THE INSTITUTE OF MARINE ENGINEERS

76 Mark Lane, London EC3 7JN   Telephone: 01-481 8493   Telex: 886841

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'UNCLE JOHN'

A Semi-submersible Multi-purpose Support Vessel for Oil Exploration and Production

J.M. Houlder CBE

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'Uncle John': A Semi-Submersible Multi-Purpose Support Vessel for Oil Exploration and Production

J.M. Houlder CBE

Houlder Offshore Limited

SYNOPSIS

'Uncle John' is a dynamically-positioned diving support and oilfield construction barge which went into service in 1977. The paper briefly describes the offshore industry and the environment in which the vessel was designed to operate, including the drilling techniques. The design of the vessel, its main tasks, the weather conditions in which it can operate and the operational experience to date are discussed, as well as the command and management structure which caused problems in the early days.

OFFSHORE OIL EXPLORATION AND PRODUCTION : AN OVERVIEW

Exploration

Seismic is used to locate offshore geological formations where an accumulation of hydrocarbons is likely. At present, only drilling can establish the presence of these hydrocarbons. In many cases the oil or gas leaked away thousands of years ago.

The drill largely consists of 30-ft lengths of drill pipe which are screwed together. The drill pipe is rotated by means of a square section at the top which passes through a square hole in a rotating table. The drill bit, at the bottom of the drill pipe, crushes the formation. Fluid is pumped down through the drill to wash the debris up to the surface on the outside of the drill pipe.

A typical drilling operation consists of lowering a temporary guide base to the sea-bed. This guide base comprises a flat plate with a large hole in the centre; four guide wires are attached to the corners. The drill pipe is fitted at the bottom with a large-diameter drill, and is centred between the four guide wires by a primitive form of yoke. This enables the drill pipe to enter the hole in the temporary guide base. Water is pumped down the drill pipe to bring debris up to the sea-bed, and a hole some 3 ft in diameter is drilled to a depth of a few hundred feet.

J.M. Houlder commenced an apprenticeship with Cox & Co., Ship Repairers, Falmouth, and subsequently joined H. Clarkson & Co. Ltd, London, shipbrokers. After taking first place in the Institute of Chartered Shipbrokers examination, he was appointed a Director of Houlder Brothers in 1938. During the war he was Dock Superintendent of Tobruk during the siege, for which he was awarded the MBE. He was appointed Director of Furness, Withy & Co. Ltd in 1954 and Chairman and Chief Executive of Houlder Brothers in 1970. He has been particularly involved in the design of vessels for the carriage of LPG and similar cargoes, as well as semi-submersibles and diving support vessels. Mr Houlder was appointed Chairman of Houlder Line in 1961; he is also Chairman of Houlder Comex Ltd, Comex Houlder Diving Ltd, Houlder Marine Drilling Ltd and Kingsnorth Marine Drilling Ltd. He is an Administrator of Comex SA and Comex Services SA of Marseilles, and also a member of the Executive Board and of the General, Technical and Classification Committees of LRS. He has been President of the Society for Underwater Technology and is a member of the Council of the RINA.

The drill is then withdrawn and the 'foundation pile' is lowered. This consists of thick-walled tube, of about 30-in diameter, with the 'permanent base' welded to the top. This is lowered into the hole as was the drill. This welded base sits in some form of socket in the temporary guide base, so that the foundation pile (or '30-in' as it is often called), can take up an exact vertical position. The drill then re-enters the foundation pile with a packer (an expansible plug) at the bottom, enabling cement to be pumped down the drill pipe and back to the surface between the foundation pile and the surrounding formation. This gives a firm mechanical base for further operations.

The permanent base is then connected to the surface drilling rig by a large-diameter pipe, made up in sections, with a telescopic joint at the top. This, like all vertical pipes in the oilfield, is referred to as the 'riser'. It guides the drill for further entries into the hole, and enables drilling fluid which has been pumped down the drill pipe to be returned to the surface, where it can be cleaned for pumping down again. The chips of debris are taken out and examined.

The foundation pile may provide a mechanically secure base, but it is unlikely to be cemented into a formation which can seal off gas and oil. A suitable formation, which will be gas- and oil-tight, may not be encountered until the drill has gone down several thousand feet. When this is reached, a 'string' of pipe called 'casing' is lowered down from the drilling rig through the riser, the foundation pile and the hole itself until the well head, which has been screwed to the top of the string of casing, rests in the permanent guide base.

Cement is then pumped down this casing (which may be about 18-in diameter), as in the case of the foundation pile. The cement forms an oil/gas-tight seal between the casing and the formation. The well head itself makes an oil/gas-tight joint with a 'blow out preventer' (BOP), which is placed on top of the well head after the riser has been temporarily disconnected; after this the riser is then re-connected to the top of the BOP.

The BOP is an extremely complex and expensive device weighing several hundred tons. It contains a source of self-contained energy which enables it to grip the drill pipe by means of rams, which are shaped to fit and make an oil-tight joint. It also has blind rams to shear right through the drill pipe in an emergency. This prevents oil/gas escaping through the annular space between the drill pipe and the casing. The BOP is controlled from the surface by hydraulic hoses. Attached to the riser are kill and choke lines which enable drilling fluid to be introduced or withdrawn from below the rams at high pressures or, if the drill pipe has been cut by the blind ram, to circulate through the drill pipe itself.

Mud circulation is the basis of all well control, as it enables the gravity of the drilling fluid (or mud) to be adjusted. It has to be heavy enough to keep the oil/gas from escaping from the formation, but not so heavy that it fractures the formation and disappears into the cracks. The BOP rams are only closed if gas is encountered at pressures which the mud currently in use cannot control.

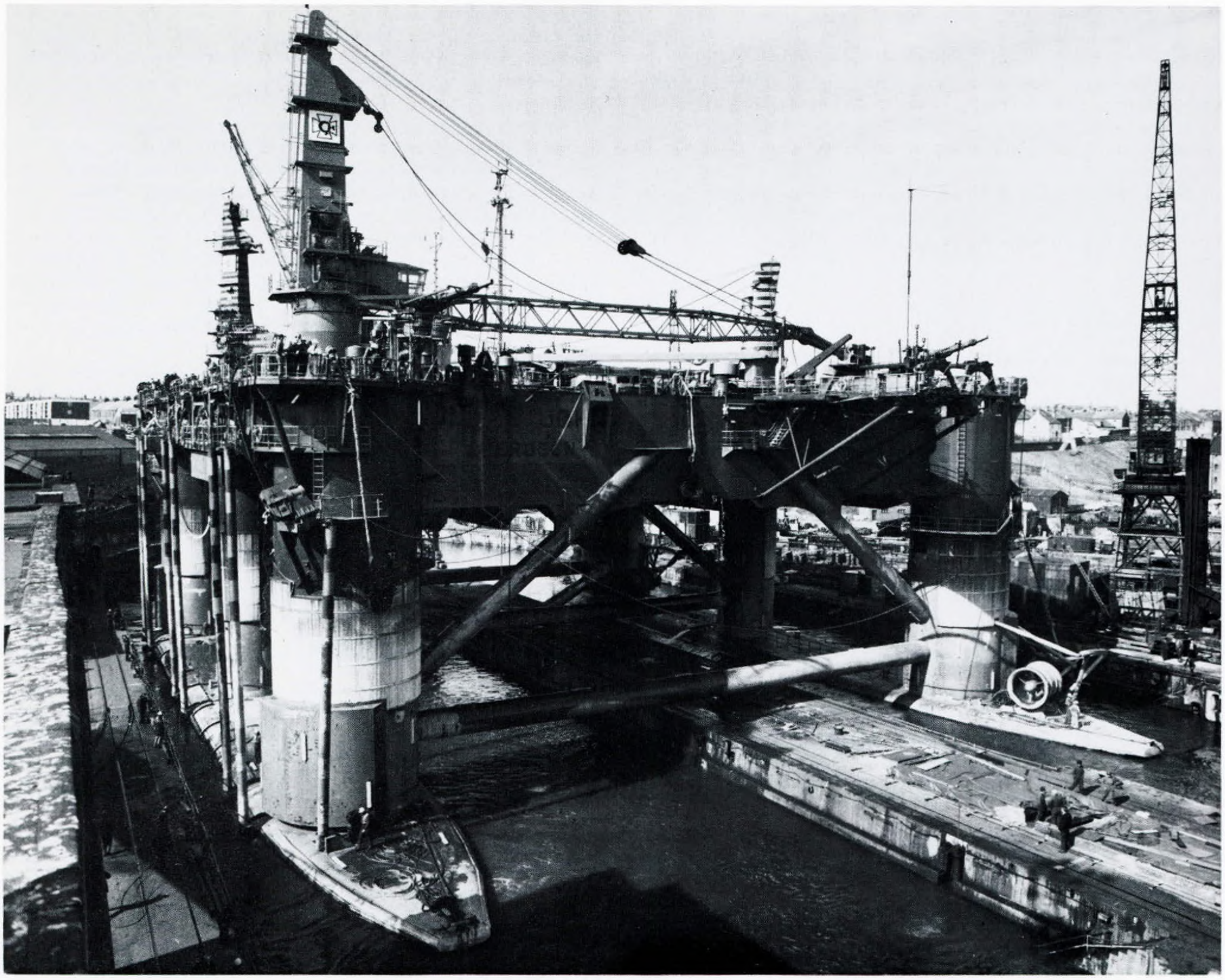


FIG 1 *Uncle John* **: simultaneous use of two drydocks**

When it is impossible for the mud to meet these criteria, it is necessary to protect the formation from fracturing by running another string of casing inside the 18-in. Heavier mud can then be used.

Ultimately, oil may be reached. It is necessary to ensure that it is the oil which comes to the surface, and not the water which may be below it. One method is to carry a string of casing to a level below that of the oil, and then fill the casing and the space outside it with cement up to the level of the oil. The casing is then perforated at the desired level by means of a gun which fires bullets.

Production

'Sub-sea completion'

When production begins the oil will be withdrawn by 'tubing', which replaces the drill pipe; the annular space, between the tubing and the casing above the perforations, will be blocked by a packer. The annular space above the packer will be filled with mud. There is usually some arrangement whereby, if needed, a tool can be lowered on the wire line down the tubing to open a port at the bottom out of which the mud can run into the space below the tubing and up the tubing itself. This 'kills the well', as the weight of mud is sufficient to keep oil or gas from coming out of the formation.

The tubing at the top is connected to the 'Christmas tree', which will also provide access to the annulus between the tubing and the casing. This enables mud to be circulated at any stage during the well's life. The Christmas tree is in fact a 'poor man's BOP'.

The tubing itself will have a 'downhole safety valve' below the mud line, which will close if there is pressure loss in a control line running to the control centre on a fixed platform. These downhole safety valves suffer from erosion and require periodical maintenance, a difficult and dangerous job. This was one of the first tasks for which *Uncle John* (see Fig. 1) was intended.

Platforms

Although the 'sub-sea completion' described above is quite straightforward in theory, there are practical difficulties. These are such that, until quite recently, virtually all exploration wells drilled by floating drilling rigs were plugged and abandoned after they had been tested—a waste of two or three million pounds.

The producing wells themselves were then, and usually still are, drilled from the top of fixed production platforms, about the size and shape of the Eiffel Tower if made in steel, or the equivalent in concrete. Steel platforms are carried to site on top of a large flat barge, and launched by tipping the barge. Concrete structures are towed and sunk in position.

One reason for adopting a platform above the surface is that the gas must be separated from the oil at or as near atmospheric pressure as possible. Otherwise, as pressure drops, a gas/oil mixture in a pipe would develop into sections of gas separated by slugs of oil, which pass through a pipeline much slower than gas. It is impossible to avoid a pressure drop if oil is to flow a substantial distance, and the gas will separate out as soon as the pressure drops below a certain point.

The lower part of a platform, known as a jacket, is usually positioned without superstructure. The superstructure is then placed on top by a barge with a big crane. The latest barges of this type are semi-submersible and carry a pair of cranes (one of 2000 t capacity, and one 3000 t capacity) able to work in the open seas. The superstructure will contain all the equipment necessary for separating oil and gas, and delivering the oil into the vertical 'riser'—this takes the oil to the sea-bed where the riser is 'tied in' to a pipeline. This is a particularly difficult connection to make.

This pipeline may be quite short, and lead to a tanker loading buoy; or it may be several hundred miles long, to the shore. The pipelines from other platforms and other oilfields may have to be 'tied in'; making these tie-ins has been the most important task undertaken by *Uncle John* to date.

The usual method of constructing pipelines is that pipes are transported to the pipe-lay barge in 40-ft lengths which are welded together on its deck. The welding work is divided over a number of welding stations, so that a new length of 40-ft can be added to the pipeline every 7 min or so. The assembled pipe is paid out over the stern, controlled by a friction brake. This contains sufficient tension to prevent the 'sag bend' from buckling where the pipe approaches the sea-bed. The 'over bend', where the pipe leaves the barge's stern, is prevented from buckling by a supporting structure known as a 'stringer'.

SEAL Christmas tree

It was apparent from an early date that to drill exploration wells only to abandon them, and then to repeat the operation, was an extremely wasteful way of producing oil. BP, Total, Mobil, Westinghouse and a group of small companies formed a consortium known as SEAL, to develop alternative production techniques. It succeeded in producing a Christmas tree which could be installed without divers in very deep water; it also had a completely reliable control mechanism together with facilities for changing out the entire operating mechanisms. A great deal of know-how and experience was obtained.

The SEAL wellhead was intended to require a special small dynamically positioned semi-submersible for its installation, and this triggered off our studies which led to *Uncle John*.

UNDERWATER PIPELINE TIE-INS

It soon became apparent that the subsea wellhead was only a small part of the subsea offshore oil production work and that pipeline tie-ins were of even greater importance.

Underwater pipe connections were traditionally made by lifting the pipeline to the surface by means of a row of pipe davits along the side of a flat barge and welding a flange to the end. If a flange can also be fitted, or already exists, on the end of the other pipe to be joined, a connection can be made by divers on the sea-bed, using a made-to-measure joining link or 'spool piece'. However, in water deeper than about 50 m it is impracticable to lift a pipeline to the surface due to the high risk of buckling.

In any case, there will be no flanges for a connection if the need is due to damage to the pipeline. Numerous types of mechanical connectors have been devised to overcome this problem but none has been a complete success. Changes in temperature, resulting in major forces created by the expansion and contraction of a long length of pipeline, present a major problem.

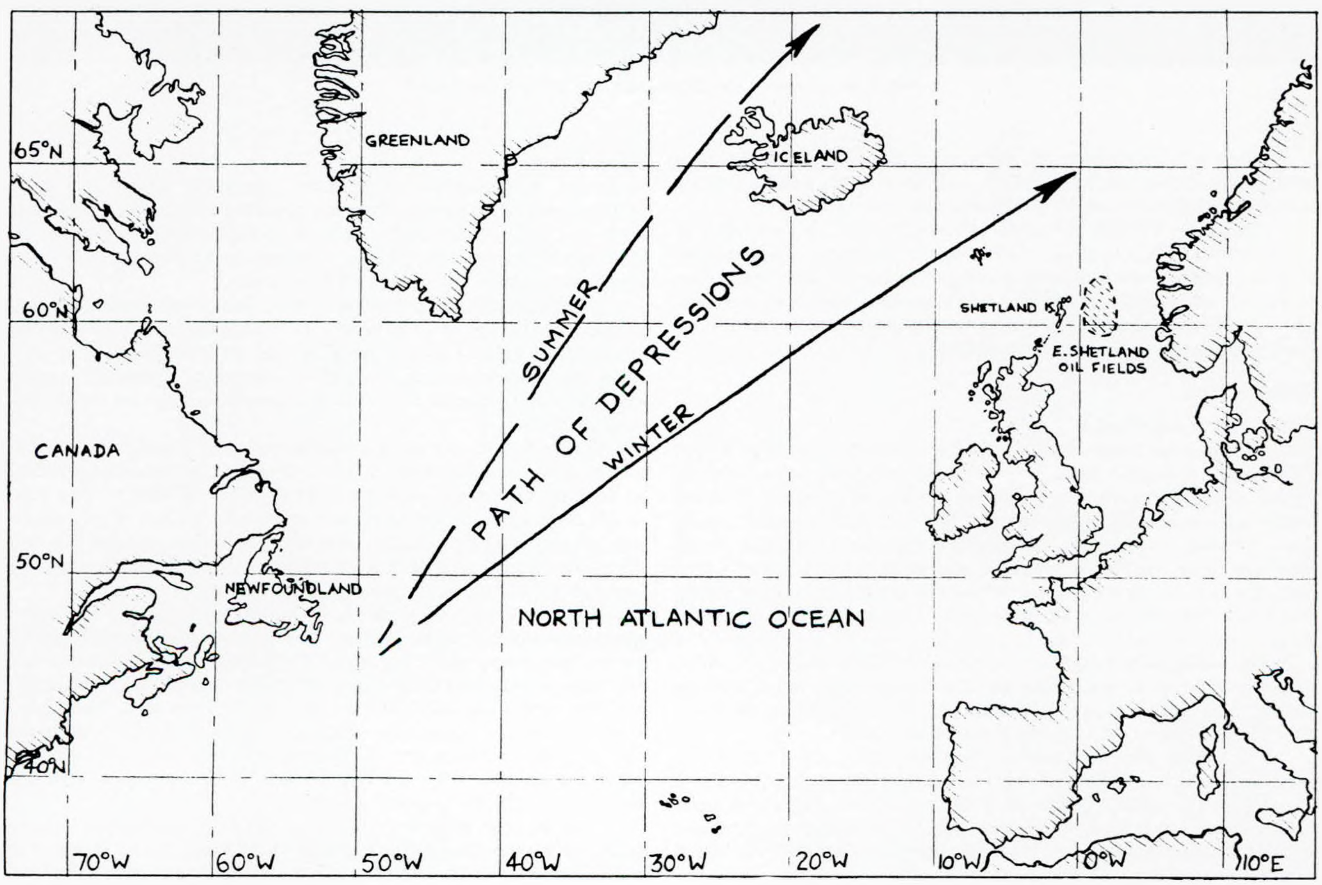
A more satisfactory means of pipe connection is hyperbaric welding, i.e. the welding is carried out at the high ambient pressure at the sea-bed. A habitat is built over the join, and water is expelled by helium under pressure so that the weld can be made in the dry. This technique is highly specialized.

The main problem in making tie-ins with the larger pipes is the sheer size and weight involved. A large spool piece may be up to 100 m in length, and weigh up to 80 t. Both ends have to be positioned exactly by divers; in the case of a flange connection, the individual bolts may weigh 100 kg each. For a welded connection, the pipes to be joined usually overlap and have to be cut to length. This is a difficult task for divers, owing to the extensive reinforcement in concrete weight coating surrounding the pipe. Thereafter, the pipelines have to be lined up and their ends machined to provide the correct chamfer, etc. for welding. Finally, a short pup piece is introduced which exactly fills the gap with a tolerance in the order of 1 mm.

Underwater maintenance

Once an oilfield is in production, there still remains an immense amount of subsea work to be performed. Keeping the bottom clear of debris and removing wellheads no longer required, are among the simplest. There is the never-ending task of inspection. Major repairs include the complete change-out of corroded risers; replacing riser clamps; or repairing fractures in platforms themselves by means of clamps: these are typical tasks.

FIG 2 Generalization of North Atlantic weather



The desired pipeline system may change from that originally envisaged, requiring the introduction or removal of subsea valves, or introducing Tee pieces or otherwise tapping an existing pipeline. It is sometimes possible for this to be done while the line is in service and under pressure, in which case it is referred to as hot tapping.

DESIGN CONSIDERATIONS

We decided that pipeline tie-ins were to be the most important function for *Uncle John*, but that it must be capable of performing most of the tasks described above as well. It then became necessary to take some very important decisions.

First, was work to be carried out over the side, over the end or through a central moonpool? We decided 'over the side', and remain convinced that this was the correct decision for a semi-submersible which is only likely to roll 1 or 2 deg while operating.

Second, should there be one big crane? We decided on two small cranes (100 t capacity each), capable of lowering loads to the sea-bed in 200 m of water. This was a controversial decision, as a big S-shaped spool piece may be 100 m between the ends and approaching 80 t in weight. It was suggested that there would be great difficulty in slinging two cranes in step while lowering was in progress, but this has in fact presented no problems.

Third, should the vessel maintain position by anchors; or by a combination of computer-controlled, dynamically-positioned (DP) propellers? Our customers recommended anchors, and four anchors were provided. However, they were only used for the first week or so and we were able to persuade our clients to let us try DP alone, after which the anchors were never again used. These have now been removed (except for a classification anchor forward and aft).

Operational environment and limiting conditions

The environment in which *Uncle John* was intended to work was envisaged as the East Shetland Oilfield. Here, the water depth is about 140 m (460 ft); and, at 60°N, the weather is reputed to be amongst the worst in the world. Figure 2, a generalization of the North Atlantic weather, shows that an endless series of depressions originates in the vicinity of Newfoundland and proceeds north-easterly across the North Atlantic.

In winter, the preferred route is between the Shetlands and Iceland, so most of these depressions pass either to the north of the East Shetland Oilfield or fairly close to it. Some, however, may pass well clear, either to the north or to the south. This series of depressions produces a westerly gale about every 7–10 days, with winds of up to 50 knots and significant wave heights of up to 7–8 m. In summer, the depressions tend to pass much further away and have less effect.

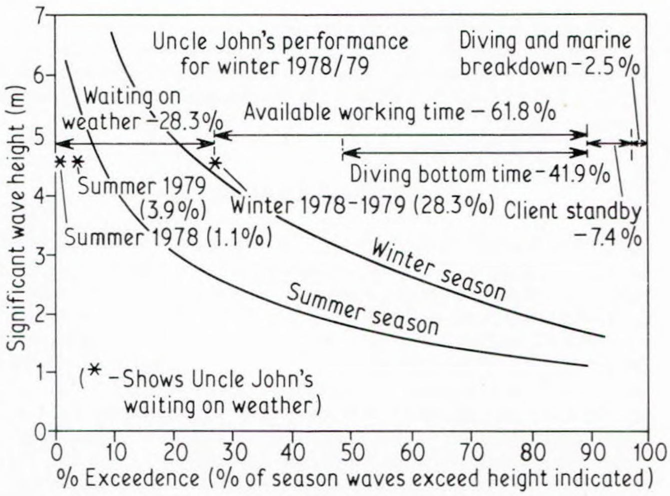
Waves are usually described in terms of 'significant' wave height. This means the average of the one-third highest waves, measured from crest to trough, over a short period. Every few hours a wave of twice the significant height is experienced. Measurement by experienced observers is fairly reliable, particularly if they have an opportunity of periodically comparing their estimates with the more precise figures given by wave rider buoys which carry integrating accelerometers.

Fully-arisen sea (FAS)

There is no exact correlation between wave height and period, and wind speed. This is not always appreciated. Wave amplitude builds up slowly when a wind begins to blow, and the effective period increases from, typically, 4–5 s at the beginning to 8– 9 s or more as time goes by. Furthermore, the wind has to act over a long stretch of sea, known as the fetch, to achieve maximum wave build-up.

If there is sufficient fetch, and the wind has been blowing long enough to achieve these maximum waves, the sea is described as a 'fully arisen sea' (FAS). There is an exact correlation between wind speed and an FAS, but, in the North Sea, this is never reached for gale force winds. This is due to limitations of fetch caused by land or, equally important, to the limited size of the North Atlantic depressions themselves.

Owners like to express the performance ability of their vessels by stating the weather conditions in which they can operate in the open sea. They are then free to select the optimum heading. This, however, is the exception rather than the rule, as in most cases an oilfield diving support vessel will be required to work close to a platform with no choice as to either position or heading.



Data from East Shetlands Oilfield, 61°N. Summer: 15 April – 14 September (5 months); Winter: 15 September – 14 April (7 months).

FIG 3 Average significant wave height excedence (seasonal basis), hindcast 1952-1973

A DP vessel may have to stop operating because it does not have sufficient power to maintain station, with an adequate reserve, in the face of the prevailing wind. Our experience is that significant wave height gives a more reliable indication as to whether or not work will be possible, bearing in mind the many factors involved; and that there is some sort of relation between wave and wind.

If the performance claims of the owners, or the Det norske Veritas (DnV) performance criteria, were to be taken at their face value it would be possible for all diving support vessels to operate for 90% of the time. We prefer to find what percentage of the time our vessels do in fact operate and, by cross-checking this percentage with the wave statistics, to ascertain the *average* limiting wave conditions for work.

Figure 3 gives the percentage of time during which significant wave heights exceed certain figures. On the right of Fig. 2, it will be seen that, for 90% of the time, significant wave heights exceed 1.25 m; while in summer they exceed 6 m for only about 3% of the time. These figures were compiled by a major oil company for the East Shetland Oilfield and coincide with our experience over the last 5 years. DnV works on figures considerably less severe.

Some very interesting conclusions can be drawn from Fig. 2. We claim that *Uncle John* operates, on the average, in significant wave heights of up to 4.8 m. From Fig. 2 it can be seen that there is not an enormous difference, whether this figure is 5 or 4.6. Consequently, attempts to improve the performance of this type of vessel are coming up against the law of diminishing returns.

However, our experience with monohulls is that the limiting significant wave height is, on average, about 2.5 m. In this range, small variations in performance ability will have a marked effect on the amount of work achieved in summer; while in winter, the work capacity of monohulls is, in any case, very limited. Vessels vary greatly in performance and each vessel gradually acquires its own reputation. Market forces, quite unconsciously, appear to adjust rates of hire for individual vessels according to their performance abilities.

Movement of the vessel may ultimately prevent a diving bell being mated with its chamber, even if the bell can pass through the air/water interface. It will obviously impede work when spool pieces etc. are being lowered to the sea-bed by means of cranes. However, there is an additional problem for pure diving work such as inspection. Is it considered necessary to be able to jump surface divers to provide a safety back-up for divers working from a bell?

For example, a few years ago, SSI had a bell wire break while lowering a bell with divers in it, and the bell started to drop. The umbilical cable (which supplies breathing gas, hot water, power and communications) was still intact, and ultimately jumped its sheave and jammed. Fortunately, this brought the bell to a halt about 50 m below the surface, without breaking the umbilical. A surface diver was lowered on a crane hook to attach the hook to the bell, and there was no further problem. If the sea had been too rough the surface diver might have not been able to dive or might even have lost his life. This is not only an example of when a bell has required outside diver assistance.

The need for surface diving may therefore be a limiting factor in the operation of a diving support vessel, even if the bell can be operated in very bad weather. The ultimate solution is obviously two complete bell systems, but usually this is not possible on the smaller vessels.

DESIGN OF VESSEL

The general form of *Uncle John* (Fig. 4) is not unlike the well-known Aker H-3 drilling rig. There are two streamlined pontoons, which each support the superstructure by means of three columns. In operation, the draught is 15.5 m and the air gap 5.0 m. Over the last four winters, a survival air gap of 7.5 m has been sufficient for all the gales encountered, and no damage of any sort has been experienced to the underside of the hull, notwithstanding the many projections.

This air gap is much less than that recommended by the classification societies. In our experience, the classification societies' figure is approximately right for drilling rigs. The difference may be due to the fact that *Uncle John* works without anchors and can rise and fall with waves in a gale, whereas the vertical movement of drilling rigs is impeded by their anchors. *Uncle John*'s heave response to small waves is gratifyingly small; but, as the waves and their period become longer, so the vessel begins to respond. By good fortune, *Uncle John*'s dimensions have achieved these satisfactory characteristics.

The streamlined hulls of *Uncle John* were designed for high speeds in excess of 12 knots. This was a mistake. In practice the vessel in transit invariably needs to carry the maximum payload, so the freeboard of the pontoon is only a few centimetres. Under these circumstances, every wave hits the columns and causes a noticeable deceleration of the vessel. Surface speed is almost entirely dependent upon sea conditions, varying from about 4 knots if the vessel has been forced to submerge to survival draught in a gale, to 8 knots under favourable open-sea conditions. On trials in flat calm water, the speed achieved was in excess of the 12 knots specification.

The fore and aft propulsion is provided by two variable-pitch propellers on the stern, each driven by two 1500 hp electric motors. We had difficulty in persuading all concerned that, since *Uncle John* was not an ordinary ship, it was extremely undesirable for the propellers to go automatically into full pitch ahead in the event of a control failure.

The design was far advanced before we discovered that the propeller manufacturers had automatically incorporated this full ahead feature, but the problem was overcome by providing a robust mechanical trip to stop the motors if the propeller goes into more than 90% of maximum pitch in either direction.

OPERATIONAL PERFORMANCE

Uncle John was designed to maintain its position if any propeller fails; but, if one propeller gave full power in the opposite direction to that desired, there would be problems.

Uncle John has the same power from side to side as fore-and-aft, this being provided by six transverse thruster propellers each of 1000 hp. Four are installed in tunnels in the pontoons, with two more on top of the starboard pontoon deck.

After *Uncle John* was in operation, we thought that, if we built another vessel, it would be provided on the underside with thrusters which would have the capability of rotation over 360 deg. This arrangement would have been much more efficient than our combination of fixed fore-and-aft and fixed transverse thrusters. For maintenance, the thrusters could have been removed by divers.

However, regular drydocking has been found to be an absolute necessity and we are very thankful that the complete set of thrusters does not have to be removed each time *Uncle John* goes into dock. The reasons for having to drydock are so varied and unanticipated that it will probably be a long time before regular drydocking becomes unnecessary for DP vessels.

Drydocking is achieved by the simultaneous use of two drydocks (Fig. 1). This may be unusual, but creates no problems.

The limiting factor on *Uncle John*'s performance is astern power. The designer of any form of diving support vessel would be well advised to pay particular attention to this, as it will be found necessary to work stern on to the sea nearly as often as bow on. Some propeller designs obtain a little extra efficiency ahead at the cost of considerable loss of efficiency astern. The need to work stern on to sea creates problems for the supply boat type vessel having an open stern with low freeboard.

FIG 4 *Uncle John*

The dynamic positioning control system was manufactured by GEC Ltd, with design input from the Houlder Organisation. We have two complete taut wire systems and an acoustic system comprising four hydrophones which can work with up to three beacons on the sea-bed.

Accuracy of positioning

In operation, position is usually maintained by means of two taut wires (one used as back-up), but the acoustic system is invaluable for positioning the vessel when returning to a work site after an interruption or for such tasks as lowering a spool piece into a precise position. The order of accuracy aimed at in positioning the vessel or lowering an object to the sea-bed is of the order of 1 or 2 m. The display in the control room shows, on the same screen, the position of the vessel in relation to the target position as given by the two taut wires and all three beacons (if they are all in use). All these position indications are usually within a circle 2 or 3 m in diameter.

The acoustic system was originally checked by putting two beacons 30 m apart on a spool piece and lowering this to the sea-bed. One of these beacons was used as a reference beacon for ascertaining the position of the vessel. The vessel was then moved around to find the worst heading from the acoustic point of view, while the position of the other beacon was being recorded. The results of this test are shown in Fig. 5, from which it will be noted that all the readings were included in a rectangle of 1.54 m by 0.89 m; and this includes two sets of acoustic errors.

Uncle John is, at present, unique in its ability to position accurately both ends of a spool piece by the simultaneous use of two cranes. Without this facility it is necessary to use guide wires to direct the ends of spool pieces into the correct position; this involves considerable delay. Consequently, our customers have made use of *Uncle John*'s mobility to send it round the oilfield, to lower all the required spool pieces to the sea-bed for other diving support ships to work on, and to make flanged or welded connections.

Cranes

Each crane is fitted with a line-out meter and with a repeater of the line-out meter of the other crane. The dive control superintendent has repeaters of both line-out meters. A pneumo-fathometer system is fitted as a back-up.

Manoeuvring the vessel

Uncle John has a transit control station, but this is not manned while the vessel is at work. All DP, machinery and communication controls are centred in one control room. This is adjacent to the radio room and the dive control, and has a view over the working side of the vessel. This is important since, on occasion, the deck edge has been as close as 10 ft to a steel structure whilst in the open sea. The control room is manned at any one time by two CROs, who all have either sea-going navigating or engineer officers' qualifications. They work 12 h on and 12 h off, as do all other offshore personnel.

To move the vessel, there are four pairs of buttons: one pair for ahead and one pair for astern; one pair for to port and one pair for to starboard. The inner button of the pair is labelled '.5 m', while the outer button is labelled '5 m'. The buttons may be pressed repeatedly. For example, to move 2.5 m to port, the inner port button must be pressed five times. Changing heading is equally straightforward: the desired heading is simply dialled in.

Obviously, any unprogrammed movement of the vessel can be disastrous. *Uncle John* is instructed to cease operating if weather conditions are such that the loss of any one diesel generator or any one propeller would result in loss of position holding. The six transverse thrusters provide redundancy in excess of this requirement, and it has been possible to meet these criteria for months on end with one thruster permanently out of action.

On one occasion a thruster ran away into full pitch. *Uncle John* still maintained station with other thrusters providing compensating thrust but there was chaos in the control room. All alarms were sounding, all red lights flashing, the generator on emergency stand-by starting up, and all generators on 10 min overload. Most of the thrusters were either full ahead or full astern, creating problems for the CROs as to which thrusters to shut down. Thus it is essential to record the order in which alarms occur, as well as to try and avoid this type of failure, to trace the cause of the trouble.

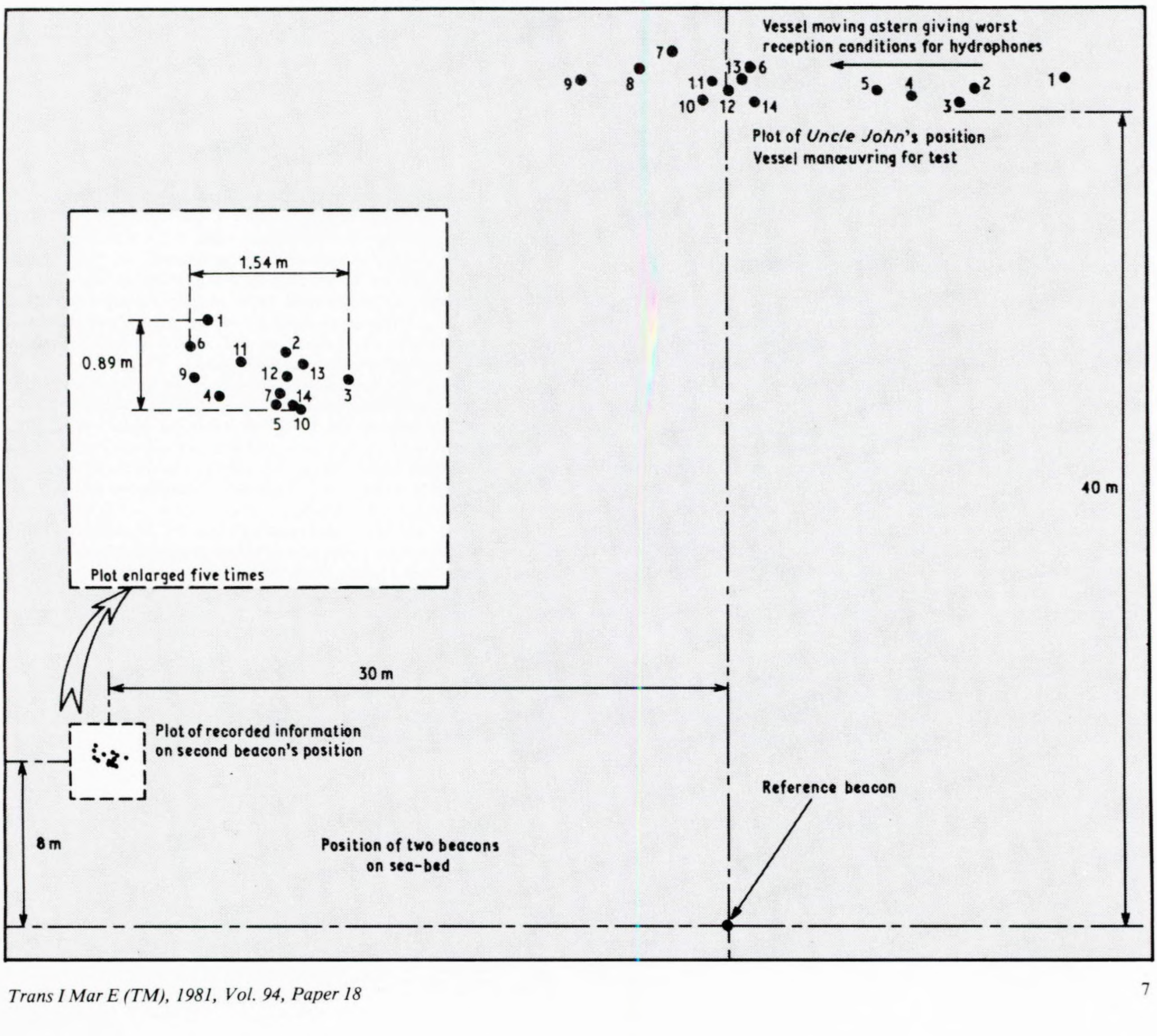
Diving support vessels can work in very bad weather when unrestricted as to heading and *Uncle John* can probably work in very much worse weather than any other diving support vessel in the world. The vessel is provided with a pen recorder printout of all the important parameters: heading, displacement fore-and-aft, displacement port and starboard, wind speed, wind direction and power to thrusters.

Figure 6 consists of an annotated length of this printout, taken when the weather was bad and diving operations were in progress. It will be noted that a dive was in operation throughout, and that the divers were disconnecting hydraulic hoses at a depth of 145 m. The vessel was being maneouvred to divers' instructions and the cranes were in use. The wind reached a maximum of 57 knots with an average of up to 44 knots. There was a long-period swell which makes life difficult for a semi-submersible; but, notwithstanding this, the vessel never moved further than about 3 m from the target position.

The vessel's emergency capability is illustrated by the following episode. At the end of October 1979 the northern North Sea encountered an exceptionally severe and prolonged storm which caused all vessels other than *Uncle John* to leave the field.

This started with a brief gale between the 18th and 20th October, with the average wind speed building up to 55 knots (peaking 57 knots) and waves building up to 7.5 m significant. There was a short lull on the 21st, when the waves dropped off to 2.5 m. From the 21st through to the end of the month the weather became steadily worse. The average wind speed increased from 30 knots at the start to 63

FIG 5 Accuracy test of acoustic beacon position reference system



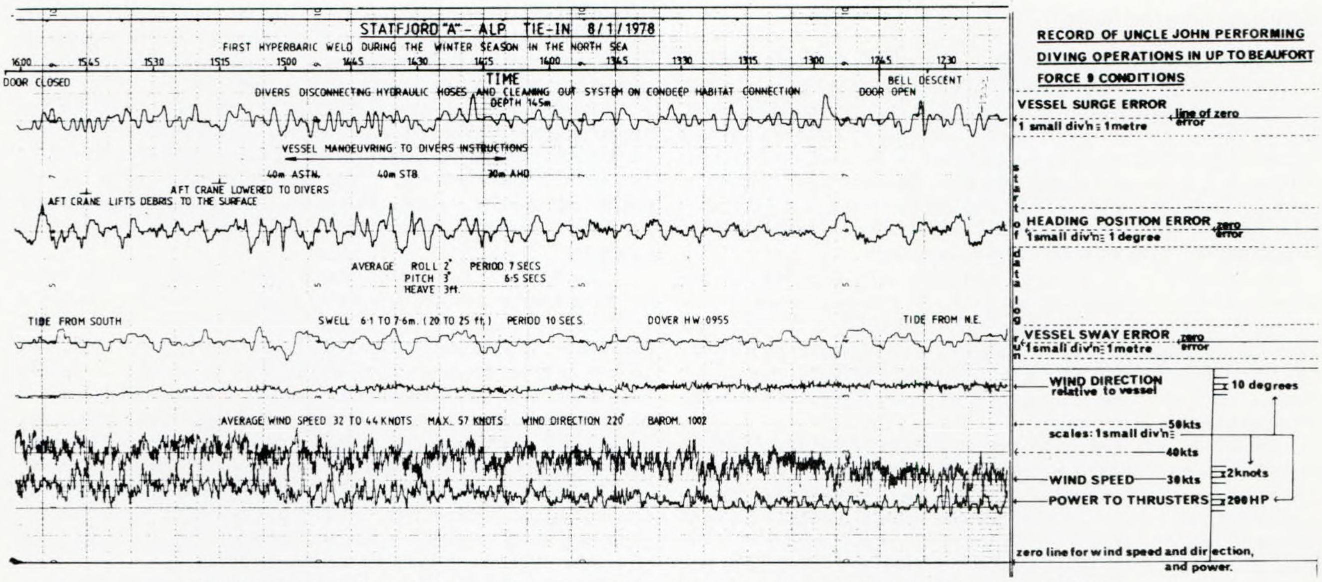


FIG 6 Record of *Uncle John's* performance: diving operations in up to Beaufort force 9 conditions

knots on the 31st, with maximum gusts of up to 84 knots. The significant wave height reached 10.5 m, the minimum being 4.5 m during the entire period.

On the 31st *Uncle John* was requested to proceed to the Shetland Islands to take on helifuel and bunkers for emergency supply to the Brent Field, since no supply boats had been operating for some time. *Uncle John* reached Fetlar after 8 h steaming, and loaded 34 tanks of helifuel, 400 tons of fuel oil, provisions and fresh water. She was back in the field by the afternoon of 2nd November and commenced supplying all Brent installations. On 3rd November the wind rose to 89 knots.

Uncle John also has a water spraying function which might prevent a platform being burnt to the water level. Happily, *Uncle John* has not been called upon for this type of operation, but the vessel does have the necessary monitors and pumps.

Command and management organization

The very few offshore failures which have occurred could all be traced back to faults in the organizational set-up; technical problems were the effect rather than the cause. If there is a confused chain of command on shore, the confusion is repeated and multiplied on board the vessel. For a complex job there must be one man on shore with complete authority over all concerned.

We started operations with the diving management at one end of a prefab and the marine management at the other. This became mirrored afloat; half those on board reported to the diving manager whilst the captain reported to the marine manager. A project manager, nominally in complete overall command, had little real authority. The situation came to a head one day when all the marine personnel were engaged in handling stores and maintenance and the diving personnel likewise. The project manager was, literally, standing by himself trying to handle heavy chain. The customer, who was paying many thousands of pounds per day for the vessel, was not amused and the ensuing row led to our present organization which has worked extremely satisfactorily ever since.

Uncle John is managed by a management company, Houlder-Comex, with nominal capital. The board is composed equally of directors from Houlder (the shipping company) and Comex Houlder (the diving company). The board has an executive committee consisting of one Houlder director and one Comex director. The Manager on shore, who cannot be bypassed, reports to the executive committee, and has under him a Barge Superintendent on board the vessel, who is responsible for getting the work done.

The Barge Superintendent has under him the Barge Master (the legal master of the vessel); the Chief Mechanic (this enables vessel maintenance to be co-ordinated, with construction work); the Dive Superintendent, and the Deck Foreman. The Barge Master is in charge of the CROs (control room operators).

CONCLUSIONS

The building of another *Uncle John* is not contemplated, because all the oil companies have taken advantage of the tax relief position to build vessels of this type for themselves when there is sufficient work to justify it. If we were to build another such vessel, the main change would probably be in the location of the control room. This is a difficult problem, as the control room should be large enough to contain all the machinery controls as well as the DP controls, and should be adjacent to the radio room and the dive control, and a *sine qua non* is maximum unobstructed deck space.

Uncle John meets these criteria but lacks an all-round view, which is most desirable. The limited view from the control room is compensated to some extent by the provision of radars on all four corners of the vessel. With specialized training and practice, this would probably provide a satisfactory solution but there are too many other things to do to be able to give much training for this activity, and the problem has not been solved.

Otherwise, we were reasonably fortunate in our choice of parameters. Dimensions and power are about right, but subdivision could be improved. Astern thrust should be considerably improved, possibly by having fore-and-aft propellers on all four corners of the vessel. As previously stated, we would not have thrusters which rotate, notwithstanding their greater efficiency, on account of the drydocking problems.

We are presently researching the cause of fatigue defects encountered on *Uncle John* and are investigating the effect of proposed modifications by experiment and analysis. It is hoped that the findings will form the subject of a future presentation.

Discussion

MR. C. A. BAINBRIDGE (Lloyd's Register of Shipping): It has been interesting to hear about the operational experience of *Uncle John*. As one of the Classification Societies involved with this vessel, we can state that this is one of the most carefully-documented operational experiences for semi-submersibles.

After the *Alexander Kielland* accident, Lloyd's Register of Shipping began an investigation into the operational experience of several of these sophisticated vessels. Mr Houlder made available to the Society the daily Master's logs over the first 3 years of operation, since 1977. These data are recorded every 4 hours and include platform heading, wind speed and direction, significant wave height, period and direction, significant swell height, period and direction as well as platform motions, temperature, location, etc. My comments and questions are based on the results of our analyses of these data.

On the subject of directionality, as *Uncle John* is dynamically positioned, the operational bias is towards 'head-on'. In fact, over the whole period investigated, *Uncle John* operates about 10 deg off head-on with the prevailing wind and seas approaching the port bow, because of the offset of the projected area of the helideck and other deck structures. This effect is clearly evident through all wave heights above 2 m.

There was no record of a wave of height of 6 m or above approaching the rig at more than 45 deg to its centreline. In any case, these wave heights would only occur for between 2–3% of the time during the summer months. Any stress measurements to investigate the effect of directionality would require *Uncle John* to be operated deliberately in a non-optimum mode; i.e. beam-on and, especially during a winter period, in this mode.

Regarding calibration, Lloyd's Register of Shipping were sponsors to the Shell Brent B instrumentation project. As *Uncle John* was working in this area, a calibration study was performed on the 5 months which overlapped with the *Uncle John* Master's logs. Preliminary results indicate good agreement at lower wave heights and an overestimation for waves above 8 m.

With regard to the air gap recommendations by Classification Societies, our investigations show that the vessel was at survival draft on 30 occasions during the first 37 months of operation (some 9.9% of the time) and not all at design extreme storm conditions. For semi-submersibles the Society recommends that model tests be performed to confirm that those parts of the structure not designed for wave impact will, indeed, not be subjected to these loads for extreme conditions at each draft.

In the paper, regular drydocking is mentioned as an absolute necessity. Has the time for this operation been included in Fig. 3?

The documented operational experience of *Uncle John* will be an invaluable aid for future designs and Mr Houlder is to be commended for this presentation. I look forward to his future presentation on the stress monitoring of *Uncle John*.

K. L. SEARLE (BP Petroleum Development Limited): First, could Mr Houlder explain the mode of transferring from one reference system to the tank wire system on approaching a platform?

Second, could the second speaker (Mr Young) say if any one of the fatigue analysis systems—namely strain gauge, mathematical or photoelastic models—can stand alone; or are all three complementary?

J. DAGLEISH (Submarine Engineering A/S (UK)): From Houlder Offshore's investigations into the failure of the DP system, does *Uncle John* operate within the limits of the worst failure mode or within the maximum capability of the DP system during diving and/or lowering spoolpieces?

E. J. BANNISTER (Shell International Marine Limited): The author has briefly mentioned that *Uncle John* has needed to be drydocked for a number of reasons and that, in retrospect, he wondered why his company had ever considered that routine drydocking would not be required.

Would the author please state what causes have made drydocking necessary; the type of work carried out, and the frequency of docking?

KNUT LARSEN (Wilh. Wilhelmsen): With reference to Fig. 3, the standby time seems low for summer. What WOW (waiting on weather) conditions are referred to when operation(s) started/ended?

Second, how many times have failure(s)/problems occurred with respect to DP/thrusters/generators/reference system?

Author's Reply

In reply to Mr Bainbridge, *Uncle John* normally moves away from its worksite when the significant wave height exceeds 5 m and thereafter stands by on the most comfortable heading in relation to the current sea state. Likewise, it works on this heading when free to choose. Freedom of choice probably occurs over about 50% of the working time; but, for the remainder, *Uncle John* has no choice as to the heading to be adopted. I think these facts give a complete explanation of Mr Bainbridge's figures.

It is possible to get a good idea of wave amplitudes when alongside a fixed structure; and our Barge Masters accordingly become familiar with the appearance of sea states up to about 5 m significant. In worse weather *Uncle John* is always clear of fixed structures and there is very little on which Barge Masters can base their judgement. The widely-used photographs supplied by the Meterorological Office are misleading, as they relate to 'fully arisen sea' which rarely occurs in the North Sea. The result is that, for a given wind speed, it will be found that wave heights are substantially less than those indicated in the photographs.

I fully agree the necessity for tank tests to determine the optimum air gap. *Uncle John* has a substantially larger air gap than the H-3s but has suffered no damage whatsoever on the underside of the deck; notwithstanding the presence of many very flimsy pipes (which should not have been there). Our H-3s have, however, experienced minor damage.

The time for drydocking is included in Fig. 3. It was anticipated that the only reason for scheduled drydocking would be thruster maintenance at frequent intervals. However, all drydockings to date have been necessitated by some development which was not foreseen. We have never found it necessary to drydock an anchored drilling rig—but a dynamically-positioned construction barge is something different.

In answer to Mr Searle's first question, the usual practice is to cautiously lower the first taut wire when about 100 m clear of a platform. Owing to the extreme difficulty of visually assessing range, it is usual to employ a small optical range finder. This also makes it possible to verify that the vessel is nearly stationary when the wire is lowered.

Thereafter the two taut wires are raised and lowered alternately, 'walking' the vessel to the desired position. When returning to a worksite on which the pinger is installed the approach is of course much easier, as it can be controlled by the acoustic system. Reliance is placed exclusively on the two taut wires to maintain station once divers are at work.

Regarding the second question, strain gauge, mathematical and photoelastic models are complementary.

Mr Dagleish's question can be simply answered: operations are undertaken within the worst failure limits.

In reply to Mr Bannister, some of the reasons for drydocking include: replacing protective wood sheaving; installing additional rubbing straites; installing additional buoyancy tanks; replacing hydrophones with jammed retraction mechanism; rectifying thruster defects; replacing anodes; rectifying underwater cracks in the structure; NDT of K joints, and so on.

Regarding Mr Larsen's questions, WOW begins when the master decides to stop work, by reason of weather, and ends when the vessel begins to move back to station to resume work.

There have been numerous individual failures of components of the overall sensing/DP/thruster but redundancy built into the design has been such that the vessel has never lost station.