COMPARISON OF SINGLE AND DOUBLE HULL TANKERS

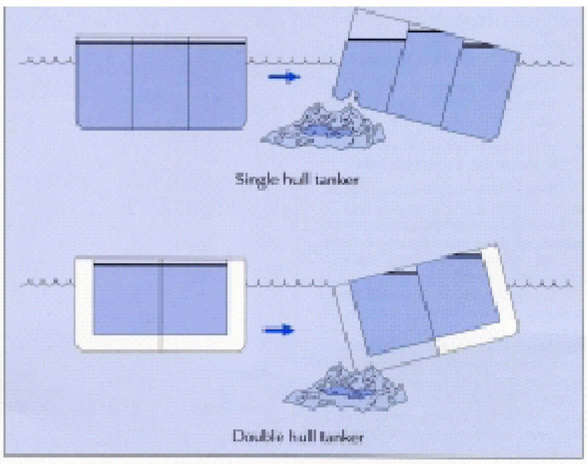
PURPOSE

1. The purpose of this discussion paper is to provide information in light of the loss of the oil tanker *Prestige* on the comparative merits and disadvantages of single and double hull tankers.

DISCUSSION

2. It has been some eleven years since the United States' Oil Pollution Act (OPA 90) and subsequently regulation 13F of Annex 1 of the International Convention for the Prevention of Pollution from Ships effectively mandated double hulls for new build oil tankers of over 5,000 deadweight tonnes as a means of preventing or reducing oil pollution in the event of a grounding or collision resulting in bottom or side shell damage.

Effect of Bottom Damage



3. A double hull tanker can be defined as a ship designed for the carriage of oil in bulk where the cargo spaces are protected from the environment by a double hull consisting of double side and double bottom spaces dedicated to the carriage of ballast water. These ballast spaces extend for the full length of the cargo carrying area and a typical form of construction is shown at Attachment 1.

4. The effectiveness of double hull tankers in reducing the risk of pollution was heavily debated during the development of the requirements mentioned at paragraph 2 above. If it is accepted that the highest risk of collision or grounding is likely to occur near ports where tankers typically travel at slow speeds in congested and constrained waters, then there is a greater probability that any collision or grounding is likely to be low energy.

5. Under these circumstances, double hulls will reduce the risk of an oil spill during the most critical part of a voyage, for example:

(a) There have been incidents in the Lake Maracaibo Channel in Venezuela when:

- *Nissos Amorgos*, a single hull tanker, struck an underwater object, puncturing its hull and spilling a considerable amount of crude oil;
- *Olympic Sponsor*, a double hull tanker, was damaged at the same location, suffered a hole in the outer hull, but the inner hull remained intact and no oil was spilled; and
- *Icaro*, a double hull tanker, ran aground but no cargo was lost.

(b) Two cases of grounding off Milford Haven in Wales are also worth noting:

- *Borga* was a double hull tanker that grounded. The outer hull was holed but there was no oil spilled because the inner hull was undamaged; and
- *Sea Empress* on the other hand was single hull, went aground in the same location and sustained damage to the hull resulting in considerable pollution to the environment.

6. When double hulls were first mandated there were a number of risk related concerns expressed. It was suggested by some that there were inherent problems with these designs that could compromise their safe operation.

7. The more significant areas of concern (with each of these items considered further below) included:

- maintenance;
- operations;
- construction;
- salvage;
- design;
- stability; and
- ventilation and access.

Maintenance

8. Proper maintenance is the responsibility of the ship owner and manager. Undetected corrosion has been an underlying cause of some of the more spectacular structural failures of tankers over the last few years, eg, *Kirki*, which lost its bow off the coast of Western Australia in 1991.

9. Failure to maintain the integrity of protective coatings and cathodic protection in ballast tanks in particular has led to leakage, pollution and sometimes fire. Maintenance of the ballast tanks of double hull tankers is just as essential, perhaps even more so since there is two to three times the surface area of internal structure to consider when compared to a single hull tanker. If coating failure of ballast tank structures happens before the end of the projected operational life, then there are significant difficulties associated with re-instating an effective coating system.

10. However, the structure within the double hull ballast spaces is far more accessible than those in a single hull ship. Usually they will be between 2 and 3.5 metres wide (or high) allowing easy close up inspection, subject to the side tanks being fitted with side stringers to serve as inspection platforms at reasonable intervals. There should therefore be no reason for neglecting the inspection and maintenance of this structure and its coatings, subject to compliance with standard safety precautions prior to ballast tank entry.

11. Cargo tank internal inspection on both single and double hull tankers remains problematic; however, with a lengthy process of tank washing, gas freeing and ventilation required before these tanks can be entered safely. Close up access can also be difficult if adequate staging is not provided, as most “cherry pickers” will not pass through cargo tank access openings and the alternative of partial flooding of the tank together with use of a raft is often less than satisfactory. This issue has been recognised, however, and permanently fitted arrangements for close up internal inspections will be required to be provided on both new and existing tankers before 2005.

Operations

12. Double hull tankers have two distinct operational disadvantages in terms of stability (see also paragraphs 32-36) over single hull tankers. First, for a given depth of ship, adding a double bottom raises the ship’s centre of gravity and thereby reduces the ship’s reserves of stability. Second, free surface effects in cargo and ballast tanks during cargo operations may cause double hull tankers to lose stability and suffer an angle of loll, particularly if the design does not incorporate a longitudinal centreline bulkhead subdividing the cargo space. The necessary operational procedures to maintain stability in such cases may restrict cargo operations.

13. The most obvious potential hazard which all operators of double hull tankers need to guard against is that of cargo leakage into the ballast spaces. Leakage can arise from small fractures in bulkhead plating between cargo and ballast tanks caused by unpredicted local stress concentration, fatigue, construction defects, or eventually corrosion through failure of the ballast spaces’ protective coating system. The structural design of double hull tankers renders them more susceptible to minor failures of this type than single hull ships.

14. Sediment build up in ballast tanks has proved to be more of a problem for double hull than single hull tankers. The cellular nature of the double bottom ballast tanks can result in much greater retention of ballast water sediment, especially when ballast is taken on in estuarial waters, bringing an increase in the potential risks associated with the transfer of unwanted marine pests.

15. Piping systems in double hull tankers can be fully segregated with cargo pipes able to be run almost exclusively through cargo tanks and ballast pipes through ballast tanks. This overcomes the problem with single hulled tankers whereby a leaking ballast pipe run through a cargo tank can sometimes become a potential source of pollution by contaminating the clean water ballast.

16. Double hull tankers in general give improved cargo out turns over single hull ships. The smoother internal tank surfaces coupled with pump suctions recessed into wells in the double bottom make cargo discharge and tank washing much easier, giving an overall reduction in cargo residue retained within the cargo spaces.

Construction

17. Modern shipyards adopt factory production line techniques to improve productivity and reduce ship construction times. This can put pressure on quality and an owner's new building supervision team needs to be alert to several critical aspects of double hull tanker construction.

18. Probably the most significant of these is the protection of the ballast tanks. The interiors of these compartments are the areas most prone to attack because of the extremely corrosive nature of salt water carried within them on unladen voyages.

19. This aspect attains far greater significance in a double hull tanker because of the increased surface area of the structure inside the ballast tanks. Because these tanks are much longer and narrower than those in single hull tankers, their surface area can be two to three times that of the ballast tanks in a single hull ship.

20. Although protective coatings are an obligatory requirement of the major classification societies, it is left to the owner to choose the type, number of coats and ensure that they are properly applied, as well as making the decision on whether to fit anodes to help further reduce the potential for internal corrosion.

21. The confined spaces of double hull ballast tanks, whether sides or bottom, are far more restrictive to work in than the comparatively spacious ballast tanks of the single hull tanker, so anything of this nature over above the yard standard is generally at the request and additional expense of diligent owners, because it adds production complications for the shipyard.

22. Some features of the double hull design make life easier for the builder. The double sides and double bottom form natural three-dimensional rigid building blocks, less susceptible to deformation than the predominantly two-dimensional components of the single hull ship. However, the number of cruciform joints where primary structural members terminate on double skin structure is significantly increased. Many of these are located in critical areas (defined as areas where high stress levels combined with potential stress concentration features may lead to premature failure of primary structure).

Salvage

23. If a double hull tanker should run aground and rupture the outside shell, the available damage statistics suggest that the inner hull will, in most cases, not be breached. A single hull tanker, by contrast, would spill some cargo that would lighten the ship and make it easier to re-float. The size of the spill would largely

depend upon the extent and location of the damage, resulting heel angle and associated tidal action.

24. Damage to an 'L' shaped double bottom ballast tank on the other hand would cause flooding on one side resulting in a considerable list should the ship not come to rest on supporting ground, but remain free-floating. This may need to be corrected by the filling of an opposite tank. In any case, if the ship remained aground with damage to an 'L' shaped tank, then the consequent heel when the ship floated free would need to be considered in the salvage plan.

25. In the Prestige incident, one side was flooded and the ballast tanks on the opposite side were filled to bring the ship upright, causing the hull stresses to exceed the design limits by some 68%. The relative merits of single and double hull designs in the event of a casualty will depend on weather conditions at the time, as well as the availability and competency of the salvors but, in general, it will probably take longer to re-float a damaged double hull than a similarly damaged single hull tanker.

Design

26. The tanker designs produced by today's shipbuilders, although approved by all the major classification societies, are based on the assumption that the owner will undertake all necessary repairs to the fabric during its lifetime. There is no such thing as a maintenance-free tanker. The design process therefore, although important, is not the sole factor in determining the long-term integrity of the structure.

27. The history of ship structural design is one of evolution rather than revolution. Designers learn from past experience and each new ship tends to be a development of a previous successful design. This is because of the extremely complex interaction of the many variables that affect the stresses in the structure of a ship at sea, eg:

- structural design—plate thicknesses, local stress concentrations, stiffness and proper transmission of loads;
- construction quality—for instance, alignment, local imperfections, the quality of steel and welding (see para 24 above);
- distribution of the cargo weight in the ship;
- static and dynamic forces of the sea and waves resulting from heaving, pitching, rolling and possibly slamming;
- vibration from machinery;
- random corrosion; and
- the complex internal distribution of stresses between primary, secondary and tertiary structures.

28. Clearly, the 'design' or calculated stress levels in any element of the structure should have a safety factor based on previous successful experience. It is

impossible to calculate accurately the true stress levels in service throughout any tanker's structure entirely from first principles.

29. The difficulty of accurately predicting stress within the structure of a double hull tanker is compounded by the higher hull girder bending moments. Double hull tankers operate with global stress levels some 30% higher than those with single hulls because of the uniform distribution of cargo and ballast over the length of the ship. In a single hull tanker, the ballast tanks can be positioned to minimise longitudinal bending and shear stresses, resulting in values well below the acceptable maximum.

30. The consequence is most likely to be small fatigue fractures in early years of service, especially in larger double hull tankers, unless great care is exercised in the design detail and supervision of workmanship during construction.

31. Whilst these issues are important they are less relevant in existing designs of single hull tankers. From a practical perspective, particular attention has to be paid to the detection of fatigue cracks in the structure of double hull tankers to minimise the potential for cargo leakage into ballast tanks and the associated hazard presented by an accumulation of hydrocarbon gas within these confined spaces.

Stability

32. The transverse stability—the ability of a ship to remain upright and a measure of its resistance either to take on a list or to capsize completely—of single hull tankers has never really been a problem. Single hull tankers need longitudinal bulkheads which run throughout the length of the cargo tanks to provide longitudinal strength. The transverse spacing of these bulkheads can be chosen to give tank sizes of approximately equal capacity and bottom support structure of manageable proportions.

33. This is not the case with double hull tankers where the inner hull provides sufficient longitudinal strength without the need for additional longitudinal bulkheads for structural purposes, resulting in much wider cargo tanks with substantially increased free surface effect.

34. The free surface effect is the degradation in transverse stability which occurs when there are slack surfaces—the liquid surface in any tank which is not filled so full that surface movement is effectively restricted by the deck structure in way of the tank hatch.

35. When combined with the effect of the double bottom ballast tanks that effectively raise the centre of gravity of the cargo, there is a consequential large reduction in intact stability. This can readily occur during simultaneous cargo and ballast handling operations and requires careful management of all liquid transfer operations, ideally supported by the provision of appropriate quality operational information on board the double hull tanker in question.

36. In terms of damage stability, ensuring compliance owing to the intact stability issues referred to above is not easy and much more care needs to be taken in

distributing the cargo on board a double hull than single hull tanker. Whilst this task is helped by the use of on board computers, it is underpinned by the need to provide an accurate and comprehensive trim and stability manual, ideally before the ship enters commercial service.

Ventilation and access

37. The cellular nature of the wing and double bottom tanks of double hull tankers makes the adequate ventilation of these spaces an important issue given personnel will be expected to regularly and safely enter them to check for corrosion, cargo leakage and ballast water sediment build up.

38. Proper consideration has to be given at the design stage to ensure the provision of sufficient openings to permit good ventilation, because tank entry is a safety critical operation on board any tanker, but especially so in the circumstances mentioned above where access is particularly constrained and the provision of timely assistance especially restricted by the hull's structural configuration.

39. Ease of access for close up structural inspection is an issue for all oil tankers, especially in the case of the comparatively large single hull tanker cargo and ballast tanks. Rafts, remotely controlled vehicles, both in and out of water, ladder access and staging are all used with varying degrees of success.

40. In the case of double hull tankers, whilst the double bottom ballast spaces are easier to inspect, this may not be the case for the side tanks unless "inspection friendly" fore and aft stringers, horizontal structural members running the length of the tanks, are provided at convenient heights to serve as platforms for this purpose.

41. Cargo tanks on board double hull ships, being comparatively free of internal structure, need some provision for inspection of the deckhead areas, especially if heated cargoes are being carried when corrosion can be expected to be much more rapid because of the vacuum bottle or "Thermos" insulating effect stemming from the double hull design itself.

CONCLUSION

42. AMSA currently inspects all high-risk oil tankers under its port State control regime, defined as being all eligible oil tankers of age 15 years and over and oil tankers of construction other than double hull regardless of age.

43. These inspections usually take place once the tanker in question has safely reached port and are of necessity limited in the extent to which structural areas can be examined given the hazardous nature of the cargo these ships carry.

44. The structural integrity of an oil tanker, be it single or double hull, relies not only on the good quality of initial design, construction and continuing competent operation, but also on an effective program of inspection, maintenance and repair being conducted by the owner/operator.

45. The standards of design, construction, maintenance and operation of double hull tankers is every bit as important as those of their single hull predecessors.

All those who have responsibility for monitoring these standards must be aware of the different problems posed by double hulls and the appropriate inspection and check procedures to counter them.

46. Any tanker, which is not properly designed, constructed, maintained or operated, regardless of its hull construction configuration, poses a greater risk than one that is of good quality design and construction, well maintained and diligently managed and operated throughout its working life.

Acknowledgement

The Australian Maritime Safety Authority gratefully acknowledges the use of material in the form of text and illustrations provided by the Oil Companies International Marine Forum (OCIMF) during the preparation of this discussion paper.

Attachment 1

Double Hull Construction