Building on experience

Concern about cargo spills and leaks ensures that the lessons learned through experience are quickly incorporated into the design of the next generation of tankers

The era of the modern oil tanker began in December 1976, a point at which the tanker industry had reached its nadir. An overtonnaged fleet and depressed freight markets had pushed cost-cutting practices into new realms of irresponsible behaviour and safety standards to new lows.
The catalyst for change was the US, then, as now, the world's largest importer of oil and the greatest 'user' of tankers. Two incidents that month, in fact within 48 hours of each other, had prompted President Jimmy Carter to launch his campaign against the new enemy of "substandard shipping". These were the sinking of an ageing tanker called Argo Merchant with the loss of 27,000 tonnes of heavy fuel oil after the ship grounded on a shoal off the US East Coast and an explosion onboard the tanker Sansinena as she discharged gasoline in Los Angeles harbour.
The investigation of the Sansinena wreckage showed that the tank venting system which directed volatile cargo vapours skywards out of harm's way was full of holes. It was determined that leaking gasoline vapours from the vent stacks had spread out over the main deck until they eventually found a source of ignition. Nine people were killed and 58 injured as a result of the blast.

Get Carter

In response to these incidents and several similar, albeit less dramatic, tanker casualties in domestic waters at the time, the US Coast Guard inspected a total of 2,650 foreign-flag tankers that visited the country's ports during 1977. More than 50 per cent were found to be in breach of applicable safety standards and, in all, over 8,000 violations of these standards were discovered.
President Carter put together a portfolio of remedial measures, calling for, among other things, double bottoms in tankers, segregated ballast tanks (SBTs) and an improved system of ship survey and certification. The US president said that his administration was going to implement these measures unilaterally but first he offered the Intergovernmental Maritime Consultative Organisation (IMCO, the forerunner of today's International Maritime Organisation (IMO)) the opportunity to consider the proposals for adoption internationally.
In the event, IMCO took up the cudgels on behalf of the US president. Although the Organisation did not provide Carter with his double bottoms, virtually all his other proposals were adopted, plus a few more besides.

The 1978 Protocols

The improvements to tanker design initiated by President Carter were wrapped up in the 1978 Protocol to the 1973 Marine Pollution (MARPOL) Convention. Under the protocol all new tankers of 20,000 dwt and above had to have SBTs that were protectively located to help shield the cargo tanks in case of a collision or grounding. The new regime also introduced the concept of crude oil washing (COW) in which the cargo itself is used as the tank cleaning medium. The measure, which was made mandatory for new tankers and accepted as an alternative to SBTs on existing tankers, represented an important step forward in the drive to minimise contact between water and oil cargo residues.
In a related development, the 1978 Protocol to the Safety of Life at Sea (SOLAS) Convention stipulated that an inert gas system (IGS) must always be used when COW is operated.

MARPOL 73/78 also introduced stricter requirements for the survey and certification of ships in an attempt to close the loopholes available to operators resulting from inadequate enforcement of the regulations. For example, ships must undergo an initial survey before being put into service or before an International Oil Pollution Prevention (IOPP) Certificate is issued and at least one periodical survey has to be carried out during the period the IOPP Certificate is valid. Under the new controls tankers became subject to either unscheduled inspections or mandatory annual surveys by the national administration.

Upgrading the regime

The MARPOL tanker design regime has continued to be revised and updated over the past two decades, most notably by the 1992 amendments promulgated in response to the March 1989 Exxon Valdez grounding accident. These amendments, which entered into force in July 1993, are aimed at minimising the accidental outflow of oil from tankers, i.e. that due to collisions and groundings. Among other things, the measures call for new tankers of 5,000 dwt and above to either be fitted with double hulls or be built to a design which affords an equivalent measure of protection from a pollution prevention viewpoint. In the absence of viable alternative designs, owners have specified the double-hull configuration for all their newbuildings.

More recently, the break-up of the tanker Erika in the Bay of Biscay in December 1999 prompted IMO to agree measures which will speed the phase-out of older, single-hull tankers and increase the level of scrutiny given to hull structures as these ships near the end of their operating lives. In addition, new ships will have to be provided with improved means of access within the cargo area to enable close-up inspections and steel thickness measurements.

Safety on record

A review of the international oil spill record shows that marked improvements in tanker pollution prevention began in the early 1980s, shortly after the 1978 MARPOL Protocol took effect. Operational pollution from tankers, for example, was reduced from approximately 700,000 tonnes in 1980 to 150,000 tonnes in 1989.

Many argue that double hulls have brought even greater benefits and that the 1992 MARPOL amendments represent the greatest single improvement in tanker design from a pollution prevention point of view. The fact that the US has not had a single tanker accident resulting in a major release of oil since the Exxon Valdez is used to back up this argument. Furthermore, each year since 1990 the average barge spill in the US has been larger than the average tanker spill, and barges have consistently spilled more oil than tankers, with the exception of 1997.

The good news about reductions in US tanker spills is being repeated elsewhere in the world, and the overall record is improving as the percentage of double-hull tankers in the world fleet steadily increases. At about the same time the double-hull share of the world fleet passed the 50 per cent mark earlier this year, the International Tanker Owners Pollution Federation Ltd (ITOPF) reported that the incidence of accidental tanker spills from recognised international seaborne trade in 2001 was arguably the lowest since the organisation began compiling its database of accidental oil spills from tankers, combined carriers and barges in 1974.

ITOPF categorises incidents by size, with large spills defined as greater than 700 tonnes of oil. Analysis of data for the year 2001 shows only three recorded incidents over 700 tonnes, the largest being the Baltic Carrier which spilled 2,400 tonnes of heavy fuel oil cargo as a result of a collision in the Baltic Sea in September 2001.

Double troubles

Notwithstanding the undoubted benefits of the tanker double-hull configuration, including flush tank walls, easier cleaning and improved cargo out-turns, its introduction in the early 1990s opened up new challenges for naval architects. The

need to consider the behaviour of a complex very large crude carrier (VLCC) hull structure in a seaway over the service life of the ship was but one aspect of this new discipline. Accessibility and maintenance programmes for voluminous ballast tank spaces and the oil outflow characteristics of damaged double hulls also needed scrutiny.
While the deck and bottom plating in double-hull tankers have lower permissible corrosion margins, experience of the fatigue performance of structural details associated with the new generation of steels was limited. In addition, modern ships do not have the same plentiful supply of inert gas that the older, more heavily scantlinged steam turbine tankers possess.
As experience with double-hull tankers in service accumulated during the 1990s, several problem areas came to light where the original IMO requirements needed some amendment. For example, several lolling incidents on medium-sized double hull tankers with single-tank-across arrangements prompted IMO to pass a new regulation mandating that future newbuildings be designed with adequate intact stability.
Also, when it was discovered that raking damage could lead to the capsizing of double-hull tankers, IMO had to introduce a raking bottom damage criterion in the MARPOL Convention and, later on, a new regulation to enable a more effective assessment of accidental oil outflow resulting from collisions and groundings.

Role of class
Classification societies responded to the challenges posed by double-hull tankers by developing sophisticated, computer-based design tools to implement construction and lifetime ship care procedures such as structural design assessment, fatigue design assessment and construction monitoring. In general, monitoring service experience with double-hull tankers to date has revealed satisfactory structural performance.
As ballast spaces in double-hull tankers have surface areas approximately 250 per cent greater than those in a single-hull ship, ballast tank coating standards and a suitable access arrangements to carry out inspections are critical. Proper application of the paint system, followed by rigorous maintenance, will ensure that the volume of steel that has to be replaced over the life of the ship is minimised. Light-coloured ballast tank paint systems have proved effective in facilitating inspections.

Cargo tank corrosion
Ironically, cargo tank corrosion has proved to be more of a problem. The smooth cargo tank surfaces made possible by the double-hull arrangement were expected to result in less residues and, thus, less pitting. In fact, the opposite has been the case. A number of double-hull crude oil tankers have suffered pitting corrosion in the inner bottom plating and/or in the ullage space at the top of the tank. Although not a widespread phenomenon, the corrosion intensity in the reported cases has prompted a vigorous industry investigation.
Several theories as to the cause of such corrosion, including the presence of millscale, the use of certain types of steel, water dropout from inert gas, the carriage of sour crudes rich in sulphur and the possibility that sulphur-producing bacteria may thrive in the cargo spaces of double-hull tankers, have been put forward but, as yet, there are no definitive answers. The so-called "thermos bottle effect", in which double skin slows down the cooling of the crude oil by the sea, is also believed to be a factor.
The industry investigation - Abnormal Corrosion to Crude Oil Cargo Tanks (CRUCOR) - has been carried out as part of a larger study called the Physical Behaviour of Crude Oil Influencing its Carriage by Sea (CRUCOGSA). CRUCOR has revealed that water dropping out of inert gas is a key factor and that sulphur is a key ingredient in the corrosion process. However, these are by no means the only

factors. There are no easy answers to the problem of cargo tank corrosion in double-hull crude oil carriers and more research is required.

Cargo tank coating

Of course, one possible solution is the coating of horizontal surfaces in cargo tanks that will be carrying crude oil, especially the inner bottom plating and the tank deckhead.

Cargo tanks of crude oil tankers have traditionally not been coated as it has never been deemed to be a cost-effective exercise, particularly in the older, single-hull tanks where cargo tank corrosion was a slow process and never posed major problems. However, several owners have recently opted to specify the coating of horizontal surfaces in their newbuildings as the best way of ensuring that they are not troubled by accelerated pitting and other cargo tank corrosion early on in the ship's operating life.

Hellespont Shipping, for example, has coated the cargo tank bottoms in its four 442,500 dwt ultra large crude carriers (ULCCs) built by Daewoo. In addition, the ships have been painted white above the waterline to reduce the daily expansion and contraction of the cargo tanks due to thermal fluctuations. Expansion brings in air, and thus increases the risk of corrosion, while contraction leads to the loss of hydrocarbon vapours and, as a result, has a negative commercial impact.

By reflecting the heat of the sun, the white paint also helps to minimise the degradation of the epoxy ballast tank coatings on the ULCCs due to thermal cycling. Hellespont has also inerted the ballast tank spaces on the ships, a practice which should not only slow any corrosion that might be taking place but also minimise the risk of explosion due to leaking cargo vapours.

Using computer power

The initial concerns about double-hull tankers on the part of ship designers - corrosion in the ballast tanks and the fatigue strength of key structural members - are essentially long-term problems, if indeed they materialise to the extent envisaged. Not enough time has elapsed to assess whether the early fears are justified.

Rather than succumb to calls from the pessimists for more stringent structural strength criteria for tankers, the industry in general is more disposed to awaiting the results of the enhanced survey programme and the ISM Code before introducing new legislation. Furthermore, the use of today's powerful IT systems should enable the ship's structural condition to be continuously and closely monitored.

Life-cycle commitment

Tanker owners are more aware than ever before that they are being asked to make a major, life-cycle commitment when ordering a new ship. It behoves the shipowner to specify a design which goes beyond the minimum rule requirements and anticipates maintenance demands, minimises life cycle costs and facilitates safe operations. Inherent in this commitment is close superintendency of the ship construction process, and a close liaison with the classification society and the shipbuilder throughout the ship design and fabrication period.

This philosophy was embodied, for example, in a series of 285,000 dwt tankers built for Shell at the end of the 1990s. The VLCCs have 3-metre deep double bottoms and double sides 3.5 metres wide, much greater than the mandated 2-metre minimum, for structural reasons. The design features wing cargo tanks with virtually flush walls while the structural cross ties linking the two longitudinal bulkheads are located in the centre tanks.

The Tanker Structures Cooperative Forum and the North American Ship Structure Committee (SSC) both do good work in seeking to identify and eliminate marine structural failures. The reorganised SSC has taken on the task of pinpointing gaps in the knowledge of ship structural performance and developing a research programme to bridge the gaps.

Current IMO requirements and class rules represent a reasonable minimum standard for double-hull tankers. As further safety and environmental risks are identified, the regime will be improved accordingly.

Over the longer term the trend will be towards more performance-based regulations, as tanker owners participate more actively in the design and construction process to ensure the production of ships commensurate with the industry's needs.