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A Review of Double Hull Tanker Oil Spill Prevention Considerations

Report to Prince William Sound RCAC

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Photo: T/V Alaskan Maiden (Alaska Department of Environmental Conservation photograph)

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Table of Contents

Executive Summary

Over the past twenty years, the US oil tanker fleet, including those vessels involved in the Trans-Alaska Pipeline System (TAPS) trade in Prince William Sound (PWS), has undergone major engineering and structural improvements to comply with federal and international standards requiring that new oil tankers be constructed with double hulls, while older single hull vessels are phased out of US and international fleets.

Double hull tankers have traditionally been viewed as offering a higher level of oil spill prevention as compared to single hull construction, because the outer, double hull of the vessel can be penetrated without causing a release of cargo. Several studies have demonstrated that the rate of oil outflow from a double hull tanker involved in a grounding or hull breach is generally less than from other tanker designs. Practical experience supports these studies, as there have been a number of incidents where a double hull tanker's outer hull has been breached, but pollution has been avoided by the containment afforded by the intact inner hull.

However, a double hull does not, in and of itself, prevent an oil spill from occurring. Its prevention value lies in reducing spill size or severity if the tanker does experience a hull breach or accident.

Oil spill statistics clearly show that overall oil spillage rates from tankers have been on the decline for the past few decades. Recent studies comparing oil spillage rates from tankers based on hull design seem to suggest that double hull tankers spill less than pre-MARPOL single hull tankers, double bottom tankers, and double sided tankers. However, post-MARPOL single hull tankers with segregated ballast tanks actually seem to have similar spillage rates to double hull tankers. Overall, it is difficult to make meaningful comparisons between the aging fleet of non-double hull tankers and the newer OPA 90 and MARPOL double hull designs, because of a relatively limited data set. Additional studies may help to further clarify the relationship between tanker hull configuration and oil spillage rates.

There continues to be some disagreement regarding the overall prevention value of a double hull oil tanker. A 2003 report published by the Oil Companies International Marine Forum (OCIMF) cautions that the complex design and structure of double hull tankers can make them more susceptible to maintenance and operations problems. Like all vessels, double hull tankers can still be prone to catastrophic structural failures, particularly if they are not maintained and operated to high standards.

Perhaps the most important consideration in evaluating the overall oil spill prevention value of a double hull tanker design is the role of human factors – human and organizational errors – in oil spills and tanker accidents. While research shows that most crude oil tanker accidents involve the interaction between humans, organizations, and systems or equipment, oil spill and accident prevention measures are often disproportionately focused on the engineering or technological "fixes," since these are the most easily remedied. As the new classes of double hull tankers that transport oil become increasingly reliant on engineered systems and automated

technologies, the humans that operate these systems are subjected to new challenges that may actually increase accident risks. And while accident risks with a technological basis can often be remedied through engineering, accidents that involve human-technology interactions are much more difficult to address.

Double hulls are a key component of the oil spill prevention system, but they are not the only component. A double hull does not in and of itself *prevent* an accident or chain of events that could lead to an oil spill from occurring; its reduces oil spill risks by reducing the amount of oil that might be released if an incident or accident should occur. The only way to safeguard against the potential for future oil spills from double hull tankers is to create and maintain an effective prevention system including engineering and human factor components.

A Review of Double Hull Tanker Oil Spill Prevention Considerations

Report to Prince William Sound Regional Citizens' Advisory Council
December 2009

1 Introduction

1.1 Purpose and Scope

The Prince William Sound Regional Citizens' Advisory Council (PWSRCAC) commissioned this report to consider how the transition from single hull to double hull tanker design might impact the overall risk of oil spills from tankers.

As the U.S. tanker fleet transitions from single to double hull vessels, this report considers how double hulls have been documented to reduce oil spillage. The report also considers limitations to the oil spill risk reduction offered by double hulls, and discusses additional measures that may further reduce or prevent spillage from oil tankers.

1.2 Transition of U.S. Oil Tanker Fleet from Single to Double Hulls

Over the past twenty years, the US oil tanker fleet, including those vessels involved in the Trans-Alaska Pipeline System (TAPS) trade in Prince William Sound (PWS), has undergone major engineering and structural improvements to comply with federal and international standards requiring that new oil tankers be constructed with double hulls, while older single hull vessels are phased out of US and international fleets.

The Oil Pollution Act of 1990 (OPA 90) and the 1992 and 2003 amendments to the International Convention for the Prevention of Pollution from Ships (MARPOL) both contain requirements relating to the hull configuration of oil tankers. Under these national and international requirements, all oil tankers over 5,000 gross tons (GT) calling on US and most international ports must have a double hull. These requirements have been phased in gradually to allow time for the ship design and construction. By 2010 most of the US and international tanker fleet will have double hulls; by 2015 single hull oil tankers over 5,000 GT will be completely phased out.

Double hull tankers have traditionally been viewed as offering a higher level of oil spill prevention as compared to single hull construction, because the outer, double hull of the vessel can be penetrated without causing a release of cargo. The potential for a double hull to avert a major oil spill in the event of a hull rupture has been demonstrated many times in incidents involving double hull tankers where the outer hull is compromised but no oil spill occurs. However, a double hull does not, in and of itself, prevent an oil spill from occurring. Its prevention value lies in reducing spill size or severity if the tanker does experience a hull breach or accident.

The goal of reducing spillage was one of the major factors driving the shift in national and international policy toward requiring double hull design for oil tankers. This report considers a range of factors associated with the question of how well, and to what extent, double hulls can be expected to reduce the overall risk of oil spills from tankers.

2 Role of Double Hulls in Reducing or Preventing Oil Spills from Tankers

2.1 Tanker Hull Configuration

A double hull tanker is a ship designed to carry oil in bulk in which the cargo spaces are protected from the environment by a double hull consisting of a double side and double bottom. These spaces, which may be filled with ballast, extend for the full length of the cargo carrying area, and a typical form of construction for a double hull tanker is shown in Figures 2.1 and 2.2. (AMSA, 2002)

The effectiveness of double hull tankers in reducing the risk of pollution was heavily debated during the development of both OPA 90 and the MARPOL double hull amendments. The basic rationale used to support double hull requirements at both the federal and international level is that double hulls reduce the risk of oil spills that occur during a low energy grounding or collision. Because most accidents occurring in or near ports typically involve lower vessel speeds, and because the risk of grounding or collision is typically highest in port areas, double hull tanker designs offer a reasonable option for reducing oil spill risks from tankers under these circumstances (AMSA, 2002).

As the international tanker fleet transitions to double hulls, more examples become available of the potential for double hulls to reduce or even prevent oil spills under certain scenarios. There have been a number of incidents where a double hull tanker's outer hull has been breached, but pollution has been avoided by the containment afforded by the intact inner hull (Shiptalk, 2009).

Figure 1.1 Typical Single and Double Hull Configurations

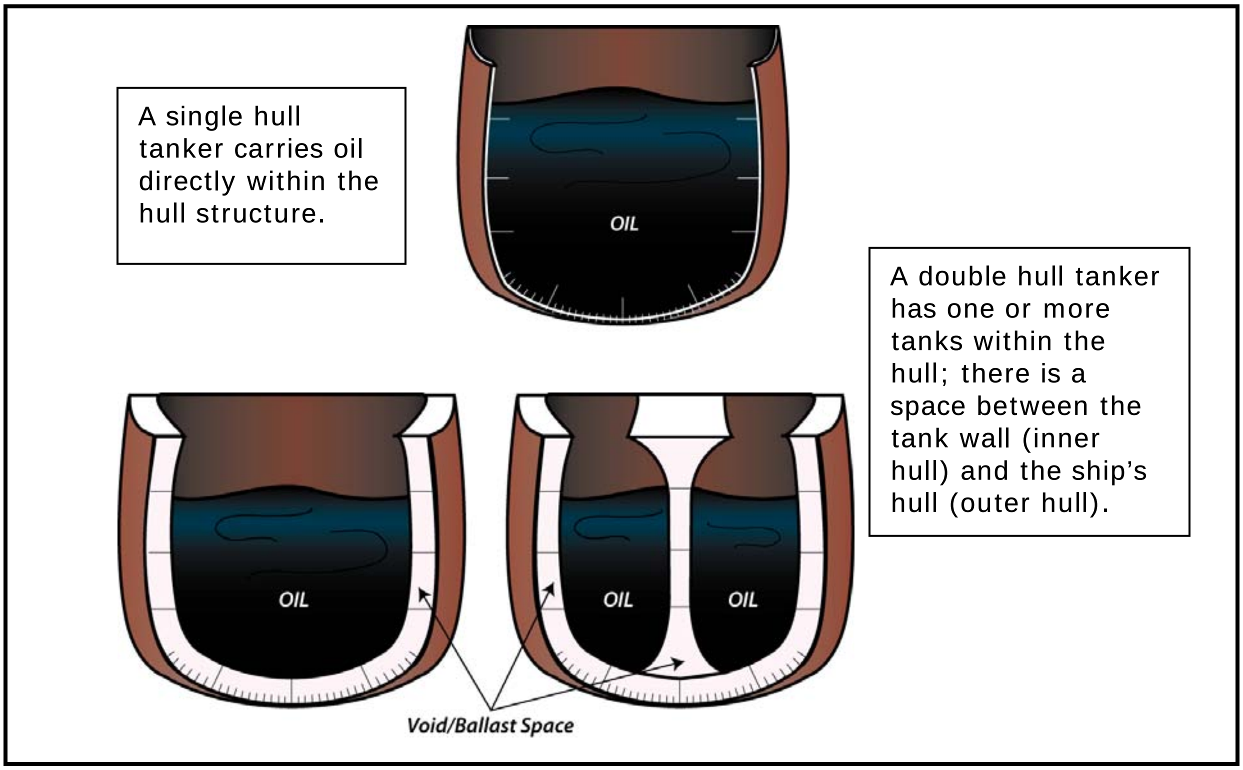


Figure 2.2 Double Hull Tanker under construction, showing tank spaces and double hull/ballast area (Source: AMSA, 2002)

2.2 Outflow Analyses of Single and Double Hull Tankers

A 1989 report published by the Coast Guard in the wake of the *Exxon Valdez* oil spill predicted that, had the vessel been built with a double bottom, the 11 million gallon oil spill could have been reduced in size by as much as 50 per cent (Tweedie, 1989). This type of analysis spurred several research efforts within the US to attempt to better understand and quantify how the amount of oil spilled from double hull tankers might differ from single hulls.

The 1989 Coast Guard report was presented during the congressional hearings that followed the 1989 oil spill; the same hearings ultimately resulted in passage of the 1990 Oil Pollution Act. The Coast Guard study considered the possible consequence of a spill from three variations on the *Exxon Valdez*'s single hull: one would have a 6.7 foot double bottom and wing ballast tanks, the second a 19 foot double bottom and no wing ballast tanks, and the third an 11.5 foot double bottom with no wing ballast tanks.[1] The hull shape, cargo capacity, and amount of segregated ballast were kept the same for all alternatives.

The study then calculated the outflow rates for each variation based on the assumption that the vessel ran aground and sustained the same damage as the *Exxon Valdez*. Oil outflow was calculated for two different grounding conditions – (1) vessel ran aground and remained at a 56-foot draft and (2) vessel ran aground, tide went out, and waterline was 47 feet forward and 54 feet at the stern. Oil outflow was also calculated for one collision scenario. For the third hull design alternative, oil outflow was estimated as a maximum and minimum amount, depending upon different variables.

The study found that the variations on hull design were predicted to have reduced the outflow amount by between 25% and 60%, depending upon the grounding scenario. It also found that the outflow amount would have *increased* for a collision scenario from between 22% to 52% depending upon hull configuration. The study concluded that wing tanks seem to offer the best protection against collision outflow for the particular scenarios considered, but that the double bottom shows a higher impact in reducing outflow from groundings, for the scenarios analyzed. While the 19-foot double bottoms showed the highest preventative effect for oil spills from groundings, they were found to be lacking in basic damage stability and therefore not a realistic alternative.

The Coast Guard study concluded that double bottoms offer protection against spills from groundings while double sides are more protective for collisions. The report also concludes that in scenarios where both the inner and outer hulls of a double hull vessel are penetrated, oil outflow may be slowed by oil getting trapped in ballast space between hulls. The report theorized that a slower outflow rate might improve the chances for successfully containing and removing the oil. The Coast Guard report also considers a number of counter-arguments against double hulls and dismisses most (Tweedie, 1989).

[1] The third alternative design was actually developed following an initial analysis of the first two designs for both grounding and collisions.

A 1998 report by the National Research Council compared double and single hull designs to evaluate oil outflow rates, ship stability and survivability, and structural integrity.[2] The study used a methodology developed by the IMO and found that the arrangement of cargo and ballast tanks has a major influence on the effectiveness of reducing oil outflow and also on intact stability (NRC, 1998).

Similar to the Coast Guard study, the 1998 NRC study found that oil outflow from a double hull tanker will occur only if the extent of penetration exceeds the distance between the inner and outer hulls (thereby piercing the cargo tank). The expected spill size is directly related to the number of cargo tanks breached and their size, therefore the likelihood of a double hull tanker spilling oil is heavily influenced by the configuration and dimensions of double bottom and wing tanks. There is therefore a tradeoff between the internal subdivision of cargo tanks and the spacing of bulkheads from tank boundaries – larger cargo tanks have the potential to spill more oil, while smaller tanks that are configured closer to the bulkhead increase the likelihood that more than one tank could be damaged. The study also showed that the subdivision of cargo and ballast tanks by centerline bulkheads can be important to reducing oil outflow in the event of a collision or grounding.

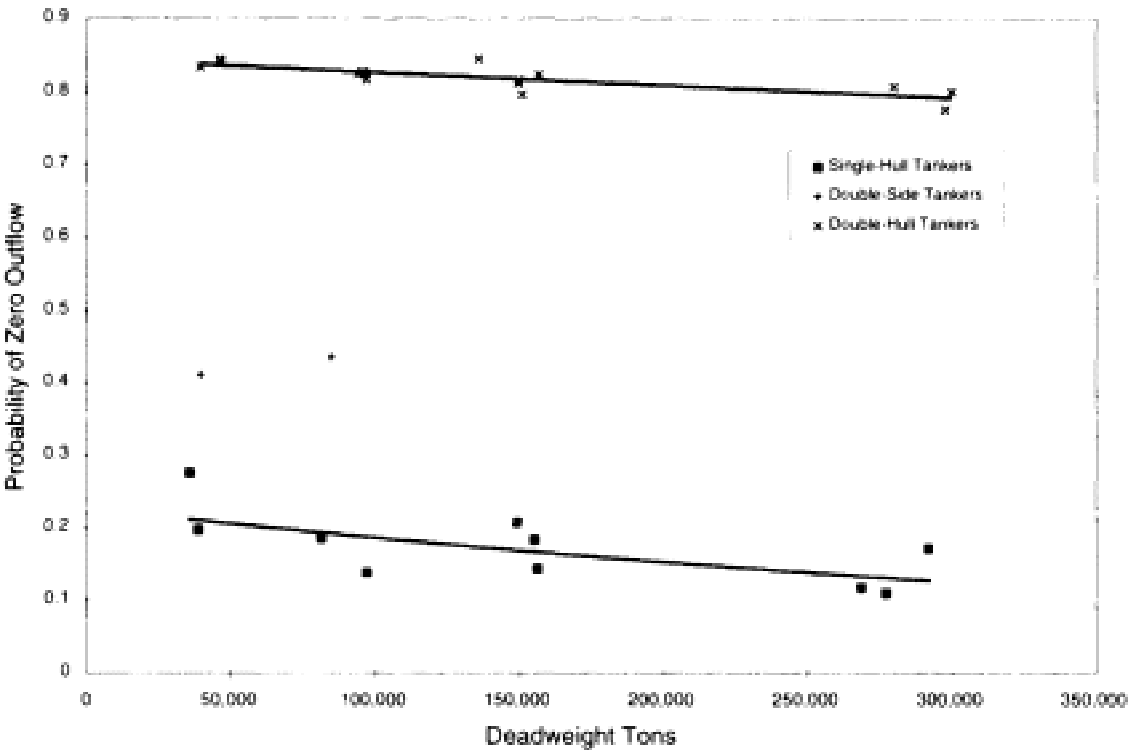
The 1998 NRC report cites a 1996 engineering analysis that estimates the probability of zero outflow (no oil spilled) from single vs. double-hulled tankers, finding that the probability of zero outflow is four to six times higher for double hull tankers than for single hull tankers. Therefore, the projected number of spills for double hull tankers compared to single hull tankers is expected to be one-fourth to one-sixth the number of spills projected for single-hull tankers (Michel et al., 1996).

The 1998 NRC report also considers survivability (the ability of a vessel to survive – not sink or capsize – after sustaining hull damage). The analysis showed no discernible difference between survivability characteristics of single and double hull tankers. Survivability was attributable more to the degree of compartmentalization within the engine room and adjacent spaces.

The 1998 NRC study also considered intact stability of double hull tankers. This is not a concern for single hull tankers, which are generally stable under all loading conditions. However, the study found that certain double hull tankers can become unstable during cargo and ballast operations, due to an increased height of the center of gravity and the large free surface effect. Single tank-across designs seem to be the least inherently stable (NRC, 1998).

[2] This report builds on a 1991 report that considers many of the same issues.

Figure 2.2 Probability of zero outflow for single and double hull tankers (Source: Herbert Engineering Corporation, 1996)



During the late 1990s and early 2000s, the National Research Council's (NRC) Transportation Research Board developed a methodology and approach for assessing the environmental performance of alternative tanker designs relative to double hulls. The resulting methodology was applied to evaluate tanker designs for two vessel sizes (150,000 DWT and 40,000 DWT) for both single and double hull designs. The analysis involved structural damage and outflow calculations for collision and grounding scenarios involving each tanker and oil spill fate and transport simulations in four different geographic locations to provide both design comparisons and consequence measurements (NRC, 2001).

Similar to the earlier USCG analyses, the NRC study showed that a double hull is effective in reducing the number of spills due to grounding, but that in some cases a collision scenario would result in a spill from the double hull design but no spill from the single hull. The double hull designs reduced the number of spills (compared to single hulls) by up to 67% in some scenarios, while the double hull vessels had larger average spill sizes for spills due to collision than single hull vessels. The transverse subdivision of tanks had a strong impact on the outflow results.

Since the analyses performed in the NRC study were specific to the hull designs and scenarios analyzed, the results of the study are not meant to provide general conclusions regarding oil spills from single vs. double hull designs. However, since the analysis examined multiple scenarios for specific single vs. double hull designs, it does provide insight into whether the alternative single hull design was equivalent to the double hull design. Overall, the double hull design was found to be superior in minimizing outflow rates and reducing overall environmental consequences. The 2001 NRC report emphasizes the importance of measuring consequences to overall assessment of design, to put the outflow estimates into context.

While the NRC study concludes that double hulls are superior to the single hull designs considered in the analysis, the study recommends that the methodology used for this analysis be applied to evaluate other alternative hull designs as compared to a double hull. While the report recommends that the USCG follow up with additional analysis and methodological refinement for evaluating alternative tanker designs, there has been little additional work by the Coast Guard in this area.

3 Comparing Data on Oil Spills from Single and Double Hull Tankers

3.1 Worldwide Tanker Oil Spill Trends and Causes

The International Tanker Owners Pollution Federation (ITOPF) maintains a worldwide database of accidental oil spills from tankers, combined carriers and barges. This is used to generate statistics on numbers and sizes of spills, and to identify causes of spills. The ITOPF database contains information on both the spill itself (amount and type of oil spilled, cause and location) and the vessel involved. For the purpose of analysis, the ITOPF categorizes oil spills by size: <7 tonnes (2,155 gallons); 7-700 tonnes (2,155 gallons to 215,500 gallons); and >700 tonnes (215,500 gallons). Of the nearly 10,000 incidents in the ITOPF database, approximately 84% fall into the smallest category (less than 2,155 gallons).

ITOPF oil spill statistics show not only that the majority of spills fall into the “small” category, but also that the occurrence of medium and large-sized oil spills from tankers, worldwide, has been steadily declining. Figure 3.1 summarizes the statistics for medium (2,155 to 215,500 gallon) and large (>215,500 gallon) spills. Moreover, the increase in total oil spillage from tankers over the past four decades has occurred amid a steady increase in tanker operations (see Figure 3.2).

However, oil spills do still occur, and according to a 2005 study conducted by the ITOPF, the majority of tanker spills are attributed to accidental causes (e.g. collisions, groundings, hull failures, fires and explosions) rather than operational causes (spills that occur during loading, bunkering, etc.). Nearly all of the largest recorded spills have been caused by accidents. According to the ITOPF study, just over half of the tanker spills of less than 2,155 gallons that occurred between 1995-2004 were caused by accidents. For spills ranging from 2,155 to 215,500 gallons, 86% were caused by accidents. For spills over 215,500 gallons, 97% were caused by accidents (Huijer, 2005). Figure 3.3 summarizes this data.

The ITOPF statistics show that the size and frequency of oil spills from tankers has generally decreased over the past several decades, and that the vast majority of medium and large sized spills are caused by accidents. Since accidents play such a prominent role in contributing to the amount of oil spilled from tankers, it stands to reason that the key to preventing or minimizing oil spillage from tankers is to either reduce the risk of accidents occurring or to reduce the potential for oil to spill if an accident does occur.

Figure 3.1 Number of medium and large sized spills per decade from 1970-2008 (Source: ITOPF)

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Figure 3.2 Seaborne oil trade and number of tanker spills over 7 tonnes, 1970-2008 (Source: ITOPF)

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Figure 3.3 Percentage of Spills in Three Size Categories by Causes, 1995-2004 (from Huijer, 2005)

	% of Spills <2,000 gallons	% of Spills 2,000 – 205,000 gallons	% of Spills >205,000 gallons
OPERATIONS			
Loading/Discharging	35	13	0
Bunkering	4	0	0
Other Operations	**9**	**1**	**4**
Total Operations	**48**	**14**	**4**
ACCIDENTS			
Collisions	16	51	23
Groundings	13	24	62
Hull Failures	15	3	0
Fire & Explosions	2	3	12
Other/Unknown	7	5	0
Total Accidents	**53**	**86**	**97**
Notes: Percentages do not add up to 100 in all cases. Discrepancies of 1% are assumed to be caused by conventions used by the study's authors to round numbers. Original study used metric tons rather than gallons. (<7t, 7-700t, >700t) These measures were converted to gallons using a conversion factor of 294 gallons/ton and rounding to the nearest 100 gallons.			

3.2 Impact of Hull Design on Tanker Pollution

A study conducted in 2006 by researchers at the Technical University of Athens analyzed the oil spill rate per year of ship operation by hull type using a Lloyd's Marine Information Service Lts (LMIS) database of AFRAMAX oil tankers (Papanikolaou et. al 2006). AFRAMAX tankers include crude oil tankers, shuttle tankers, product carriers, and chemical/oil tankers that typically operate in the Baltic, Black Sea, North Sea, and Mediterranean. These tankers are similar to the Alaska trade tankers, although somewhat smaller. Ore/oilers, combined carriers and chemical tankers are excluded from this category because their design and layout differs from the other vessels in the AFRAMAX class. The AFRAMAX fleet accounts for approximately 19% of the total worldwide tanker fleet (Papanikolaou et. al 2005).

The 2006 study analyzed 789 accidents, occurring between 1978 and 2003, and distinguished tankers into five categories: pre-MARPOL single hull tankers (lacking segregated ballast tanks), MARPOL 75/78 single hull tankers (with segregated ballast tanks), double bottom tankers, double sided tankers, and double hull tankers. The analysis showed that the tonnes spilled per ship year for the total period (1978-2003) was 56.2 tonnes/ship year for the pre-MARPOL single hull tankers, 0.86 tonnes/ship year from the single hull tankers with segregated ballast tanks, and 0.17 tonnes/ship year from the double hull tankers. Figure 3.4 shows a summary of these findings, for the periods from 1978-1990 and 1991-2003.

Overall spillage from MARPOL tankers with segregated ballast tanks and double bottom tankers declined during 1991-2003, as compared to 1978-1990. Overall spillage from all tankers, double sided tankers, and double hull tankers, increased very slightly during 1991-2003 as compared to 1978-1990. The increase in tonnes spilled/ship year for double hull tankers from 0 to 0.2 over the two time periods is not significant, and likely reflects a comparative increase in the fleet size. The overall amount of oil spillage from pre-MARPOL single hull tankers tripled during 1991-2003 as compared to 1978-1990, most likely due to the aging of those vessels as they were phased out of operation.

The 2006 AFRAMAX hull design study compared the percentage of double hull vs. non-double hull tankers involved in accidents and found that while these percentages were similar, the resultant oil spill amounts per ship year for double hull tankers was significantly smaller than the corresponding rate of non-double hull configurations. This study finds that while double hull tankers spilled less than non-double hulled tankers, the double-sided and double-bottom configurations were not as effective as the double hulls at reducing spill amounts. And, surprisingly, this analysis showed that while the pre-MARPOL single hull tankers performed worst overall, the single hull tankers with segregated ballast tanks actually performed better (had a lower total amount of spillage per ship year) than did either the double sided or double bottom tankers. The authors suggest, "It is worth pondering here whether the regulators would have been so keen to legislate the accelerated phase-out of the single hull/segregated ballast tank tankers had they been aware of these findings." (Papanikolaou et. al 2006) The author also cautions that because of the small data set of tanker spills that was considered, particularly for double hull and double bottom fleets which were still relatively small during the 1990s, it may be too early to draw definitive conclusions. A primary reason for this caution is the fact that oil spill statistics can be significantly skewed by a single, catastrophic event.

The AFRAMAX study also looked at the impact of ship's age on tanker accidents (both accident rate and oil spillage amounts) and found that the relationship was not straightforward. Middle-aged tankers appeared to be more sensitive to non-accidental structural failures as compared to older and younger ships, particularly so for single hull vessels. The authors concluded that the double hull fleet was still too young to be conclusively assessed, although it was noted that occurrence of non-accidental structural failures in double hull tankers at the ages of 1 and 2 years old "could be a source of some concern."

Figure 3.4. AFRAMAX Oil Pollution Rates by Hull Type – Period 1978-2003

Period 1978-1990						
	All Tankers	SH-non SBT	SH-PL-SBT	DB	DS	DH
Years	13	13	13	13	11	6
Ship years	5,041	4,119	484	146	243	49
Accidents w/o spill	525	445	36	25	18	1
Accidents w/spill	32	28	2	2	0	0
Total spill quantity	135,095	129,341	1,377	4,377	0	0
Tonnes spilled/ship year	26.8	31.4	2.8	30.0	0.0	0.0
Period 1991-2003						
	All Tankers	SH-non SBT	SH-PL-SBT	DB	DS	DH
Years	13	13	13	13	13	13
Ship years	6,611	2,127	1,286	226	850	2,122
Accidents w/o spill	204	91	22	15	27	49
Accidents w/spill	28	14	7	1	2	4
Total spill quantity	231,199	221,845	140	0	8,851	363
Tonnes spilled/ship year	35.0	104.3	0.1	0.0	10.4	0.2

Key:
SH-non SBT - pre-MARPOL single hull tankers without segregated ballast tanks
SH-PL-SBT - MARPOL 75/78 single hull with protectively located segregated ballast tanks
DB -double bottom tankers
DS - double side tankers
DH - double hull tankers

3.3 Review of Washington State Tanker Incident Data

The ITOPF data discussed in Section 3.1 shows an overall trend toward reduced oil spill occurrences and volume over the last few decades. The AFRAMAX analysis described in Section 3.2 shows that double hull tankers have significantly lower pollution rates than single hull tankers with non-segregated ballast tanks, but notes that the data set (through 2003) includes a comparatively smaller number of vessels and ship years for double vs. single hull tankers.

Because this report is concerned specifically with double hull tanker operations in Alaska, it would be useful to review tanker data from Alaska to compare accident and oil spill statistics for single and double hull tankers. Unfortunately, there is no publicly available data set with this information. Instead, a review of the tanker incident database maintained by the Washington Department of Ecology was conducted. This analysis shows that the proportionate number of oil spills by year from single hull vs. double hull, double bottom or double sided vessels has changed since the first year of record (1985).

As shown in Figure 3.5, for each year from 1985 through 1997 (with the exception of 1989), significantly more single hull tankers spilled oil in Washington than double hull tankers. Beginning in 1998-1999, there is a shift in these proportions, with double hull vessels accounting for more spills each year from 1999 to 2009. This shift is likely attributable to the phase-out of single hull tankers in U.S. waters. While the total number of oil spills seems to be trending downward with the shift toward double hulls, it is interesting to note that the highest number of oil spills from double hull tankers in any single year (15 spills in 2001) is equal to the highest number of spills from single hull tankers in a single year (15 spills in 1992).

The Washington data set on tanker incidents was also examined to compare trends in the types of incidents that have occurred over the past 24 years based on hull configuration. Figures 3.6 through 3.8 show the number of incidents by hull type and year for three major categories: Equipment, material or structural failure; Fire and explosion; and Loss of Propulsion or Steering (note that these are not oil spills, but reported incidents). Since 2003, incidents involving equipment/structural failure and loss of steering/propulsion have been much more prevalent among double hull vessels, while the fire/explosion data is more variable. For incidents involving equipment/structural failure and fire/explosion, overall numbers have trended downward since the early-mid 1990s. However, the trend is less obvious for incidents involving loss of propulsion/steering, with a relatively high number of incidents involving double hull tankers during several years of the past decade.

While the Washington data set is relatively small, it does provide some insight into the fact that double hull vessels are still involved in incidents and oil spills. It also supports the conclusion from the AFRAMAX study that our understanding of oil spill risks and occurrences from double hull tankers may require several more years of data compilation and review, because the fleet has undergone such rapid change and transition.

Figure 3.5 Number of Oil Spills from Tanker per Year, in Washington State, from 1985-present (Source: Washington Department of Ecology, 2009).

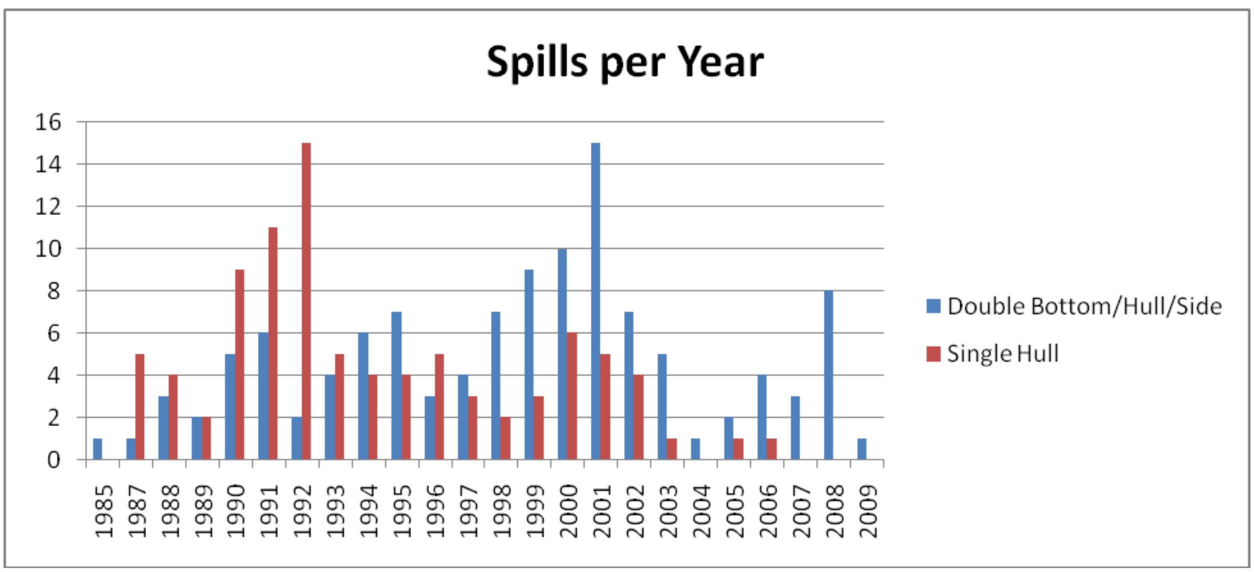


Figure 3.6 Number of Tanker Equipment/Structural Failure Incidents per Year, in Washington State, from 1985-present (Source: Washington Department of Ecology, 2009).

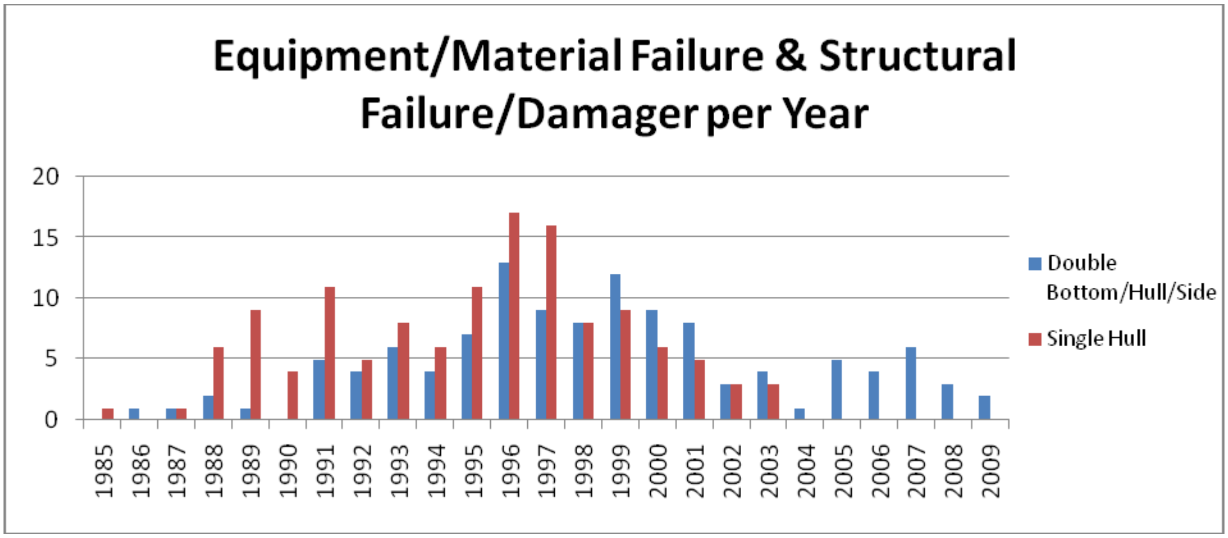


Figure 3.7 Number of Tanker Fire/Explosion Incidents per Year, in Washington State, from 1985-present (Source: Washington Department of Ecology, 2009).

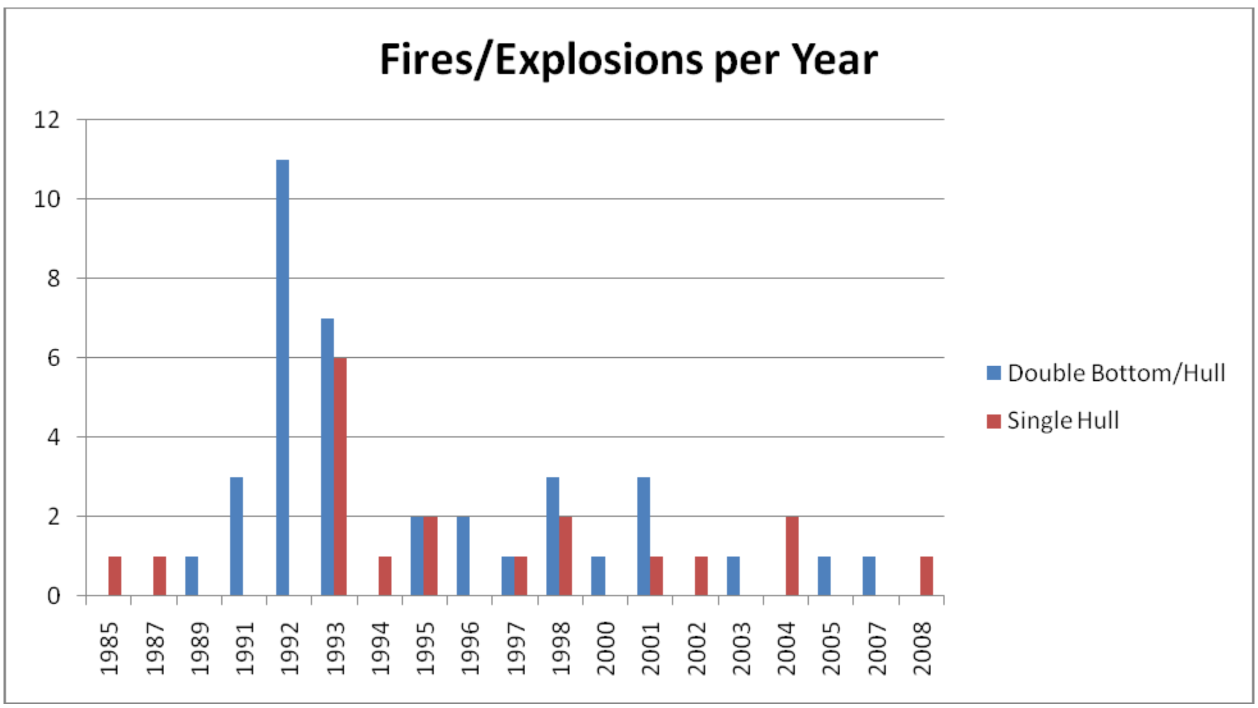
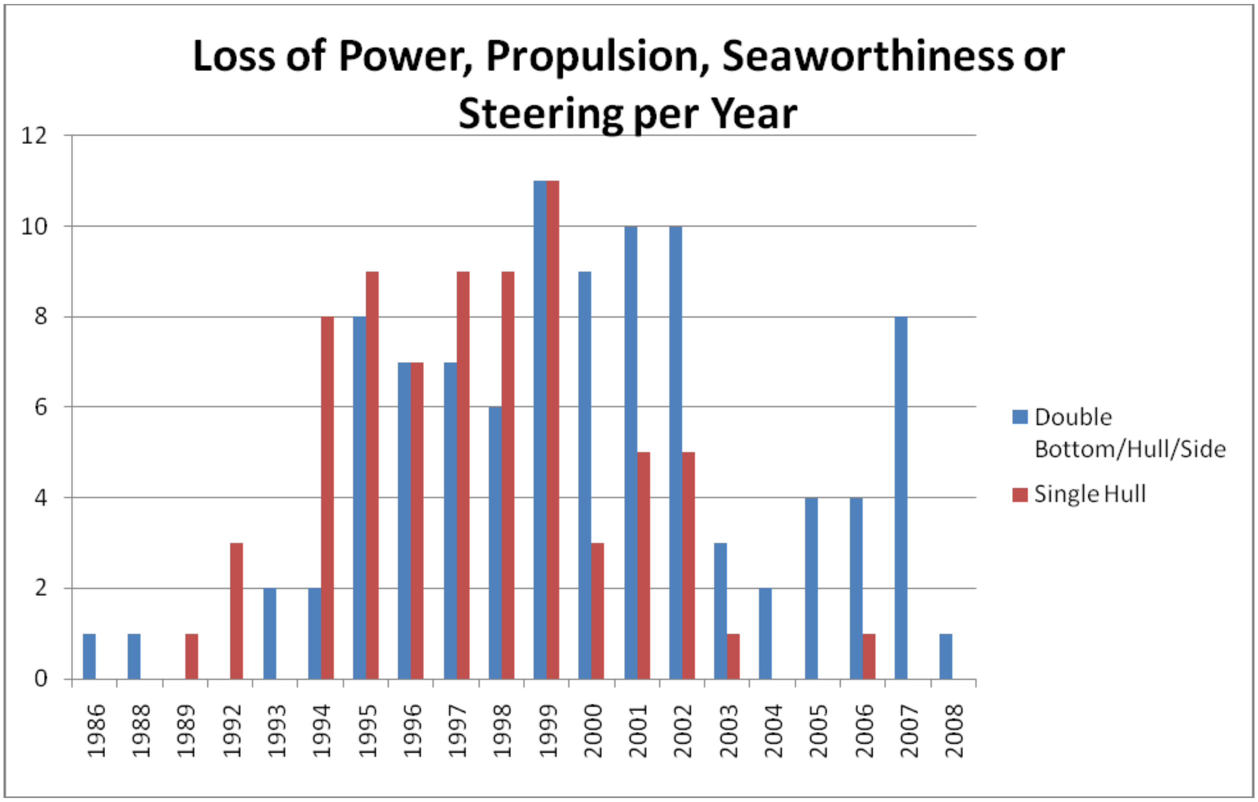


Figure 3.8 Number of Tanker Loss of Propulsion/Steering Incidents per Year, in Washington State, from 1985-present (Source: Washington Department of Ecology, 2009).



4 Disadvantages of Double Hull Tankers

While it seems clear that double hulls have the potential to reduce overall spill size by reducing outflow rates, particularly in groundings and low-energy collisions, there has been some debate regarding the overall spill prevention improvements that double hulls offer. Table 4.1 lists some of the advantages and disadvantages of double hull tanker design as compiled by the NRC during a 1998 survey of industry representatives. Since then, additional study and analysis has verified and expanded upon many of the concerns regarding tradeoffs in the double hull design.

Figure 4.1 Pros and Cons of Double Hulls (NRC, 1998)

	Advantages of Double Hulls	Disadvantages of Double Hulls
Cargo Operations	• Faster cargo discharge and good cargo out-turn • Easier and faster cleaning of cargo tanks	
Construction		• Higher cost – more steel required and longer construction time
Inspection and Maintenance		• Higher maintenance cost • Need for continuous monitoring and maintenance of ballast tank coatings
Operational Safety		• Structural safety concerns, intact stability, and increased still-water bending moment • Difficult access to and ventilation of ballast spaces

A 2003 report published by the Oil Companies International Marine Forum (OCIMF) cautions strongly against the tendency to view double hulls as a guaranteed prevention against oil spills from tankers. The report cautions that the complex design and structure of double hull tankers can make them more susceptible to maintenance and operations problems. The report emphasizes that double hull tankers can still be prone to catastrophic structural failures, particularly if they are not maintained and operated to high standards (OCIMF, 2003).

In 2004, the European Maritime Safety Agency (EMSA) assembled a Panel of Experts to consider some of the issues raised in the OCIMF report and to document the known safety concerns that arise from the change from single to double hull geometry. Both the OCIMF and the EMSA reports describe how double hull vessels may be prone to safety risks or equipment failures due to their design, stability, construction, operations, and maintenance.

4.1 Structural Design

Structural design factors such as plate thickness, stress concentrations, stiffness, and load transmission are determined based on complex calculations. There is some inherent unpredictability in assessing a vessel design, as it can be impacted by construction quality (e.g. quality of steel and welding), distribution of cargo weight in the ship, static and dynamic forces experienced underway in open seas, vibration from machinery, and the complex internal distribution of stresses between primary, secondary, and tertiary structures within the vessel (OCIMF, 2003).

Hull design is an iterative process where design improvements are based mostly on lessons learned through previous design flaws. This, combined with difficulties in predicting how structural design will play out in terms of vessel operations, means that first generation designs are especially vulnerable to flaws. The shift from single hull to double hull design for oil tankers represents a significant change in design approach. With this shift in structural design comes a new level of uncertainty regarding the anticipated stress levels and how they may impact the vessel's structural integrity. There can be a significant lag time between vessel design and identification of problems or issues that may be related to the design (OCIMF, 2003).

4.2 Hull Stress and Fatigue

Accurate stress prediction in double hulls is more complicated than in single hull configurations, because in a double hull vessel there is uniform distribution of cargo and ballast over the ship, as compared to a single hull tanker where ballast tanks can be positioned to minimize longitudinal bending and shear stresses. The number of cruciform joints where primary structural members terminate on double skin structure is significantly increased in double hull construction. 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).

A double hull tends to be stiffer than a single hull, and this can affect residual stresses induced during construction and local stresses induced by operational loads, both of which may initiate fatigue cracks (NRC, 1998). As a result of these design features, double hull tankers may operate with global stress levels 30% higher than single hull vessels. These higher stresses increase the risk of buckling failure, and this risk increases over the life of the vessel because of corresponding reductions in plate thickness caused by corrosion. The higher stresses can also increase the likelihood of developing small fatigue cracks (OCIMF, 2003).

Fatigue cracks, which may occur on all vessel types, can propagate over time and if no action is taken (repairs, etc.) then a major structural failure may occur. Fatigue cracks are associated with cyclical stress and can be linked to poor design, 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 (EMSA, 2004). Figure 4.2 shows a fatigue crack in the transverse web plating of a wing water ballast tank in a single hull tanker.

Figure 4.2 Example of fatigue crack (from single hull tanker)

4.3 Structural Corrosion and Tank Coating

Accelerated corrosion in cargo and ballast tanks has been documented in some double hull tankers, although the phenomenon is not unique to double hull design. In some double hull tankers that carry heated oil cargoes, a higher corrosion rate has been attributed to the 'thermos bottle effect', where heated cargoes retain their loading temperatures for much longer periods, promoting increased corrosion due to warm humid salt laden atmospheres in ballast tanks, acidic humid conditions in upper cargo tank vapor spaces and warm water and steel eating microbes on cargo tank bottom areas. Figure 4.3 shows uncoated 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. In some cases, these pits can penetrate 40% of the steel thickness within the first five years of the vessel life (EMSA, 2004; NRC, 1998; and OCIMF, 1997).

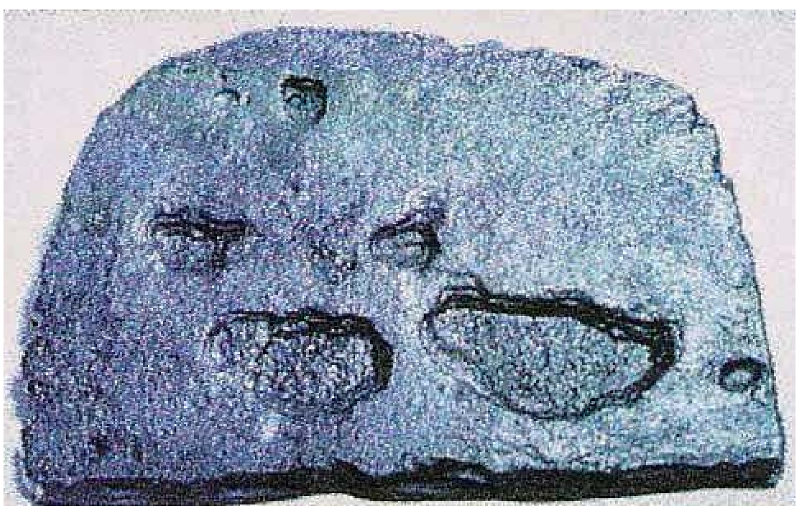
In double hull tankers, the spaces most at risk from the effects of corrosion are the ballast tanks and the underdeck structure and bottom areas within the cargo oil tanks. Double hull tankers have increased surface area inside their ballast tanks, compared to typical single hull configurations, because ballast tanks in double hull tankers are typically long and narrow. (OCIMF, 2003). The coated area of segregated ballast tank in a typical double hull tanker can be more than eight times that of a similar size vessel constructed to pre-MARPOL single hull standards, which makes the task of maintaining ballast coating a much more significant task for double hull tankers (Kennedy, 2006). Corrosion problems in older double hull vessels have led to major steel replacement in some vessels and have contributed to the scrapping of a number of others (NRC, 1998).

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), while corrosion to the under deck structure within the cargo tank area can lead to a reduction in longitudinal strength. Degradation or failure of protective coating can lead to corrosion of steel work that may required major hull repairs. In the worst cases, corrosion can lead to a major structural failure of the hull (EMSA, 2004).

One of the most effective means for preventing corrosion is to protect the hull structure with an efficient coating system. However, the protective coating applied during vessel construction does not always remain effective during the lifetime of the vessel. Improper maintenance of protective coatings and cathodic protection in ballast tanks can lead to leakage and sometimes to fire risks. Once the protective coating has broken down, it can be extremely difficult to repair. Figures 4.4 and 4.5 show ballast tanks from two ships of the same age (13 years). In Figure 4.4, the ballast tank coating was properly applied, while in Figure 4.5 it was not. (EMSA, 2004).

In 2006, the IMO issued performance standards for ballast tank coating. These standards went into effect in 2008 and will apply to any vessels constructed thereafter. However, the potential still exists for improper tank coating to cause corrosion in vessels constructed before 2008.

Figure 4.3 Steel plating taken from cargo tank in double hull tanker showing pitting corrosion brought about by microbial attack (Source: EMSA)



Figures 4.4 Properly applied ballast coating in 13-year old vessel (Source: IACS)

Figure 4.5 Improperly applied ballast coating leads to significant corrosion in another 13-year old vessel (Source: IACS)

4.4 Ballast Space Ventilation

Ventilation of ballast tanks is another concern that has been documented for double hull tankers. Trials carried out in shipyards have shown that it can be extremely difficult or even impossible to force air through a 'U' shaped ballast tank in order to exhaust it. If ballast areas cannot be properly ventilated, then they cannot be safely accessed to check for corrosion, leakage or mud build-up (EMSA, 2004).

Naval architect Jack Devanney, founder of the Center for Tankship Excellence (CTX), has reported extensively on the potential dangers from ballast space ventilation problems on double hull tankers. Devanney's forty-year career in the maritime industry includes vessel engineering and design as well as owner/operator of crude oil tankers with several different shipping companies. Devanney (2006) explains that the manner in which double hull ballast tanks are configured to surround cargo tanks creates the opportunity for small leaks from the cargo tanks to cause a buildup of hydrocarbon vapors in the surrounding ballast tanks. This hydrocarbon vapor poses a serious explosion risk.

This problem existed to a lesser extent in pre-MARPOL vessels that were configured with segregated ballast tanks contiguous to cargo tanks. In fact, the buildup of hydrocarbon vapors in ballast tanks due to small cargo leaks has been shown to be a major contributor to several major fire or explosion incidents. During the 1970s, two separate ore-bulk-oil (OBO) carriers suffered catastrophic explosions due to vapor leaks into double bottom ballast space. Both ships, the *Berge Istra* and the *Berga Vanga*, suffered from leaks from oil into the double bottom ballast tanks. Eventually, on both ships, the vapors in the ballast tanks came into contact with an ignition source, causing the vessels to explode and sink (Devanney, 2006).

Mud or sediment buildup in the ballast space can also be a particular problem for double hull vessels because the cellular nature of the tanks makes it easier for sediments to become trapped, and can create issues when managing ballast water to eliminate the transport of invasive species (AMSA).

4.5 Maintenance

The structural integrity and ultimately the safety of oil tanker hulls is linked to maintenance and operating practices. No matter how well designed and built a tanker may be, it must be properly maintained and operated. A report by the Oil Companies International Marine Forum that compares double and single hull tanker designs finds that "double hulled tankers because of their complex design and structure are potentially more susceptible to problems of poor maintenance and operations" (OCIMF, 2003).

Proper maintenance and operational standards is the responsibility of the ship owner. Hull maintenance relies on regular inspections and survey of internal hull structures, which can be extremely difficult. While hull maintenance is mandatory under the ISM Code, maintenance procedures, practices and periodicity are not specified for double hull tankers. The Safety Management System (SMS) requirements under the ISM do require that the operator develop maintenance procedures specific to the type of tanker. Self-assessment and certification programs implemented by the OCIMF also include maintenance requirements.

Regular maintenance and inspection is the key to identifying and correcting many of the other deficiencies discussed in Sections 4.1 through 4.4 of this report. When issues such as hull fatigue or corrosion goes undetected, major problems may ensue. For example, undetected corrosion was identified as the cause of one of the more spectacular structural failures of tankers over the last few years, the *Kirki*, which lost its bow off the coast of Western Australia in 1991 and spilled approximately 5.4 million gallons of crude oil. Figure 4.6 shows an image of the *Kirki* with the damaged bow section missing. (AMSA)

Further investigation into the *Kirki* incident showed that the causality was likely due to a combination of factors related to poor maintenance and to vessel design. When the vessel ran into heavy weather off the Western Australia coast, a combination of major corrosion in the forward ballast tank (loose steel banging around) and hydrocarbon vapor escaping from small leaks in the forward cargo tanks created a fire. A series of fires occurred, each one ignited by vapors and loose steel and then extinguished by sea water, until an entire section of the bow fell off (Devanney, 2006).

A report published by the Center for Tankship Excellence, which compiles data on probable causes of tanker accidents, notes that "failure to maintain ballast tank steel has put far more oil on the water than any other cause." (Devanney, 2006) Again, this statement highlights both the importance of preventative maintenance and the issues association with tank coating and corrosion.

Figure 4.6 Tanker *Kirki* showing missing bow section (Source: AMSA)

4.6 Equipment Problems on Alaska Class Double Hull Tankers

The potential for first-generation vessels to experience unexpected problems due to unforeseen design flaws or equipment failures is not unique to double hull tankers, and does not mean that the ship's overall design is necessarily flawed. However, these failures are important reminders that new ship designs may have problems that do not emerge until several years or longer into the vessel's operational life.

In 2007, in the wake of several minor structural failures on the Alaska Class of double hull tankers operating in Prince William Sound, the Alaska Tanker Company (ATC) issued a report addressing the nature of these failures and the steps taken to prevent their recurrence. The ATC report notes that overall, these types of failures, which range from loss of propulsion to rudder failures, are "not extraordinary for a new Class of vessels." Specific design flaws noted in that report include defective rudder designs which led to cracking of the steel. This required modification and refitting of rudders on all Alaska Class tankers in 2005 (ATC, 2007).

Problems have been observed with the bolted equipment removal plate (BERP) covers on several Alaska Class double hull tankers due to deformation that has occurred as a result of normal stresses on the deck plates. The BERP covers are fitted on the deck and allow access to the ballast piping and valves inside the oil tanks. The BERPs have been observed to deform, which is attributed to the deformation of the large longitudinal openings underneath the BERP caused by stress to the deck plates during normal operations. Most of the BERP deformation is absorbed at the bolted joint, and if this deformation is severe enough, the bolts can loosen and leaks can occur. To address this problem, the BERP covers have been redesigned to withstand deformation with a lower risk of leaks occurring. (ATC, 2007).

Problems with anchors on Alaska Class tankers have also been noted on several occasions. In one case, the starboard anchor on the Alaska Frontier was lost altogether in heavy weather on a voyage from Valdez to California during late 2006. Just a few days later, the Alaska Navigator's port anchor failed and was lost at sea. An investigation of the remaining anchors on these two vessels showed a number of cracks, three to six inches in length, on many of the anchors. Replacement anchors were located and placed on all Alaska Class tankers while a metallurgical analysis was performed to attempt to identify the cause of the failure (ATC, 2007).

The Alaska Frontier has also experienced thrust bearing failures on at least three separate occasions. Subsequent investigations showed that the failures were caused by problems with the lubrication system, and lubrication systems have been re-engineered on all Alaska Class tankers (ATC, 2007).

The Alaska Navigator has also experienced other problems that point to additional design flaws in the Alaska Class tankers. Most notably, the failure of a mooring bitt during normal docking operations at the Valdez Marine Terminal in 2006 highlighted a Class-wide flaw in the way the mooring bitts had been cast that had the potential to cause premature failure of these bitts in all Alaska Class tankers. New mooring bitts were fabricated during 2007 to replace the defective bitts (ATC, 2007).

5 Human Factors

5.1 Role of Human Factors in Tanker Accidents and Oil Spills

As much as 80% of oil spills and marine accidents have been attributed to human factors – either individual errors or organizational failures (Hee et al., 1999; Rothblum, 2006). Technological improvements such as double hulls can reduce the severity of an oil spill caused by groundings or collisions, but they cannot interrupt the chain of events that may cause the accident to occur in the first place.

Published studies suggest that technological changes and improvements to vessel technologies do not necessarily reduce the likelihood of a human-caused spill or accident (Johnson, 1996). In fact, technological improvements may *increase* accident risks due to increased complexity of the system, skills- or knowledge-based lapses in operator abilities, or risk compensation behavior at the individual or organizational level. Increased automation often results in reduced manning levels, which can increase the number and complexity of job tasks assigned to each operator while simultaneously removing or reducing the operator's ability to bypass or override automated systems in an emergency.

One study on human factors and accident rates concludes that human inputs to technological and engineering processes may actually contribute to accident risks from the beginning stages of equipment design. The study describes how design flaws may go undetected until an engineering project has entered the construction phase. Rather than re-design the flaws, the construction phase will attempt to work around these deficiencies. Or, in some cases, additional flaws and defects will be introduced during the construction phase. Either way, the deficiencies may still be undetected or unsolved as the vessel moves to operations. Human operators may be oblivious to the flaws until an incident occurs, or they may recognize and work around the flaws. Either way, at some point there is the potential that the flawed system may ultimately fail, and that the contribution of human factors to attempting to mask or patch the problem could exacerbate the consequences. (Hee *et al.*, 1999)

A review of safety incidents involving double hull tankers operating in the State of Washington shows that several incidents involving loss of primary propulsion systems on board double hull tankers were attributed to human error. Four loss of propulsion incidents involving U.S. flag tankers (*Polar Enterprise*, *Polar Endeavor*, and *Alaskan Navigator*) that occurred during 2006-2007 were attributed to human factors, ranging from procedural errors to improper maintenance. In a communication regarding problems with the Alaska class of double hull tankers, the Alaska Tanker Company notes that "in some instances, the response to a failure was sub-optimal due to lack of knowledge of the complexity of the Alaska Class vessels." (ATC, 2007)

Human performance breakdowns are rarely the result of a random error, but more likely the result of a poor conscious choice or decision. As such, it is extremely difficult to isolate the specific human factor or factors that cause accidents; yet, this level of specificity is necessary in order to correct the problem. When an accident is attributed to operator error, the first reaction is often to "correct" the problem by adding training or replacing an individual operator or class of operators; however, this will not prevent a problem from recurring. Instead, a systematic analysis is required to determine *why* the operator made the error, in order to intervene at the appropriate point (Besco, 2004).

5.2 Prevention Measures Targeting Human Factors

A 1998 NRC study that considers the OPA 90 double hull requirements notes that the implementation of double hull requirements does not erase the need for prevention programs that address human factors. The major protection afforded by double hulls occurs in a scenario where a grounding or collision has already occurred, and the double hull serves to prevent oil from spilling or to mitigate the size or severity of the release. Human factors interventions work to prevent accidents and oil spills much earlier in the accident timeline – by preventing the critical failure or series of events that lead to the grounding or collision in the first place.

There have been a number of US and international initiatives that have focused on shipboard accident prevention by targeting human and organizational errors. Most of these interventions have been put in place over the past decade, and they have been credited in part for some of the reduced oil spillage described in Sections 1 and 2 of this report. These human-focused prevention initiatives include the International Safety Management (ISM) Code, new training requirements for watchstanders, enhanced navigational equipment requirements, and industry-led best practices, certification and vetting programs.

5.2.1 ISM Code

The International Safety Management (ISM) Code is an International Maritime Organization (IMO) initiative that focuses on prevention measures geared toward human factors. The ISM Code is intended to improve the safety of international shipping and to reduce pollution from ships by impacting the way shipping companies are managed and operated. The ISM Code is included as an amendment to the International Convention for the Safety of Life at Sea (SOLAS), with mandatory compliance required for all signatories to that convention (Moore and Roberts, 1995).

To comply with the ISM Code, a company must develop, implement and maintain a safety management system, which includes a number of functional requirements, including safety and environmental protection policies, procedures for reporting accidents and non-conformities, and emergency management procedures.

The USCG adopted the ISM code into the federal oil spill prevention regulations for oil tankers operating in U.S. waters. Ships calling at U.S. ports must complete an ISM audit through either the USCG or a USCG-recognized organization such as the American Bureau of Shipping (ABS). Auditors issue a document of compliance to the owner and a safety management certificate to the vessel. USCG inspectors can review the audits for any ship entering a US port and can require an audit for any ship they suspect does not comply with its safety management system.

While the ISM code does not guarantee compliance with its pollution prevention and navigational safety standards, it is generally considered to have improved shipboard operations, maintenance and safety.

5.2.2 Improved Navigational Equipment, Situational Awareness, and Watchstanding Practices

Many human-caused tanker accidents involve errors of navigation or watchkeeping. Personnel on the ship's bridge make navigational errors, or even fall asleep during their watch. A number of initiatives ranging from navigational equipment requirements to training programs for licensed mariners have attempted to address these issues.

Over the past two decades, navigational systems and technologies have improved significantly. Vessel traffic management and control systems are in place in many major ports, allowing vessel traffic managers to monitor and control vessel traffic in busy waterways. Tankers are now required to be fitted with Automatic Radar Plotting Aids (ARPA), Electronic Chart Display and Information System (ECDIS) and Automatic Identification Systems (AIS). ARPA is a marine radar system that can alert bridge personnel when they are at risk of collision with another vessel. ECDIS allows shipboard personnel to use sophisticated computer-based navigational systems in place of paper charts. AIS places a tracking beacon on each vessel that transmits information about the ship's location, movement, cargo, and vessel particulars which can then be accessed over the internet.

The Standards of Training, Certification, and Watchkeeping (STCW) Code requires all personnel serving aboard tankers to have completed tanker-specific training, based on their position on the ship. Because watchstander mistakes and errors are a major contributor to human-caused tanker accidents, the STCW Code has been widely acknowledged as reducing the potential for oil spills and other accidents on tankers. The STCW requirements have been adopted into US Coast Guard regulations and became mandatory for most classes of licensed mariners in 2002.

The US Coast Guard and various industry organizations have also developed guidelines for bridge resource management, crew rotation, and other shipboard practices that may contribute to the risk of a human-caused accident or oil spill.

5.2.3 Industry Vetting and Self-Inspection Programs

Organizations like the Oil Companies International Marine Forum (OCIMF) have developed certification and self-assessment programs aimed at improving tanker safety and prevent oil spills. OCIMF is a voluntary association of oil companies that ship and store crude oil and oil products. Their mission is to promote safe and environmentally sound operation of oil tankers. The Tanker Management Safety Assessment (TMSA) program administered by OCIMF requires that tanker operators benchmark their activities against industry best practices, and provide this information prior to engaging in any charter operations. The Ship Inspection Report Program (SIRE), also administered by OCIMF, actually involves a complex assessment where independent inspectors inspect vessels against a set of criteria including tanker design, operations, maintenance, and past performance. The SIRE report provides a rating of the tanker's overall operations and environmental protection practices, which can then be compared to other vessels.

Classification societies have also implemented similar programs, although they do not all adhere to the strict standards that OCIMF has put in place to ensure objectivity on the part of the inspector.

6 Discussion

A study by EMSA estimates that by the end of 2004, the percentage of the worldwide tanker fleet (tankers above 5,000 DWT) with double hulls was 65% by tonnage and 56% by number. This estimate was derived from data provided by the International Association of Tanker Owners (Intertanko) and Lloyd's Registry of Vessels. Five years later, these numbers have undoubtedly increased, particularly as the phase-in deadlines approach in the US and Europe and under IMO regulations.

While double hulls may reduce the amount of oil spilled under certain grounding and collision scenarios, they are not a perfect prevention measure because they do not protect against spillage under all circumstances. Moreover, while double hulls can reduce the severity of an oil spill, they cannot interrupt the chain of events that may cause the accident to occur in the first place. Double hull tankers, like their single hull predecessors, are susceptible to hull fatigue, corrosion, stability issues, and a range of other design flaws. There can be a significant lag time between the engineering design of a new vessel and the discovery of inherent flaws in the design or construction, which is evident in some of the class-wide problems that have been noted in the U.S.-flagged double hull fleet. By the time these problems are detected, multiple vessels may have already been built and put into service.

The 2006 AFRAMAX study discussed in Section 3 of this report generally aligns with the ITOPF tanker oil spill trends; both analyses show a trend toward overall reduction in the amount of oil spilled by tankers. The causal relationship between hull design and spill risks and occurrences is less clear due to limited data. While it is reasonable to assume that some proportion of the overall reduction in spillage from tankers is attributable to the fleet transition from single to double hull tankers, there are a number of other factors that have undoubtedly contributed to the reduction in tanker oil spills over the past several decades.

In addition to the double hull requirements discussed in this report, the Oil Pollution Act of 1990 (OPA 90) contained a number of additional requirements that have undoubtedly contributed to a reduction in oil spillage and in overall oil spill risks from tankers. These include a much stricter liability paradigm that has created the incentive for ship owners to adopt internal prevention measures geared toward reducing oil spill risks. OPA 90 also put specific prevention measures in place in a few high risk U.S. waterways, including Prince William Sound, Alaska, where all laden oil tankers must be accompanied by at least two high-powered tug escorts. Stricter inspection standards have been put in place by the US Coast Guard, and Regulated Navigation Areas have been established with specific requirements for oil-carrying vessels in certain geographic areas and/or under specific environmental conditions (such as the presence of sea ice).

OPA 90 also established requirements for oil spill contingency planning and response capabilities, although most of these requirements address the capacity to respond to and clean up an oil spill, rather than to prevent an oil spill.

A study was done in the late 1990s to consider the differential effectiveness of OPA 90 on reducing oil spills during transfers as compared to spills that occur during accidents. The study considered the overall reduction in spill statistics in the context of OPA 90 and used a regression model on a small data to look at whether there were differences in the occurrence rate of accident-related oil spills vs. transfer spills. The study contended that OPA 90's spill prevention measures focused primarily on spills caused by accidents, and found that in fact there had been a greater reduction in spills caused by accidents post-OPA 90 than there had been in transfer-related spills. The study recommended that US oil spill prevention policies be tailored to address all types of spill risks. While the analysis did not focus on double hulls *per se*, it highlights the fact that oil spill prevention measures designed to minimize spills from accidents, such as double hulls, do not prevent oil spills caused by transfers. (Talley et al., 2003)

While research shows that most crude oil tanker accidents involve the interaction between humans, organizations, and systems or equipment, oil spill and accident prevention measures are often disproportionately focused on the engineering or technological "fixes," since these are the most easily remedied. As the new classes of double hull tankers that transport oil become increasingly reliant on engineered systems and automated technologies, the humans that operate these systems are subjected to new challenges that may actually increase accident risks. Accidents caused by technological failures are more easily remedied than those with human causes, therefore the contribution of human factors to accidents may actually *increase* as technological improvements and regulatory measures are enacted to address engineering and structural components. And while accident risks with a technological basis can often be remedied through engineering, accidents that involve human-technology interactions are much more difficult to address.

7 Conclusions

Despite documented issues with double hull tanker design, construction, operations, and maintenance, the double hull is generally accepted to provide a reduction in overall spill risk compared to single hull tankers. However, double hulls do not guarantee that no oil will be spilled. The potential for a catastrophic oil spill from a double hull tanker is real, and the consequences could be just as damaging as major oil spills from single hull carriers.

Problems with double hull tanker design, construction, operation and maintenance have been well documented over the last thirty years. One organization has characterized the current situation as a crisis, citing the "urgent need to enhance port-State control measures to ensure that sub-standard double-hull tonnage is not overlooked in the current push to tackle sub-standard single-hull tankers." (Seas at Risk, 2009)

Recommendations for improving double hull tanker safety include greater redundancy in new builds, mandatory minimum standards for the construction and repair of vessels, and stricter standards, oversight, and enforcement by port states and classification societies. While significant efforts to address most of these issues are ongoing, none of these can be achieved overnight. Even if all of the problems with double hull vessel design are remedied in new vessel construction and operation, there are still a significant number of double hull tankers already in operation that are vulnerable to future failures and mishaps. Programs and policies must also be developed and implemented to ensure that the mariners who operate these highly complex vessels have the training and abilities necessary to ensure safe operations.

Double hulls are a key component of the oil spill prevention system, but they are not the only component. The only way to safeguard against the potential for future oil spills from double hull tankers is to create and maintain an effective prevention system that provides multi-layered against oil spills and accidents, including engineering and human factor components.

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