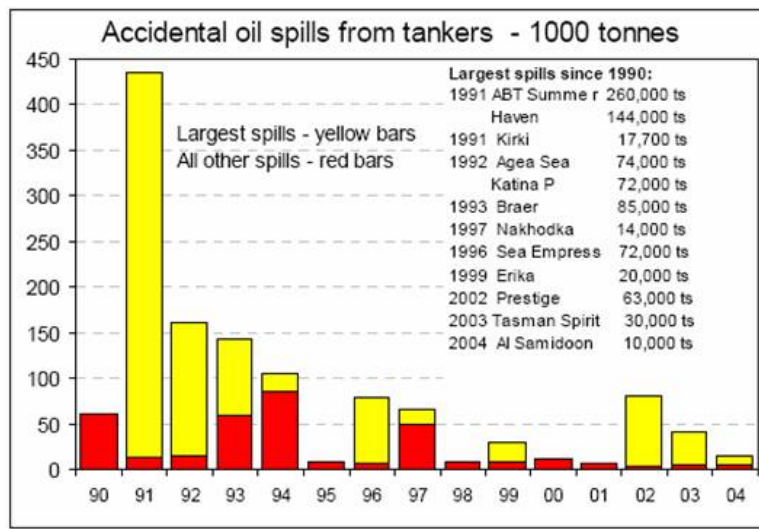
The background to the phase out of single hull tankers and the introduction of mandatory double hull structural arrangements for tankers is now a matter for history. Tanker losses and the catastrophic environmental pollution that is associated with such incidents are events that society has indicated they will no longer tolerate<sup>2</sup>.

One of the principal ongoing tasks that the Maritime Community faces is to ensure that all practicable measures are taken in order to minimise the risks to life and to the environment associated with the transport of oil by sea. This process has been underway for some time now and real progress has been made and continues to be made. However, the oceans will always provide a challenging environment for the transport of oil by ships and in the future, accidental spills and environmental pollution will undoubtedly re-occur.

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<sup>2</sup> For a listing of major tanker oil spills since the Torrey Canyon disaster in 1967 see the table in **Attachment 3**

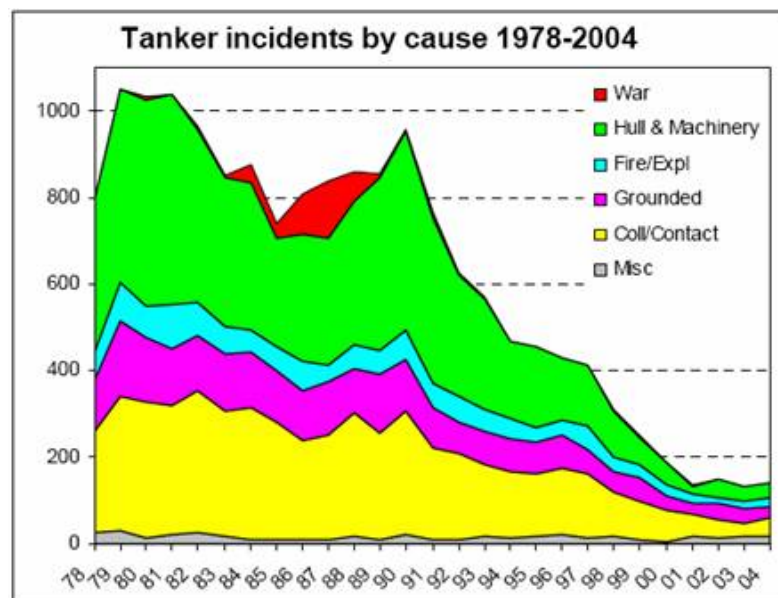
## Oil spills:



Source: INTERTANKO

The introduction of double hull structural arrangements for tankers has clearly been an important step forward in reducing the risk of spills. Already a number of cases have occurred in which a tanker's outer hull has been breached, but pollution has been avoided by the containment afforded by the intact inner hull.

Notwithstanding these factors there are still a number of possible initiators that can lead to structural damage with the potential for consequential oil spills. Fire, explosion, collision, grounding, machinery or hull structural failure and human factors are only to name but a few.



Source: INTERTANKO

Whilst it is recognised that for low energy collisions and minor groundings, the double hulled tanker is much less likely to spill oil than a single hulled tanker, for some of the incidents that are recorded above a double hulled tanker may fare no better than its single skinned predecessor.

OCIMF paper: Double hull tankers - are they the answer? ref.10

*"Double Hulled vessels are regarded by some as the answer to all the problems of transportation of oil at sea without pollution. Whilst it is acknowledged that double hulled vessels have some advantage over single hulled vessels, indeed they will provide added security in low impact collisions and groundings, both designs will be inadequate if poorly maintained and operated.*

*Double Hulled tankers because of their complex design and structure are potentially more susceptible to problems of poor maintenance and operation. Double Hulled tankers may only be the answer if combined with; high quality operation, maintenance, classification surveys, and proper policing by flag state and port state."*

Additionally, following on from the operational experience that has been gained to date, from double hull tankers in service, there are concerns that are specifically related to the double hull arrangements of this new class of vessel. (OCIMF paper: Double hull tankers - are they the answer? ref.10).

*"The obvious hazard, which all operators of double hull tankers will need to guard against, is that of cargo leakage into the ballast spaces. .... Leakage arises from small fractures in bulkhead plating between cargo and ballast tanks which may be caused by unpredicted local stress concentration, fatigue, construction defect or, eventually, corrosion through failure of the protective coating system. The structural design of double hull tankers renders them more susceptible to minor failures of this type than the single hull designs. Apart from taking even more care at the design and construction phases, regular inspection of the structure to detect incipient failures will be a necessary operational routine."*

It is these issues and these circumstances that have led EMSA to form the 'High level Panel of Experts', whose principal task is to further improve the increased levels of safety that are provided by this new generation of vessels.

#### **4. Areas for consideration**

During the course of its meetings, the Panel identified a number of issues that it felt warranted consideration and which would be a cause for concern if not adequately addressed. The principal concerns noted by the Panel were:

1. Accelerated structural corrosion in water ballast and in cargo tanks;
2. The lack of mandatory provisions relating to coatings for cargo and ballast tanks;
3. Fatigue;
4. A demanding and difficult maintenance regime which, if not properly observed could lead to structural deterioration;
5. Lack of mandatory and harmonized procedures for monitoring workmanship and standards of construction during the vessel's new building stage;
6. Lack of mandatory and harmonized procedures for monitoring workmanship and steelwork repair standards during vessel repairs;
7. Inconsistencies between Classification Societies in their approach to inspection and survey - during new building and during repairs on vessels in service.

Other issues that were raised by the Panel were:

8. Possible use of inert gas in ballast spaces;
9. Hydrocarbon gas detection in ballast spaces;
10. Alignment (misalignment) between structural members (may lead to failures in service);
11. Structural geometry and member thicknesses;
12. Access for structural surveys in service;
13. Robust designs and fitness for purpose;
14. Corrosion margins on new building hull structural elements.

The Panel felt that the IACS Joint Tanker Project (JTP) on common structural rules for tankers (due to enter in force on 1 January 2006), recent amendments to SOLAS relating to permanent means of access and the IMO amendments to Resolution A.744(18) would provide some answers to the concerns associated with items 10. - 14. that are listed above, and on this basis these issues were not considered in any great depth by the Panel.

## **5. Findings and discussions on areas for concern identified by the Panel.**

### **1) Accelerated structural corrosion in water ballast and cargo tanks:**

A limited but significant number of double hull tankers have been found to be suffering from accelerated corrosion in areas of their cargo and ballast tanks. It is now generally agreed that the 'thermos bottle effect', in which heated cargoes retain their loading temperatures for much longer periods, promotes an environment within the cargo and ballast tanks that is more aggressive from the viewpoint of corrosion (as temperatures rise, corrosion activity increases - warm humid salt laden atmospheres in ballast tanks, acidic humid conditions in upper cargo tank vapour spaces and warm water and steel eating microbes on cargo tank bottom areas - all factors which promote corrosion).

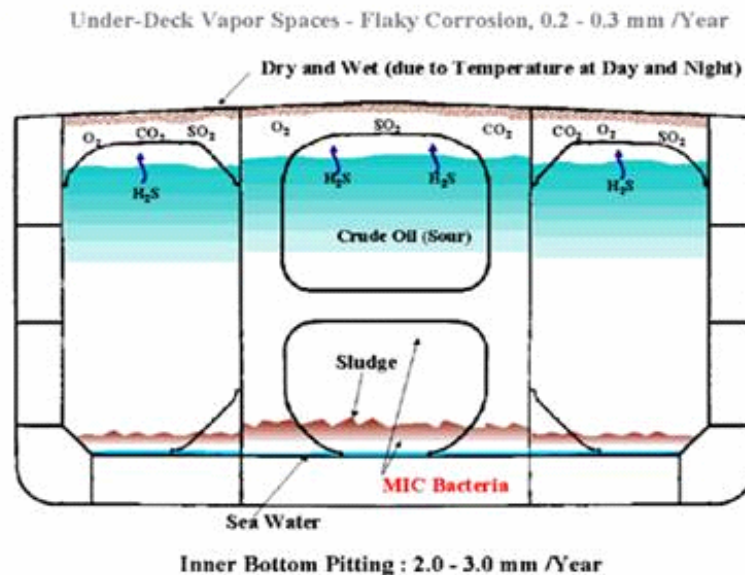
If corrosion remains undetected during surveys, loss of tank integrity and oil leakage into the double hull spaces may occur (increased explosion risk). In the worst cases, corrosion can lead to a major structural failure of the hull.

One of the most effective means for preventing corrosion is to protect the hull structure with an efficient coating system. In double hulled tankers, the spaces most at risk from the effects of corrosion, are the sea water ballast tanks and the underdeck structure and bottom areas within the cargo oil tanks.

Cargo tanks (OCIMF paper 1997: *Factors influencing accelerated corrosion of Cargo Oil Tanks* ref.11)

*"Individual tankers usually exhibit a unique, but controllable corrosion pattern. However, recent experiences of OCIMF members have indicated problems in new single and double hull tonnage from excessive pitting corrosion of up to 2.0 mm per year in the un-coated bottom plating in cargo tanks due, inter alia, to microbial induced corrosion processes. In addition accelerated general corrosion up to and exceeding 0.24mm per year has been found in vapour spaces. This type of wastage and the increased rate of corrosion, which is much greater than that which would be normally expected, give cause for serious concern."*

## **Deck & Inner Bottom Corrosion**



Source: INTERTANKO

## **2) The lack of mandatory provisions relating to coatings for cargo and ballast tanks:**

### *Ballast tanks*

It is a SOLAS '74 requirement that the ballast tanks of tankers be provided with corrosion prevention systems and currently this is best achieved by means of protective coatings.

*SOLAS '74 as amended, Regulation II-1, 3-2.1:*

*"1 This regulation applies to oil tankers and bulk carriers constructed on or after 1 July 1998.*

*2 All dedicated seawater ballast tanks shall have an efficient corrosion prevention system, such as hard protective coatings or equivalent. The coatings should preferably be of a light colour."*

Guidance that is associated with this requirement is given in the IMO "Guidelines for the selection, application and maintenance of corrosion prevention systems of dedicated seawater ballast tanks (IMO resolution A.798 (19))".

A problem that is often noted in the ballast tanks of ships in service is premature failure of the tank's protective coating system and once failure has occurred, rapid corrosion of the unprotected steel will follow soon after. Another problem is that, following coating breakdown, it is extremely difficult to repair or reinstate the failed coating system to the standard that was achievable during the new building stage.

The Panel agreed that it is of the utmost importance for coatings to be correctly applied at the vessel new building stage. Additionally it was felt that the best way to achieve this would be for mandatory performance standards, including a minimum target life, to be established for all ballast tank coating systems. The Panel noted that work on this issue was currently underway within the DE sub-committee of IMO.

The following photos show the ballast tanks of two ships of the same age (13 years). During construction, both ships were coated with an epoxy system, the application of the ballast tank coating for the ship in the first photo was correctly done, whilst that for the ship shown in the second photo was clearly poor. The photos show the importance of using correct application procedures (surface preparation and paint system application) and of coating selection.

*Photos courtesy of IACS (Ref 7 - IACS Recommendation 87)*



**Correct paint application, ballast tank condition after 13 years (a bulk carrier double bottom tank is shown in this example)**



***Poor paint application, ballast tank condition after 13 years (a bulk carrier top side tank is shown in this example)***

#### Cargo Tanks

Currently there are no requirements (within SOLAS '74) for the cargo tanks of oil tankers to be provided with corrosion prevention systems. However, accelerated corrosion has been found to be present within the cargo tanks of a number of oil tankers particularly those carrying crude oil or transporting residual fuels.

Pitting corrosion to the inner bottom plating within cargo tanks can lead to cargo leakage into the double bottom spaces (giving increased risk of explosion and pollution during ballasting operations) whilst corrosion to the under deck structure within the cargo tank area can lead to a reduction in longitudinal strength which gives rise to the possibility of a more serious structural failure occurring.

The Panel noted that this issue is under consideration within other fora; however the Panel have also noted that, to date, no significant progress appears to have been made on this issue.

The Panel considered that this concern should be tackled promptly and also that the best means of preventing corrosion within these spaces would be for mandatory protective coatings to be provided for the underdeck and inner bottom plating areas.

In addition to protecting the steel structure in these areas, this measure would also enable easier and more effective inspections and surveys to be carried out 'in service'.

The Panel also recognised that, when mandating protective coating systems for these vulnerable areas within the cargo tanks, a suitable performance standard (including a minimum target life for the coating) would need to be established and mandated for such coating systems.

Notwithstanding the above, there are a number of tankers, which only operate on dedicated trades and carry relatively benign oil cargoes. Corrosion rates for these vessels are known to be much less than for those carrying more aggressive oil cargoes. The Panel therefore agreed that in such cases, provided the vessels will always carry benign oil cargoes, a relaxation in the mandatory tank coating requirements that are outlined above could be considered, however this would have to be clearly noted in the ship's Class or Statutory certification.

### 3) Fatigue:

Fatigue cracks, which may occur on all vessel types, are associated with cyclical stress and can be linked to 'optimised' ship structures, poor design details, corrosion, stress concentration, incorrect use of high tensile steel and a vessel's trading patterns/area of operation. Fatigue cracks are generally found on older vessels although they have been found on vessels within five years of delivery.



Photo showing a fatigue crack in the transverse web plating of a wing water ballast tank in a single hull tanker

*Courtesy of Technology Development*

Fatigue cracks can propagate over time and if no action is taken (repair, renewals, design modifications etc) then a major structural failure may occur.

Current practice is for fatigue cracks to be repaired as and when they are found during surveys.

However different fatigue failures warrant different repair actions:

For example:

- A 20 year old tanker which is found to have fatigue cracks in its shell longitudinal stiffeners, at their intersections with transverse web stiffening members, would warrant a detailed structural survey with close up examination of all suspect locations followed by repairs in those areas that were found to have failed (*local repairs where failure found*).
- The same problems occurring in a 10 year old tanker would warrant a detailed structural survey with close up examination of all suspect locations followed by repairs and reinforcement of the areas that had failed, together with proactive measures (e.g. reinforcement or possibly design improvements) in similar areas of the hull structure deemed to be at risk (*repairs with local modifications if appropriate in damaged areas and in similar suspect areas*).
- The same problems occurring in a 5 year old tanker would warrant a detailed structural survey with close up examination of all suspect locations followed by a structural analysis to identify the reasons for failure, together with proactive measures (e.g. reinforcement or possibly design modifications) in all areas that had been identified by the analysis to be at risk (*general analysis after detailed inspection followed by substantial improvements and modifications*).

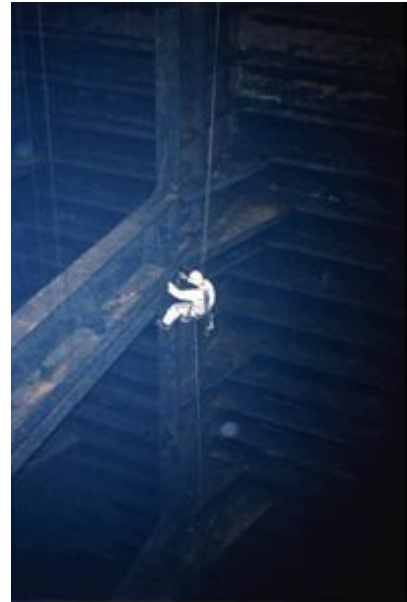
The Panel considered that a unified and effective approach for tackling fatigue failures in tanker hull structures is desirable in view of the potential that minor fatigue cracks have to grow into more serious structural failures.

**4) A demanding and difficult maintenance regime which, if not properly observed could lead to deterioration of the hull structure:**



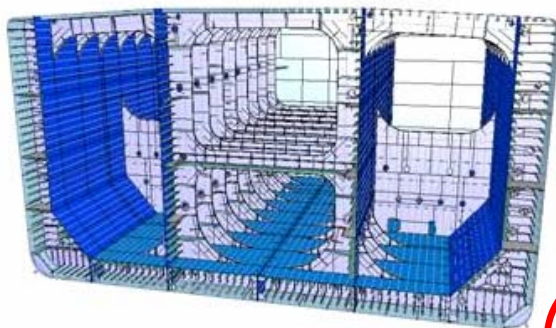
Courtesy of DNV

**Large tankers have many internal spaces containing complex structure**



**They are difficult to survey:**

- Internal tank spaces are generally dark, wet, slippery and dirty with no ready means of access to much of the tank structure



**And very difficult to maintain.**



The images of the VLCC on the preceding page give some indication of the size and complexity of the hull structure of a large contemporary tanker. As an example, a VLCC with an overall length of 333m, a breadth of 60m and a depth of 30 m, would have some 350,000 m<sup>2</sup> of internal areas that require to be inspected and maintained, with critical elements such as water ballast tanks (218,700 m<sup>2</sup>) and bottom and top of the cargo tanks (55,000 m<sup>2</sup>). Structural maintenance on large vessels is difficult and this becomes even more difficult as the vessel ages. However for the responsible owner, neglecting maintenance is not really an option as a lack of maintenance will allow hull structural corrosion to occur unchecked and may also facilitate the propagation of potentially serious structural defects.

Whilst hull maintenance is mandatory under the ISM Code, maintenance procedures, practices and periodicity have not, as yet, been specified for the hull structure. The Panel considered that a unified and consistent approach to hull maintenance by vessel owners, would contribute positively to the safety of Tanker structures. (Ref 4. TSCF Tanker maintenance manual – currently being updated).

***5) Lack of mandatory and harmonized procedures for monitoring workmanship and standards of construction during the vessel new building stage:***

Whilst hull construction standards exist (ref. 9 IACS recommendation 47 Shipbuilding and Repair Quality Standard) they are not mandatory and it is common practice for Classification Society surveyors to work with the construction standards of the particular shipyards in which they are contracted. Such yard standards usually incorporate and exceed the IACS quality standard.

Modern shipyards have construction methods and techniques that generally promote quality of construction, attainment of standards and satisfactory workmanship. However, tight building schedules and pressures to reduce costs can sometimes mean that the formal quality control regime is relaxed and the assurance of structural integrity that is provided by this regime, may be affected.

The Panel considered that a harmonized and effective approach to assuring hull construction quality during new building was desirable from the viewpoint of preventing latent defects being incorporated within a vessel's hull structure. The Panel also considered that it would be useful if a mandatory international standard for hull new construction was established which gave minimum requirements for fabrication tolerances, workmanship etc. This then could be a reference tool that shipyards, Classification Societies and owners would be able to refer to at the time a vessel is built.

***6) Lack of mandatory and harmonized procedures for monitoring workmanship and steelwork repair standards during vessel repairs:***

The comments outlined in paragraph 5) above are also applicable for vessels undergoing structural repairs whilst in service.

***7) Inconsistencies between differing Classification Societies in their approach to inspection and survey - during new building and during repairs on vessels in service:***

The Panel considered that it was a matter for concern that different Classification Societies provided different levels of supervision during a vessel's new building stage and during repairs on vessels in service.

The Panel acknowledged that different Classification Societies have different rules that pertain to their assignment of Class. However with regard to the statutory survey obligations they assume when issuing Load Line and Safety Construction certification, it was felt that harmonization and commonality in approach was desired.

IACS (JTP) has developed common rules for Double Hull tankers for the purposes of eliminating competition between Societies on issues that can affect a vessel's structural robustness. The Panel considered that some measure of commonality should also be introduced for vessel new building and repair surveys in order to remove the possibly

adverse aspects that competition (during such surveys) may have on a vessel's structural integrity.

The Panel agreed that IACS' current development work on harmonized procedures and standards for hull classification new construction surveys, should be supported. Moreover, once this has been concluded, the Panel feels that a similar approach could be developed for initial statutory surveys. The harmonized procedures should cover the scope and depth of surveys and also acceptance criteria when appropriate.

#### **8) Possible use of inert gas in ballast tanks (double hull spaces):**

This was discussed by the Panel and the mandatory provision of this control measure was not considered to be justified:

Benefits:

- Reduces the possibility of explosion in double hull and bottom spaces following leakage of hydrocarbons from cargo spaces;
- In some instances (for example, when the inert agent is nitrogen) inerting can reduce corrosion in ballast spaces.

Disadvantages:

- Feedback received from vessels in service has indicated that cargo leakage into the double hull and double bottom spaces has not proven to be a significant problem in those vessels;
- Inerting with flue gas and the carry over of combustion residues within the inert gas, can promote corrosion within the double hull and double bottom spaces;
- Inerting would tend to discourage inspections of double hull and double bottom spaces due to the gas freeing procedures that would need to be completed prior to tank entry.

#### **9) Hydrocarbon gas detection in ballast tanks (double hull spaces):**

The Panel agreed that a mandatory provision for constant monitoring of tank atmospheres within double hull, double bottom and other spaces adjacent to the cargo tanks should be sought\*.

Benefits:

- Would proactively detect the presence of hydrocarbon gas within the monitored spaces so that following a leak, precautionary measures could be initiated (introduction of inert gas etc.) which would reduce the risk of explosion;
- Could assist the detection of structural defects in cargo tank boundary plating (corrosion, cracks or damage);
- Provides a relatively inexpensive and useful alternative to the previous proposal for continuous inerting of double hull and double bottom spaces;
- Many of the newly built double hull oil tankers have monitoring devices already installed and experience shows that these are reliable and efficient.

Negative factors:

- Possibility of equipment malfunction giving personnel an erroneous indication of a safe tank atmosphere;
- False alarms;
- The expense associated with retrofitting a constant sampling and monitoring system on existing vessels.

\*Note: fixed gas detection equipment is not proposed for vessels that are provided with constant inerting systems for hull spaces adjacent to cargo tanks.

## **6. Recommendations**

*(see also summary table on page 20)*

On the basis of the Panel's findings and discussions on areas of concern, the recommendations of the Panel are:

### **Recommendation 1: Establish a mandatory performance standard for ballast tank coating systems in new vessels.**

**Concern:** *Corrosion in Ballast tanks caused by premature coating breakdown.*

**Control measure:** *Improved coating performance.*

The Panel agreed that the performance standard that is being developed for the ballast tanks of Bulk carriers (with a 15 year target life) would be a suitable standard to mandate for the ballast tanks of double hull tankers. The Panel also noted that this performance standard is due to be finalised at the next IMO DE meeting in February 2006.

*At DE 48 (2005), the sub-committee recommended that the proposed performance standard for protective coatings should be expanded in scope to include coatings for "all ballast and void spaces on all types of ships". However some member states are now questioning whether coatings are needed in void spaces. Similarly the proposed technical specification that is associated with the coating performance standard is still being debated within the DE correspondence group.*

**Implementation:** SOLAS '74 Reg II-1/3-2 should be amended to introduce a mandatory performance standard (and target coating life) for the coatings that are required in the ballast tanks of new double hull tankers. Developments in the DE correspondence and working groups should be closely followed to ensure the establishment of satisfactory technical provisions.

### **Recommendation 2: Establish mandatory provisions for coating the deckhead and tank top structures within the cargo tanks of new vessels.**

**Concern:** *Corrosion in Cargo tanks on uncoated deckhead and tank top structures.*

**Control measure:** *Provide protective coatings in these two critical areas.*

Problems of accelerated corrosion in the cargo tanks of double hull oil tankers have been noted, specifically on the deckhead structure and on the tank's inner bottom plating.

**Implementation:** SOLAS '74 Reg II-1/3 should be amended to mandate additional corrosion protection (coatings) for the internal deckhead and tank top areas of cargo tanks in new build oil tankers. To accomplish this, a paper proposing mandated coatings for these two areas would need to be initiated by an IMO member state.

The Panel agreed that for new vessels, in which benign cargoes would always be carried or when such vessels were intended for specified trades in which the risk of accelerated structural corrosion had not been evident, an exemption from the proposed mandatory coating requirements, which are detailed above, could be incorporated within the proposed amendment to SOLAS '74, however this would have to be clearly noted in the ship's Class or Statutory certification.

### **Recommendation 3: Establish a mandatory performance standard for cargo tank coating systems in new vessels.**

**Concern:** *Corrosion in Cargo tanks.*

**Control measure:** *Establish performance standard for cargo tank coatings.*

The Panel agreed that in order to avoid premature breakdown of the cargo tank coating system (that is proposed in Recommendation 2 above) a specification and performance standard should be developed for such systems.

**Implementation:** SOLAS '74 (Reg II-1/3) should be amended to introduce a mandatory performance standard (target coating life) for the coatings that are recommended for the cargo tanks of new double hull oil tankers. IACS should develop this standard in cooperation with Industry by means of their joint working group on corrosion. Thereafter a paper proposing a mandatory coating standard would need to be initiated by an IMO Member State.

**Recommendation 4: Ballast tank coatings should be effectively repaired following breakdown.**

**Concern:** *Corrosion in Ballast tanks following coating breakdown.*

**Control measure:** *Repair and maintain coating.*

There is no mandatory requirement for repairs or maintenance to be carried out on tank coatings after breakdown. However a coating repair standard has recently been developed by the IACS working group on corrosion and this is available on the IACS website (IACS Recommendation 87) The Panel agreed that coating breakdown in tanks should be tackled effectively but considered that some service experience and feedback, from using the IACS coating repair standard, would be necessary prior to considering a mandatory provision.

**Recommendation:** It is recommended that vessel owners repair and maintain the tank coating systems on their vessels in accordance with the coating repair standard that has been developed by IACS (*IACS Recommendation 87: Guidelines for coating maintenance and repairs for ballast tanks and combined cargo/ballast tanks on oil tankers*).

**Recommendation 5: Double hull tanker structures should be maintained effectively.**

**Concern:** *Corrosion and fatigue in ballast and cargo tanks.*

**Control measure:** *Hull maintenance.*

**Implementation:** The maintenance of tanker structures is already mandatory for vessel owners (by virtue of the ISM Code) however appropriate procedures and standards for repairs and maintenance still need to be established. The industry should develop harmonised maintenance procedures for tanker structures which should be the norm and against which any evaluation of the condition of the structure should be made. *The updated TSCF maintenance manual could be the means by which this is introduced in conjunction with IMO requirements or linked to Classification.*

**Recommendation 6: Common procedures to be established to deal with significant fatigue failures.**

**Concern:** *Cracks due to fatigue.*

**Control measure:** *Develop a suitable response to fatigue failures that includes fatigue analysis when appropriate and pro-active repairs or modifications as may be necessary*

The Panel agreed that there should be appropriate and uniform methods for dealing with significant cases of fatigue and they considered that this could best be achieved by providing guidance for field surveyors that would enable them to assess and identify significant failures. The guidance should also lead to procedures being followed that were appropriate to the failures that were found, including fatigue analysis and assessment, pro-active repairs, recommended repair methods and means of reinforcement. Additionally, a system of formal communications between owners, operators, class and builders should be established, to enable information on vessels with significant fatigue to be transferred between interested parties, when sister or similar vessels were known to be in service.

**Implementation:** IACS to develop guidance for identifying significant failures caused by fatigue and the procedures to be followed when dealing with such cases. Revisions to IMO Resolution A.744 (18) should also be considered.

**Recommendation 7: Harmonize standards of workmanship and construction during tanker new building and during repairs.**

**Concern:** *Variations in workmanship and construction standards during new building and during repairs.*

**Control measures:** *Establish minimum standards for hull construction and harmonize the content, standards and procedures of the initial hull Classification survey. Harmonize the content and standards of initial statutory surveys. Establish and harmonize standards for hull repairs on existing vessels (including TSCF recommendations for structural repairs).*

**Implementation:** IACS to develop standards, procedures and requirements that will enable the harmonization of hull Classification surveys (with a view to issuing as a Unified Requirement). Modifications to IMO Resolution A.948 (23) should be considered to improve statutory surveys.

**Recommendation 8: Fixed hydrocarbon gas detection system to be provided in spaces adjacent to cargo oil tanks.**

**Concern:** *Cargo seepage into spaces adjacent to cargo oil tanks.*

**Control measure:** *Fixed hydrocarbon gas detection system to be provided within double hull and double bottom spaces of tankers to allow constant monitoring of tank atmospheres.*

**Implementation:** SOLAS '74 Reg II-1/5.7 to be amended to require that fixed hydrocarbon gas detection systems, giving constant monitoring of double hull and double bottom tank atmospheres, are made mandatory in new double hull tankers (only on vessels that are required to be provided with an inert gas system in the cargo tanks: 20,000 DWT and above)

IACS to establish standards and requirements for a suitable fixed hydrocarbon gas detection system (possibly by means of a joint working group with Industry).

**Recommendation:** The owners and operators of existing double hulled tankers should be encouraged to consider fitting fixed hydrocarbon gas detection systems, giving constant monitoring of double hull and double bottom tank atmospheres.

**Summary of recommendations for new and existing double hull tankers (vessels > 5000 DWT unless stated otherwise).**

The Panel has made recommendations for action on double hull oil and chemical tankers (as defined within SOLAS '74) as detailed below:

- Recommendation 1. Applicable to new vessels only – oil and chemical tankers;
- Recommendation 2. Applicable to new vessels only – oil tankers only;
- Recommendation 3. Applicable to new vessels only – oil tankers only;
- Recommendation 4. Applicable to all vessels – oil and chemical tankers;
- Recommendation 5. Applicable to all vessels – oil and chemical tankers;
- Recommendation 6. Applicable to all vessels – oil and chemical tankers (= >150m);
- Recommendation 7. Applicable to all vessels – oil and chemical tankers;
- Recommendation 8. Applicable for new vessels and recommended for existing vessels – oil and chemical tankers (20,000 DWT and above).

| Concern                                                                           | Recommended Control measure                                 | Proposed means of implementation                                                                                         | Drivers                                                                               | Comments                                                                                   |
|-----------------------------------------------------------------------------------|-------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|
| <b>Corrosion in Ballast tanks</b><br>(premature coating breakdown)                | 1. Improved coating performance                             | Introduce mandatory requirements for coating performance standards within SOLAS '74 (Reg II-I/3-2)                       | EMSA<br>EU COM.<br>EU Member State(s)                                                 | A coating standard is currently being developed by the IMO DE sub-committee                |
| <b>Corrosion in Cargo tanks</b><br>(on uncoated deckhead and tank top structures) | 2. Provide coating in these two areas                       | Introduce requirements for coatings on cargo tank deckhead and tanktop areas within SOLAS '74 (Reg II-I/3)               | EMSA<br>EU COM.<br>EU Member State(s)                                                 | Draft IACS Unified Requirement is already in existence                                     |
| <b>Corrosion in Cargo tanks</b><br>(on uncoated deckhead and tank top structures) | 3. Establish a performance standard for cargo tank coatings | Introduce mandatory requirements for coating performance standards within SOLAS '74 (Reg II-I/3)                         | IACS<br>EMSA<br>EU COM.<br>EU Member State(s)                                         | IACS joint working group on corrosion to develop a suitable coating standard               |
| <b>Corrosion in Ballast tanks</b><br>(following coating breakdown)                | 4. Repair and maintain coating                              | Vessel owners are recommended to maintain and repair coatings in ballast tanks in accordance with IACS Recommendation 87 | Industry to monitor results of coating repairs carried out in line with IACS standard | *See link to IACS' recommendation below                                                    |
| <b>Corrosion and fatigue in ballast and cargo tanks</b>                           | 5. Harmonised hull maintenance procedures to be established | Hull maintenance to be mandatory for vessel owners (ref. ISM and TSCF Maintenance manual)                                | Industry, EMSA, EU COM.<br>EU Member State(s)                                         | Content of TSCF maintenance manual to be considered by the Panel when updating is complete |

|                                                                                                    |                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                    |                                                                                                    |
|----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|----------------------------------------------------------------------------------------------------|
| <b>Cracks due to fatigue</b>                                                                       | 6. An appropriate response to fatigue failures to be developed that includes fatigue analysis when appropriate and pro-active repairs or modifications as may be necessary                 | IACS to develop guidance for field surveyors<br>Modifications to IMO Resolution A.744(18)                                                                                                                                                                                                                                                                                                                                        | IACS,<br>EMSA, EU<br>COM.<br>EU Member<br>State(s) |                                                                                                    |
| <b>Variations in workmanship and construction standards during new building and during repairs</b> | 7. Hull construction standards to be established. Harmonize the content, standards and procedures of hull Classification surveys. Harmonize the content and standards of statutory surveys | IACS recommendation 47 "Shipbuilding and Repair Quality Standard" to be mandatory (as a minimum) for new and existing vessels (and give reference to TSCF recommendations for repairs where appropriate – see <i>example in picture gallery</i> ). IACS to develop unified requirement for initial hull classification surveys. Modifications to IMO Resolution A.948(23) should also be considered to improve statutory surveys | IACS<br>EMSA<br>EU COM.<br>EU Member<br>State(s)   |                                                                                                    |
| <b>Cargo seepage into ballast tanks (Double hull spaces) New Vessels</b>                           | 8. Provide fixed hydrocarbon gas detection system to allow constant monitoring of double hull tank atmospheres                                                                             | SOLAS '74 Reg. II-1/5.7 to be amended to require provision of fixed gas detection systems in new tankers greater than 20,000 tonnes DWT (for new vessels)                                                                                                                                                                                                                                                                        | IACS<br>EMSA<br>EU COM.<br>EU Member<br>State(s)   | IACS to establish standards and requirements for a suitable fixed hydrocarbon gas detection system |
| <b>Cargo seepage into ballast tanks (Double hull spaces) Existing double hull vessels</b>          | 8. Owners to be recommended to install a fixed hydrocarbon gas detection system on existing vessels to allow constant monitoring of double hull tank atmospheres                           | Industry best practice                                                                                                                                                                                                                                                                                                                                                                                                           | Industry                                           |                                                                                                    |

\* <http://www.iacs.org.uk/latest.htm#REC87>

## **7. Conclusion**

The work of the Panel has resulted in this report which has identified and summarised a number of issues that many in the Maritime sector have been aware of for some time.

The concerns that have been identified are both real and significant and it is considered that action is now needed from both regulators and Industry to mitigate the risks that these issues pose to the safe and clean transportation of oil by ships at sea.

## **8. References**

1. Papers presented at the 'Maritime Safety Seminar on Double Hull Tankers' hosted by the European Commission in November 2003
2. IACS 'Common Structural Rules for Double Hull Oil Tankers' draft for comment (June 2004)
3. TSCF 'Guidance manual for tanker structures' 1997
4. TSCF 'Guidelines for the inspection and maintenance of double hull tanker structures' 1995
5. TSCF 'Guidelines for ballast tank coatings systems and surface preparation' 2000
6. Revised IMO Resolution A.744(18) (as amended) and as detailed in "Draft amendments to the guidelines on the enhanced programme of inspections during surveys of Bulk Carriers and Oil Tankers" (*adopted at MSC 80, May 2005, in force 1 January 2007*)
7. IMO resolution A.798 (19) "Guidelines for the selection, application and maintenance of corrosion prevention systems of dedicated seawater ballast tanks"
8. IACS Recommendation 87 "Guidelines for coating maintenance and repairs for ballast tanks and combined cargo/ballast tanks on oil tankers"
9. IACS recommendation 47 "Shipbuilding and Repair Quality Standard"
10. Revised Survey Guidelines under the Harmonized System of Survey and Certification IMO Resolution A.948(23) - adopted on 5 December 2003
11. Double hull tankers - are they the answer? OCIMF paper 2003
12. Factors influencing accelerated corrosion of Cargo Oil Tanks. OCIMF paper: September 1997
13. IMO MSC paper 77/2/6 - 21.3.03 New building standards by INTERTANKO
14. Experience with double hull tankers – an owners viewpoint, Paper presented by Bergesen at TSCF meeting October 2000
15. New Class rules for protective coating - Paper presented at the 8th ICMS/SNAME New York Metropolitan Section Symposium in New York, May 22-23, 2000
16. Corrosion protection of cargo tanks - Paper presented by Chevron at TSCF meeting October 2000
17. Double hull tankers and corrosion protection Dragos Rauta, Tim Gunner and Johnny Eliasson - INTERTANKO 2004
18. SOLAS 1974 as amended Corrosion prevention of seawater ballast tanks (tankers and bulk carriers)
19. MARPOL 73/78 Annex 1 Regulations for the prevention of pollution by oil

## **9. Initial distribution:**

Hard copies to all Panel Members;

To be freely available on EMSA's and other Panel member's websites (pdf download).

## **10. Glossary of terms used in this report**

*Note: the explanatory text that is given for these terms relates to the usage of the terms within this report only.*

### **Single hull tanker:**

A vessel carrying oil or chemical cargoes in which the cargo spaces are separated from the sea by means of the hull which is formed by a single steel skin.

### **Double hull tanker:**

A vessel carrying oil or chemical cargoes in which the cargo spaces are separated from the sea by means of the hull which is formed by two steel skins, arranged to form protective tanks or voids around the spaces which carry cargo.

### **IMO:**

The International Maritime Organization - The International Maritime Organization is a specialized agency of the United Nations which is responsible for measures to improve the safety and security of international shipping and to prevent marine pollution from ships.

### **IACS:**

The International Association of Classification Societies. IACS membership is comprised of the world's ten major Classification Societies.

### **JTP:**

IACS Joint Tanker Project – project undertaken by IACS members with the objective of establishing common structural rules for tankers

### **SOLAS:**

The International Convention for the Safety of Life at Sea - an International Convention dealing with the safety of ships, developed by the IMO.

*Note the references to SOLAS regulations that are contained within this report relate to SOLAS 1974 as amended, consolidated version (2004).*

### **MARPOL:**

The International Convention for the Prevention of Pollution from Ships - an International Convention dealing with prevention of pollution from ships, developed by the IMO.

### **VLCC:**

Very large crude carrier - a large tanker designed to carry crude oil

### **TSCF:**

Tanker Structure Co-operative Forum – An industry body that establishes and publishes best practice and guidance relating to the design, construction and maintenance of tanker structures.

### **ISM Code:**

International Safety Management (ISM) Code - means the International Management Code for the Safe Operation of Ships and for Pollution Prevention, developed by the IMO

## **11. Attachments**

- Attachment 1** - Tanker Panel: Terms of Reference.
- Attachment 2** - Details of delegates who have attended Double Hull Tanker Panel meetings.
- Attachment 3** - Details of Major tanker oil spills since 1967.
- Attachment 4** - Picture gallery.

**Double Hull Tankers: High Level Panel of Experts****Terms of reference**

## 1. Scope

To collect and analyse feedback from experience in the design, construction, operation, maintenance and survey of double hull tankers of all types and sizes and identify factors that may have an adverse impact on the structural integrity of the vessels.

## 2. Objective

To produce a concise summary report that proposes solutions for any areas of concern that the Panel has identified together with recommendations for action. The report should also suggest methods by which its proposals may be implemented and this may include:

- 2.1 Amendments to IMO requirements
- 2.2 Amendments to Classification Rules
- 2.3 Improved guidelines for Industry
- 2.4 Enhanced 'in-service' maintenance
- 2.5 Research

## 3. Background

Following the introduction of double hull structural arrangements for tankers in the late eighties and early nineties, concerns over hull corrosion and fatigue in the cargo and ballast tank areas of these new tanker designs have been voiced in a number of quarters.

As a significant amount of new double hull tonnage is due to be completed within the next few years, it would be prudent to identify any improvements that could address these concerns, as soon as is practicable and possible.

## 4. Work

- 4.1 The Panel will consider and report on increased levels of corrosion and fatigue that are being noted in double hull tankers.
- 4.2 The Panel will assess any additional areas of possible concern (if any) on double hull tankers.
- 4.3 The Panel will try and establish why these factors are arising and suggest practical solutions or means of mitigation for the areas of concern that have been identified.
- 4.4 Solutions or means of mitigation should be considered for both new and existing ships.
- 4.5 Initial questions that the Panel may wish to address are contained in Annex 1.

## 5. The Panel:

The Panel will be made up from representatives of:

Association of European Shipbuilders and Repairers (AWES)  
*Now The Community of European Shipyards' Associations (CESA)*  
 Baltic and International Maritime Council (BIMCO)  
 European Commission (DG TREN)  
 European Maritime Safety Agency (EMSA)  
 International Association of Classification Societies (IACS)  
 International Chamber of Shipping (ICS)  
 International Maritime Organization (IMO)  
 International Association of Independent Tanker Owners (INTERTANKO)  
 Oil Companies International Marine Forum (OCIMF)

Additional bodies may be invited if deemed necessary by the Panel.

6. Procedural:

- Project administration and secretariat will be provided by EMSA.
- The Panel will be chaired by EMSA.
- If the Panel is unable to come to a collective agreement on any significant issue, the issue may be recorded within the report.

7. To be established:

- Working procedures
- Timeframes
- Meetings
- Reporting guidelines
- Working groups

Annex to the Terms of Reference

Initial discussion areas that the Panel may wish to consider:

1. Does cargo type and heated cargo give rise to accelerated corrosion? How would this impact on the DH tanker designs?
2. Does the vessel's area of operation/trading pattern affect its fatigue life and/or corrosion performance?
3. Are some structural details more susceptible to corrosion and fatigue than others?
4. Is the problem widespread and what proportion of the double hull fleet is experiencing unexpected corrosion and/or fatigue problems?
5. Vessel age - after what period of time do the effects of corrosion and fatigue start to become significant?
6. Does the increased use of high tensile steel contribute to concerns over corrosion and fatigue?
7. Hull structural arrangements for tankers have been optimised in recent years, should consideration be given to increased scantlings in vulnerable areas or would a higher level of inspection and maintenance be more cost effective than the increased steel weight that an increase in scantlings would bring?
8. Where is the corrosion occurring and which structural members are subject to fatigue?
9. When vessels have been allowed reduced scantlings in association with an approved corrosion control coating scheme, does this adversely affect their fatigue life and/or corrosion performance?
10. Coatings are mandatory for ballast spaces in tankers but not for cargo spaces. Additionally standards for coatings and their application are not mandatory, does this situation merit further consideration?
11. For vessels that have experienced coating breakdown and accelerated corrosion, what details relating to the vessel's coating systems exist (specifications, records/history)?
12. Are coating guarantees from suppliers effective in delaying the onset of corrosion?
13. Coatings may be maintained in service, is this effective?
14. The use of sacrificial anodes - does this have a significant effect in preventing corrosion in ballast tanks?

Details of delegates who have attended Double Hull Tanker Panel meetings:

Baltic and International Maritime Council (BIMCO):

Philip Embiricos

The Community of European Shipyards' Associations (CESA) (formerly AWES):

Nenad Flesch  
Nick Granger  
Rafael Gutierrez  
Ronald Horn  
Reinhard Lüken  
Frederico Spranger

European Commission (DG TREN):

Bernardo Urrutia Garro

European Maritime Safety Agency (EMSA):

Ron Drysdale  
Dimitris Fokas  
Ib Matthiesen

International Association of Classification Societies (IACS):

Roberto Cazzulo (RINA)  
Vaughan Pomeroy (LR)  
Jean-François Segretain (BV)  
Robert Spencer (ABS)  
Kirsi Tikka (ABS)  
Andrew Alderson (RINA)

International Chamber of Shipping (ICS):

Hans-Richard Hansen  
Björn Södahl  
David Tongue

International Maritime Organization (IMO):

Heike Hoppe

International Association of Independent Tanker Owners (INTERTANKO):

Dean Tseretopoulos  
Stefan Nyström  
Dragos Rauta  
Peter Swift

Oil Companies International Marine Forum (OCIMF):

Andrew Alderson  
Christopher Barras (TSCF)  
Andrew Dogherty  
Robert Drysdale  
Henriette de Boer

**Major tanker oil spills since 1967**

| Vessel                     | Date of spill | location                        | Oil (Tonnes spilt) | Hull type (single or double skin) |
|----------------------------|---------------|---------------------------------|--------------------|-----------------------------------|
| <i>Atlantic Empress</i>    | 1979          | Off Tobago, West Indies         | 287,000            | single                            |
| <i>ABT Summer</i>          | 1991          | 700 nautical miles off Angola   | 260,000            | single                            |
| <i>Castillo de Bellver</i> | 1983          | Off Saldanha Bay, South Africa  | 252,000            | single                            |
| <i>Amoco Cadiz</i>         | 1978          | Off Brittany, France            | 223,000            | single                            |
| <i>Haven</i>               | 1991          | Genoa, Italy                    | 144,000            | single                            |
| <i>Odyssey</i>             | 1988          | Off Nova Scotia, Canada         | 132,000            | single                            |
| <i>Torrey Canyon</i>       | 1967          | Scilly Isles, UK                | 119,000            | single                            |
| <i>Sea Star</i>            | 1972          | Gulf of Oman                    | 115,000            | single                            |
| <i>Irenes Serenade</i>     | 1980          | Navarino Bay, Greece            | 100,000            | single                            |
| <i>Urquiola</i>            | 1976          | La Coruna, Spain                | 100,000            | single                            |
| <i>Hawaiian Patriot</i>    | 1977          | 300 nautical miles off Honolulu | 95,000             | single                            |
| <i>Independenta</i>        | 1979          | Bosphorus, Turkey               | 95,000             | single                            |
| <i>Jakob Maersk</i>        | 1975          | Oporto, Portugal                | 88,000             | single                            |
| <i>Braer</i>               | 1993          | Shetland Islands, UK            | 85,000             | single                            |
| <i>Khark 5</i>             | 1989          | Off Atlantic coast of Morocco   | 80,000             | single                            |
| <i>Aegean Sea</i>          | 1992          | La Coruna, Spain                | 74,000             | double (OBO)                      |
| <i>Sea Empress</i>         | 1996          | Milford Haven, UK               | 72,000             | single                            |
| <i>Katina P.</i>           | 1992          | Off Maputo, Mozambique          | 72,000             | single                            |
| <i>Prestige</i>            | 2002          | Off the Spanish coast           | 63,000             | single                            |
| <i>Exxon Valdez</i>        | 1989          | Prince William Sound, Alaska    | 37,000             | single                            |
| <i>Erika</i>               | 1999          | Bay of Biscay France            | 22,000             | single                            |

**Coatings during newbuilding**

**Hull construction**

Double hull tanker in the building dock:



*Courtesy of Hempel A/S*

The ballast tanks have been coated during the block stage (grey), the cargo tanks have not yet been coated (structure still in prefabrication primer):



*Courtesy of Hempel A/S*

### Block fabrication stage

Steelwork preparation prior to cleaning and application of coating:



*Courtesy of International Marine Coatings*

Surface preparation on a side tank block prior to application of protective coating (block steelwork with red prefabrication primer undergoing sweep blasting):



*Courtesy of International Marine Coatings*

Manual stripe coating of vulnerable areas and locations that are difficult to spray after first coat and prior to application of the final coat (to ensure adequate film thickness):



*Copyright Jotun paints*



*Courtesy of Hempel A/S*

Internal structure in a double bottom tank after coating:



*Courtesy of Hempel A/S*

Side tank block after coating:

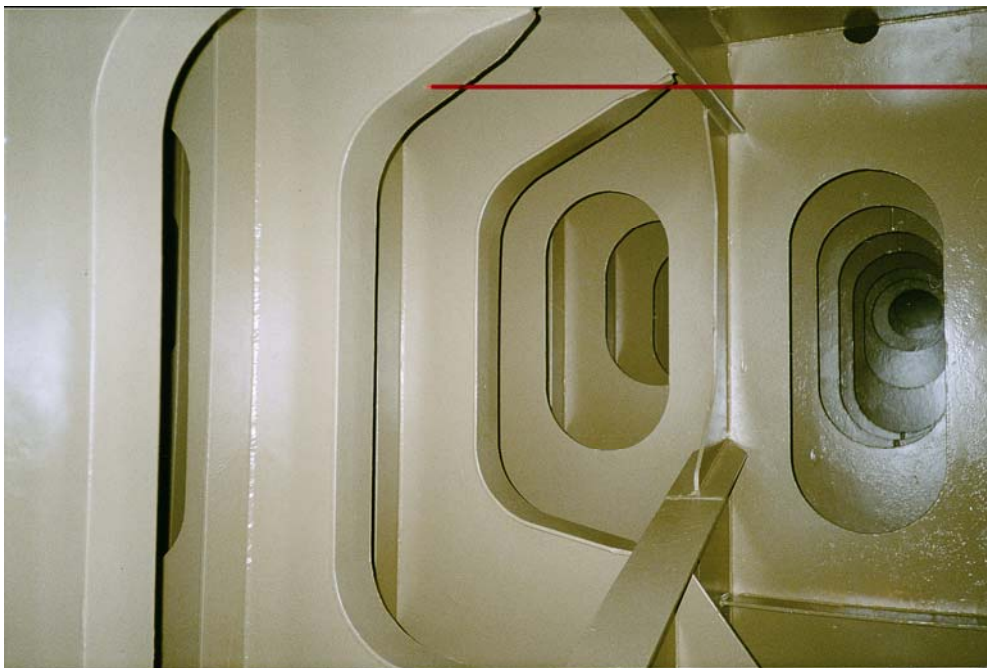


*Courtesy of International Marine Coatings*

Views inside a newly coated double bottom water ballast tank:



*Copyright Jotun paints*



*Copyright Jotun paints*

A newly coated cargo tank after completion of outfitting:

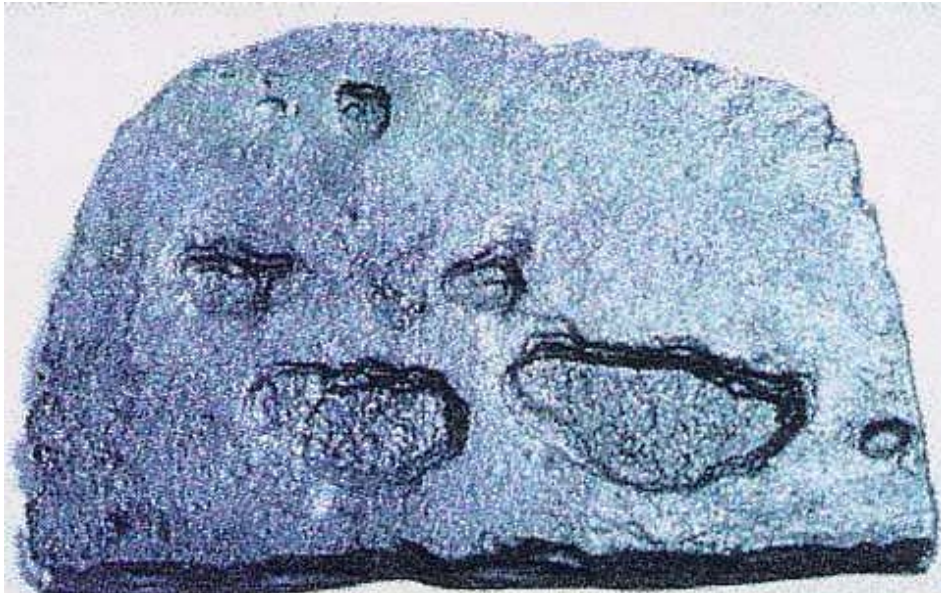


*Courtesy of International Marine Coatings*

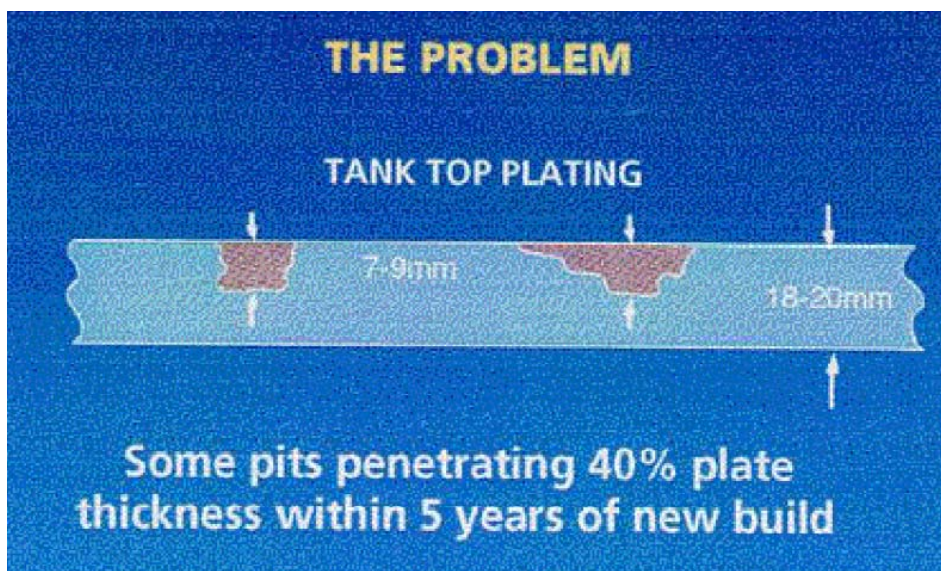
## **Corrosion and coatings on vessels in service**

Images courtesy of INTERTANKO and OCIMF

Steel plating taken from the inner bottom of a cargo oil tank in a double hull oil tanker showing pitting corrosion brought about by microbial attack:



Pitting in the top plate of the double bottom of a cargo tank - microbiologically induced corrosion (MIC) (Source: Sigma Coatings):



### **Ballast tank coatings on vessels in service**

Premature coating breakdown: after 3 years of service:



Sister ship to that shown in the previous photograph coated to a different coating specification:

- coating performing well after more than 7 years in service:



Premature coating breakdown (blistering) after 5 years of service, tank shown after touch up repairs have been carried out:



Ballast tank in which the coating system has provided steelwork protection for more than 20 years:



Ballast tank coatings in a double hull oil tanker after 10 years of service. The coatings have performed satisfactorily although they now need to be maintained to enable continued protection of the tank structure:



Ballast tank coatings continued:



## Coating breakdown in ballast tanks

General coating breakdown without loss of structure:



*Copyright Jotun paints*

Structural loss due to corrosion:



*Courtesy IACS*

Premature coating breakdown: flaking (possibly due to excess humidity or surface contamination at the time of coating):



*Copyright Jotun paints*

Premature coating breakdown at block erection joints, probably due to inadequate surface preparation prior to coating:

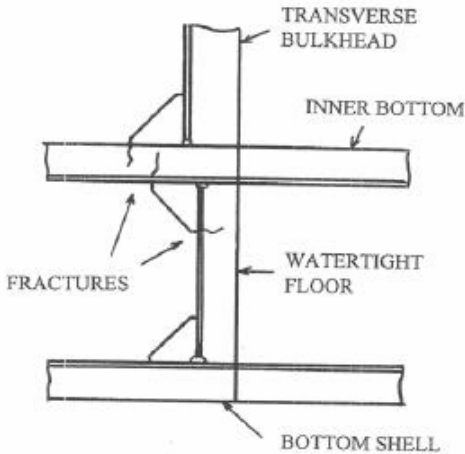
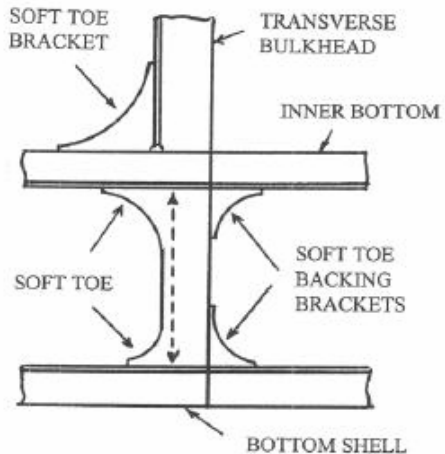


*Courtesy of International Marine Coatings*

## Repairs on vessels in service

Tanker structure co-operative forum:

An example from the catalogue of structural details showing typical fatigue damage and a recommended means of repair:

| <b>LOCATION :</b> BOTTOM BALLAST TANK<br><b>EXAMPLE :</b> CONNECTION OF LONGITUDINALS TO<br><b>NO 1</b> WATERTIGHT FLOORS                                                                                                                                                                                                                                                                                 |                                                                                               | <b>GROUP</b><br><b>NO 4</b>                                                         |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| TYPICAL DAMAGE                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                               | PROPOSED REPAIR                                                                     |
|                                                                                                                                                                                                                                                                                                                         |                                                                                               |  |
| <b>FACTORS CONTRIBUTING TO DAMAGE</b> <ol style="list-style-type: none"> <li>1. Asymmetrical connection of bracket in association with a backing bracket which is too small.</li> <li>2. Relative deflection between adjacent floor and transverse bulkhead.</li> <li>3. Inadequate shape of the brackets.</li> <li>4. High stresses in the inner bottom longitudinal and the floor stiffener.</li> </ol> |                                                                                               |                                                                                     |
| <b>FIGURE</b><br>20                                                                                                                                                                                                                                                                                                                                                                                       | <b>TANKER STRUCTURE CO-OPERATIVE FORUM</b><br><b>SUBJECT: CATALOGUE OF STRUCTURAL DETAILS</b> | <b>FIGURE</b><br>20                                                                 |