Future naval tankers - bridging the environmental gap - the cost effective solution

Andy Kimber, BEng, CEng, MRINA
BMT Defence Services Limited, UK
Arne Magne Vik,
Skipskonsulent A/S, Norway

SYNOPSIS

The impending introduction of international legislation against single hulled tankers, including IMO MARPOL Annex I regulations 13G and 13H, the US Coast Guards OPA90 and the recent EU regulations, are driving the commercial tanker operators to replace much of the older tanker and product tanker fleets with new construction vessels. Whilst there is little fundamental change in the basic modern products tanker design from its predecessors, some of these new tankers are also including other design features to minimise hazards that may lead to environmental accidents and to improve operating efficiency and costs. The pressure to adopt the commercial regulations for naval tankers is increasing in many countries as the potential negative publicity associated with an oil spill from a naval vessel would be significant. However, many of the existing replenishment tanker designs are expensive due to the limited numbers that are built and they are often designed by naval design teams with limited experience of modern tanker practises. The longer life of the naval tanker and the extended procurement timescales compared to the short lived commercial tanker also leads to the adoption of innovation in tanker design being driven by the commercial sector.

This paper discusses a family of affordable naval replenishment vessels developed by a joint design team drawn from commercial ship designers Skipskonsulent and naval designers BMT Defence Services. Both are independent design consultancies, based in Bergen, Norway and Bath, UK respectively, and are complementary in their naval and commercial pedigrees. This family of designs draws on the wide experience of the two companies, offering the pull-through of the best commercial tanker design practice into the naval environment. This approach builds directly on the innovations being developed in the current generation of commercial tankers whilst retaining the key understanding of replenishment ship operations in the naval environment. The family of ships are scalable in size and capability through careful design of systems allowing capability growth. As both companies are strictly independent from manufacturing interests, the designs are offered without ties to shipbuilders and no equipments are pre-selected.

Author’s Biography

Andy Kimber is a Managing Naval Architect at BMT Defence Services Limited, where he leads the Naval Architecture Future Platforms Team. He has undertaken a variety of future ship and options studies over the past three years. Previous to this role, he held the position of Platform Architecture Manager for the Thales CVF team for three years. Andy has a wide experience of design, in service support and disposal activities since joining BMT Defence Services in 1990, after completing a degree in Naval Architecture and Ocean Engineering at University College London between 1989.

Arne Magne Vik is the Managing Director of Skipskonsulent A/S. He has worked for Skipskonsulent as a Naval Architect, Project Manager and the Head of the Project Development Department and has extensive knowledge of the design and conversion of commercial vessels of many types. He has wide experience including naval architecture and the design of ship arrangements, the development of technical specifications and in the client and project relations. He was trained in Naval Architecture and Marine Engineering at Bergen Technical College between 1980 and 1982.
INTRODUCTION

Few in the business of ship design have not been aware of the debate and subsequent legislation covering the withdrawal of the single hulled oil carrier and its replacement by the doubled hulled tanker. Since the introduction of the US Oil Pollution Act in 1990 and the revised IMO MARPOL Annex I regulations, commercial operators have moved to replace older single hull tankers with double hull tankers ahead of the final phase-out date in 2010.

This replacement programme is well underway with significant numbers of double hull product and crude carriers being built predominately in China and other mostly Asian ship builders as well as in smaller numbers in Europe and South America.

However, the impact of the single hull phase-out programmes of MARPOL Regulation 13G and OPA90 has been slower to appear in the world’s navies, with few double hull replenishment tankers entering service and replacement programmes likely to extend beyond the 2010 deadline. This slow adoption of the new rules is an inevitable consequence of the longer service lives and slower procurement rates in the naval sector; an average naval tanker could expect to serve for thirty years, suggesting that by 2010 only vessels build in 1980 or before would normally be the subject of replacement, some tens years prior to the first regulations governing the introduction of double hulls.

CHANGING ENVIRONMENTAL AND OPERATIONAL REGIME

MARPOL 73/78 Annex I was amended through adoption of Regulation 13F that requires all future tankers greater than 5,000 tonnes deadweight shall be provided with a double hull (or an alternative arrangement). Starting in 1995, Regulation 13G began the process of applying double hulls to existing tankers and a phase-out schedule for single hulled vessels was begun. The schedule has been progressively revised in light of a number of high profile incidents, such as the M/V ERIKA incident in 1999. The key date affecting vessels of the size and type operated by navies is the final 2010 deadline for the phase out of Category 2 and 3 tankers.

Alongside the MARPOL Regulations, the US Oil Pollution Act of 1990 also required future tankers to be double hulled and a similar phase out schedule for single hulled tankers was enforced; again 2010 is a key date for final withdrawal of single hulled vessels.

A review of the world’s naval replenishment tanker fleet quickly demonstrates that many of the vessels predate the current double hull legislation. In the first instance, the introduction of new regulations would not necessarily be of concern to many navies, who are able to claim exception from the regulations through their national statutory processes. For instance, in the Reference [1] enacts MARPOL 73/78 into UK legislation and states “These Regulations do not apply to any warship, naval auxiliary or other ship owned or operated by a State and used, for the time being, only on government non-commercial service”.

Today many navies are facing more scrutiny of their operations, particularly with respect to health and Safety and Environmental Protection. A legal exemption is no longer an acceptable method, as demonstrated by statements made in the UK regarding the Royal fleet Auxiliary’s tanker fleet. On 6th of March 2003, the Secretary of State for Defence stated that “The Ministry of Defence's policy remains that, where practicable, we will comply with standards required by legislation .....”. This is in line with the policy of achieving “at least as good as” statute in regards environmental policy for the navy and wider armed forces. It also represents a very real issue that the vessels could be refused entry to the waters and ports overseas on the grounds of non-compliance, as expressed by Admiral Sir Alan West, Reference [2], “… you do not have to abide [with the regulations]—there is a let-out clause—but generally in the UK we do not like doing that sort of thing and there is a real issue that some countries might say, "I am sorry, I am not having you coming here", so there is an issue there, plus some of our Oilers are getting extremely old and therefore they are costing more and more to run and maintain, and we are actively looking at the moment at this tanker issue”.

March 2006 Page 2 of 10 © BMT DEFENCE SERVICES LTD
So it is that many of the Navies currently operating single hulled tankers have come to the conclusion that they should seek compliance, if not by 2010, then at the earliest possible time thereafter.

Beyond the replacement of existing single hulled replenishment tankers, the current transition in types of military operation is effecting the aspirations of navies currently without such vessels. The increasing use of blue water capable vessels by regional powers and peace support / keeping operations being conducted by the smaller military nations has lead some to the conclusion that a potentially global capability and blue water operations as a required capability. This brings the need to support newly acquired surface warships away from home but with in the tight constrains of a small navy.

**Evolving the Commercial Tanker**

The design of the latest commercial product tankers have evolved greatly in recent years, specific drivers behind this being:

- Introduction of the double hull and bunker tank location legislation;
- New regulations and high penalties associated with operating tankers in “sensitive” areas;
- The search for improved operability and reduced running costs.

A significant change that is occurring in commercial tanker is the increasing adoption of twin screw designs. The introduction of twin screws is a response to increasing concern of oil pollution through loss of steerage and the increasing number of Special Areas and Particularly Sensitive Sea Area (PSSA) defined through IMO, Reference [3].

In addition to an improved propulsive efficiency resulting from dividing the installed power between two plants, full redundancy in the propulsion plant is achieved. This allows the ship to be operated with a critical failure in one of the propulsion lines. Maintenance can also be performed, with a complete shutdown of one of the propulsion engines/plants, without having to take the vessel out of service or off-hire and therefore no loss of revenue is incurred. Additionally, water and fire tight sub-division may be arranged on the centrel ine, resulting in two separated engine room compartments that will provide redundancy with regard to flooding and fire.

In developing the twin screw tanker, designers have adopted the “twin skeg” hullform, such as the example shown in Fig 1.

![Fig 1 Twin Skeg Hullform](image)

The twin skeg hullform and the reduced size of the propulsion engines on each shaft compared to a single engined vessel allows the possibility of locating the engines further aft in the engine room/hull. The length of the engine room can thereby be reduced which results in a larger cargo capacity. Additionally, by using medium speed engines, further space saving, a more easy arrangement and an easier shipyard installation are achieved.
Finally, a small number of tankers are now being built with diesel electric propulsion to gain the potential operating savings these offers, something more normally associated with warships or cruise ships rather than bulk carriers.

CONCEPTS FOR REPLACING NAVAL TANKERS

Several navies are now actively exploring the routes to compliancy and three distinct routes emerge; double hull existing single hull tankers, convert commercial vessels or build new.

Each of these solutions has benefits and disadvantages, which are explored below.

Double Hull Existing Vessels

With many navies operating existing single hull tankers which potentially have life beyond 2010, the modification of these vessels to double hull configuration is one potential solution. This has the benefit that a new vessel procurement programme does not have to be initiated, a major hurdle for many navies. Commercial double hull conversion projects have been undertaken, so this appears an attractive option.

Unfortunately, the double hull solutions sought by naval operators often preclude the simplest option, the addition of sponsons to the hull. Whilst this approach is the simplest and cheapest method and therefore attractive to commercial operators, the inherent impact on vessel speed is not acceptable to naval operators. Therefore naval tanker double hull conversion studies have focused on the subdivision of the existing tankage to create new water ballast wing tanks.

In fact, the hull shape and smaller size of a naval tanker does not lend itself to double hulling; the shape of the hull means the introduction of internal longitudinal bulkheads requires shaping to the outer hull and the lost cargo capacity is often significant and critical, potential up to 30% of the total cargo volume available.

Commercial Conversions

Converted commercial tankers have been utilised by many navies since the earliest days of replenishment at sea; the Royal Fleet Auxiliary’s LEAF Class are a prime example of a converted commercial vessel. Hence, the most immediate solution to the double hull regulations is to study new conversions. The clear advantages here are the ability to quickly procure and convert a tanker by or shortly after the 2010 deadline; the basis ship is by its nature compliant with MARPOL and other legislation and the cost is perceived as less than a new building naval replenishment ship.

In fact, today the rising price of double hull tankers and the high cost of conversion are making this option unattractive; a modern, new products tanker can cost as much as $40M and as much again to convert. These high purchase prices are being driven by the currently profitable markets in oil which make the modern double hulled products carrier a valuable commodity and one for which the price is likely to remain
high for some time; indeed the current high charter rates will affect the availability of commercial hulls for naval use as key commercial operators may not wish to part with the required tonnage.

However, there are also draw backs to these conversions. A commercial tanker lacks the speed often required for task group operations (typically commercial tankers maximum speeds are 14 to 15 knots), accommodation is more limited (usually a complement of 20) and naval features such as flight decks and self defence are difficult to integrate due to the small length aft of the cargo tanks, as shown in fig 3.

The other significant issues such as a lack of accommodation and the difficulty in providing aviation facilities, which results is a significant package of conversion work, affecting many areas of the vessel. The conversions require a lot of piecemeal modifications and usually significant nugatory effort in order to provide access to the affected areas.

The commercial tankers available are likely to far exceed the size required by many naval operators with products tankers now mostly of 35,000 to 40,000 tonnes deadweight. This, combined with their slower service speed and lack of accommodation space, makes the commercial conversion much less attractive for the modern naval replenishment ship. Despite this, where funds are considered too limited for a new build and the timescales are limited, the commercial conversion is likely to remain a prime choice for the “support” tanker.

**New Build**

The most attractive technical solution is to procure a new build, purpose designed replenishment vessel. Today there are few modern examples of the dedicated replenishment tanker, but the available double hull designs are limited due to the small number of navies who procure new build vessels. They are often built by naval shipyards and whilst using commercial design influences they are usually far more expensive than commercial tankers and are not affordable solutions for many navies seeking some degree of blue water capability.

Advances in the design of commercial tankers, driven particularly by increased regulation and severe penalties for oil pollution, suggest the time is right to consider a new generation of affordable naval replenishment tankers, focused on high environmental protection and affordability. The question is can such a design be achieved at around the same budget as a conversion and what are the advantages of going for a new build?
THE AEGIR DESIGNS

Hence, there exists an attractive proposition for the regional navy to consider a purpose built naval replenishment tanker which is derived from the current commercial practises and uses the maximum of design practise pull through to achieve an affordable programme at low risk. Such a design would not necessarily be a direct derivation of an existing design, rather using mature commercial design practise to de-risk the process.

This may best be approached through the direct teaming of commercial and naval designers to pull through the broadest understanding of commercial designs and naval operational constraints. This forms the foundation of the AEGIR\(^1\) design concept.

By combining a number of basic design features, which are all being used in the latest commercial tanker designs, a double-hulled naval replenishment tanker series has been developed for international markets. The designs offer significant environmental protection features, including propulsion and manœuvring systems redundancy, full protection of cargo and fuel, and economical propulsion and power production in all operational modes and at higher speeds than for conventional naval replenishment tanker designs.

To illustrate the AEGIR family, four designs have so far been developed. Three represent scaleable versions of the Fleet Tanker, the fourth a mixed consumable AOR. All share many similar features.

Fleet Tankers

The three Fleet tanker designs span the deadweight range of ocean going replenishment tankers and the characteristics are shown in Table I below.

<table>
<thead>
<tr>
<th></th>
<th>AEGIR 10</th>
<th>AEGIR 18</th>
<th>AEGIR 26</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Length, metres</td>
<td>145.6</td>
<td>175.0</td>
<td>196.6</td>
</tr>
<tr>
<td>Moulded Breath, metres</td>
<td>20.8</td>
<td>25.0</td>
<td>28.3</td>
</tr>
<tr>
<td>Design Moulded Draught, metres</td>
<td>7.65</td>
<td>9.2</td>
<td>10.45</td>
</tr>
<tr>
<td>Deadweight, tonnes</td>
<td>10,000</td>
<td>18,000</td>
<td>26,000</td>
</tr>
<tr>
<td>Cargo Capacity, cubic metres</td>
<td>8,000</td>
<td>16,000</td>
<td>24,000</td>
</tr>
</tbody>
</table>

1 Named Aegir after the Norse god of the sea.
The designs feature stream type tensioned span wire rigs for the transfer of fluids; DIESO, AVCAT and Fresh Water. The larger AEGIR 18 and 26 designs features locations for up to four rigs and the small AEGIR 10 locations for two rigs.

The equipments for the replenishment system (hydraulic or electrical power systems, air systems for the tensioning system) are located in the deck house below the replenishment control station. The latter is conventionally arranged, between the rigs with maximum visibility for the operators.

A stern refuelling rig is also provided on all the designs, located below the flight deck.

### Aviation

A flight deck is provided for a 10 tonne medium helicopter. On the AEGIR 18 and 26, a Hangar is also provided to allow deployments on the vessel for short periods. The provision of a flight deck on a commercial conversion is possible though not ideal; provision of a hangar space is essentially impossible without complete redesign of the superstructure. Their inclusion in the AEGIR design from the outset is a feature that adds significant potential.
To increase the ship speed and installed power with a conventional single propeller propulsion system, the propeller diameter must be increased significantly, which may be difficult due to hullform and draught restrictions. If the propeller diameter is not increased, it will lead to a lower propulsive efficiency, due to higher revolutions and a higher loading on the propeller.

For this reason, it is very appropriate that the power is divided between two propellers that can then have a larger diameter, low revolutions compared to the propeller load and reduced power density. Hence, propulsive efficiency will be significantly improved.

The hullform should ideally be arranged as a "Twin-skeg" hullform as this would contribute positively to the propulsive efficiency, because of a higher hull efficiency due to higher mean wake and also a higher relative rotative efficiency compared to an open shaft twin screw system.

A twin skeg hull form will also allow for a fuller hullform in the aft ship, compared to a open shaft aft ship hullform, i.e. the LCB can be shifted towards aft, without having a large negative effect on the ship resistance. It can instead improve the ship resistance characteristics because the foreship hullshape can be made more slender. The increased service speed of a replenishment tanker with a maximum speed of about 18knots will of course also require a more slender hullform than for a commercial tanker with a service speed at about 15 knots.

The propulsion plant for the AEGIR is arranged with medium speed diesel engines, controllable pitch propellers driven via reduction gearboxes, as this allows for optimum propeller revolutions to be selected because reduction gearboxes are fitted. The sustained operating speed of 18 knots is achieved with two 7,500kW engines. Shaft generators are provided on each shaft in additional to dedicated diesel generators. Finally, bow thrusters are fitted, which is now common place on commercial and increasingly naval tankers.

**Flexibility in Propulsion System and Power Production and Supply**

In all normal operation one or both of the shaft generators will be used to supply the ship with electrical power, and during discharge operations, one of the plants can be used to supply power to discharge cargo. During manoeuvring operations the shaft generators may also supply power to the bow thrusters. This means that installed auxiliary power can be reduced to a minimum, whilst maintaining safety and emergency response.

The shaft generators/electromotors can be sized to be up to half the power of a main diesel propulsion engine. The power take out from one main engine can be divided to two propellers by using the shaft generator as a generator on one side and electromotor on the other side. The main engine will be disconnected from reduction gear where the generator is acting as an electromotor.

In addition to the full redundancy achieved with a twin engine/twin screw plant, this allows the propulsion plant to be arranged in a way such that both propellers can be driven with one engine, thereby providing full manoeuvrability even with the failure of one main engine. Additionally, the vessel may be run on one engine allowing maintenance of the other or if a reduction in service speed/power is used to reduce engine hours. This is done by arranging the reduction gears with a PTO/PTI (PowerTakeOut/Power Take In), where a combined shaft generator/electromotor is connected.

Alternatively, a higher auxiliary power may be installed. This power can than be used to boost the propulsion power by using both shaft generator as motors, taking power from the auxiliaries, supplying the propellers together with the main engines, in maximum speed sprint mode. This would be in cases when higher service speed then the normal service speed is required.

**Accommodation**

The complement required has been built from first principles, considering both the required man power at action stations / replenishment stations and the basic complement breakdown by role / grade. In addition,
generous provision has been made for additional berths for training, passengers and where applicable an embarked flight.

For the AEGIR 18 and 26 a total of 80 berths are provided, 65 are available on the smaller AEGIR 10.

The accommodation is based on a comfortable naval standard and incorporates single, twin and four berth cabins.

**Mixed Commodity AOR**

For the navy that requires more stores support at sea, the AEGIR 18R is a multi-commodity AOR based on the same hull as the AEGIR 18 and is shown in Fig 8.

The principal change is the introduction of a cargo hold of 1350m$^2$ in place of the aft most cargo tanks. A reduced fluid cargo of 12,000m$^3$ is provided. The cargo hold may be configured as required, but nominally would contain refrigerated, dry provisions and ammunition. Its location aft of the tank section principally offers reduced vulnerability to the deep cargo munitions, removing them from the forward part of the hull where collision with another ship or other obstruction is most likely.

The superstructure has also been extended forward over the cargo hold. This provides space adjacent to the cargo lift servicing the hold for the reconstitution of replenishment stores prior to conducting a RAS. The extended superstructure also offers significantly enhanced accommodation with 180 berths provided.

Replenishment is conducted by four dual use solid/fluid rigs and by VERTREP for solid stores. A central clear route is provided from the superstructure along the RAS deck, with a widened route beneath the replenishment control office.

![Fig 8 AEGIR 18R; Principle changes from AEGIR 18](image)

**CONCLUDING REMARKS**

Over the coming decade, many navies will have to address how best to meet the international regulations governing tanker design. For many regional powers, there will continue to be a need for replenishment tankers to support extended operations but the double hull legislation will make the purchase of non-compliant second hand vessels unattractive.

The choice between a new build naval replenishment tanker and converting a commercial vessel requires careful consideration of the costs, timescales and required capabilities. The emergence of new, affordable naval replenishment tanker designs, such as the AEGIR, offers the potential to introduce new vessels which exploit the latest commercial design practices and may be considered low risk due to the maturity of these features within commercial vessels. Significant improvements in capability are possible through the incorporation of features such as flight decks and extended accommodation from the outset, and this makes these designs more attractive than the commercial conversion, particularly as the price of commercial tankers continues to be very strong in the second hand market.
BIBLIOGRAPHY

1. MARPOL 73/78, Annex I.


REFERENCES


2. Select Committee on Defence Wednesday 24 November 2004.

3. IMO Resolution A.927(22).