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Double Hull Tankers – Are they the answer?

Summary

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.

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Introduction

Are double hulls the answer? The shift to double hull designs will reduce the likelihood of oil spillage but only if they are:

- maintained to a higher standard than is apparent in some ships today,
- operated by personnel who are well trained and committed to their jobs; and
- designed and built to high standards.

They can help reduce the pollution from the many minor grounding and collision incidents which usually occur within port limits when the ship is under pilotage.
Double hull tankers can still be prone to catastrophic structural failures, if not maintained and operated to high standards.

It should also be recognised that, when Builders are increasingly driven to optimise designs to remain competitive it is left to Owner/Operators to insist on maintaining, or sometimes enhancing, previous standards and designs. In particular there is a need for higher standards in building specifications to address the critical importance of fatigue detailing, surface preparation, ballast tank coatings and enhanced means of access for ease of inspection in ballast and cargo tanks. There are numerous guidelines for good practice however none are enforceable and are dependent upon the owner/operator paying. That is if the shipyard allow as they are very often not compatible with existing shipyard production practices.

It is worthy of note that while currently there are no international mandatory standards for safety of vessels with regard to, strength, fatigue life, coatings and corrosion limits. There is however a proposal in IMO by Bahamas and Greece to introduce a minimum mandatory standard.

1. Maintenance

Proper maintenance is the responsibility of the ship owner and manager. It is not the responsibility of the classification society, the flag State, the underwriter or the charterer. These latter bodies can exert some influence on the maintenance of the ship but they will never be in a position to see or learn as much about the condition of the ship as the manager. Nevertheless, the influence which these organisations wield has a heavy commercial impact - detention, withdrawal of certificates, loss of business - and it is essential that their monitoring activity is reinforced as it represents the best deterrent to lack of maintenance.

Undetected corrosion is a major cause of some of the spectacular structural failures we have seen in the last few years (Figure 1). In particular, failure to maintain the integrity of protective coatings and cathodic protection in ballast tanks 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 structure compared with a single hull tanker. If coating failure of ballast tank structures arises before the end of the projected operational life, there are significant difficulties associated with reinstating an effective coating system.

The cellular nature of ballast spaces significantly increases the cost and difficulty of removing original failed coating, surface preparation and recoating. The alternative is to continue operating with the additional disruption imposed by the annual inspection of all ballast spaces which will be required by Class in cases where coating condition is defined as “poor”. However, once significant coating failure is experienced the rate of corrosion on exposed areas will accelerate to the point where extensive replacement of steelwork will soon be required. Therefore, coating life could in fact become the deciding factor in determining the economic trading life of double hull designs.

The structure in the double hull spaces is far more accessible than the ballast tanks of a single hull ship. Usually they will be between 2 and 3.5m wide (or high), allowing easy close-up inspection provided the side tanks are fitted with side stringers to serve as inspection platforms at reasonable intervals. There should therefore be no excuse for neglecting the inspection and maintenance of this structure and its coatings. ***International Safety Guide for Oil Tankers and Terminals (ISGOTT)*** guidelines do, however recommend that ballast tanks are not entered while the ship is loaded with cargo, but that weekly sampling of the atmosphere for hydrocarbon gas is undertaken during loaded voyages. Inspection inside ballast tanks is greatly facilitated by the use of light coloured coatings. Not only does this make the detection of any cargo leakage much easier, it also makes the operation much safer (Figure 2).

Fig 1.
Failure due to undetected corrosion

Fig 2.
Light coating improve visibility and safety during structural inspections

Inspection inside cargo tanks is much more difficult as it requires a lengthy process of washing, gas freeing and ventilation before they are safe to enter. Some double hull tankers have suffered rapid corrosion inside the cargo tanks, which are often not coated. **OCIMF has published a paper on this problem which appears to be far more serious than on single hull tankers. *(Factors Influencing Accelerated Corrosion of Cargo Oil Tanks)***

Further guidance on the inspection and maintenance of double hull tankers is given in a book published jointly by the Tanker Structures Co-Operative Forum, the International Chamber of Shipping (ICS) and OCIMF. ***Guidelines for Inspection and Maintenance of Double Hull Tanker Structures***

2. Operational Issues

Operational safety on double hull tankers was recognised at IMO as requiring special consideration and industry representatives were asked to draw up a set of guidelines. These are now included in the latest edition of the ***International Safety Guide for Oil Tankers and Terminals (ISGOTT)*** In addition to highlighting the potential problems of stability and ventilation referred to above, the guide gives useful advice on:

- routine monitoring of empty ballast tanks for hydrocarbon gases;
- action to be taken in the event of cargo leakage;
- procedures to be followed if a ballast tank must be inerted as a result of cargo leakage into the tank; and
- advice on gas freeing, cleaning and entry after inerting.

The obvious hazard, which all operators of double hull tankers will need to guard against, is that of cargo leakage into the ballast spaces. The ISGOTT document is a useful guide to handling this situation. 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.

Mud build up in the ballast space should be expected to be even more of a problem than with single hull tankers. Experience with gas ships indicated that when ballast is taken on in estuarial waters, the cellular nature of the tanks causes a much higher retention of mud that is the case in the wider ballast tanks of a single hull ship. Some owners have fitted ballast tank washing systems to combat this effect.

Piping systems in double hull tankers will be fully segregated, with cargo pipes running almost exclusively through cargo tanks and ballast pipes through ballast tanks. This overcomes the problem which exists today of ballast pipes running through cargo tanks and becoming a potential source of pollution by cargo leaking into the pipes and through into the clean ballast. It does mean, however, that replacement of the ballast pipes will be more difficult since they will be threaded through access holes in the floors of the double bottom tanks, as they are in bulk carriers and other dry cargo ships with double bottoms. Removal of old pipes will require the cutting of large openings in the bottom shell plating or inner bottom.

There is no doubt that significant advantages in cargo operations will accrue from the change to double hulls. This will especially benefit product carriers, which carry high value cargo, and where even better outturns can be expected. The smoother internal tank surfaces and pump suctions recessed into wells in the double bottom will make cargo discharge and tank washing much easier and lead to reduced cargo residue in the tanks.

3. Construction Issues

Modern shipyards adopt 'factory' techniques to improve productivity and thus reduce ship construction times. Whereas a VLCC might have taken two years to build in the early 1970s, double hull VLCCs are now being built, from first steel cutting to delivery, in about eight or nine months. This puts a great deal of emphasis on doing the job correctly first time - corrective work or request by owners to follow “Industry Best Practices and Guidelines” causes delay and disrupts the shipyard's production programme. This in turn puts pressure on quality and an owner's supervision team, needs to be alert to several critical aspects of the construction of double hull tankers.

Probably the most significant of these is the protection of the ballast tanks. The ballast tanks, which carry sea water as ballast when the tanker is on its return (empty) voyage are the areas most prone to corrosion because of the extremely corrosive nature of salt water. 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 is two to three times that of the ballast tanks in a single hull ship.

Although protective coatings are an obligatory requirement of the major classification societies, it is up to the owner to choose the type and number of coats, ensure that they are properly applied and decide whether to fit anodes as well. Shipyards will argue that their standard preparation procedure is adequate even though it fails to meet the standards recommended by experts and paint manufacturers. The standard coating specification from the builder will usually be inadequate for the expected lifetime of the ship, again to keep the build cost down and minimise the impact on production. The confined spaces of the double hull ballast tanks, whether sides or bottom, are far more unpleasant to work in than the comparatively spacious ballast tanks of the single hull tanker and good ventilation through the design of openings is very important. Maintainability also needs to be designed into the vessel and here is an area where currently there are no enforceable standards, anything included at present is generally at the request and expense of, diligent managers and operators, as it adds complication to production for the shipyard.

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). It is vital that in these locations, the importance of enhanced standards of fit up, alignment and inspection, which vary greatly from yard to yard, are recognised and implemented by the Designers, Builders and Class. Another area where there is guidance available which is generally at odds with shipyard production practice.

4. Salvage of a double hulled tanker

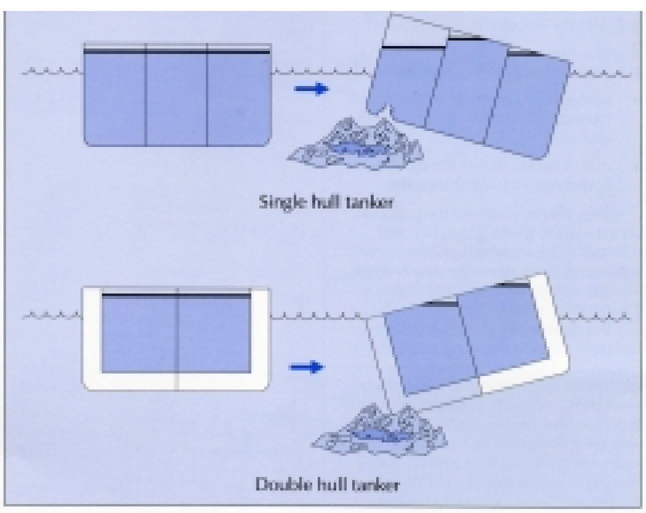
If a double hull ship should run aground and rupture the outside shell, the available damage statistics suggest that the inner hull will, in most cases, not be breached and no oil will be spilt. However, on smaller tankers the damaged space might easily be a 'U' shaped tank, allowing free flooding right across the double bottom and up to the outside water level each side of the cargo tank. Thus a considerable weight of flood water would be admitted, making the ship sit more firmly on the bottom and more difficult to re-float. A single hull tanker, by contrast, would spill a small amount of cargo which would lighten the ship and make it easier to re-float (Figure 3). Damage to an 'L' shaped double bottom tank on the other hand, would cause flooding on one side resulting in considerable list should the ship not come to rest on the rock but remain free-floating. This would need to be corrected by the filling of an opposite tank. 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.

In the Prestige incident one side was flooded and the ballast tanks on the opposite side were filled to bring the ship upright, this caused the stresses to exceed the design limits by some 68%.

The relative merits of single and double hull designs depend on weather conditions at the time and on the availability of salvors. It might in some circumstances be advantageous to have the ship sitting more firmly aground until salvage equipment arrives.

Salvors have indicated that they would prefer to salvage a ship with a double bottom as it gives them the option of using air pressure to expel the flood water. This is certainly true of dry cargo ships, which do not have to meet the raking damage criterion and have greater subdivision in their double bottom tanks. Nor do they have interconnected side and bottom tanks. The use of air pressure then becomes a feasible salvage technique. Almost certainly it will take longer to re-float a damaged double hull tanker than a damaged single hull tanker, during which time the weather conditions could be critical.

Fig 3.
Effect of Bottom Damage



5. Design Issues

Structural Design

The structural integrity of oil tanker hulls relies not only on good quality of initial design and construction but also on an effective programme of inspection, maintenance and repair being conducted by the owner or his manager. However well designed and built a tanker may be, it will not provide trouble-free service unless it is well operated. 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 and construction process therefore, although important, is not the sole factor in the long term integrity of the structure.

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. Whenever this course has been abandoned - as in the rapid growth in size of tankers in the 1960s and the large open hold container ship designs of the 1970s - structural problems have materialised sooner or later due to the lack of relevant service experience. A shift from single hull design to double hull design represents a similar departure from established successful designs. Despite the advent of ever more powerful computers and increasingly sophisticated structural analysis programs, structural design remains a largely empirical process and it is still impossible to produce a successful design exclusively from first principles. This is because of the extremely complex interaction of the many variables which affect the stresses in the structure:

- 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;
- 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.

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 the tanker's structure entirely from first principles. However, safety factors for large double hull structures are not yet available for the simple reason that there is little service experience. Although there is already some successful service experience from gas ships and smaller double hulled product carriers, it will be several years before the structural design of double hulled VLCCs can be proved. In the meantime, generous safety factors need to be incorporated into the design.

The utilisation of higher tensile (HT) steel in double hull designs, driven by builders to minimise steel weight and retain competitive edge in the world markets, is again an important factor. When used extensively for primary and secondary structure, particularly within the ballast tank spaces, the resulting increases in deflections and stress levels will impact negatively on their fatigue lives and also upon the effective lifetime of coating systems. Thus the incorporation of extensive amounts of HT steel will potentially have more impact on the operational performance of a double hull design compared with single skin. Therefore, it falls upon the Owner/Operator to try and limit the extent of HT steel incorporated in new builds, usually at extra cost to themselves.

The difficulty of accurate stress prediction is compounded by the higher hull girder bending moments of double hull tankers (Table 1). These arise because of the uniform distribution of cargo and ballast over the length of the ship, whereas in a single hull tanker the ballast tanks can be positioned to minimise longitudinal bending and shear stresses, resulting in values well below the classification society maximum (Figure 4).

Table 1

Stresses in double hull tankers (ballast condition)

VLCCs – same dimensions and hull shape	Double hull tanker	Single hull tanker
Still water bending moment (TM)	695 200	183 400
Wave bending moment (TM)	1 074 500	1 074 500
Total bending moment (TM)	1 769 700	1 257 900
Minimum midship I/y (m^3)	95.770	95.770
Required I/y (m^3)	101.125	95.770
Seagoing Stress (N/mm^2)	**171.7**	**128.8**

Seagoing stress of double hull VLCCs will be 33% greater than seagoing stress of single hull VLCCs

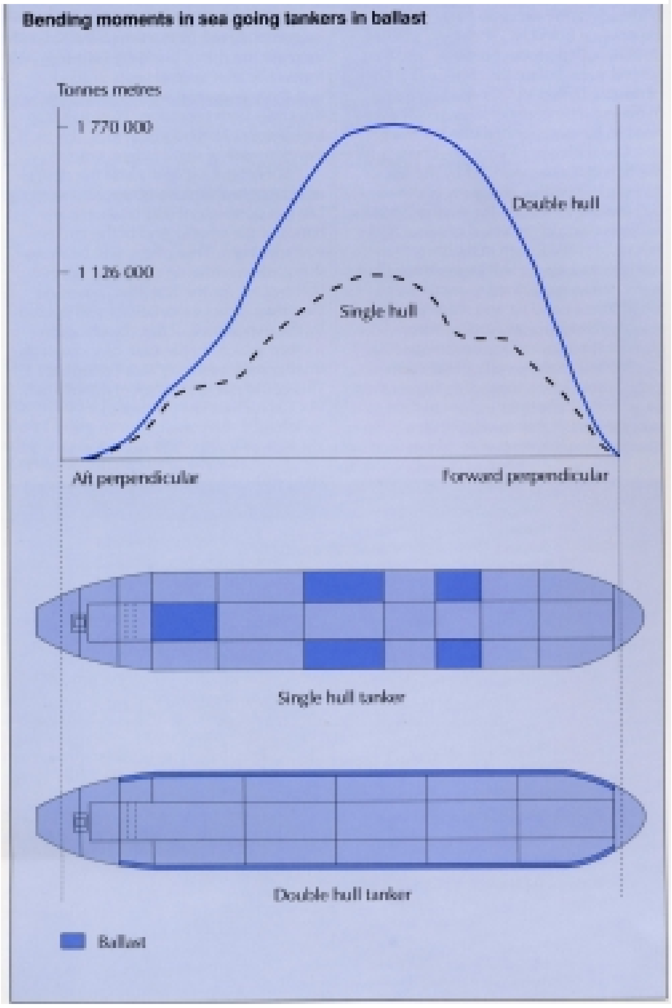
TM = Tonnes metres
I/y = Inertia/distance from neutral axis
N/mm^2 = Newtons per square millimetre, a measure of stress

Double hull tankers will operate with global stress levels some 30% higher than those with single hulls - close to the maxima acceptable to classification societies - unless an owner spends a substantial amount on extra steel thicknesses and suffers the attendant increase in design draught, or builds in extra ballast tanks to reduce bending moments. Commercial pressures mean that few, if any, owners are willing to suffer these financial penalties. These higher stresses will increase the risk of buckling failure - especially after several years in service and the consequent reduction in plate thickness from corrosion. They will also increase the likelihood of the development of small fatigue cracks.

Many shipyards worldwide designed double hull tankers for the first time based on their own direct calculations and guided by the experience of the classification society, which, in the case of some of the smaller societies, may also be limited. This could put the design of double hull VLCCs, for example, closer to 'revolution' than 'evolution' in the absence of service and operational experience and safety factors. The consequence is most likely to be small fatigue fractures in the early years of service, especially in larger double hull tankers, unless great care is exercised in the design detail and workmanship during construction. Some of the major classification societies have put much effort into studying these problems and are confident that they can achieve a successful structural design first time.

Some of the first generation of double hull tankers suffer from defects in poor design details, such as poor alignment of the cruciform joints, poor support of the lower knuckle between cargo tank and ballast tank and lack of understanding of the need for good weld profiling in areas of higher stress. None of these issues was relevant on single hull tankers. There is still a learning process as these problems and others are detected and solved. In the meantime all operators of double hull tankers have to be on their guard to detect fatigue cracks as quickly as possible to prevent crude oil leaking into ballast tanks or the contamination of valuable product cargoes with ballast water. Perhaps the greatest concern is that of an accumulation of hydrocarbon gas inside an empty ballast tank.

Fig 4.



Intact Stability

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. Meeting damage stability criteria in the event of damage to the outside shell plating can sometimes be difficult for smaller tankers with a relatively narrow beam, but there are generally no constraints on loading and de-ballasting operations of single hull tankers imposed by lack of stability. This situation has changed with the introduction of double hull tankers.

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. The inner hull of double hull tankers already provides sufficient longitudinal strength and no further longitudinal bulkheads are necessary for structural purposes. Shipyards therefore built double hull tankers with no longitudinal subdivision inside the cargo tank section, so that a single tank extends across the ship from double side to double side (Figure 5). Recent changes to the MARPOL convention have prevented this practice on new ships, but not before many had been built. It is possible to produce designs of this nature for tankers up to about 150 000 tonnes dwt. Inclusion of a further longitudinal bulkhead obviously increases the weight of steel, making the design more expensive, less marketable and less attractive to a prospective owner.

Fig 5.

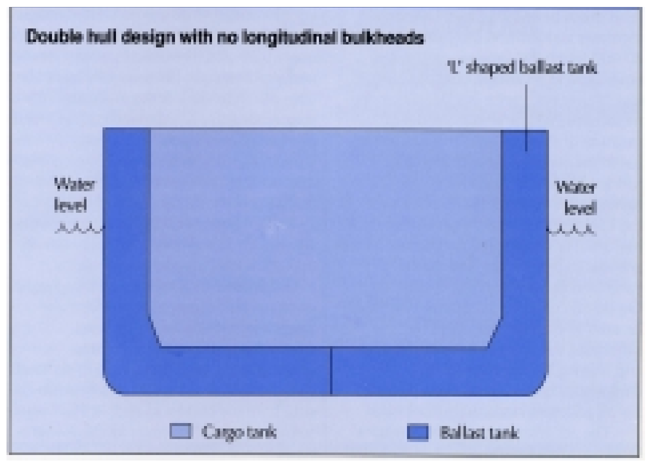
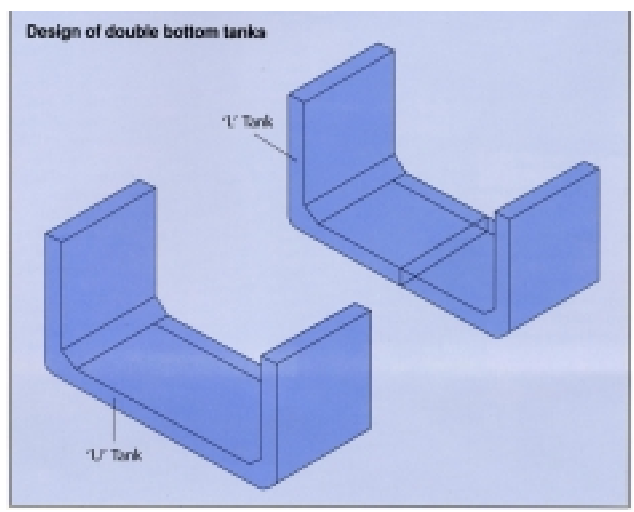


Fig 6.



The result of having these very wide cargo tanks is a substantially increased free surface effect.
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. Combined with the

double bottom, which raises the centre of gravity of the cargo, there is a consequent large reduction in intact stability. This can occur almost instantaneously during simultaneous cargo and ballast handing operations. In the case of a 40,000 tonne dwt product carrier it is equivalent to an almost instantaneous loss of over one metre in GM value - the metacentric height which is a direct measure of ship stability. This has already led to instances of these ships taking on a sudden list during cargo handling. The immediate solution is better training of the cargo officers and the provision of high quality information on board, so that positive stability is retained throughout cargo and ballast handling operations.

On-board computer programs which can be used to plan the discharge by simulating the sequence of operations and alerting the operator to any dangerous condition which could arise are an additional valuable aid.

Damaged Stability

The second aspect of stability concerns the need to load tankers so that they will survive specified types of damage (The International Convention for the Protection of Pollution from Ships, MARPOL, Regulation 25). The smaller the ship the more difficult a task this becomes. Checking a proposed seagoing condition against all the possible damage scenarios can be a laborious process and one which all Chief Officers cannot easily undertake. Ship builders usually have little understanding of the pressures surrounding this activity and can be persuaded only rarely to provide sufficiently comprehensive guidance in a form which is easily understood. Fortunately the use of computers is of assistance here. Most loading instruments are already based on personal computers and additional programs are now available for checking intended loading patterns. These programs can be integrated with the trim and stress calculator, giving a quick and easy solution to the problem. The only difficult part can be the extraction of sufficient data from the builder to enable the software supplier to cover all the owner's requirements.

Owing to the intact stability problems referred to above, compliance with damaged stability criteria is now not so easy and considerable care needs to be taken in distribution of the cargo. For example, there are instances where a cargo of warm product can be loaded in compliance with the regulations; but on cooling, the cargo surface is slightly lower down the tank and, because of the deck camber, the free surface effect has increased to a point where the stability is unsatisfactory. A conscientious officer will check for these small details but others might not. This raises the question of the policing by Flag or Port States of this particular regulation. It is notoriously difficult to apply Regulation 25 effectively in practice. A Flag State may approve certain specific cargo loading conditions in a trim and stability manual, or it may even approve some form of stability envelope. But there is nothing in practice to prevent a ship from distributing cargo either in contravention of the approved conditions or in a manner which has not been specifically approved. This had led to situations where cargo has been declined by one ship but a sister ship, operated by a different company has accepted it. This is undoubtedly an area in which the conscientious operator is penalised and where tighter vigilance by flag and port States is required.

Ventilation and Access

Full scale trials carried out in a shipyard on completion of a double hull tanker of about one million barrel capacity have shown that, unless carefully designed, it can be impossible to blow air from the deck down one side of a 'U' shaped ballast tank and exhaust naturally from the other, despite the fact that an apparently ample number of openings are provided. This is due to the cellular nature of the wing and double bottom tanks. Personnel entry Into these spaces - which is necessary to check for corrosion, leakage and mud build-up - will be hazardous unless proper consideration is given at the design stage to the provision of sufficient openings to permit good ventilation. This is a feature which is usually not fully appreciated by shipyard designers who have no operational experience.

The importance of good access has been endorsed by the Report of the Donaldson Enquiry following the 'Braer' incident in 1993 and more recently by submissions to the IMO by the Bahamas Flag Administration. Current surveys on VLCCs demonstrate how difficult it is to obtain close-up access to inspect the structure inside large tanks. Rafts, remotely controlled vehicles (both underwater and above), 'mountaineering' and staging platforms have all been tried with varying degrees of success. These problems can be solved at the design stage by the provision of permanent walkways for access to those parts which need to be closely inspected. Structure inside double bottom tanks will be relatively easy to inspect, but other tanks will have little or no structure inside from which to permit a close inspection. The double side tanks, for instance, can easily be made more 'inspection friendly' by the addition of some fore and aft stringers - horizontal structural members running the length of the ballast tank – at convenient heights which can serve as inspection platforms. Cargo tanks, which will be relatively free from internal structure, will need some provision for inspection of deckhead structure, especially when heated cargoes are carried and corrosion can be expected to be more rapid.

6. Conclusion

It should be recognised that the current poor perception of the industry has not been acquired simply because double hull tankers have not been used extensively. The standards of design, construction, maintenance and operation of double hull tankers is every bit as important as those of their single hull predecessors and the tanker industry cannot afford to relax its vigilance in these areas. All those who have a responsibility for monitoring these standards - in particular the management of the owning company - must be aware of the different problems posed by double hulls and implement appropriate inspection and check procedures to counter them.

Double Hulled Tankers, Are they the answer? – Not necessarily because

Poorly designed, constructed, maintained and operated double hull tankers have as much if not more potential for disaster.

Well maintained, diligently operated, high quality tankers whatever the construction are the answer.

Further information can be obtained from:
Oil Companies International Marine Forum
27 Queen Anne's Gate
London SW1H 9BU
Tel: +44 (0)20 7654 1200
Fax: +44 (0)20 7654 1205
Email: enquiries@ocimf.com
www.ocimf.com