

## **Protection of Bunker Tanks**

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**Executive summary:** There are currently no requirements for protectively locating bunker tanks within cargo vessels. A number of recent bunker tank spills have occurred in environmentally sensitive regions and have demonstrated that even relatively small spills can have a significant environmental impact and incur substantial cleanup costs. In the wake of such spills, regulators have initiated a debate on the need for enhanced regulations related to protection of all tanks carrying fuel oil irrespective of the type of the ship. This paper gives a brief description of the current regulatory developments for the protection of bunker tanks in all ship types. It also presents briefly a recent study carried out by the US Society of Naval Architects and Marine Engineers (SNAME) aimed at establishing the relative risk of bunker spills from different ship types, developing a methodology for calculating expected oil outflow from bunker tanks in large commercial vessel accidents; and evaluating the influence of alternative tank configurations on projected oil spillage;

Ladies and Gentlemen,

INTERTANKO is very honoured to have been invited to this Conference and, in response to your invitation, to contribute to raised awareness among ship operators of the forthcoming regulations for the protection of bunker tanks on all ship types. The presentation will give the background information for this rulemaking development, briefly explain the rulemaking proposal but also look into the current bunker tank arrangements in different commercial ships and what could be the impact of these arrangements on a potential fuel oil spill in case of accidental damage of the bunker tanks.

I wish to acknowledge from the very beginning that this presentation is extensively based on the work and the findings of the SNAME Ad Hoc Panel for the Evaluation of Accidental Oil Spills from Bunker Tanks. I am thankful to the members of the SNAME Panel for allowing me to use their information in today's presentation. This was the good news I have. The bad news is that the time allocated to this presentation does not permit me to go too much into the details of the SNAME work. However, you would be welcome to further consider the SNAME report through their internet address, which will be given at the end of my presentation.

But first, for those less familiar with INTERTANKO, let me say that we represent some 250 independent tanker owners and operators (oil, chemical gas and tankers) from 45 countries that operate over 2100 tankers. INTERTANKO is a supporter of SNAME, which will be very much involved in this rulemaking development. We support rational and practical requirements that would improve further the protection of the marine environment.

**Background - Do we really need protection bunker tanks?**

On a global basis, the maritime industry has excellent records for safety and environmental protection. In the wake of the Exxon Valdez accident, the tanker industry was subject to continuous regulatory change and introduced self imposed better practices. As a result of this, there was a dramatic reduction in the spillage of oil from tankers world-wide.

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The reductions in oil spillage realized by tankers and tank barges has not carried over to other vessels, and in the 1990s *other vessels* have become responsible for an increasing percentage of the total oil spillage. Although tanker cargo oil spills, tanker operational discharges and pipeline spills are still responsible for the majority of "Transportation of Petroleum" inputs, the contribution of the bunker spills has actually increased, as shown in the following graphs. The graph below is from the 2002 Study "*Oil in the Sea III: Inputs, Fates, and Effects*" carried out by the Ocean Studies Board and Marine Board of the US National Academy of Sciences. ("Consumption of Petroleum" includes land-based runoff, operational discharges from other vessels and atmospheric deposition).

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Further information can be obtained from the more detailed breakdown of spills by source carried out in the SNAME Study. This indicates that during the period from 1992 to 1997, ships were responsible for about 54% of the oil spilled into US waters. Of this, freighters were responsible for about 4% of the total oil spillage in the US waters, while oil spills from tankers accounted for 5%. The category of *freighters* includes commercial cargo vessels such as bulk carriers, containerships, ro-ros, and general cargo ships. (The *other vessel* category includes freight barges, tow and tugboats, fishing boats, unclassified vessels, and all other vessels except tankers, tank barges and freighters).

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### Spill Volume in US Waters by Source (for period 1992-1997)

A number of recent spills have occurred in environmentally sensitive regions such as the coasts of Alaska and Oregon, and Humbolt Bay in California. Spills such as that from the Kure (about 4,500 gallons spilled in Humbolt Bay) have demonstrated that even relatively small spills can have a significant environmental impact and incur substantial cleanup costs. Some of these accidents are briefly presented in an annex to this presentation.

It is also noteworthy that some 3 years ago, the International Tanker Owners Pollution Federation, ITOPF, which was set up to give assistance in case of oil spills at sea, has enlarged its membership to types of large commercial ships other than tankers. In its last few Annual Reports, ITOPF records having given more assistance in pollution accidents from non-tanker vessels than in those from tankers. Even though the aggregate amount spilled from bunker tanks is potentially much less than from a major tanker accident, the nature of these bunker fuels and their impact on the marine environment have given rise to the expectation that bunker

tanks should be designed and built with a better protection against damage caused in collision and grounding.

All this background information indicates that it was only a matter of time until new regulations for better protection of bunker tanks against spills caused by groundings and collisions are proposed.

## REGULATORY FRAMEWORK

There are currently no requirements for protectively locating bunker tanks within cargo vessels. Regulation 13F of MARPOL 73/78 requires all new tankers above 5,000 DWT to have a double hull, a mid-deck, or an alternative arrangement approved by the International Maritime Organization (IMO). OPA 90 mandates double hull construction for all new tank vessels calling US waters. However, both regulations apply only to cargo oil tanks, and any fuel oil tanks located within the cargo tank length. The cargo tank length extends from the aft-most cargo tank boundary to the collision bulkhead. As tankers typically have their bunker tanks arranged in the engine room, these tanks can be located adjacent to the shell.

In the wake of a spill from the wood-chip carrier *New Carissa*, the US Congress has initiated debate on the need for enhanced regulations related to fuel oil carried on commercial freighters. However, to date there has been no rulemaking follow-up in the US.

Last March, the IMO agreed with a proposal from The Netherlands to develop a new MARPOL regulation for the protection of fuel tanks against damage caused in collision and grounding. In brief, the Dutch proposal can be summed up as follows:

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The proposed rule would apply to:

- ships with an aggregate fuel oil capacity greater than 300 m<sup>3</sup>
- building contract placed on or after 1 January 2006
- delivery on or after 1 January 2008

The protection of fuel tanks would be ensured through:

- individual oil fuel tanks should have a maximum capacity of 2000 m<sup>3</sup>
- double hull protection for fuel tanks on ships with an aggregate fuel capacity above 5,000 m<sup>3</sup>
- in ships with an aggregate fuel capacity of 300-5000 m<sup>3</sup>:
  - (a) double bottom with a depth  $B/15$ , with a minimum value of 0.76 m provided that the maximum capacity of each fuel tank does not exceed 700 m<sup>3</sup> or
  - (b) double bottom as above and double sides with the width  $w = 0.4 + 2.4 DW/20,000$  (m), with a minimum value of 0.76 m.

The IMO agreed to finalise and adopt the new regulation in 2005. The regulation would, of course, apply only to new buildings.

## The SNAME Study

Before these regulatory developments took place, the industry itself has taken some steps to study the necessity of better protection of bunker tanks and how such protection could be

quantified. Probably the most advanced work done so far was the Study developed by the US Society of Naval Architects and Marine engineers or SNAME. The scope of their study was to:

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- establish the relative risk of bunker spills from different ship types,
- develop a methodology for calculating expected oil outflow from bunker tanks in large commercial vessel accidents;
- evaluate the influence of alternative tank configurations on projected oil spillage;
- assess the capital costs associated with each configuration, and the impact on safety and vessel operations; and;
- present findings and recommendations for mitigating accidental oil spillage from bunker tanks.

The assessment of risk was extended to evaluate the frequency of such accidents. This has been done by using the United States Coast Guard database of petroleum spills occurring within the navigable waters of the US. The USCG database includes information on the amount of spillage, the type of vessel involved, and causality. The frequency and volume of spillage from bunker tanks on freighters is estimated through analysis of these historical data. The SNAME Ad Hoc Panel also examined six accidents involving breaching of fuel oil tanks. These case histories provide insight into the types of accidents that occur, and the severity of hull damage encountered.

Arranging double hull protection around the bunker tanks is one means of mitigating the risk of spillage. The location and size of the fuel oil tanks also influence the likelihood and expected volume of oil spills. The relative effectiveness of these alternatives was investigated by applying the oil outflow analysis methodology, which I will talk about later on, to twenty-five existing cargo vessels as follows.

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- 10 tankers (2 x VLCC, 3 x Suezmax, 2 x Aframax, & 3 x Panamax)
- 6 container ships (1 x Post- Panamax, 2 x Panamax, & 3 x Feedership)
- 5 Bulk carriers (1 x Capesize, 1 x Panamax, and 3 x Handysize)
- 4 other vessels (1 x LNG carrier, 1 x Livestock carrier, 1 x RO/RO vessel, & 1 x Cruise ship).

#### **Standard Design Practices**

The vessels are representative of the wide variety of bunker tank arrangements currently in service. Design considerations lead to different bunker tank arrangements for different ship types.

- Tankers: The HFO tanks are usually arranged in one or two pairs of wing tanks (see arrangements T1 and T2). This allows for short piping runs, and avoids passing HFO piping through ballast and cargo tanks. The double-hulled spaces forward of the engine room are dedicated to cargo oil, maximizing cargo cubic.

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- Containerships: Typically, the majority of HFO is allocated to wing tanks outboard of the cargo holds. These tanks are distributed longitudinally through the midship region, such that bunkering or consuming fuel oil does not significantly alter trim or stability (see C1). Additionally, there will be some bunker oil storage in engine room wing tanks.

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- SLIDE Bulk Carriers: Capesize bulk carriers usually carry their fuel oil in engine room wing tanks similar to tankers. For the smaller Handysize or Panamax ships, HFO is most commonly allocated to center double bottom tanks. Alternatively, bulk carriers may have HFO in the outboard double bottom/wing tanks, or arranged in deep tanks forward together with engine room tanks (see B1).

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The table below summarizes typical capacities for HFO and DO tanks for various sizes of tankers, containerships, and bulk carriers. The high-powered post-Panamax containerships have the largest HFO storage requirements, with the total HFO capacity for recent newbuildings exceeding 7,600 m<sup>3</sup> (2 million gallons). The HFO is usually distributed in a number of wing tanks, such that the capacity of any one tank does not generally exceed 1000 m<sup>3</sup> (264,000 gallons). In comparison, VLCCs have tanks as large as 3,400 m<sup>3</sup> (898,000 gallons), as the HFO is typically allocated to one or two pairs of ER wing tanks.

<b>Tankers</b>				
Description	Panamax	Aframax	Suezmax	VLCC
DWT (MT)	50,000	90,000	150,000	285,000
HFO (m <sup>3</sup> )	1700	2900	3800	7500
DO (m <sup>3</sup> )	220	320	370	400

<b>Containerships</b>				
Description	750 TEU	1500 TEU	Panamax	Post-Pmax
DWT (MT)	9,000	20,000	45,000	75,000
HFO (m <sup>3</sup> )	700	2000	5600	7600
DO (m <sup>3</sup> )	130	200	330	430

<b>Bulk Carriers</b>			
Description	Handysize	Panamax	CapeSize
DWT (MT)	30,000	70,000	160,000
HFO (m <sup>3</sup> )	1300	2200	4000
DO (m <sup>3</sup> )	130	270	300

Typical Bunker Capacities

### Outflow Calculation Methodology

To assess the relative effectiveness of alternative arrangements for protectively locating bunker tanks, probabilistic oil outflow calculations were carried out for all these ships. The methodology used (similar to that in the IMO guidelines for approval of alternative tanker designs and the draft regulation for evaluating accidental outflow for new tankers) contains a probabilistic-based procedure for assessing oil outflow performance. Probability density functions describing the location, extent and penetration of side and bottom damage are applied to a vessel's compartmentation, generating the probability of occurrence and collection of damaged compartments associated with each possible damage incident. All fuel oil is assumed to outflow from tanks penetrated in collisions, whereas outflow from bottom damage is based on pressure balance calculations. Outflow parameters are developed by combining results from all damage cases:

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- The *probability of zero outflow* represents the likelihood that no oil will be released into the environment, given a collision or grounding casualty which breaches the outer hull.
- The *mean outflow parameter (Om)* is the non-dimensionalized mean or expected outflow. It is assumed that the double hull provisions of MARPOL Regulation 13F assure adequate protection against the likelihood of spills, and therefore *OM* is an acceptable measure of merit

If the *probability of zero outflow* is 0.80, it then follows that 20% or 20 out of 100 accidents will be spill events. The combined outflow from these 20 spills is the *mean outflow* multiplied by 100. The calculation results for the *probability of zero outflow* and *mean outflow* are presented for each tank configuration, as well as spill frequency (number of spills per 100 accidents) and total outflow per 100 accidents.

The probability of damaging each cargo tank is calculated. This is the probability that a tank will be breached, either alone or in combination with other tanks, and equals the sum of the probabilities for all of the unique damage cases which involve that particular cargo tank.

The methodology described in the IMO draft regulation on accidental outflow was applied in these calculations, with the following adjustments to accommodate the analysis of bunker tanks.

- The IMO procedure assumes all cargo tanks are 98% full. When evaluating the bunker tank outflow, three independent sets of calculations were run, assuming bunker tanks were 98% full, 54% full, and 10% full. The outflow results from these three sets of calculations were then combined in a ratio of .25:.50:.25, to simulate the consumption of fuel oil during the course of the voyage.
- The IMO procedure specifies the calculation of bottom damage outflow based on hydrostatic balance principles. A minimum outflow equal to 1% of the tank capacity is assumed for oil tanks bounding the lower shell. This provision accounts for losses from initial impact and dynamic effects such as current and ship motions, for designs like the mid-deck tanker having tanks initially in hydrostatic balance. However, 1% of tank capacity is not adequate to cover losses from a double bottom tank, as studies indicate that a water bottom of up to 1 metre would be introduced by a 3 knot current. For this study, the 1 metre water bottom is assumed, resulting in losses of 50%, 4%, and 1% of the tank capacity when the initial tank filling levels are 98%, 54%, and 10% respectively.
- The probability distribution function for the longitudinal location of side damage for tankers assumes a homogeneous distribution over the ship's length. IMO data for cargo and passenger vessels used for developing the damage stability regulation indicates an increased likelihood of damage forward. The "cargo vessel" distribution is applied for analysis of the bulk carriers and containerships.
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### **Presentation of Outflow Results**

The results of these assessments are shown in the graph below.

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An average mean oil outflow parameter of 0.013 was obtained for the *Tankers*, which is considerably less than the values for the other ship types. Four of the ten tankers had double-hulled bunker tanks. These all performed well, with mean outflow values between 0.004 and 0.007. Also, modern tankers have their bunker tanks located in the upper portions of the engine room. This aft location is less susceptible to side damage, and their relatively high position within the hull protects these tanks from grounding damage.

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## Mean Outflow Parameter - Alternative Tanker Arrangements

For the *Containerships* examined, the average mean oil outflow parameter is 0.035. The containerships tended to have tanks located in either wings or double bottoms, distributed about the amidships region. The tanks tend to have relatively large surface areas bounding the shell, increasing their vulnerability.

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For the *Other Vessel* types, the average mean oil outflow parameter is 0.027. The Cruise Ship has the smallest value at 0.009. This is the result of only a small percentage of the bunker oil tanks having contact with the shell of the vessel. The remainder of the vessels examined in the group have their bunker oil tanks located on the side shell and bottom shell, which results in larger  $O_M$  values.

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The *Bulk Carrier* group has the largest average mean oil outflow parameter at 0.040, and has the widest range of results. Design B5 has a very favourable mean outflow parameter of 0.009. With the exception of one small starboard tank, the bunker oil is arranged clear of the hull plating. The Capesize bulk carrier, B1, also exhibited a relatively good performance ( $O_M=0.020$ ), as its bunker tanks are located in the engine room, well above the bottom shell. Bulk carriers B2 and B3 have the highest mean outflow parameters in this study, at 0.072 and 0.071 respectively. In both of these vessels, all of the bunker oil is stored in large bottom tanks, spanning over 50 percent of the vessel length and 70 percent of the breadth.

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## Conclusions

The results of the SNAME probabilistic oil outflow analysis on the 25 vessels indicate a wide variation in bunker oil outflow performance in the existing fleet. Most designs have bunker oil tanks located adjacent to the shell. These are, of course, more vulnerable to damage than double-hulled tanks. The risk of penetrating a tank during a collision, allision, or grounding tends to increase with the area of the side shell bounding the tank. Also, tanks located forward and tanks located adjacent to the bottom shell are particularly vulnerable. The distance of double-hulled tanks from the shell and the size of the tanks are also contributing factors to outflow performance.

Providing double hull protection for bunker tanks reduces both the number of spills and the quantity of outflow, but comes at a cost. This cost is especially high for containerships, smaller bulk carriers and smaller tankers, as the size of the ship must be increased. Before implementing outflow regulations on bunker tanks, cost-benefit analyses should be carried out to ascertain the relative cost effectiveness of double hull protection and other options.

The development of bunker tank arrangements for new vessels requires careful consideration of many operational issues.

This study illustrates the many alternative approaches a designer can employ when seeking to enhance environmental performance with respect to oil outflow from collisions and groundings. These include modifications to tankage configuration, as well as to the location and size of tanks.

It is my personal view that any outflow regulations pertaining to bunker tanks should be performance-based, allowing optimization of the design. This would not necessarily dismiss the effectiveness of double hull protection, which can be used in its straightforward concept. However, a rigid deterministic regulation would for sure limit the ability of designers to seek alternative solutions which would be equally valid for some ship types or for some ship sizes. A performance based regulation would give the designer the freedom to optimize the bunker tank arrangement with regard to operational considerations and cost, while assuring a desired standard of performance.

#### **SNAME Future Work and call for contributions.**

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If you have comments or questions regarding the methodology/background, or would like to be involved with this committee please contact Arthur Haskell: [arthur.haskell@alum.mit.edu](mailto:arthur.haskell@alum.mit.edu) or visit the SNAME website for Ad Hoc Panels at: [www.sname.org/committees/tech\\_ops/bunkertank/home.html](http://www.sname.org/committees/tech_ops/bunkertank/home.html).

## APPENDIX

### REPRESENTATIVE CASE HISTORIES OF BUNKER OIL SPILLS

Case histories for six accidents involving damage to bunker tanks are summarized below. These include two high energy collisions (the *President Washington - Hanjin Hong Kong* and the *Alexia - Enif*), two allisions (the *Julie N* and the *Kure*), and two groundings (the *Kuroshima* and the *New Carissa*).

#### President Washington

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#### President Washington

In May 1994, at the entrance to Pusan Harbor, the containership *Hanjin Hong Kong* struck the containership *President Washington* on the port side near amidships. The bow of the *Hanjin Hong Kong* penetrated the side shell of the *President Washington* in way of an empty bunker tank and an adjacent ballast tank, extending about 2.5 metres beyond the longitudinal bulkhead. Two adjacent cargo holds were flooded. There was only minor oil pollution to the harbour from the residual HFO in the damaged bunker tank. The tank arrangement on the *President Washington* is representative of most containerships where the significant percentage of bunker oil is stored in wing tanks outboard of the cargo holds. However, it is likely that the extent of damage from the penetration of the *Hanjin Hong Kong* bow would have exceeded any practical double hull protection of the bunker tank in this high energy collision.

#### Enif

In July 1995 the 230-metre bulk carrier *Alexia* collided with the 157-metre bulk carrier *Enif* in the Gulf of Mexico near the entrance to the Mississippi River. The *Alexia*'s bow imbedded in the port side of the *Enif*, just aft of amidships. It extended into No. 3 Hold, approximately half way through her beam. As a result of the collision three bunker tanks and one diesel oil tank on the *Enif* spilled approximately 360 m<sup>3</sup> (95,000 gallons) of mixed diesel and IFO 180. There was only bow structural damage to the *Alexia* with no oil spillage.

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#### Enif and Alexia

The ships were successfully separated and lightered without additional spillage. After the third day only sheens were reported around the *Enif*, and visible evidence of the spill disappeared a few days later. The port bunker tank and centreline diesel oil tank on the *Enif* were damaged from direct contact with the *Alexia* bow. The starboard bunker tank was damaged from the resultant shifting of the cargo of coiled steel plate. The impact and penetration of the *Alexia* bow caused the hatch covers to collapse into the hold below causing collateral damage to a double-bottomed bunker tank at the forward end of the hold. The force of this collision and the extent of bow penetration was so substantial that the double hull protection afforded by the outboard port bunker tank failed to protect the diesel oil tank. Similarly, there are no practical

design options that would have prevented the collateral damage to the port side and double-bottomed bunker tanks.

### Julie N

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### Julie N

In September 1996 the product tanker *Julie N* struck the south side of the Million Dollar Bridge in Portland, Maine, as the ship transited the draw span. Pilot error was the cause of the accident. The contact with the bridge buttress resulted in an oil spill of 353 m<sup>3</sup> (93,200 gallons) of heavy bunker fuel and 327 m<sup>3</sup> (86,400 gallons) of No. 2 home heating fuel, cargo oil. The oil spill covered 13.7 miles of shoreline and led to a massive clean-up response. Total costs reportedly approached \$50 million. The damage to the *Julie N* occurred below the waterline, on the port side of the bow just aft of the collision bulkhead. The side shell ripped open – the hole measuring approximately 10 metres in length by 4 metres in depth. A HFO bunker tank located immediately aft of the collision bulkhead was breached, and the bulkhead at the forward boundary of the port cargo tank was ruptured. The transverse penetration into the bunker tank from the contact with the bridge buttress was limited, and there is a good possibility that double hull protection would have prevented this oil spill.

### Kure

In November 1997 the 195-metre bulk carrier *Kure* contacted the pier while shifting berth at the Louisiana Pacific Dock in Humbolt Bay. Damage to the hull consisted of a 350mm hole about 3 metres above the waterline in way of a forward bunker tank. About 17.2 m<sup>3</sup> (4537 gallons) of IFO 180 was discharged into the bay before the hole could be plugged. The local wetlands and shoreline were heavily impacted by the oil spill. Double hull protection would certainly have prevented the spill from this minor and very localized puncture through the hull.

### Kuroshima

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### Kuroshima

In November 1997, the 116-meter refrigerator ship *Kuroshima* went hard aground at Summer Bay near Dutch Harbor, Alaska. The grounding resulted in the breaching of two double bottom bunker tanks and about 174 m<sup>3</sup> (46,000 gallons) of heavy fuel oil spilled. An additional 288 m<sup>3</sup> (76,000 gallons) of HFO was pumped from the ship to holding tanks ashore to prevent further spillage and to lighten the ship. The salvage effort took three months to free the ship, and a costly oil cleanup and recovery operation ensued. This oil spill would likely have been averted if the bunker tanks were located outside of the double bottom spaces.

### New Carissa

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### New Carissa

In early February 1999 the wood chip bulk carrier *New Carissa* drifted aground off the central Oregon coast. Initially, though hard aground on a sand bottom, there was no known oil spill. As storm seas pounded the ship against the bottom, oil began to leak from the ship, and pollute the nearby coastline. Bunker fuel was located in three centreline double-bottomed tanks below Cargo Holds No. 2 to No. 4, and an additional double-bottomed tank on the portside below Cargo Hold No.5. Diesel oil was stored in the starboard double-bottomed tank across from the No. 5 DB. At the time of the grounding the ship had approximately 60% bunkers on board, consisting of about 1,363 m<sup>3</sup> (360,000gallons) of HFO and 114 m<sup>3</sup> (30,000 gallons) of diesel oil. It is difficult to know how much HFO escaped from the grounded vessel, and how much burned-off during the salvage operation. Estimates of HFO spillage range from 189 m<sup>3</sup> (50,000 gallons) to 265 m<sup>3</sup> (70,000 gallons). To date, salvage and oil spill clean-up costs have exceeded \$20 million. The bunker tank arrangement on the *New Carissa* was typical of many bulk carriers where bunker oil is predominantly stored in double-bottomed tanks below the cargo holds. However, it is uncertain whether alternative bunker tank arrangements would have averted this spill. The structural failure and breaking up of the vessel would probably have opened up any tanks in the midships region of the vessel.

*Source: Cargo Ship Bunker Tanks: Designing to Mitigate Oil Spillage, Keith Michel, President, Herbert Engineering Corp., Thomas S. Winslow, PE, Consultant, Oakland, CA*