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ENGINEERING ASPECTS OF OFFSHORE SUPPLY VESSEL OPERATIONS

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The offshore oil and gas industry started in European waters in 1964. Since that time, the role of the vessels employed to support the variety of vehicles used to search for, locate, procure and distribute oil and gas had developed to keep pace with and hopefully ahead of the ever changing requirements. This paper must, therefore, cover a broad picture and be of a general, rather than a specific nature. It will describe, briefly the development of the supply vessel, explain its method of operation and the machinery necessary to carry out that operation. Some special problems engendered by the environmental conditions of the operation and the qualities of crews required to perform safely under these conditions will be discussed, with a few illustrations of the challenges that arise and are overcome. A look into the future will be hazarded. Opinions expressed in this paper are those of the author and do not necessarily reflect the thinking of fleet operators.

INTRODUCTION

It is a relatively short period of time since drilling for oil onshore literally walked off the beach and became "offshore". Initially drilling took place in minimum water depths close to land in soft weather locations. Today "offshore" can mean location drilling in 300 metres of water at distances in excess of 250km from base in some of the world's most severe weather areas and the offshore industry has witnessed tremendous technological advances in all aspects.

In the last ten years, and more particularly in the last five, since the North Sea has proved to be a gigantic oil well, the industry has moved further north. Here, in areas of operation where weather conditions over protracted periods can justifiably be termed appalling, surface support has made even more rapid advances. The initial stage has been the development of a rough weather area supply vessel often termed a "North Sea" type — purpose built for such conditions.

Over the same period the function of the supply vessel has also dramatically changed from being a simple carrier of materials and general supplies to that of a vessel which combines the roles of rig anchor handling and towing with that of supply work. Such a unit is now termed as anchor handling tug supply vessel.

The types of vessels that have evolved from offshore operations have had to support offshore drilling rigs, whether they are fixed platforms, jackups, drillships or semi-submersibles. They have also had to support other aspects of offshore activity such as construction, pipe laying, pipeline survey, seismographic survey, diving and submarine activities.

Table I gives brief details of the various craft that have been developed to keep the oil rigs operating.

To encompass more remote fields of operation the author's company's fleet incorporates eighteen vessels designated Lloyd's Ice Class. These include one designated Ice Class One Star, which is in effect an ice-breaker. These vessels are, therefore, constructed to operate in all spheres from the Arctic to the Tropics, with the consequent addition of machinery and systems necessary to those requirements.

The tug/anchor handling/supply vessel is the "Jack of all trades." The increased volume of work and the production phase has now necessitated the building of specialist vessels such as the pipe carrier, the platform supply vessel and the fireboat.

METHOD OF OPERATION

Although a number of types of vessels have been described, the remainder of the paper will deal with the anchor handling/tug/supply vessel, which is the most versatile and consequently the most hard worked.

The vessel operates from a base port, where supplies can be delivered for onward transportation to the rig. The position of the base port is determined by the theatre of operations and in many instances it can be far from perfect, either in location or facilities. Shallow waters, silting estuaries, rotting vegetation, flotsam and jetsam and a host of marine perils lay in wait for the poor supply vessel in some parts of the world. Loading arrangements vary from the highly sophisticated to the distinctly primitive. Shore assistance with repairs can range from a large dockyard to the local bicycle repairer, but usually when an oil base port is established an enterprising engineering firm moves in if one does not already exist.

The journey from the base port to the drilling location can be as short as one hour or as long as two days. Depending on the phase of operation the vessel may be running a shuttle service or only carry out two supply trips a week. It may leave port and not return for two weeks. One of the author's company's ships has been out for over three months with crew changes being affected by helicopter, but this is most unusual.

Supply Operation

In logistic terms, the supply operation is simple enough, but wind, tide and sea conditions can make it quite difficult and exciting, and considerable feats of seamanship are necessary. The vessel approaches the rig and depending on the prevailing weather and tide conditions, it drops it own anchor at a suitable point, swings around and manoeuvres astern to the rig in a position where mooring ropes can be lowered by crane and secured to the bitts on its port and starboard quarters. The rig crane then commences to unload its deck cargo with lifts being secured to the crane hook by the ship's crew. If the rig requires any of the pumpable commodities available it lowers a hose (usually 100mm bore) which is connected to the appropriate discharge connexion and pumping is commenced as soon as possible. It must be appreciated that the deck of the supply vessel can be rising and falling by as much as six or

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TABLE I

Type	Size L x B x D (m)	Power Range kW	Speed km/h	Bollard Pull tonnes	Description and usage
1) Survey vessels (seismic and other)	Various	Various	—	—	Originally conversions of basic supply vessels, stern trawlers incorporating additional accommodation, equipment, workshops etc. Some purpose built vessels are in use.
2) Stand-by vessels	Various	Various	—	—	This duty is covered by a range of units from supply vessels to ex-trawlers and tugs. Main requirement is safety of life in emergency.
3) Crew boats	30 x 7 x 2.5	750 to 1000	37	—	Generally purpose built high speed boats for rig crew changes in fair weather areas. Not suitable for use in heavy weather conditions.
4) Tugs (a) utility (b) ocean towing (c) location moves (d) anchor handling/ barge work	25 x 7 x 3 36 x 10 x 6 30 x 9 x 4.5 36 x 10 x 5	450 to 900 1800 to 4100 1500 to 1800 1500 to 2200	18 24 to 28 22 24	— 30 to 65 20 to 26 30 to 40	A large range of vessel types employed in the duties indicated on a world wide basis.
5) Supply vessels (basic) Supply vessels (platform)	50 x 9 x 4 TO 60 x 12 x 6	1000 to 3000	22 to 26	—	A purpose built vessel for transport of supplies on deck in the form of drilling equipment and under deck in the form of oil, water, drill water, cement and mud in bulk. Additional facilities for carriage of personnel and provisions.
6) Anchor handling supply vessels	55 x 11 x 5	1800 to 2200	22 to 24	33 to 40	A purpose built vessel for performing the duties of the basic supply vessel and in addition handling, overhauling and positioning rig anchors.
7) Anchor handling/ Tug/supply vessels	58 x 11 x 5 60 x 12 x 5.5 63 x 13.5 x 6	300 to 4100 4200 to 5000 5300 to 7500	24 to 28 26 to 29 26 to 29	45 to 65 70 to 82 80 to 100	A purpose built vessel incorporating all the duties of the above two classes but at higher powers for deeper water and in addition undertaking ocean towing and rig location towing.
8) Pipe carriers	80 x 17 x 7	3400	26 to 29	—	Purpose built for the supply of large quantities of pipe to the pipe laying barges.
9) SBM line boats	20 x 6 x 3.5	375 to 525	19 to 22	—	A purpose built vessel for handling tanker mooring lines and hose strings for work at single buoy mooring locations.
10) Fire boats	Semi-Submersible	20 000?	26 min	—	Not yet evolved, but probably a multi-purpose fire fighting, diving support, bad weather supply vessel.

seven metres in relation to the rig under bad conditions and hoses and mooring ropes must be secured with this in mind. On completion of unloading and after receiving any backload from the rig the vessel lets go the mooring ropes, which are again recovered by the crane, recovers its own anchor and either returns to base port or takes further instructions from the rig.

Should the weather be too severe to moor to the rig and an important piece of deck cargo is urgently required, a "snatch lift" is carried out. This involves the supply vessel manoeuvring into a position, free of anchors or mooring ropes, below the crane and remaining there long enough for the load required to be picked off the deck — the vessel then stands off. If the weather is too severe even for a "snatch lift" the supply vessel wallows about until the weather abates sufficiently for it to go into the rig to discharge its cargo.

The Anchor Handling/Towing Operation

When the rig has completed drilling it is the duty of the vessel to move it to its new location. The main deck is cleared of cargo and the rig anchors are lifted. Each anchor is marked by a buoy weighing about three tonnes, from which a pennant of 52mm wire is led to the crown chain of the anchor. The anchor itself weighs 15 tonnes and is usually attached to the rig with 75mm chain cable.

The vessel backs up to the buoy, lassoos it and heaves it over the 1500mm diameter free running stern roller. The pennant wire is stoppered off, the buoy disconnected and hauled up the deck and lashed out of the way. The pennant is then connected to the work wire on the winch drum. The anchor is then broken out, (sometimes quite a lengthy job) using winch and main engine power and heaved onto the after deck of the vessel where it is checked, and as it is very often fouled, cleared by the ship's crew. The vessel then backs up to the rig and the anchor is housed by the rig's own winches, the pennant wire being passed back to the rig crane for securing on the rig.

When approximately half of the anchors have been raised and housed, one of the vessels carrying out the operation secures a short tow to the rig to hold it in position while the rest of the anchors are lifted. On completion of lifting the anchors the rig de-ballasts to the towing position and the vessels start the tow. The tow wire, 1000m of 52mm steel wire rope, is streamed from the main winch and is connected to the rig via a nylon towing spring.

On arrival at the new location the rig drops two anchors on one side and is held up on the otner by the vessels. When it is exactly on location (the site has been buoyed by a survey boat fitted with navigation aids) one vessel holds the tow while the other(s) commence re-laying the anchors. When sufficient anchors are laid to ensure the security of the rig the last vessel releases its tow and commences anchor work.

To lay an anchor the vessel backs up to the rig, takes the anchor pennant from the crane and attaches it to its work wire. The rig drops the appropriate anchor and the vessel hoists it to its stern roller, runs it, trailing its cable, to the required position, lowers it and buoys is off.

When all anchors are laid and holding, drilling operations can commence and the vessel returns to the supply duty.

machinery must be fast acting and under direct control from the bridge. "Driving" a supply vessel is similar in many respects to driving a car where engines, thrusters and rudders are operated by instinct and direct action rather than by the passing of orders to a helmsman and an engine operator. Manoeuvring must, of necessity, be capable of being controlled from at least two positions and all controls are duplicated at forward and after ends of the bridge. The steering is by electrically operated tiller, the engine control by pneumatics and the thruster(s) by electric control of the motor and/or teleflex control of the diesel engine if of the direct drive type.

The engine control system is fitted with timing delays so that the rate of increase from idling to full power is controlled automatically, no matter how quickly the control levers are operated. A third pneumatic control position is available in the engine room should it be necessary to switch to local control of the engines. Hand control can also be effected in an emergency.

As will be seen from Table I, the propulsion power of a supply vessel is considerably greater than that of a conventional vessel of this size. This power is basically available for towing and anchor handling, but it is also available for normal manoeuvring.

Manoeuvring

The question of whether to use controllable pitch or fixed pitch propellers with reversing gearboxes is one that is eminently debatable and will be discussed later.

One bow thruster at least is essential for ease of manoeuvring, particularly in the case where nozzles are fitted, because nozzles substantially reduce the effect of lateral thrust of the propellers. Two types of thrusters are used, they are (a) the direct transverse thrust which gives port or starboard thrust only and a higher power output/power input ratio than (b) the omnidirectional type. However, the thrust through 360° can be used to move the vessel ahead or astern when fine touches are required. In calm weather the omnidirectional thruster can drive the vessel ahead at up to four kilometres per hour, a useful auxiliary to have available.

The twin rudders are naturally linked together at the tiller heads and either motor can operate both rudders. The time for 35° port to 35° starboard at full ahead is 13 seconds with all systems in operation. Power steering is backed up by a hand pump on the bridge.

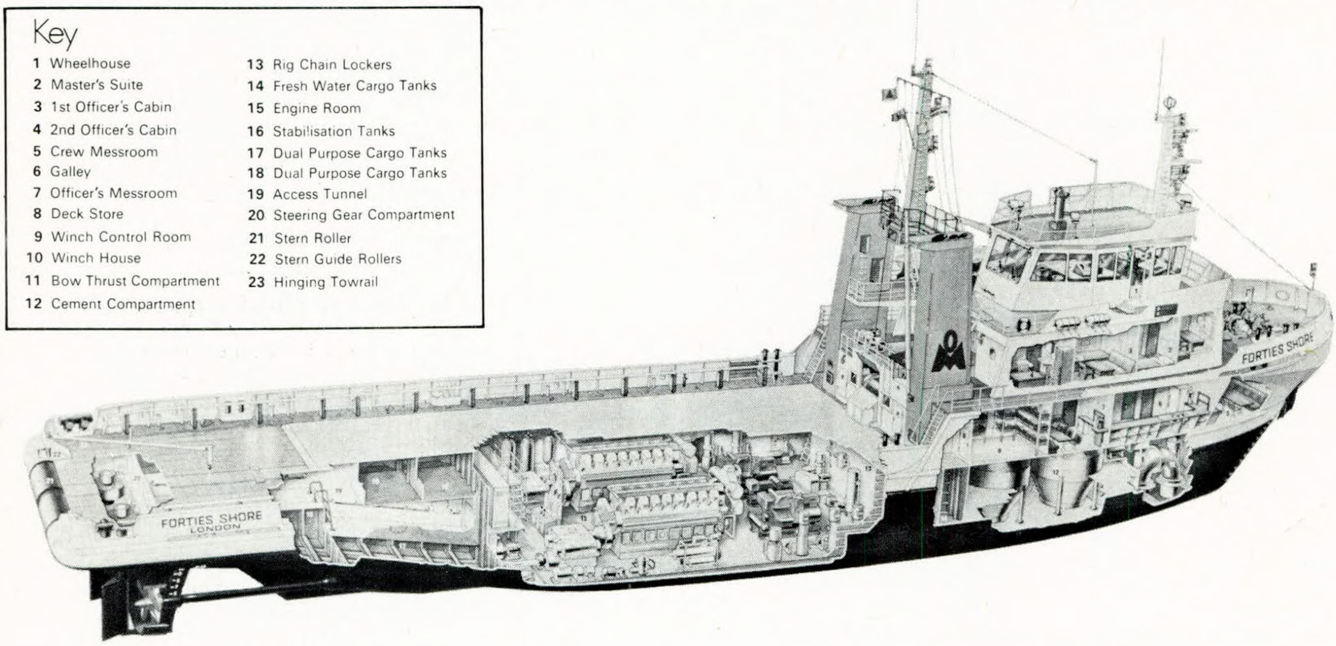

Fig. 1

MACHINERY REQUIREMENTS TO MEET THE ROLE OF THE VESSEL

The machinery required to meet the needs of the operation briefly outlined will obviously need to be robust and reliable. Over sophistication must be avoided, but sufficient automatic and remote control systems must be incorporated to enable the vessel to work efficiently and safely.

Propulsion Machinery

The accepted propulsion system at present is diesel drive of twin propellers combined with one or more thrusters and twin rudders mounted directly behind the propellers. In the case of the tug/anchor handling vessels the propellers are usually enclosed by fixed towing nozzles.

The vessel must be highly manoeuvrable. The propulsion

MACHINERY FOR SUPPLYING, ANCHOR HANDLING AND TOWING

This can be listed as follows:

1) cargo pumps for discharging fuel, drill water and

potable water;
2) high capacity air compressors for discharging bulk chemicals;
3) winches for anchor handling, towing and movement of deck cargo;
4) refrigerated cargo space (limited) for carriage of frozen food;
5) derricks for loading and unloading.

Apart from the deck cargo carried, which is of a considerable variety and not for discussion here, the supply vessel is a miniature tanker and bulk carrier. It carries fuel, water and "mud chemical" in bulk. The requirement for any or all of these commodities varies with the type of operation. All are carried in tanks and have to be pumped or "blown" to the rig through hoses.

Pumping

The liquids carried for rig use have to be discharged up to a height of 65 metres. ideally, the pumps used should be of the positive displacement type to cope with this head and to eliminate air evacuating machinery.

The tank space available on the supply vessel, after a proportion has been set aside for fuel and potable water, consists of triple purpose tanks which can contain fuel, drill water or ballast. Drill water is fresh water in which a certain amount of contamination can be accepted.

Three cargo pumps are usually fitted for fuel, potable water and drill water/ballast respectively. They normally have a discharge capacity of 80 t/h at a head of 40 metres. Their systems are interchangeable, so that each pump can pump any commodity. To avoid the possibility of contamination this interchangeability can only be effected by use of bolted change-over chests or blanking plates.

All tanks capable of carrying fuel are fitted with remote operated quick shut-off valves. When pumping fuel, an automatic shut-off valve is fitted to the deck connexion, to prevent spillage in case of rapid disengagement.

Bulk Chemical

Bulk chemical is usually either cement or barytes, the main materials used by the rig in course of drilling. These materials are stored in the vessel in tanks of about $35m^3$ capacity. Discharge is effected using compressed air. The powder is fluidized by admitting air through a permeable surface into the tank to a pressure of 2.7 bar and flowing it via a discharge valve, pipes and hoses, to the rig's storage tanks. The compressors used for this operation produce about $15m^3$ of free air per minute at 3 bar.

Deck Machinery

The claim that the windlass of a supply vessel does more work in one year than most vessels' windlasses do in the life of the ship is not an exaggerated one.

The supply vessels anchor is repeatedly dropped and recovered in considerable depths of water. 150 metres was the norm until recently, but 350 metres is now becoming common. A line pull of over 20 tonnes is now required for a ship size that would, under normal conditions, have a windlass with a six tonne line pull.

The windlass is freqently deluged with masses of salt water. The maintenance of its bearings, bushes and gearing needs to be frequent and intensive.

The main winch has progressed from being a single drum with a 25 tonne stall pull to a monster with three drums, 75mm chain wildcats, a bare drum line pull of 150 tonnes and a variety of speed ranges from 10m/min at maximum pull to 100m/min at maximum speed, with a control system of considerable complexity.

This winch is invariably driven by an engineer, who when in the control cabin has both a clear view of the after deck and a view of the winch drums. He also has direct communication with the bridge and the after deck. Some vessels have the winch controls duplicated on the bridge.

Subsidiary winches and capstans consist of lower powered (three to ten tonne line pull) winches which, through various arrangements can be utilized to move cargo around the decks, operate the derricks, tension mooring ropes and hold spare tow wires.

Some vessels have powered gantries which traverse the after deck, their own hydraulic cranes and even powered half decks that can be moved, complete with cargo, from the fore to the after end of the cargo deck. Operator's views of such equipment and its value vary considerably.

Refrigeration Plant

Refrigeration plant is comparatively large for the size of vessel because at times it is necessary to carry refrigerated stores to the rig.

Ship Support Machinery

Ship support machinery, that is, the basic requirements to operate any seagoing vessel, must still be considered, but these equipments are in no way particular to supply vessels. The power requirements are, of course, considerable and generating power of 750 kW is available on the latest ships.

Usage of Machinery

Perhaps this section should be entitled "Abusage of Machinery" which the author hopes will be readily understood. We are all aware of the ideal conditions under which one should run diesel engines. This ideal is never achieved in a ship, but most ships run between two points (which are usually in sheltered waters) at a fairly constant speed and load. Even generator requirements can be predicted with some degree of accuracy so that load sharing can be applied.

Consider, then, the tug/anchor handling/supply vessel in its various roles. In the normal supply role it leaves port when loaded and proceeds, usually at about75 per cent power, to the oil rig. Securing to the rig for unloading usually involves a spell of heavy manoeuvring. Once secured the engines remain idling for periods of up to twelve hours and the bow thrust engine or generator is doing the same—all have to be ready for instant action should the need arise but are only used occasionally to ease tension on mooring ropes or to deal with wind and tide changes. Released from the rig, the engines burst into life with a puff of black smoke and it is hoped that most of the carbon build-up has burnt off and that the turbochargers are not too badly fouled. The vessel then either returns to port, goes to another rig for a repeat performance, or remains on stand-by, when it can stop one engine and maintain way on the other.

When the anchor handling operation takes place, the loads on main engines and generators fluctuate wildly for lengthy periods. Every engine on the ship is in full operation accepting all conditions from idle to overload in order that the operation can be completed safely and efficiently at maximum speed — a rig move constitutes dead time for the rig and reduction of dead time is economically essential. Rig moves are normally carried out when the weather forecast is reasonable but once started must be completed as quickly as possible. A rig with half its anchors up is itself in a dangerous position should the weather suddenly worsen.

When the tow is under way, the main engines can have a good steady spell of high output, but can easily be overloaded if not handled carefully. The power/speed curve distorts terribly when something resembling the Eiffel Tower is on the end of the tow wire and the weather blows up.

When the tow is complete the anchors have to be re-laid. This constitutes the most testing time for the ship's machinery and is one of the main reasons for the supply vessels great increase in propulsion power over the last five years.The bollard pull required to run a 15 tonne anchor attached to 75mm chain cable for a distance of 800 metres in water depths of 300 metres is quite staggering. This, the greatest mechanical effort of the vessel, concludes with one of the most difficult of the winch operations, lowering the anchor in the exact position to ensure correct location of the rig.

Maintenance of Machinery

The supply vessel is usually engaged on a time charter basis, in certain cases for years at a time. The vessel is then a "taxi with the meter running" and must be available at immediate notice to carry out any of the operations for which it was chartered. The normal agreement allows one days maintenance per month of operation. Maintenance periods are then planned with the Charterer to suit operation requirements.

Mechanical failure while on charter is naturally frowned upon. A supply vessel which fails to deliver the goods and holds up the drilling operation, even for a matter of hours, becomes an expensive support to the drilling rig.

Because of its unpredictable schedule of operation there is no set time in port when planned maintenance programmes can be carried out. Even when in port, particularly the busy oil ports like Aberdeen, the game of "Musical Boats" prevents periods of even a few hours being predicted with any certainty. Add to this the fact that the machinery is operated under far from ideal conditions and it can be seen that the completion of all maintenance work necessary to ensure complete reliability becomes an even bigger problem than it is under steady and predictable conditions.

Plans have to be made so that the contingency and the emergency, that so often become the norm, can swing smoothly into operation when necessary.

The primary answer to the total maintenance problem is to have seagoing staff who maintain constant vigilance to detect incipient defects and eliminate them. The minor, but extremely important, preventative maintenance schedules must be carried out diligently to ensure that breakdown maintenance is eliminated as far as possible.

This boils down, of course, to good watchkeeping practices, which with the advent of automation, are fast becoming a thing of the past.

The unmanned machinery space, in the author's opinion, is an ideal that has not yet been reached without the enormous expense of sophisticated monitoring systems, as well as the space in which to fit them and the technical know how to put them right when they go wrong.

A recent survey showed that the incidence of serious fires in machinery spaces has risen in ships with U.M.S. This is primarily because not only the materials and conditions for a fire to exist have been present, but the fire must have started before the detection equipment can raise the alarm. By the time the alarm is answered it is often too late to do anything but adopt major fire fighting techniques.

The author feels sure that this is analagous to the protection of the machinery. The defect has to be present before the monitoring devices will sound an alarm or shut a machine down. Once the defect is present, particularly in a high speed engine, it is often too late. The good watchkeeper can take action in time, he can also 'feel' that something is not quite right in the sound of an engine or even the smell of it before a gauge moves off a set point sufficiently to sound an alarm.

The secondary part of the total maintenance problem is to have a balanced shore support system to cope with major planned maintenance, surveys and of course the occasional breakdown.

When considering this aspect, the limited headroom and restricted access to the machinery spaces of a supply vessel necessitates major maintenance being balanced out over the period of the full cycle. If all major routines are attempted at the same time the resulting congestion and chaos in the machinery spaces would defeat the object of the maintenance.

From the "breakdown" viewpoint, the failure of an auxiliary does not put the vessel out of operation. "Belt and braces" are built into most auxiliary systems so that it can continue to operate efficiently and safely while repairs are effected.

This is not the case with main engines however. Only in exceptional circumstances of calm weather can the supply vessel continue to operate with one main engine out of action.

Great emphasis is placed on the maintenance of the main engines. It is vitally important that they are correctly tuned and that power limiting and manoeuvring control devices are always in correct operation.

When overload conditions exist for short periods, a slightly overloaded cylinder is not readily detectable, but after a few apparently normal operations, this condition can result in partial or complete piston seizure, with disproportionate consequences. Similarly, during long periods of idling, a badly tuned engine may not be firing on one or two cylinders, resulting in dangerous deposits of lubricating oil in the exhaust system and bad long term effects on ancillary drive gears and turbochargers.

SPECIAL PROBLEMS

Propeller Fouling

Even though the propellers are well tucked away, the most repeated mechanical breakdown is caused by fouling of propellers, more so with nozzles fitted than without because objects can wedge between the propeller and the nozzle. Emergency dockings are frequently necessary to clear fouled propellers, or repair the damage caused by fouling of propellers, to shaft seals and propeller blades.

It has already been mentioned that the supply vessel operates under conditions of navigational hazard (i.e. in close proximity to a large and heavy structure) in some atrocious weather conditions.

Propellers can become fouled at the rig by ropes, wires, or even chain cable and, in the shallow harbours previously mentioned, by fenders, wires, baulks of timber, rocks and a variety of jetsam. It is surprising how tough a tractor tyre can be to remove when it becomes wedged between a propeller and a nozzle. In one instance and one instance is stressed, a vessel picked up the following from a river bed:

> "Five metres of 25mm diameter wire rope, ten metres of 30mm polypropylene mooring rope, one tractor tyre, half a motor tyre and a 115 litre oil drum."

Fortunately divers managed to remove all this and there was no apparent damage to propeller or seal.

Damage through propeller fouling does not confine itself to the propeller and seal only, however. In the case of controllable pitch propeller, the internal operating gear can become strained or damaged. With reverse/reduction gearboxes, clutches can burn out when engines are stalled. Particularly when at any great power, there is a danger of tailshaft, intermediate shaft and crankshaft failure.

This particular problem alone is one that has considerable bearing on whether or not to fit c.p. propellers to supply vessels.

The author considers the following points to be relevant:

In Favour of C.P. Propellers

i) Finer control of manoeuvring, particularly in the lower powers, when in close proximity to the oil rig;
ii) elimination of expensive clutching machinery and gearbox;
iii) achievement of a better range of propeller configuration for the towing/free running periods of the vessel's operation.

Against C.P Propellers

a) Introduction of expensive and sophisticated machinery to control the pitch;
b) necessity to fit an automatic declutching device in the event of exceeding maximum torque when propeller fouled;
c) shaft and propellers rotating continuously while working with wires overside, increasing the risk of propeller fouling;
d) cost and down time incurred in repairing a cp system after bad propeller fouling and specialist equipment/parts required;
e) additional cost of survey when drawing tailshafts — approximately three times the cost of normal tailshaft survey.

It may be concluded from the above that the author is not in favour of controllable pitch propellers being fitted to supply vessels, particularly when the use of an omnidirectional thruster is available for fine manoeuvring touches.

Bulk Chemical Discharge

This is an operation that is new to most seagoing engineers joining the offshore supply industry. The discharge of bulk cement or barytes at maximum rates is something that to date can only be achieved through experience. The author understands that a company has recently devised an automatic method to give maximum discharge rates under all conditions and will be very interested to read about it when the information is available. However, obtaining a maximum discharge rate entails the monitoring of a number of variables, their assessment and resultant control of valves and compressors. This sounds a simple enough problem to control automatically, until one realizes that the important measurement is the density of the mixture in the discharge line, which for maximum discharge rate, must be equal to the weight of the column that the air pressure available can adequately support. At present, most systems use an air pressure of 2.7 bar in the ships' tanks. Any greater pressure would necessitate tanks of a much heavier construction adding cost and unwanted weight to the vessel. Discharging bulk chemical from shore to ship and **vice versa**. at the same level, is fairly simple but discharing it to a height of 40 metres is a little more difficult.

It is essential that bulk powder of this kind is kept completely dry and free of impurities. Where loading conditions are "primitive" it is possible for the powder to contain moisture and pieces of cement bags while loading. The moisture, if not of too high a content, creates small boulders of cement in the tank which are impossible to discharge. The bits of paper sack tend to clog and foul discharge valves and bends.

The air used for discharge must be after cooled, drained, de-misted, drained, reservoired and drained before being admitted to the bulk tank. Even a refrigeration system to consense all moisture out of the air has been considered. The operation of discharging is one that requires constant attention. The density of the mixture in the tank varies throughout the discharge of the tank. Consequently, to maintain the previously mentioned constant density of the mixture in the pipeline, purging air is admitted at strategic points in the discharge system. This purge air also assists in changing flow direction without powder fall-out. Fixed pipe lines, both aboard the vessel and on the rig must be clean internally and be constructed in a manner to promote steady flow. Bends must be suitably radiused and straight lengths should be either vertical or horizontal, to reduce powder fall-out to a minimum. The pressure differential must also be kept constant, because variations cause interruption of the flow with consequent powder fall-out. The $35m^3$ tank holds approximately 50 tonnes of cement, or 60 tonnes of barytes, and against a head of 40 metres these should be discharged, under ideal conditions, in 45 minutes and 90 minutes respectively. Conditions are seldom ideal, but these and even faster rates have been achieved. Discharge to 65 metres head has not yet, to the author's knowledge, been attempted. It will be slower, but it will be achieved.

PERSONNEL

However good the tools to do the job, the operation of a supply vessel will ultimately rest with the officers and men who go to sea in it and perform their duties in the most demanding conditions. Further development of these vessels will depend on the operational feed back from seagoing staff, so that efficiency and safety can be improved.

From the account of the operation, it would appear that being an engineer aboard a supply vessel offers little but hard work and discomfort. No suite of rooms for the Chief Engineer and his wife, but a job that entails watchkeeping and spanner work as well as paper work and administration. It does however offer a challenge and great job satisfaction. Boredom and the same old routine are non-existent. Every job is different and, since the industry is still relatively young, great developments have still to take place. The search for oil is world-wide and vessels to support the oil development programme will be required for many years to come. Many newcomers to the industry react quite violently and leave very quickly; it is not everyone's cup of tea. Those who stay are very satisfied. In ships of this size, with a total crew of ten or eleven, the challenge and rewards do not appear to be sufficient for some, the work too hard or too demanding for others. As an engineer, one is responsible for the mechanics and electrics of the whole ship. No armies of mechanics or cleaners are available, just the engineer on a single-handed watch with an officer and crew member on the bridge. Physical fitness and mental alertness are of paramount importance, every member of the team must do his share and anyone who has to be "carried" does not last very long in the offshore supply business.

Some interesting challenges have arisen in the course of operations and the answers have been produced either by close co-operation between oil companies, operations and support groups or by the efforts of individuals at their job.

Challenge

What does one do with an iceberg off the coast of Labrador that is drifting on a possible collision course with a semi-submersible rig, at anchor and drilling as quickly as possible in the few Summer months in which it can operate?

Answer: Obtain a reasonably powered supply vessel, a team of iceberg flow plotters and devise a method by which the vessel of some 3000kW power can "lasso" the ten-million ton iceberg and move it sufficiently to deflect its course from one of possible destruction to one of safety. Supply vessels are now on regular "iceberg patrol" off the coast of Labrador from July to November. This year, as well as a "lasso", a giant vacuum sucker is being tried out as method of fixing a tow wire to an iceberg.

Challenge

How does one supply a mother and an umbilical cord to a miniature submarine being used to survey under-sea pipelines and proposed pipeline runs.

Answer: Obtain a supply boat, fit a "hanger" on its deck and a large 'A'-frame on its stern and, using the supply boat's winch, lower the submersible gently into the water and allow it to do its task, then recover it to the deck of the supply boat.

Challenge

A supply vessel is engaged in towing a semi-submersible oil rig to a new location. Three supply boats are engaged on this operation and weather conditions deteriorate until a force ten gale is in full swing. The ships can only take a safe course and hold on to the rig with sufficient power to ensure that drift is minimal and that too great a strain is not placed on tow wires. Suddenly the port main engine stops and investigation shows that the camshaft drive idler has lost a few teeth and the whole camshaft train is in a mess. A check through the spare gear reveals that all the spare parts required but one — a spare camshaft pinion—are available.

Answer: The Master holds the tow with one engine and calls the lead tug, which has similar engines — he has a camshaft pinion aboard which he floats down on a lifebuoy. It is picked up and given to the Chief Engineer, the time is 2330. By 0800 the next morning the ship is back in operation with both engines engaged and the tow still held.

Feats of seamanship, backed up by engineering knowledge, skills and inventiveness are almost commonplace in this fledgling industry.

What of the future? We already have self-positioning drill ships capable of drilling in great water depths and being self-supporting for protracted periods. What high payload, high speed, supply ships will be necessary for these? Semi-submersible supply/fire fighting/diving support vessels with great power and manoeuvrability are already on the drawing boards or under construction. Will the total concept become subsea, where wind and waves have less effect? What disciplines and attitudes will be required on the vessels that are yet to be evolved and what calibre of man is going to be necessary to accept these challenges? In the engineering discipline, the same calibre of man that raised the funnel and lowered the screw, in the past.

CONCLUSION

Offshore supply and support vessels, though relatively new to the shipping world, will be with us for many years to come. After ten years of relatively slow development the last two years have shown a great upswing in supply craft of significant power (1500kW and above). At the end of 1974, the world boasted 780 of these craft. By the end of 1976 some 1250 will be operating.

This rate of increase has levelled out somewhat, but there is little doubt that ships, to perform the variety of functions described, will continue to be built. because of its arduous task the life of the vessel is limited. New and better vessels will be built. Plenty of opportunities exist for planned expansion in this tough, but exciting, environment. British expertise in design, production and operation is available to accept this challenge.