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TRANSACTIONS (TM)

SHELL'S 84 000 DWT CRUDE/PRODUCT TANKERS

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SYNOPSIS

This paper describes the latest series of tankers built for the Dutch Operating Company Shell Tankers B.V., Rotterdam. The vessels are 84 000 dwt at design draught and have been designed for worldwide trading as well as a specific trade. Various features of the vessels' equipment are described, including the hydraulic power system, the thermal oil heating system, and the use of GRP pipes for the complete ballast system. The cargo valves are controlled by a keyboard and VDU arrangement, with the specification for operation set to ensure maximum cargo security and ease of operation. The vessels incorporate a constant-speed shaft generator driven by a five-cylinder slow-speed main engine for normal seagoing power and diesel-driven generators and hydraulic powerpacks for port and cargo pumping duties. The fuel system for the diesel generators is described with respect to the selection of the engines, the maintenance philosophy and uncertain future fuel prices. The design has taken account of the requirement for reduced manning and reduced maintenance. Further points described touch on hull form development, the central freshwater cooling system and the sludge/waste oil disposal system.

INTRODUCTION

The vessels have been designed for a deadweight tonnage of 84 000 at a draught of 12.2 m (see Fig. 1). Propulsion is by a slow-speed Burmeister & Wain engine, type 5L80 MCE, which with a fixed-pitch propeller gives an average speed of 15.6 knots (approximately 15 knots loaded, 16.2 knots in ballast) and an overall total fuel consumption of approximately 46.6 tonnes of heavy fuel per day.

The underlying design philosophy has been to obtain a vessel whose essential features would ensure long-term flexibility of operation. To produce this, particular attention was given to:

1. Cargo, designed for products and/or crudes.
2. Fuel, designed as far as practical for single fuel operation with fuels up to 700 cSt viscosity and 1010 kg/m^3 density.
3. Economic operation, designed for an overall economy of operation at a wide range of speeds.
4. Manning, designed for total operation by 17 staff.

GENERAL DESIGN REQUIREMENTS

The need for any tanker must be the requirement to move oil from one place to another, and the trade requirement must be there before any thought is given to the type of ship required or indeed whether any ship is required at all. Once a requirement for moving oil is defined, then the business of determining a means of moving the oil can be started.

For any major oil company there are a number of methods available for fulfilling a requirement to move oil. These include chartering in, buying secondhand ships, building new, or even using pipelines. The decision to build new has to be supported by concrete evidence that the freighting of such a ship is superior in the long run to any other method of moving the oil. The means of calculating this superiority is financial but the method of assessing the best option for the company as a whole is not always as simple as it might seem.

For these ships there is a defined trade. The trade is to carry white products from the new Arabian Gulf refinery at Al Jubail to Japan, and after discharge there to load crude oil from China and transport it to the refinery at Singapore. The ships would then return to the Arabian Gulf in ballast. A second arm of the trade is to again load white products in the Arabian Gulf but this time transport them to North West Europe where after discharge the ships would load North Sea crude for the United States again returning to the Arabian Gulf in ballast (see Fig. 2).

This trade is almost ideal for a tanker. The ships are carrying cargoes for more than two-thirds of their time, which is what they are meant to do, and not spending half of their

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FIG. 1: One of Shell's 84 000 dwt vessels

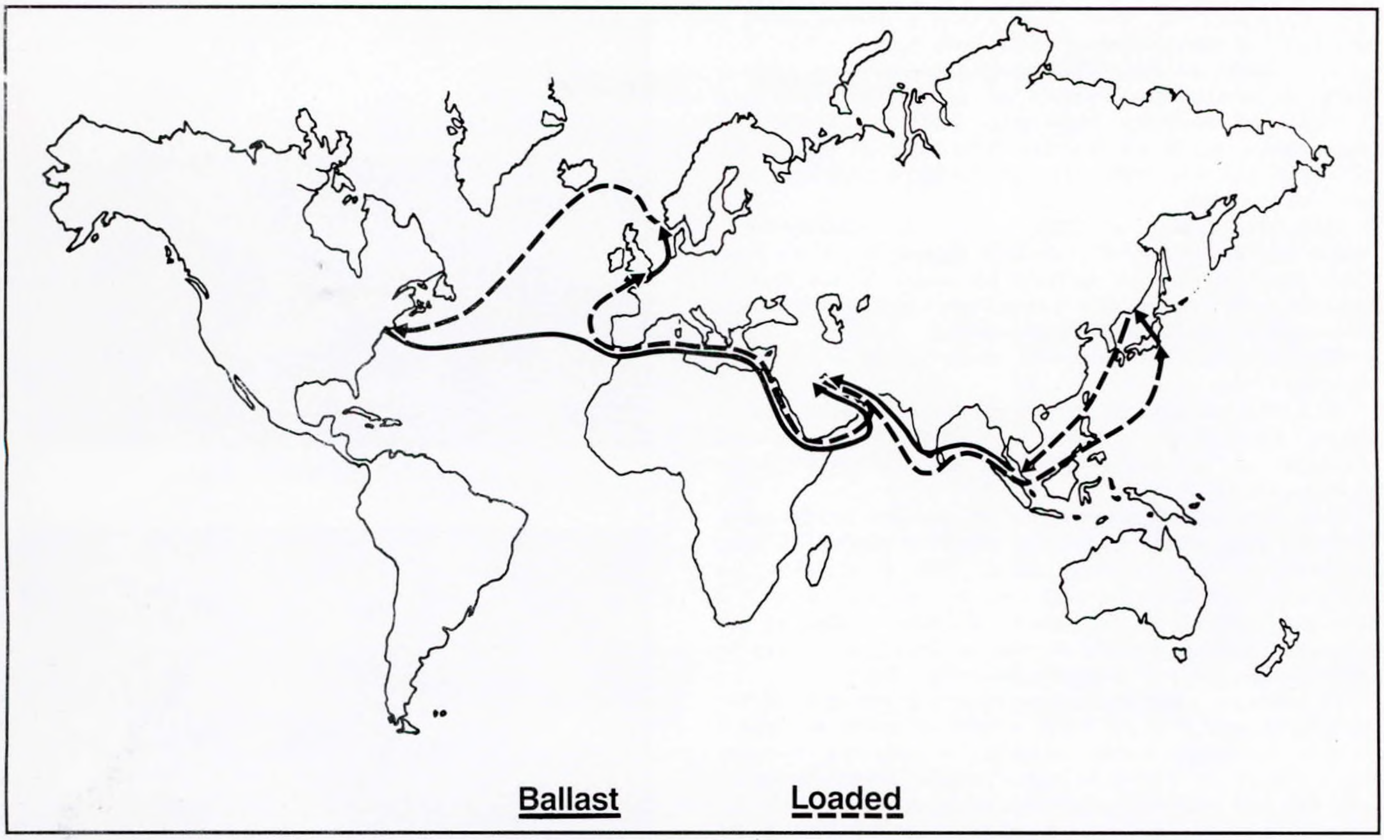

FIG. 2: Defined trade routes for design

life carrying ballast. Unfortunately we do not live in an ideal world and the future is by no means certain. The decision was therefore taken to ensure that the ships could operate efficiently assuming many future scenarios. Compromises in the design were studied so that should the ships have to trade on other routes or under other conditions than those originally intended, they would be able to trade as effectively. As a result, to make the optimum ship for the trade intended and to ensure that future changes can be managed, with least fall off from the optimum, several novel features have been incorporated into the design. These include:

1. Capability of carrying a wide range of cargoes adequately segregated.
2. Deeper draught capability for heavier cargoes.
3. Submerged cargo pumping system for more cargo capacity, deletion of pumproom and better out-turn.
4. Deck cargo heaters for clearer cargo tanks.
5. Dual inert-gas main for prevention of cross-contamination on the gas side.
6. Cargo valve control from keyboard and monitored by VDU screen.
7. Main-engine-driven generator for economy in electric power production at various ship speeds.
8. Fuel system and handling equipment to enable fuel of up to 700 cSt and 1010 kg/m^3 to be used.
9. Fuel blender for the auxiliary diesel engines to enable a balance between fuel cost and maintenance cost.
10. A thermal oil heating system for ease of operation and reduction in maintenance.
11. GRP materials used in places to combat the effects of corrosion.

HULL FORM DEVELOPMENT

The aim is always for more speed with less power, and it is no different with these ships. It is normal to contract for a certain speed at a given power in the fully loaded condition. For tankers, where for a great deal of time they are in ballast, or in the case of these vessels where some of the time may be spent partly loaded, contracting for speeds only at the fully loaded draught may not be the most beneficial for the owner.

The contract for these ships was written so that the contract speed was based upon the average speed at the design loaded and IMO ballast draughts. Many model tests were carried out aimed at improving the predicted ballast speed with no deterioration of the predicted loaded speed. Thus a hull form was produced close to the optimum for the service the ship was expected to undertake.

Although not for contract purposes, further model tests were carried out to assess the hull form performance in other situations. These tests included very light ballast tests to predict and make improvements to the performance in such situations. Other tests were manoeuvring, sea keeping and performance of the model in various sea states. The objective here was to gauge the loss of performance in various sea states and make improvements.

The contract terms specified two draughts and 'good weather' for the speed requirement. This is a move towards the expected service conditions, but the true service conditions are a combination of various draughts from full to very light and in weather from good to very bad. The aim must be to have a hull form optimised for the weather expected as well as the draughts. The results of model tests enabled a matrix of draughts against sea states to be drawn up showing the performance in each combination of conditions to allow the optimum hull form to be chosen.

CARGO AND BALLAST TANKS

The vessels have been designed as 84 000 dwt tankers with a cubic capacity of 112 000 m^3 for cargo of 0.75 specific gravity at a draught of 12.2 m. The scantling draught of 14.6 m will allow the carriage of cargoes of a higher specific gravity. For instance, cargo of a specific gravity of

0.9 would bring the vessel to its scantling draught giving a deadweight of approximately 100 000 tonnes.

The vessels are designed to carry crude oils and products either as homogenous cargoes or parcels of crudes and products simultaneously. Eight cargo tanks are provided, all centre tanks, and in addition three slop tanks are situated aft. All cargo and slop tanks are coated with a three coat pure epoxy paint system.

Each cargo tank is fitted with a hydraulically-driven submerged cargo pump of 1625 m^3/h capacity at 135 m head. Each pump is sited at the port aft corner of the tank to enhance cargo draining and located very close to the bottom of the tank so that no suction line is required.

The slop tanks are fitted with similar pumps of 450 m^3/h capacity.

With this arrangement no pumproom is required, and it allows better cargo out-turn performance and completely eliminates all maintenance problems associated with in-tank pipelines and valves.

Four fore and aft cargo mains are provided on the upper deck and each of the main cargo pumps is capable of being connected to any of these mains. This is to allow the maximum flexibility of parcel size and distribution with a minimum (reduced in the majority of cases to zero) of line admixture between parcels, as well as having the ability to discharge four grades of cargo simultaneously.

To maintain cargo segregation even with the most critical of cargoes only a single valve is used. It might be thought prudent to design in the capability of allowing swinging blank flanges or similar to ensure critical cargo segregation but with the type of valves selected, gate valves with 'O' rings inserted into the gate ring faces, experience has shown that this is not necessary (see Fig. 3).

No cargo main lines run through the cargo tanks. All cargo lines, valves and connections are on the upper deck leaving the tanks exceptionally clear. The connection from the cargo pump to the upper deck level is via the vertical pump 'stack' which houses the hydraulic supply and return lines for driving the pump. Cargo loading is achieved by dropping the cargo through the pumps.

It is known that cargo cross-contamination can occur via inert-gas lines and to prevent this a number of features have been incorporated.

First, the simple measure of ensuring that any liquid contaminants in the inert-gas line from whatever source cannot easily get into the tanks by the provision of inverted U-loops in the lines from the inert-gas mains to the tanks. Secondly, two inert-gas mains are provided, each capable of being connected by valves to any tank so that critical parcels can be separated on the gas side (see Fig. 4). Thirdly, each cargo and slop tank is provided with a pressure/vacuum valve so that once inerted, tanks containing high-flash parcels can be shut off from the inert-gas mains and other low-flash parcels.

Cargo heating is achieved by circulation through deck-mounted heaters, thus eliminating the need for heating coils in all cargo tanks except slop tanks. For heating, each cargo pump pumps cargo at slow speed through its own heater and returns it to the tank. This system is significantly more effective than the traditional method and eliminates completely the need for in-tank maintenance of heating coils (see Fig. 5).

The three slop tanks are provided to enable the collection and decanting of slops from black and white cargo tank washings.

The segregated ballast is contained in nine pairs of coal tar epoxy painted wing tanks. One submerged ballast pump for each set of wing tanks (each of 1500 m^3/h capacity) is provided.

A fore and aft line runs through each set of wing tanks connecting the tanks to each of the pumps. There are no ballast lines running through cargo tanks, nor any cargo lines running through ballast tanks.

FIG. 3 Cargo lines on deck

FIG. 4: Inert-gas branch lines, valves and loops

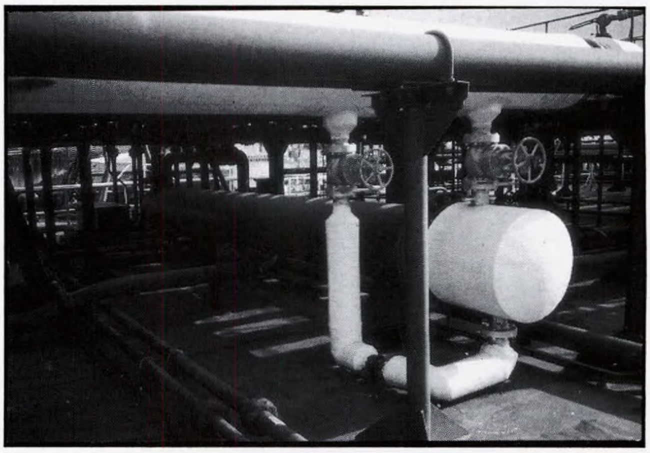

FIG. 5: Deck cargo heaters

CARGO CONTROL SYSTEM

Control of the cargo and ballast system is from the combined cargo and engine control room on the boat deck overlooking the main deck.

During the design stage, a decision had to be made regarding the means of operating valves and monitoring the cargo related parameters. For about 20 years, the standard in Shell has been to use control consoles with mimic diagrams of the cargo and ballasting systems into which the valve position switches were placed. Open/closed valve position indicators and cargo and ballast pump controls were also placed in the mimic with tank level/temperature gauges and level alarms located on a separate mimic at the top of the console.

The suggestion was made within the Shell International Marine design team that all the information on these large consoles could be put on to VDU screens and the valves operated from a keyboard. Reasons for such suggestions and advantages perceived were:

1. The shipbuilder was already involved in building ships sponsored by the Norwegian Ship of the Future programme, which involved extensive distributed computer controls.
2. Benefit was seen in VDUs to display pipeline setups for different product configurations.
3. The aim was to reduce cabling and cargo control installation costs, by distribution of hardware.
4. It would allow experience to be gained in the latest technology as well as see if the benefits were substantiated in practice, and enable this experience to be carried forward for future vessels.

There was considerable resistance to this suggestion from others of the design team who felt that potential problems may outweigh the advantages. Such a change could be accepted only if strict criteria could be satisfied. These included:

1. It should be as safe as the previous system.
2. It should enhance cargo segregation integrity whilst in operation.
3. It should be quick and easy to operate.
4. It should be as flexible as previous systems.
5. It should make keypunch mistakes difficult and make the operator aware of the consequences of his action before it takes place.
6. It should cost no more than the previous system.
7. It should be able to be overridden in an emergency.

It was concluded that the VDU/keyboard system would be able to comply with these requirements and indeed exceed them as long as correct thought was put in to the initial design and requirement for operation.

To comply, the following requirements were set out:

1. Colour graphics (7 colours).
2. Pipelines with differing grades should have differing colours.
3. Positive indication of the valve selected for operation given.
4. Valves should be able to be inhibited from operation if required.
5. Positive indication of the result (in pipeline connections) of opening the valve selected for operation.
6. Certain valves should be capable of being 'inched' with valve position indicated.
7. Simultaneous operation of valves must be possible.
8. Shut-down buttons capable of shutting down the cargo pumps or manifold valves at a stroke.

Two processing computers, keyboards and screens have been provided. This allows the simultaneous operation of cargo and ballast systems and acts as a backup in case of a hardware fault (see Fig. 6). Valve positions are shown, and where valves are provided that can be held in intermediate opening positions an indication of opening is given by means of a bar chart.

The cargo system contains over 100 valves and the ballast system 30 valves. Whereas all the information for the ballast system could be put on to one screen, the cargo system was too large to put the total information on to a single screen.

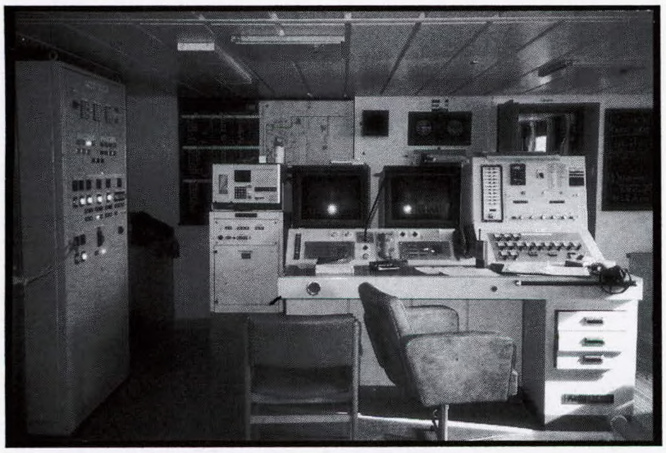

FIG. 6: Cargo control console

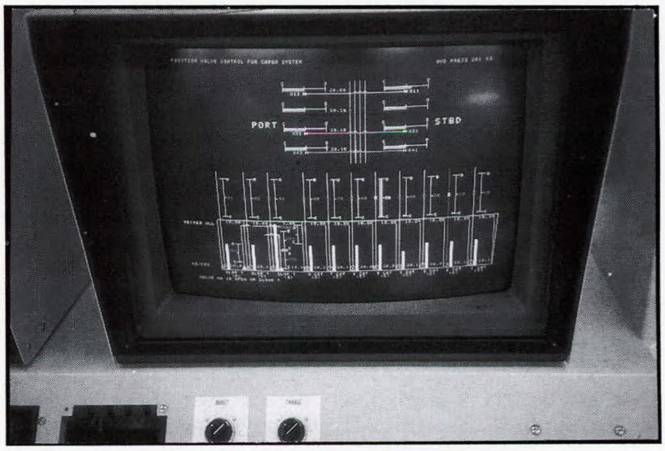

FIG. 8: Cargo VDU showing manifolds and tank situation only

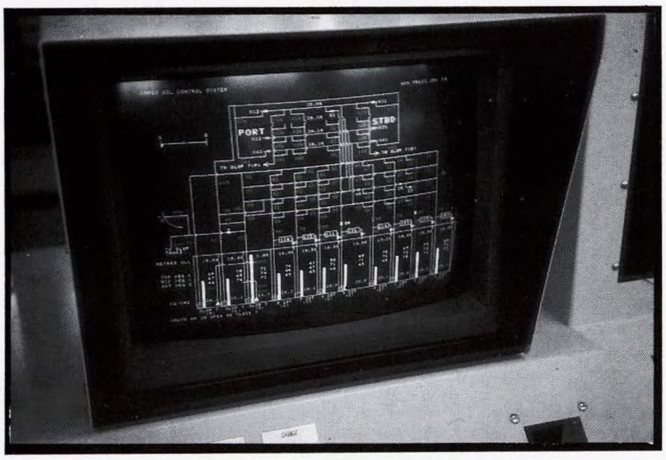

FIG. 7: VDU showing cargo system

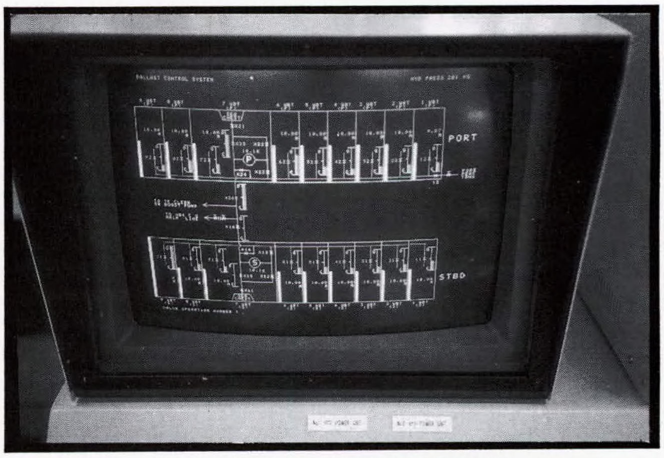

FIG. 9: VDU showing ballast system

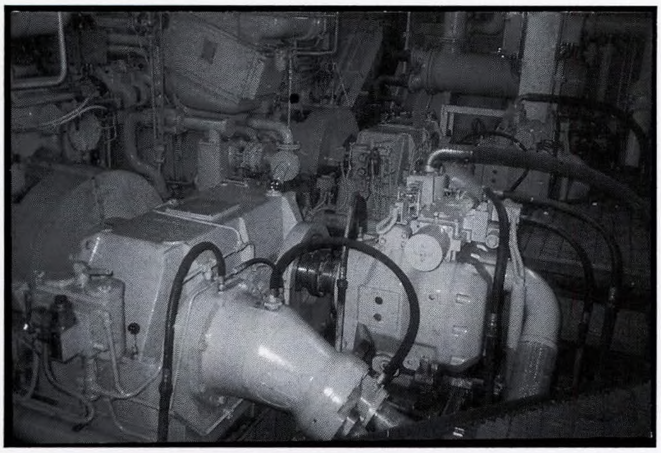

FIG. 10: Diesel-driven power unit

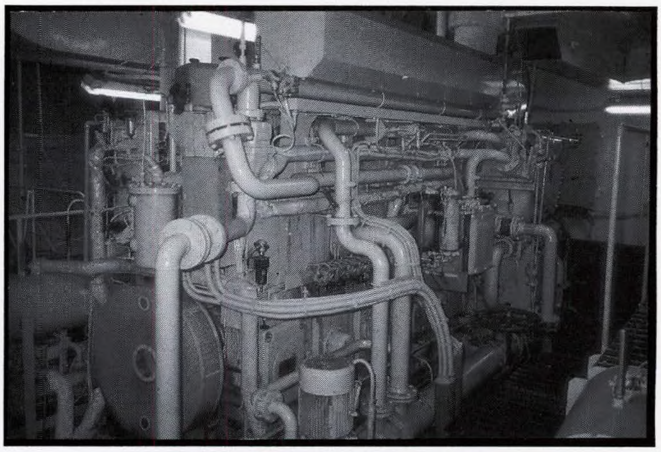

FIG. 11: Generator diesel engine

To overcome this, it was decided to divide the cargo system not into sections but into 'operational phases'. One screen graphic shows the total pipeline and valve system, including tank ullages and temperatures. With this the pipeline system can be set up connecting the relevant tanks, pumps, pipelines and manifolds (see Fig. 7).

Another screen graphic shows the valve positions of the intermediate opening valves, these being the cargo pump discharge/loading valves and manifold valves. Once the cargo system is set up, the only information required for controlling the cargo is on this second graphic (see Fig. 8). Other pages of the display show alarm settings and change facility.

A similar VDU display is provided for the ballast system. (see Fig. 9).

HYDRAULIC POWER SYSTEM

The hydraulic system was basically designed by the equipment manufacturer. The system is used to power the cargo and ballast pumps along with the tank-cleaning booster pump, the deck machinery and hose-handling cranes. The system is powered by three diesel-driven powerpacks of 1200 kW each and one 300 kW electrically-driven powerpack. One of the diesel-driven powerpacks shares a diesel prime mover with a generator. Interlocks prevent the use of the generator if the powerpack is in use and vice versa.

The main powerpacks supply hydraulic oil at a pressure of 260 bar to the system and comprise two hydraulic pumps driven through a clutch and gearbox. One of the pumps is a 600 kW fixed-displacement unit and the other is of variable displacement also of 600 kW maximum power. This variable-displacement pump can vary the oil flow from plus 100% of its output to minus 100%. In this way the powerpack itself has a capability to vary its output from zero to 100% of its total output (see Fig. 10).

In operation there are various alarms and indications to inform the operator that a powerpack is nearing its full output and a further powerpack is required to be started, or that if more than one powerpack is in use that one of the powerpacks can be shutdown. This latter feature is to prevent the driving diesel engines from operating too long on too low a load. It was considered that auto-starting and stopping under a logic control measuring the powerpack load was an unnecessary complication in this instance owing to the required operation of the fuel system, which is described later.

The electrically-driven powerpack has three main uses:

1. To drive the tank-cleaning pump, a main cargo pump and slop tank pump for tank-cleaning purposes.
2. To operate all the main cargo pumps during a cargo heating operation.
3. To provide hydraulic power in port or at any other times for deck machinery and cranes when the main powerpacks are not operating.

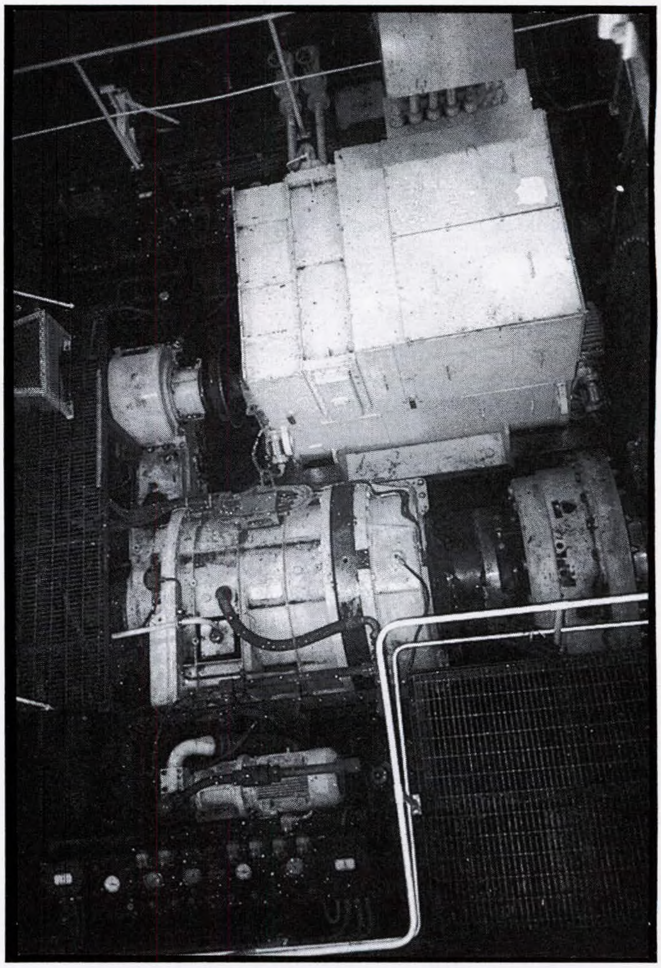

FIG. 12: Constant-speed generator drive unit

The oil used in such a hydraulic system must be cleaner than the oil that is supplied in the drum. To achieve this a rigorous flushing method had to be followed during commissioning of the system. Filters of 10 μm absolute filtration were installed in the circuit, heaters for the flushing oil were arranged and an accurate and reliable means of measuring the cleanliness of the oil provided. The flushing needed to be continued for a number of days until the correct level of cleanliness was achieved.

In-service monitoring of the oil in the hydraulic system is

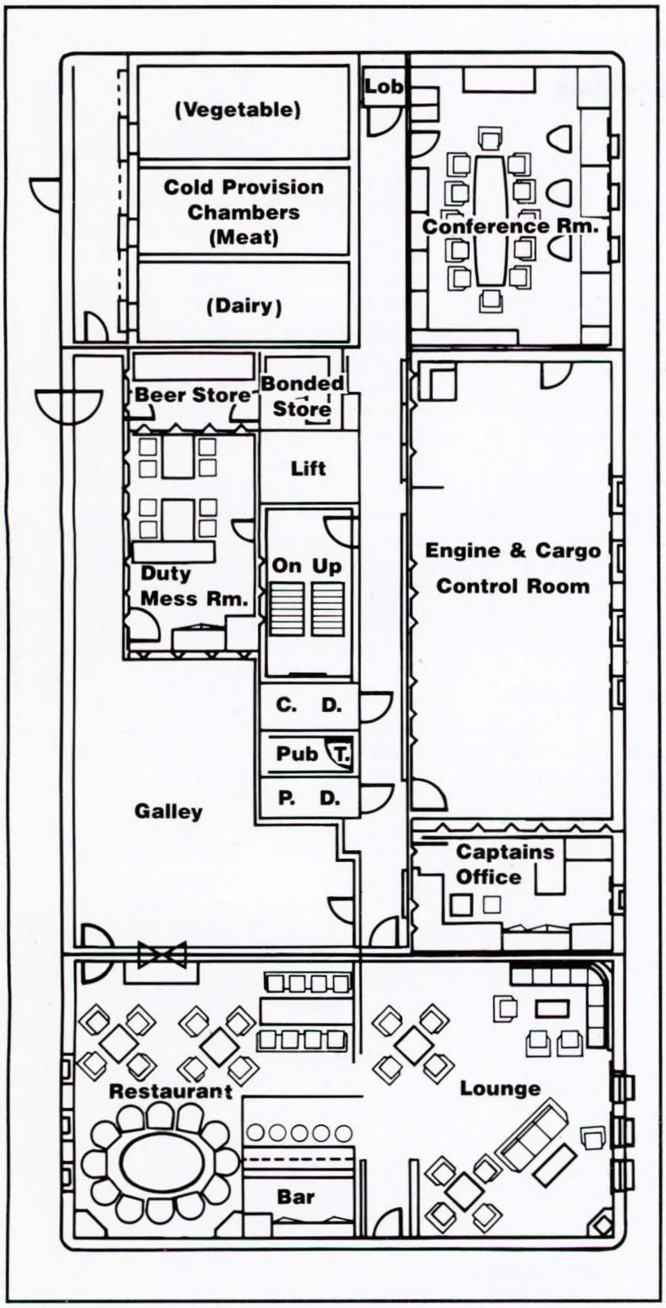

FIG. 17: General layout of the first deck

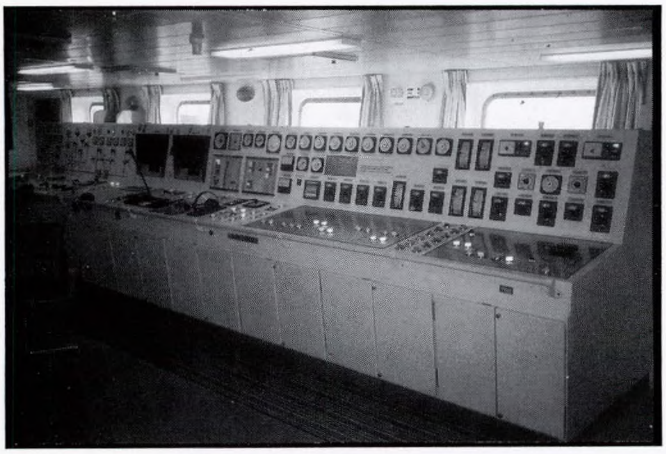

FIG. 18: Engine control console

MANNING

The vessel has been designed to enable manning a level of 17 to be achieved. Significant attention has been given to the ergonomics of store rooms and work places to cater for the reduced manning concept and this has been carried over into the living areas. The accommodation is arranged on five decks with living accommodation on the second to fourth decks.

The accommodation was designed to allow a segregation between 'working' and 'living' areas. Thus no offices for the Captain or Chief Engineer are provided in the accommodation adjacent to their suites. A common office is provided for the Chief Engineer, the Chief Officer, Second Engineer and Chief Steward on the first deck in the conference room. A small office is provided for the Captain on the same deck to allow people to be seen in private or confidential work to be carried out.

This first deck is the administration, working and 'common' deck and is shown in Fig. 17. As well as containing the Captain's office, the cargo and engine control room, and the conference room, it contains the galley, messes, stores rooms and common officers' and crew's bar, lounge and restaurant. Cold stores and provisions rooms are situated on this deck adjacent to the galley for ease of access. Visitors to the ship, in a working capacity, are therefore normally only admitted to this deck to carry out their business. There is no need for them to enter the ship's staff's 'home' on the second to fourth decks. Even visitors to the bridge such as pilots would not normally enter this section of the accommodation as they would use the lift.

The conference room contains the ship's 'management and administration' computer and is capable of seating virtually the whole ship's complement, for example for safety or administrative meetings.

Adjacent to the conference room is the combined cargo and engine control room. During periods of cargo operation frequent contact is needed between the staff operating cargo equipment and the staff responsible for the machinery operation. The combined cargo and engine control room allows this. Being situated on the first deck the view out on deck is adequate to see what is going on there. Although all cargo valve controls, tank level indications and other parameters are indicated within the control room, the desire to see what is happening out on deck is hard to overcome.

No windows are provided to view into the engine room, however, the desire having been overcome in this case. Whereas the cargo control is largely by VDUs and keyboard, the machinery control is of the conventional type in the case where a control room is provided remotely from the machinery space. A console with mimic panels has inserted into it TPL (turn, push, light) switches and indicators for operation and monitoring of machinery (see Fig. 18). A VDU-based alarm and monitoring system is provided with an alarm printer.

The decision was made to remain with what is at present the conventional machinery control system and not move to VDU and keyboard or 'latest technology' means of control. It was considered that with the many unconventional features being incorporated into the ships, an to attempt to overlay this with a control system linking all machinery, each with its own individual requirements and interface idiosyncrasies, was a burden Shell International Marine had no wish to place on the yard.

Mooring and storing are major consumers of manpower. The mooring system has been arranged so that winches are grouped at each end of the vessel, whereas it is normal to have one winch positioned in the area forward of the accommodation and one on the forward main deck. This has been done to reduce the number of men required to operate the mooring winches and be in charge of the mooring operations at the fore and aft ends. The winch controls are each side of the fore deck and each side of the poop deck for the respective winch sets. Double-drum winches are provided on the first series of three ships owing to space constraints. On the second series of two ships this space constraint was lifted and single-drum winches were provided, negating the need for manually clutching in and declutching one or other of the drums during mooring.

For hose handling and storing midships, two hydraulically-driven cranes are provided and for storing aft an electrically-driven monorail hoist is provided which can plumb the provisions stores and engine room.

Various labour-saving devices have been included to assist with engine room maintenance. These include beam transport systems at each level, permanent cleaning tanks (both chemical and ultrasonic) and centralised vacuum cleaning and high-pressure washing systems which extend to all areas of the machinery spaces.

CONCLUSIONS

The key features of the vessel's design can be summed up as follows:

- Optimum hull design
- Economic engine performance at variable speed
- Totally flexible cargo system
- Epoxy coated centre cargo tanks
- Coal tar epoxy coated, with back-up cathodic protection, wing ballast tanks.
- No cargo lines or valves in any cargo tank
- All cargo pumps of the submerged hydraulic type
- No pumproom
- No heating coils in any cargo tank
- All thermal oil heating system in both the engine room and cargo tanks
- No steam systems onboard
- All hydraulic cargo handling system
- All hydraulic deck machinery system
- Sea electrical load from a constant-speed generator drive unit
- Security of electrical supply
- Low manning concepts incorporated into the design
- Suitable for operation on anticipated future fuels

ACKNOWLEDGEMENTS

I thank my colleagues in Shell International Marine for their aid during the preparation of this paper.

APPENDIX

Machinery Particulars

Main engine	Hyundai B&W 5L80MCE, MCR 16000, CSR 14400 HP @ 80 rev/min, FOC 122.7 g/hph (+3%) @ CSR.
Turbocharger	Napier NA48 (non-cooled type).
Propeller	Lips manufactured fixed-pitch, keyless, four-blade, Ni-Al-br, Diameter 7.9 m, pitch (at 0.7 R) 5.476 m, weight 35 t.
Auxiliary engines	Stork Werkspoor 6SW80, 720 rev/min, output 1425 hp for generator duty, HFO burning FW cooled, (DO burning radiator cooled for the upper engine).
Generators and powerpacks	Fuji manufature brushless generator, output 990 kW. Hydraulic powerpack output 1200 kW.
Shaft generator	Vickers CSGD type output 1500 kW.
Thermal oil heater (Oil-fired)	Saarloos manufacture V234-150 model, fully automatic, vertical cylindrical sprial tube type, HFO burning, output 15000 kW, working temperature 150/200 °C, Burner: Saacke rotary cup.
(Exhaust gas)	Saarloos manufacture, output 1200 kW, Sootblower: Infrafone.
FW generator	Alfa Laval JWP-36-C100 ME jacket water heated, Output 20 t/d.
Air compressors	Tanable HC-277 AYL and HC-65 AYL.
GS air compressors	Sullair screw type positive displacement, SK55E 7.5.
Purifiers	Westfalia models: OSA 35-01-066/OSA 35-36-066 for fuel oil, OSA 20-02-066 for diesel oil and lubricating oil.
Cargo pumps	Frank Mohn 8 off type SD 350, capacity 1625 m^3/h @ 135 m head; 3 of type SD 200, capacity 450 m^3/h @ 135 m head; 1 off Portable pump type TK8, capacity 500 m^3/h @ 35 m head.
Ballast pumps	Frank Mohn 2 off, capacity 1500 m^3/h @ 30 m head.
Tank-cleaning pump	Frank Mohn 1 off type PB8, capacity 240 m^3/h @ 110 m head.
Cargo valves	Blakeborough flex-o-ring gate type.
Cargo control	Terasaki WE-7.
Ullage gauge	Saab SUM-21.
Ballast valves	Westad butterfly type.
Cargo valve hydraulic actuating system	Danfoss controls.
Lifeboats	Verhoef totally enclosed type.

Discussion

G. VICTORY: I should first like to congratulate Mr Woods on his excellent exposition and incidentally to congratulate Shell on this interesting new concept of the type of tanker which will be needed for the flexible trading conditions which may come upon us in the next decade, a preview of 'the shape of things to come'. It is obvious that with such an open-ended theme and with so many new developments to be covered there must be areas where a little more detail might be enlightening and my first feeling was that the paper was not very forthcoming on safety aspects.

It appears that it is intended to achieve a manning level of 17. I wonder how many of these are Engineer Officers, and how many other ranks are available for breakdowns, repairs and maintenance of cleanliness in the engine room. Obviously the vessel is intended for Unmanned Machinery Space operations so information on smoke and fire detection and on fire-extinguishing systems in these spaces would be of interest. With the control room on the 'first' deck (the 'boat' deck was mentioned in the presentation) the ease of access to the engine room in the event of an alarm of any sort is important, especially in the event of a blackout, ie no lift. Could Mr Woods say how long it would take to get adequate staff to the engine room at night whilst maintaining the necessary supervision in the control room.

Incidentally I note that there are no windows in the machinery casing, a much overdue precaution, but there are 11 forward facing windows on the first deck, five of them in the engine and cargo control room. All parameters for cargo control are situated in the control room so 'the desire to see what is happening on deck' is not a justification for a weakness in defence (as forward facing windows have been shown to be) against fire or explosion forward of the accomodation.

'Long-term flexibility of operation' require changes from crude oil to ballast and to white products between ports so the tank-cleaning methods need to have special attention as to the time available for this as, even though all cargo is carried in centre tanks with less obstructions than on ordinary tankers, sludge and deposits will form on transverse bulkheads, stiffeners and bottom spaces. One specific schedule is mentioned: (a) the carrying of white products from the Arabian Gulf to Japan, then ballast to China and the carriage of crude oil from China to Singapore, then ballast to Arabian Gulf and/or (b) white products from the Gulf to NW Europe, then North Sea oil to USA and back to the Gulf.

No great problems are seen in a change-over from white spirits to crude providing tanks have been properly drained and gas freed (to avoid static formation when loading commences) but to clean tanks after crude carriage to the standards acceptable to the shippers of white spirit could be a long and difficult procedure, especially if bad wheather is experienced at sea in the time available for cleaning between ports. I wonder what type of oil content meter is fitted and what length of time is considered adequate for this task, including the decanting of slop tanks within IMO pollution limits and whether this can be guaranteed between Singapore and the Arabian Gulf or in fact between the discharge of crude and the loading of white products during any of the foreseen or possible operations?

I was pleased to see that 14 years after the 1973 Convention all ballast is to be carried in dedicated side tanks and all cargo is to be carried in eight centre tanks each with its own submerged cargo pump, thus doing away with the pump room, the source of many a tanker fire and explosion. It is to be hoped that this improved safety concept will be carried on to tankers designed to carry only crude oil.

The paper does not mention the quantity of ballast which can be carried except by reference to the IMO ballast draught. Perhaps Mr Woods can put a figure on this, having in mind that the IMO ballast percentage covers only moderately heavy weather, but for the worst conditions 40 to 45% of dwt may be required, which in this case of maximum dwt of 100 000 would require 40 000 to 45 000 dwt of ballast. The picture of the transverse section raised doubts about this being met and I would ask are there any circumstances in which a Master might have to take ballast in cargo tanks? Incidentally, has the possibility of structural damage or static generation by the sloshing of oil in these very wide tanks, a feature which has given problems in the similar type of tank in OBO carriers, been investigated?

On page 4 it is stated that two inert-gas mains are provided having inverted 'U' bends in the line, hopefully with continuous leak-off drains or a liquid detection facility at the bottom of the loop, in order to avoid cross-contamination of the cargo. This is a good precaution. However it is also stated that 'once inerted, tanks can be shut off from the inert-gas mains'. This may be safe for high 'Reid vapour pressure' cargoes but is not safe on marginal vapour pressure or crude cargoes because the diurnal changes in temperatures and pressures may dissipate the residual inert gas and allow air to enter the tank at night, thus producing a flammable atmosphere in the tank. Perhaps Mr Woods can tell us how this possibility is to be avoided. Incidentally, has the possiblility of structural damage or of static generation in the very wide cargo tanks been investigated, as these are akin to the OBO tanks where such problems have been encountered.

Having taken such care that cross-contamination of cargoes is avoided in the low-pressure inert-gas lines, it is surprising that single valve separation is considered adequate on the relatively high-pressure cargo-oil lines. Even though the valve is a special type of gate valve with 'O' rings inserted in the gate ring faces it cannot be as effective as two similar gate valves with an open drain or a sensing point between them.

The argument that such a gate valve is better than two butterfly valves or that you may not know that one valve is leaking until the second one leaks (which has long been used by the industry to avoid double shut-off valves) does not hold water as a butterfly valve should not be used if it is unreliable and the space between the valves should always be monitored to detect any leakage through any one valve.

As to the need for a double shut off, I have seen some very funny things get into pipe lines, from nuts and bolts to a large cold chisel which shattered a large certrifugal pump, so I doubt whether any single valve could deal with such admittedly unusual foreign bodies even if, as the paper says, 'experience has shown that this (a second valve) is not necessary'.

Finally to sludge disposal. The involved procedure for dealing with relatively small quantities of fuel oil sludges, and this is all it can be because cargo sludges, like cargo oil, are not permitted to be dealt with in main engine rooms, is so complicated and time consuming that I am afraid that most of it will, as at present, go over the side. Certainly some of the solid abrasive purifier residues I have seen would, if mixed with oil, soon destroy any burner assembly, and if burnt in a furnace would require one of the old coal burner's ash hoists to get rid of the residual ash. What price 'ash pollution of the sea'. Just another problem for IMO!

D. B. FOY: In the event that the tankers would be required to carry naphthalene, would the charter call for availablity of a supply of nitrogen at the discharge terminal as shippers may bar the use of diesel-generated inert gas as it could contaminate the naphthalene. This bar may have caused an explosion on *Petragen One* in San Roque in May 1985.

J. R. WILLIAMS (Marine Design Consultants Ltd): The arrangment of auxiliary diesels in the machinery space seems to have been very generously provided for and my initial reaction on seeing the arrangement was that it had been designed by engineers, completely free from the attentions of accountants. Could the author indicate the rationale behind the arrangment, not just from an operational point of view, which obviously gives great freedom of choice and flexibility, but from a cost/benefit point of view, and how the justification was made.

Figure 16 shows the arrangment of the GRP water ballast system with a transverse cross connection in the area of the manifold. Could the author indicate if this is also GRP, or if this section had to be limited to more normal steel pipe arrangements because of fire hazard.

Regarding the thermal oil system, the text intimates that the electrical heater, powered by electricity from the shaft-driven generator, is a more efficent from of heating than the firing up of the oil-fired heater on low load. Electrical generation efficiency, by whatever diesel prime mover, can rarely exceed 45% and it is to be expected that an oil-fired heater, on a straightforward heat-balance basis, would easily attain this value. Can the author explain if there is some other factor, such as cycling of the oil-fired heater on low load, that needs to be taken into account when considering the above statement regarding efficiency.

Finally, with the benefit of some operational hindsight, if the same project was undertaken again what changes, if any, would the author care to see incorporated.

W. F. SPANNER (Spanner Marine Corporation): I believe this design would be improved if a raised forecastle extending aft for a distance not less than the maximum beam and about two metres in height was fitted. As designed the vessel is likely to ship hundreds of tons of water over the flat forecastle deck in severe weather conditions causing very large hogging stresses and the liability of deck piping and fittings being torn away or damaged. Skilful seamanship may avoid the worst of these dangers, but these hazards will always be present.

A raised forecastle would not only avert these hazards in large measure but would provide additional space which could be put to good use. A raised catwalk could also be fitted enabling visual inspection of the whole of the upper deck and fittings in all but the most severe weather conditions.

The author has said nothing about fire-fighting arrangements. Fires are an ever present hazard in ships, and it would seem that in the unfortunate event of an engine room fire or explosion all sources of power for the pumps would be lost. Are emergency generators fitted elsewhere in the ship, outside the engine room?

F. C. BOWN (Hamworthy Engineering Ltd): I was interested in Mr Woods' remark that 'although the engine builders say that their engines would burn 700 cSt fuel with a density of 1.01, we frankly did not believe them and so fitted a blender'. It is, of course, well known that viscosity is no longer the yardstick it was thought to be, but it is still an easy general reference point.

Apart from the certrifuging problems which have apparently been largely overcome, the high-density fuel also has problems with combustion. It was very interesting to see that such a well known Oil Company Owner thought it prudent to fit a blender to introduce MDO, presumably, to condition the fuel. Does the introduction of MDO not assist in diluting the other nasties now found but not highlighted by bunker suppliers?

I think the last paper by a Shipowner, Blue Star Line, also highlighted the potential obvious benefits of an in-line fuel blender at very little additional cost, and therefore it prompts me to ask if it has been necessary to fit similar devices on other diesel-driven ships where the bunker supplies are equally indeterminable. Would not a blender or a fuel conditioner be much more practical solution where additives could be introduced under controlled conditions? Could the author also advise of any off-specification fuels he has been supplied. It would be very interesting to hear if the maintenance programme has been affected by fuel quality.

Dr A. FOWLER (University of Newcastle upon Tyne): The author has produced a most interesting account of modern tanker design trends. Amongst the relatively imaginative features which he identified, the use of GRP materials for marine pipework installations looks potentially very promising.

It would be interesting to receive further details with regard to the installation and operational characteristics of these systems. Such piping arrangements are quite popular in the process and chemical industries so copious installation and operational experience can presumably be gleaned from that quarter. However, it would be useful if the author could develop the arguments for and against the use of this material in the marine environment, in the light of his experience. In particular, it would be interesting to review how cost of materials and cost/convenience of installation compare with more traditional systems. What maintenance savings are envisaged and how is the payback situation effected?

Finally, although it is possibly a little premature to ask the question, what long-term experience of reliability and maintainability is currently available?

R. W. Y. CHU (Wah Kwong Shipping Agency Co. Ltd): This is a very interesting paper and I should like to thank Shell International Marine for sharing the fruits of all the hardwork put in by its team. As a member of a newbuilding technical team, I am interested in Mr Woods' views on the following.

From the Owner's point of view, one of the most delicate and troublesome problems he has to face when seeking a charterer for a new building, especially in today's market situation in which the charterer has numerous candidates to select, is to establish the speed/fuel-consumption contract.

It is not uncommon for the Owner to be faced with the request of guaranteeing vessel speed 'in all weather' or to present a speed/fuel-consumption estimation 'up to Beaufort Scale 6'. As the traditional way to present a vessel's guarantee speed is at a certain draught and with a certain percentage sea margin, what is Mr Woods' opinion, and how would he suggest dealing with such a request.

In the paper Mr Woods mentioned the study Shell made to optimise hull form when the performance of the vessel in various sea states was estimated. Could Mr Woods give more concrete information on how these estimates were made? To my knowledge, there seems to be no naval architect who can give a confident speed prediction (without sea margin) for a vessel in weather other than 'calm sea', which is usually interpreted as Beaufort Scale 2 or 3.

Concerning cargo segregation, I was astonished to see that the paper recommends use of 'a single valve'. What makes these gate valves 'with O rings inserted into the gate ring faces' special and how they are superior to or as good as blank flanges in ensuring critical cargo segregation is not explained. I wonder about human operator error when only a single valve is used. Perhaps the highly computerised keypunch type cargo system gives inbuilt protection against misoperation. Would Mr Woods explain this design concept in more detail.

The paper emphasised several times the feature of not having any fluid piping passages across the ballast/cargo tanks. This is no doubt of merit but what would be the overall balance of risks taking into account the failure of one ballast pump (which is submerged), thus penalising half the ship's ballast system? A portable submerged ballast pump may solve the problem to some extent, but it may not seem a better solution than providing suction communication between the port/starboard wing tanks (one possible solution is at the fore peak ballast tank). There may be tanker terminals which can not allow any deck work nor can the deballast speed be as quick when a smaller portable pump is employed.

The dispute about the adoption of a VDU cargo control system and the pros and cons of a VDU system were well analysed in the paper. When my company first introduced a VDU system in the engine room control/monitoring system, similar arguments were experienced.

If the whole mimic panel is replaced by the 14 inch (or 20 inch) CRT, the operator looses his traditional target of attraction; this can be overcome as he gradually gets used to concentrating on the flickering symbols on the screen. However, even though the computer can memorize and present more data than a mimic, it cannot give the whole picture on on complete page at one instant.

The habits of the operator can be changed from getting information from a 'concrete' mimic to getting information from the CRT relatively easy although it may not be so straightforward for him to think in a similar manner to the computer: truncating the system into several separate portions, be they operationally or systematically divided.

There may also be drawbacks of time lag in calling different pages onto the screen. Thus two screens side by side is considered as essential for such a system, and not just for emergency backup.

VDUs may be useful in systems with distributed control/monitoring stations and for human/machine communications for administration or surveillance. However, it may not be able to replace all the merits of mimics.

Could Mr Woods give some information on the use of such systems in future projects after the experience gained so far.

My company also has a tanker fitted with a similar hydraulic-powered cargo pump system of the same make as that mentioned in the paper.

Concerning the extensive in-service monitoring of hydraulic oil impurities described in the paper, is this regarded as a standard recommendation or a practice of all Shell fleet vessels equipped with a similar system? What is the recommended overhaul check interval of the magnetic plugs?

One of the main targets of the unifuel concept is to save the risks of trouble caused by mixing incompatible HFO and MDO. Incompatibility may manifest itself less severely by the instability of blended fuel in a stagnant fuel line, as mentioned in the paper. However, in the worse case, problems may occur on fuel lines with the engine running as a consequence of asphaltenic sludge precipitating from the blended fuel and choking filters, pipes or fuel pumps. The generator engine in question cannot build up load and the governor has a sluggish response, not allowing proper synchronizing and resulting in insufficient total electric power for support propulsion. Thus the removal of a blender in a unifuel ship may mean more than saving bunker cost.

The overall cost estimation leading to the installation and use of the blender system as described in the paper is based on what viscosity of blended fuel — 700, 350 or 150 cSt (at 40 °C)? Was the installation cost of blender also considered? In case the 'hardware' side of the installation (engine type, heater capacity, piping layout, filter grade etc.) catered for 700 cSt unifuel burning, would it not be a waste of initial cost if the engine had to run on blended fuel thereafter?

Table DI: Staffing level

Navigation and cargo department	
Master	
Chief Officer (Watchkeeping)	
2 Semi-integrated Officers (SGO) (Watchkeeping)	4
Engineering and maintenance department	
Chief Engineer	
Second Engineer (Watchkeeping, UMS duties)	
1 Semi-integrated Officer (Watchkeeping, UMS duties)	
6 Ratings (General Purpose)	9
Balance	
Radio Officer and 3 Catering Ratings	4
Total	**17**

If at the time of contracting the vessel, a 700 cSt straight burning diesel generator was still relatively new on the market, longer operating experience should have been gathered by now. How would Mr Woods consider the future prospects of straight burning?

Central cooling water systems have been a hot topic to consider for new buildings. The main obstacles are overall cost balance and the pay-back period.

Would Mr Woods disclose how Shell came to the conclusion that the idea of a complete central cooling water system was not justified. What is the pay-back period considered and what about maintenance costs? What protection was then adopted for the seawater system lining, ferroionic protection and/or marine growth prevention?

A major problem for an Owner contemplating sludge burning in his boiler is the additional maintenance and even risk of unexpected damage. A rotary cup burner may be superior to a steam/air jet atomizing type in this regard. Burning LO sludge in the boiler's furnace is especially disliked by most boiler makers.

Are the FO sludge and LO sludge systems separated and how is the LO sludge treated?

The fuel oil sludge may also contain lots of incombustible substances. Besides homogenizing non-separated water in the wastes, will the homogenizer also crush down these incombustibles into smaller particles and what type of strainer is installed before the burner? Has the method of reducing water content in the sludge such as isolation of water drains from fuel sludge tanks, evaporation/boiling-off of water in settling tank been considered?

What is Mr Woods opinions on the fatigue failure aspect of GRP pipings?

Author's reply

I thank the contributors for their comments and questions and have again had to enlist the help of my colleagues to provide answers.

Turning first to Mr Victory's question on manning, the staffing level formulated for these vessels is shown in Table DI. Under normal conditions the Second Engineer and the Semi-integrated Officer share the UMS duties on a night on, night off basis. Running maintenance and repairs are carried out during normal working hours by these men with assistance as required from the six ratings. All ratings have attended training courses on welding, turning and general fitting and provide a positive input to mechanical maintenance.

In a major breakdown situation the Master and Chief Officer would double up on the bridge watch releasing the two bridge watch keeping SGOs to assist in the engine room. This would give a pool of five engineers and six ratings for breakdown repairs.

With regard to cleanliness, every care was taken during the outfitting stages to ensure that any leakages could not spread by judicious design of savealls and scuppers to dirty and clean bilge holding tanks. High-pressure freshwater cleaning equipment with a facility for chemical dosing has been fitted via a ring main system throughout the machinery spaces together with a wet and dry vacuum cleaning system on a similar ring main. In addition a purpose-built chemical cleaning tank with circulating pump etc. and an ultrasonic cleaning bath are provided in the purifier room. The ultrasonic bath is large enough to accept the complete purifier disc stack or a bowl.

To expand a little on some of the fire prevention on the vessels, fire detection is provided throughout the machinery and accommodation spaces using detector heads suitable for the space they are covering. Detectors are 'grouped' into areas for indication purposes on the bridge and control room. As this does not pinpoint the actual detector that has operated in a 'group', all detectors in enclosed spaces have indicators immediately outside the space to show if they have operated. This allows quick location of the alarming detector without an investigator having to look into every room in the group.

A Sigrist oil mist detector is provided throughout the machinery spaces including hydraulic equipment spaces, steering gear and powerpack areas. This equipment has significant advantages over pure fire/smoke detection equipment as it has the capability of detecting oil mists (eg sprays from leaks) without a fire being initiated.

To supplement the water fire hoses system a 'First Aid' freshwater fire hose system is provided throughout the accommodation (two sets of 25 mm hoses on reels of 25 m length on each deck level). The freshwater pressure is always available on this system and it is therefore available for immediate use.

Regarding the question on important alarms such as blackouts and ease of access to the engine room, it should be noted that an important alarm should automatically render the machinery safe or action from the control room should be capable of rectifying the matter. With the particular event of blackout no action is needed. The generator on 'standby' will start. Failing that, the generator on 'standby 2' will start followed by the plant restart sequence, leaving only systems not critical for the plant's operation to be restarted, for example accommodation fans, air conditioning units, purifiers etc.

Should total power failure occur, including the emergency diesel generator meaning that steering is lost, then action within the machinery spaces is required. Action without direction is useless. At night access from the accommodation to the engine room would be by way of the control room where the prevailing situation is learned and instructions taken before proceeding to the engine room.

I agree with Mr Victory that windows to deck in the control room are not necessary for operational purposes. Until 'fireproof' windows are readily available we should consider more carefully the disposition of and requirement for windows.

Cleaning for the carriage of white products after carrying crude can be a long and difficult task depending upon the type of crude carried and the type of white product to be carried. Unfortunately it is not possible to 'guarantee' the cleanliness of tanks for loading of white products as the acceptance depends upon the view of the loading master or shipper which, in the worst case, is that no tank carrying crude in a number of previous cargoes is clean enough! With these vessels this 'blanket' rejection will be broken down once it is demonstrated that insignificant contamination of a white product will occur after the carriage of most crudes.

The oil content monitor used is a TOKYO-KEIKI/SERES type.

Mr Victory asks for the figures on the amount of ballast capable of being carried. The answer is in Table DII. 'Full' ballast includes tanks not included in the IMO ballast calculation (fore and aft peaks) and includes fuel, stores etc. The ship is designed to carry emergency ballast in No. 4 tank (14 151 tonnes) but in our view this would only be used in an extreme case.

With reference to the very wide cargo tanks, a full analysis was carried out for sloshing in conjunction with Lloyd's Register of Shipping and modifications were made to the structure on the basis of the results.

Mr Victory also raised a question relating to the generation of static charges as a result of cargo sloshing in the main cargo tanks. Three fundamental conditions have to be satisfied before an unsafe condition can be created as a result of electrostatic generation. First, water has to be present. This situation is unlikely when the vessel is carrying products. Secondly, since the tanks will be inerted whilst the vessel is carrying cargo, a flammable atmosphere will not be present. The third condition is satisfied in that there is relative motion between the product and any contaminant water when there is sloshing in the tank. However, since the product is not a conductor of electricity, the problems of electrostatic charge generation are further reduced. Static electricity generation in these vessels is no more significant than in other tankers.

Shutting off tanks from the inert-gas mains would only be done if contamination by vapour from both inert-gas mains was possible and the cargo in the tank was either not of the low-flashpoint type or was not to be heated to above its flashpoint. Furthermore, the possibility of air being drawn into cargo tanks is not a problem as normal tanker practice should ensure that the tank atmosphere is sufficiently pressurised to allow for the overnight contraction and the pressure frequently monitored.

With reference to the use of single valves for cargo separation, the valve used gives in our view more than the equivalent of 'double valve segregation'. Admittedly two gate valves with 'O' rings in their seat faces would provide additional security against cargo cross-contamination. From experience we have not found this to be necessary. The primary seal of these valves is still made by the contact between the bronze seat ring and the bronze gate ring. The 'O' ring seal performs a secondary sealing duty if the primary faces should suffer damage. This facility is provided on both upstream and downstream sides of the valve and a drain/test plug is provided in the bottom cleaning door. Single valves of this type have given years of reliable service and we are of the opinion that the long-term reliability of a single valve of this type is superior to that of two butterfly valves. We have, on occasion, experienced seat damage due to debris being left in pipelines during newbuilding; however additional effort to avoid this problem during more recent ship constructions seems to have been successful.

In reply to Mr Victory's contribution regarding sludge disposal, we would like to make the following comments. Our 'in-house' studies have indicated that the average rate of sludge generation on a modern motor vessel is approximately 1% of the main engine fuel consumption. The quantity and quality of the sludge generated is, of course, largely dependent upon the type of fuel oil pre-treatment system in use and the quality of the fuel oil bunkered. The calorific value of engine room sludge can be as high as 60-70% of the base fuel oil calorific value. It is not our policy to burn the sludge directly but to blend the sludge with RFO, the ratio of sludge to RFO depending on the sludge characteristics. It is our belief that this approach will assist in promoting better combustion characteristics and, hence, reduce boiler fouling and maintenance.

In addition to reclaiming the inherent calorific value of engine room sludge, a sludge-handling system as outlined in the paper alleviates the more fundamental problem of sludge disposal. This is a particularly important aspect when the operator is faced with a fuel oil problem such as fuel oil incompatibility. The disposal of cargo sludge in main engine

Table DII: Amount of ballast capable of being carried

	Design draught	*Percentage*	*Scantling draught*	*Percentage*
Deadweight	83 729	—	100 371	—
IMO ballast	34 299	41%		34%
Full ballast	37 727	45%		38%
Emergency ballast	51 878	62%		52%

room plants is an unsafe practice and therefore does not warrant further discussion. The disposal of engine room waste by discharging it overboard whilst the vessel is at sea is not a practice we would support.

In answer to Mr Foy, these vessels are not certified to carry naphthalene or any other chemicals. The vessels carry crudes and basic petroleum products and therefore cargoes which require pure nitrogen for blanketing will not be carried.

For Mr Williams' question regarding auxiliary power let me explain the design route.

The original requirement for generated power was governed by the expected load during cargo tank hot cleaning. This required both thermal oil heaters in use with the associated circulating pumps and forced draught fans together with the electro-hydraulic power pack. The electrical loading under this condition was in the order of 1.5 MW. The second factor was a sea load of about 0.8 MW. Therefore for normal sea load we require a generator of greater than 800 kW capacity.

After due consideration it was decided to opt for 990 kW giving an adequate factor of safety for all eventualities. As one of the generators was fitted in tandem with one of the hydraulic powerpacks it meant that we were restricted to a single generator at the discharge port. This gave no redundancy and any problem would require the reduction of the cargo discharge rate in favour of running the generator. This gave rise to the provision of the third generator as time lost during discharge could prove expensive.

The choice of diesel engines for the hydraulic powerpacks was largely governed by the choice of thermal oil as the heating medium and therefore discounting the fitting of steam turbine drive. The power requirement for cargo pumping was 3.6 MW of input power to the gearboxes. Various configurations were considered, eg one big and two small diesel-driven power packs, one very big and one small or three identical units. The latter case was eventually chosen as one-third of 3.6 MW giving 1.2 MW was only slightly above the required generator capacity, as it had been decided to run at least one generator in tandem with a powerpack. Having now got three identical engines it took only a small adjustment in thinking to have all five engines the same and so utilise the benefit of reduced stock of onboard spares and rationalise the depot stock requirement.

Figure 16 shows the transverse cross-connection in the manifold area. This is in fact not GRP but normal steel for regulation reasons. This should have been indicated in the diagram.

In explanation for the use of the electric thermal oil heater, by utilising the capacity of the shaft generator to top up the heating load rather than firing the thermal oil heaters results in a saving in several directions. To run an oil-fired thermal oil heater requires the use of the circulating pump (100 kW), the forced draught fan (40 kW) and the burner unit motor (10 kW), none of which fully contribute to the heating requirement. The electrical thermal oil heater utilises the exhaust gas heater circulating pump which must already be in use. Therefore the first 150 kW absorbed by the electrical heater (and imparted to the heating load requirement) is effectively free.

A further influence was that during waiting time at anchor there would be no requirement for a main heater to be cycling as there would be sufficient capacity on the running generator to allow for idle time heating requirements. This would allow the engine room to be virtually shut down and still retain full facilities from the upper independent diesel generator and the electrical thermal oil heater.

Regarding changes owing to operational experience, there have been some minor alterations to improve matters, as there would be on any vessel. If we limit Mr. Williams' question to the main and more unusual features (cargo pumping system, cargo layout, heating system, power generating systems), we have found that the systems have worked well and are providing the benefits expected of them for this type of ship. The question of a change to double bottoms often occurs in the context of cargo layout. Such an arrangement definitely provides advantages regarding cargo out-turn but the questions of cost/benefit and safety must be addressed. Such questions would be addressed for similar future ships.

To Mr Spanner's question regarding a raised forecastle, I would like to say that the ship complies with the statutory minimum bow height requirements and is in fact 1.7 m greater than required. Fittings are always liable to damage in very heavy seas unless good seamanship is practiced.

A catwalk is an excellent idea and was in fact fitted to the last two ships in the series.

To give some indication of fire-fighting and power-supply arrangements a short description will be given.

As well as the statutory fire pump powered by the SOLAS generator above the main deck, an additional independent fire pump is fitted forward. This comprises a diesel-driven hydraulic unit powering a hydraulic fire pump in the fore peak tank. This pump has capacity to run the main foam system which has additional branch lines to fixed foam spreaders in the engine room. The primary fire-fighting medium in the machinery spaces is Halon.

The ship has been designed with a split main switchboard. The two full load generators and the shaft generator are connected to the lower switchboard located on the second deck, port side; the upper independent full load generator is connected to the upper switchboard located at boat deck level on the starboard side. The two boards are normally operated as a single unit connected by tie breakers and a bus duct. The consumers are divided such that the ship can be operated from either switchboard with the other totally isolated.

Mr Bown's question on MDO diluting other 'nasties' in the fuel highlights a certain slackness on my part in describing fuel. This slackness grows from the assumption, perhaps at times wrong, that higher viscosity means more 'nasties'. As well as the heating and handling problems allied to viscosity, the fuel also needs to be conditioned or modified for other factors. The questions from and answers to Mr Chu later in this discussion on the same subject would no doubt be of interest to Mr Bown.

To Dr Fowler's question I would say the major reasons for using non-metallic material, in particular glass reinforced plastic (GRP), in marine applications are:

1. Corrosion resistance.
2. Weight saving.
3. Reduced risk of environmental pollution (due to improved corrosion resistance should cargo pipes pass through ballast tanks).
4. Improved safety (emergency services are not rendered inoperable by undetected corrosion).
5. Increased efficiency and reliability (less time out of service with increased reliability of corrosion-free systems).
6. Improved economics (reduced maintenance costs in terms of both labour and materials; hence reduced manning possible; easier and cheaper handling and installation due to reduced weight; increased cargo deadweight capacity, endurance or speed or reduced fuel consumption due to reduced weight; more time in service earning revenue).

However, to realise these major benefits, GRP systems must be correctly designed and installed, taking account of the characteristics of the material which are very different from those of the metal it is replacing. Over the years Shell Seatex has developed system designs etc. which accommodate GRP pipe requirements, and where such systems have been correctly designed/installed in-service maintenance has been, in most instances, nil.

With regard to determining economics, each system must be considered individually. Such calculations for pipe systems will be dependent on various factors, eg size/diameter/thickness of pipe, number and type of fittings involved, complexity of system, type of resin required, type of joints used, and type and number of supports.

Often, the first cost of a GRP system will be higher than one of steel; however this higher cost has to be judged against the future maintenance cost for the metallic system.

To answer Mr Chu's question regarding optimising hull performance, we optimised the hull form at three draughts flat calm and carried out sea-keeping tests to see how the model performed in various weather conditions and to estimate the magnitude of impact loads to the bow and flat of bottom.

These sea-keeping tests were carried out for:

1. Regular wave, five frequencies, two directions, three wave heights and one speed, loaded.
2. Irregular wave, ballast and loaded (at two speeds), two directions, two heights.

These sea-keeping tests also let us optimise loss of speed for certain voyages, ie Japan to Gulf and Gulf to East Coast of USA only.

Concerning cargo segregation, as stated previously from years of experience in various ships, the use of a single gate valve possessing an 'O' ring in its seat ring face has proved an economic and satisfactory means of ensuring reliable long-term segregation of cargoes. Competent, well trained ship personnel have ensured that instances of cargo cross-contamination are very rare. The valves have been described earlier and we believe the VDU/keyboard control of valves enhances the security of the cargo.

Regarding the separation of the two sides of the ballast system, I would agree entirely with Mr Chu. On the later vessels of the series a cross-connection was in fact fitted in the fore peak as Mr Chu suggests.

Mr Chu's observations on the use of VDUs for mimics are very pertinent and we have tried to tackle some of the problems he notes. For these ships the use of VDUs was limited to the cargo system, one of the reasons being we did not want to make too large a step and this was our first move into VDU/mimics for control. The machinery systems were then excluded.

The use of two VDUs etc. was for the operator's benefit in that he could have cargo 'overview' on one and 'cargo operation' on the other or cargo on one and ballast on the other. We realised that one VDU could not provide enough information to satisfy the operator fully, but more than two was probably not necessary in this case. The backup ability was a secondary rather than a primary factor in supplying two operating screens.

Time lag, as Mr Chu notes, can be a problem but the speed of calling up pages was tackled at the design development prototype testing stage by upgrading computers.

In my view VDUs and keyboard control will become more and more prevalent in the future. Interface difficulties will be the hardest point to overcome but in the future standards will evolve easing this problem.

With reference to cargo pump hydraulics monitoring, the monitoring system fitted to the cargo pumping hydraulic system was recommended and developed by Shell International Marine. Variations of the system are also fitted on other Shell Fleet vessels. The recommended monitoring period for the magnetic plugs is at each complete cargo discharge.

With regard Mr Chu's question relating to fuel oil incompatibility, it is our philosophy to segregate different fuel oil bunker liftings as far as possible. In the event that different fuel oil bunker parcels have to be mixed or fuel is blended onboard then we would recommend that an incompatibility test such as the Shell Spot Test Kit should be used to evaluate the stability of the blended fuel oil at different blend ratios.

When blending fuels one criteria is the final fuel oil viscosity. However, other parameters such as CCR values etc. should also be taken into account when considering the optimum fuel blend ratio. This approach will help to alleviate any additional maintenance levels incurred when using blended fuel in auxiliary diesel generators. The ultimate, of course, is to obtain a unifuel vessel but to achieve this a good fuel oil pre-treatment and handling system is required for both diesel generator units as well as the main engine.

The utilisation of a blended fuel system on a diesel generator serves two important functions:

1. To allow the operator to use lower cost fuels with the flexibility of adjusting the blend ratio to maintain maintenance levels at an acceptable level.
2. To allow the fuel system to be changed over to MDO from blended fuel under 'controlled' conditions prior to the engine being shut down for extended periods or for maintenance.

The economics associated with using a blended fuel system would have to take these factors, as well as the initial fuel oil costs, fuel oil 'grade' availability etc., into account.

With regard to obtaining experience with burning very heavy fuel oils we are not at the moment gaining much experience owing to the shortage of supply of such fuels.

Regarding central cooling water systems, the question seems to imply that freshwater should be used for all cooling requirements in the engine room. The size of cooler (with a standby unit as well) with the capability to handle this duty would be very large indeed but in certain financial circumstances may be reasonable. We decided to rationalise the system with regard to cost/benefit and have major consumers such as main engine LO, charge air cooling and hydraulic oil cooling done by seawater and all minor consumers cooled by freshwater.

The freshwater-cooled consumers demanded a further subdivision to provide a high-temperature system and a low-temperature system. The high-temperature system was used for the generator engine cooling systems and the low-temperature system for the balance of consumers. The main engine jacket cooling system was not included in the centralised freshwater system.

The suction side of the seawater system was fabricated in mild steel with bonded rubber lining and the discharge piping was all in cupro-nickel. A marine growth prevention system was fitted and zinc anodes were provided in water boxes.

Mr Chu has also raised the question of the increased maintenance levels associated with the boilers when burning engine room sludge. Increased boiler fouling is dependent upon fuel quality and boiler design. Some boilers are not suitable for sludge burning although some boiler manufacturers have developed their boiler design to enable waste oil disposal. Blending the engine room sludge with RFO in conjunction with good sludge/fuel oil pre-treatment is one approach to reducing the boiler maintenance level when sludge burning. It is also essential when burning sludge to maintain a relatively good air flow through the boiler in order to minimise boiler fouling rates.

Regarding fatigue in GRP pipes, extensive laboratory fatigue testing of in-tank pipe lengths (simulating shipboard fatigue life-cycling) has confirmed that a correctly designed and installed GRP pipe system is satisfactory for service under the prevailing fatigue stresses imposed.

I trust these replies answer, at least in part, the contributors' questions.