Dynamic Positioning Vessels and Diving Safety

W. Thorniley MBE
Principal Diving Inspector, Department of Energy

SYNOPSIS

Diving operations in the support of the offshore oil and gas industry on the UK continental shelf are conducted under The Diving Operations at Work Regulations 1981 (which superseded the Offshore Installations [Diving Operations] Regulations 1975) and the Submarine Pipelines (Diving Operations) Regulations 1976. The author seeks to identify the failings of the dynamic positioning systems which put divers' safety at risk and explains what actions have been taken to overcome these deficiencies. He concludes that, despite diving fatalities and dangerous occurrences having been caused from dynamically positioned diving vessels, this method of station-keeping is most effective provided the guidance which has been issued is obeyed.

INTRODUCTION

Diving operations in the UK continental shelf oil and gas industry are conducted under the Diving Operations at Work Regulations 1981 (which superseded The Offshore Installations (Diving Operations) Regulations 1975) and the Submarine Pipeline (Diving Operations) Regulations 1976. The 1981 regulations require that 'Every diving contractor shall so far as is reasonably practical ensure that each diving operation is carried out from a suitable and safe place with the consent of any person having control of that place'. In the offshore industry the 'place' refers to an oil or gas platform, a pipelaying, trenching or construction barge or a diving support vessel which may be a semi-submersible or monohulled ship.

There are very few oil or gas platforms in North European waters which have 'built-in' diving systems. The ones that are so fitted provide the safest 'place' from which to operate divers. Many of the installations have diving systems placed on board, often in areas which are most unsuitable and not designed to take this equipment. It is often a compromise of interests between the diving supervisor and offshore installation manager. For many years I have been doubtful whether deploying air divers from some 30 m above the sea, in a basket suspended from a crane, meets the requirement of 'a suitable and safe place'.

The alternative to deploying the divers from the installation is to operate them from a vessel which has the advantage, particularly in 'air' diving, of reducing the vertical separation of the diver from his supervisor and compression chamber. The main drawback is that this method of operating divers often increases the horizontal distance that the diver must swim to get to his work.

Until the introduction of DP vessels, the diving support ship had to moor in close proximity to the installation. This operation in itself was not always easy as the seabed near many platforms is like one's wife's knitting after the cat has played with it. There are usually pipelines, flowlines and mooring cables from other vessels making it possibly dangerous and impracticable to lay anchors.

The ideal answer to the problem of placing the mobile diving platform in close proximity to an offshore installation is the use of DP systems. However, this method can, in itself, be of danger to divers if the ship does not operate to very high standards of station-keeping.

DANGERS TO DIVERS

Divers working from DP vessels can be put at risk by three very basic failures. First, should there be a defect in the DP system or if its propulsion units have insufficient power, it may 'drive off' or lose station owing to the elements. If divers are deployed at their work site, whether operating from a bell or from the surface, they may be dragged through an installation jacket or into one of the many other obstructions on the seabed. When this happens there is a serious risk that the divers will be killed. The next inherent danger in diving from a vessel with propulsion machinery operating is that the diver, his lifeline or other equipment may be drawn into the propeller or thruster units, with probable fatal results. Finally, there have been recent incidents of divers being snagged on taut wires and their weights when these are moved.

Bill Thorniley joined the Royal Navy in 1945 and as a seaman officer qualified clearance diver in 1956. He served in many diving appointments including research into deep diving and also commanded several ships. He resigned from the Royal Navy in 1975 and joined the Diving Inspectorate of the Department of Energy. He was promoted to Principal Diving Inspector in 1978.

DP failure

In August 1978, when DP vessels had only recently started diving operations in North European waters, the Chief Inspector of Diving issued the following Diving Safety Memorandum, which quotes from both the Offshore Installation and Submarine Pipelines Regulations.

> 'Under prohibited diving operations in diving legislation it states that "it shall be the duty of the employer of divers and the diving supervisor each to secure that no diving operations are carried on, and the duty of the diver not to carry on any diving operation from a vessel or offshore installation which is underway". Legislation goes further to state "provided that a vessel or offshore installation is using its propulsion system or a dynamic positioning system it shall not be regarded as underway if either or both of these systems are in operation and are maintaining the vessel or installation in a stationary position on a fixed heading and precautions are taken to secure the safety of the divers from those systems and the flows of water thereby created".
>
> There have been indications that some of the less sophisticated dynamic positioning systems are apt to go erratic on occasions. This could cause a highly dangerous situation if a diver is operating outside a diving bell when this happens. Considerable care must be observed when operating divers from a dynamically positioned vessel or installation. The position system should at least be fitted with a fail safe back-up system.'

Double fatal accident 1978

Despite the above warning there was a double fatal accident a few months after the above memo was issued. In this incident, the vessel did not 'drive off' but had insufficient power to overcome the effects of the wind when operating in close proximity to an installation. The divers were working from the bell at a depth of 102 m, which was 18 m above the seabed. As the weather conditions deteriorated with increasing wind, the diver was recalled to the bell with a view to aborting the dive.

When the squall had passed, diving recommenced. Gradually the weather again deteriorated and this time, with one diver out of the bell, the ship was blown against the platform. The Master went on to manual control and sounded the dive abort alarm. The diver returned to the bell but found his umbilical was snagged; this was cut, and the inner door was closed to obtain a pressure seal.

Unable to manoeuvre the ship with the joystick control and thrusters, the Master used the main engines to prevent a second collision with a semi-submersible 'flotel' moored alongside the installation.

When the bell was being recovered it was noticed at 30 m from the surface that there was considerable strain on the umbilical, guide wire and main cable. Suddenly all connections with the bell parted. It was subsequently found out that the bell had become foul of one of the flotel's mooring cables and, as the diving vessel manoeuvred to get clear, it had cut the umbilical and wires securing the bell to the ship, acting rather like a minesweeping wire. The bell plummeted to the sea bed with the pressure seal on the door breaking as the bell passed the equivalent pressure, causing it to open and partially flooding the bell.

Although both divers were seen to be alive when the bell was eventually located by a submersible, they died as a result of hypothermia due to the delay in recovering the bell.

This accident prompted the Chief Inspector of Diving to issue a further Diving Safety Memorandum in January 1979 as follows:

> 'The attention of all diving companies and Masters of vessels carrying divers is drawn to the inherent dangers of operating divers from dynamically positioned vessels especially in the close vicinity of structures and underwater obstructions.
>
> A research project has been initiated aimed at producing advice on the safety parameters to be employed when using this technique.'

Subsequent to this memo a research contract was placed by the department with Hollobone Hibbert & Associates to investigate the problem of operating divers from DP vessels. Mr Jeremy Daniel was the author of the 'Guidelines for the Specification and Operation of Dynamically Positioned Diving Support Vessels'. It was issued in 1980 jointly by the Norwegian Petroleum Directorate, with whom we work very closely, and the Department of Energy.

Accidents due to propulsion machinery

Prior to 1982 most of the DP vessels, which were being built in ever-increasing numbers, had been operating in the northern North Sea basin in support of bell divers. Though there were no more fatal accidents between 1978 and 1982 resulting from DP operations of divers, there had been many 'dangerous occurrences' due to vessels 'driving off' and the effects of thrusters.

In the summer of 1982 DP vessels started to work in the shallower waters of the southern North Sea. One diver had a lucky escape from death, owing to his presence of mind. He was diving on air, that is, less than 50 m, from an open basket, to which he had just returned when he felt a violent pull on the umbilical. He realized that it had been drawn into either an after thruster or the propeller. He quickly released his 'band mask' breathing apparatus and also his umbilical securing clip to his harness. He took the reserve mouthpiece and started breathing from the cylinder provided in the basket. If he had not realized his predicament he would have ended as another fatal accident in the Diving Inspectorate files.

This incident and another fatal accident which may have been related to air diving from DP vessels caused the Chief Inspector of Diving to issue the following Diving Safety Memorandum in November 1982:

> 'The operation of thrusters and propellors on dynamically positioned vessels can present hazards to divers. This particularly applies to surface oriented diving.
>
> Divers' umbilical lengths should be physically restricted to a length which would not permit the diver, under any circumstances, to come in contact with any thruster or propellor. Should the diver be operating from a bell or basket the same drill must apply. Whilst recovering the bell or basket to the surface particular attention must be paid by the attendant to ensure that the umbilical from the surface to the bell or basket does not form a bight which in turn could become involved in thrusters or propellors.'

Revision of guidelines

In 1982 the Department of Energy and Norwegian Petroleum Directorate jointly funded a review of the 'Guidelines for the Specification and Operation of Dynamically Positioned Diving Support Vessels'. The new publication was again written by Mr Daniel and published in both Norwegian and English by the Norwegian Petroleum Directorate in 1983.

DP accident in the Norwegian sector

In 1983 there was a further DP diving fatality, this time in the Norwegian sector, when a diver was sucked into the thrusters whilst working in the air range. It would appear that this resulted from poor tending as too much umbilical was let out, thus enabling a bight to be drawn into the thruster.

Further advice was given to the industry by Diving Safety Memorandum No. 6 issued on 6 May 1983, as follows:

> 'The level of diving accidents and incidents in air diving operations from dynamically positioned vessels is giving cause for concern and, in particular, the potential hazard arising from divers or their umbilicals becoming fouled in propellors or thrusters.
>
> Diving Safety Memorandum No. 21 of 1982 drew attention to these potential dangers. However, some companies, supervisors and divers do not appear to be following the advice provided.
>
> Regulation 5(2)(a) of the Diving Operations at Work Regulations 1981 requires that every diving contractor, so far as is reasonably practical, ensures that each diving operation is carried out from a suitable and safe place.
>
> Care must be taken in the selection of vessels and the personnel used for these operations to ensure that they have the necessary capabilities and are operated in a manner which meets the statutory requirements.
>
> Proper procedures must be written into the diving rules emphasizing the importance of close and efficient supervision, good diver attendance and full communication coverage at all times.
>
> A vessel operating on DP may not always provide the necessary suitable and safe place for diving operations and other means must be considered.
>
> If a safe diving position cannot be maintained, then it should not take place.
>
> The following list, which is not definitive, provides points for consideration when planning surface orientated diving from a vessel in the DP mode.

1. The need for good supervision.
2. The need for good diving.
3. The provision of efficient bridge/diving control communications.
4. The provision of efficient diving communications.
5. The use of a conventional bell or an open bell.
6. The position of the diver close to the task.
7. The type of diving (i.e. splash zone area, shallow, deep etc.).
8. The choice of diver umbilical (buoyant or heavy).
9. The use of cranes.
10. The use of anchors.
11. The employment of lines to the structure.
12. The possibility of demobilizing the azimuth thruster, tunnel thruster or propellors in the vicinity of the diving operation.
13. The need for emergency and abort procedures.'

THE PRESENT SITUATION

At the time of writing this (July 1984) it is obvious that not all the problems of diving from DP diving support vessels have been overcome. Recently, a vessel which, to the best of my knowledge, has been operating successfully for the past 18 months on DP, had generator failures on three occasions causing 'drift off', there being no power to operate the thruster units. On investigation, it was found that there were defects on all of the ship's five generators. This emphasizes the need for efficient testing and planned maintenance. It was an expensive failing for the owners as the ship was out of action in an excessively busy summer season for several weeks. Luckily there was no injury to personnel.

On the plus side, a large semi-submersible was planned to operate with DP in the shallow waters of the southern North Sea. We in the Diving Inspectorate were very concerned as it was due to work in close proximity to a platform with little water beneath the pontoons, in strong tides and potentially strong winds. A very searching survey of the semi-submersible was carried out on behalf of the operators and a comprehensive trials programme was conducted in similar environmental conditions to those predicted during the operation. The trials were successful and so have been the diving operations as I write this paper.

At present there have been reports of divers being put at risk by moving the vessel with the divers down. On one occasion a diver was snagged in the taut wire weight when it was being lifted. He was lucky not to suffer the effects of too rapid decompression.

CONCLUSION

I have written this paper as we in the Department of Energy Diving Inspectorate see the failures and successes of DP vessels in support of diving operations on the North European continental shelf. It is our job to be critical and I may have given the impression that this system of stationing vessels has been a disaster. I have not spent much time giving details of the many thousands of ship-hours that the DP systems have operated with successful precision and without danger to divers. Despite the failures of the past I am convinced that DP is the most efficient method of stationing a vessel close to an offshore structure. I make one provision and that is that all concerned, from the operator who selects the vessel to the owner who provides it and the diving contractor who deploys divers from it, must comply with the Guidelines and advice given by the Department of Energy and Norwegian Petroleum Directorate.

BIBLIOGRAPHY

1. The Offshore Installations (Diving Operations) Regulations 1975.
2. The Submarine Pipelines (Diving Operations) Regulations 1976.
3. The Guidelines for the Specification and Operations of Dynamically Positioned Diving Support Vessels 1980.
4. The Diving Operations at Work Regulations 1981.
5. The Guidelines for the Specification and Operations of Dynamically Positioned Diving Support Vessels 1983.
6. Department of Energy Diving Safety Memoranda Nos 19-1978, 2-1979, 21-1982 and 6-1983 issued by the Chief Inspector of Diving.

Discussion

A. N. S. BURNETT (Offshore and Marine International Services): I welcome these papers, covering as they do a range of subjects. I should like to concentrate on just one or two items.

We are a technical institution and as such concerned with technological matters, but the offshore industry is concerned with commercial gain and activities related to this end; i.e. profit. Mr Daniel's paper covered personnel and safety and training aspects; these are particularly vital in submarine work but it must be remembered that they also involve considerable expense. A recent paper on drillships presented to RINA described the duplication of manpower required in many categories on board, particularly in electronics and DP control, with more and better-trained staff required to do the job satisfactorily.

The important issue is safety—to avoid collision; to abort the system on alarm alert. Mr Harper mentioned hidden failures and it seems to me that the key question here is, how will the safety systems and equipment operate so that there is no danger of a hidden failure occurring and remaining hidden until it manifests itself in a possibly catastrophic event? Would the author care to discuss the need for a system to monitor hidden failures?

On the same question, I should like to ask Mr Barber whether his system can audit a hidden failure.

To summarize, in the offshore industry we must operate commercially but with a reasonable degree of safety. The question is, how can we do this economically and yet still show a profit at the end of the day?

CAPTAIN C. A. JENMAN (Global Maritime): First may I confirm Mr Harper's statement that Shell took a very comprehensive engineering view with the design and assessment of the MSV *Stadive*. Shell Expro awarded Global Maritime not only the FMEA mentioned but also we went on to carry out a very detailed reliability analysis for fire control and an availability study for fire fighting. Shell was keen to know the probability of the vessel being able to fight a major fire at any time in her working life.

This moves me on to the challenge offered by Mr Daniel. We have looked at mean times between failures of all DP components and we have put failures in terms of risk. This data bank is very useful in putting failures into perspective.

Assessments, as mentioned by Mr Barber, are never simple tasks and, to be effective, the surveyor has to be highly experienced and pragmatic. I notice that on the example given in Mr Barber's paper (Fig. 6) his modification does improve the system, but I recognize this design and I believe that the two transformers there are redundant and cannot both be simultaneously on line. If this is the case then a fault on one side of the high voltage board would cause an instant loss of all thruster control. High voltage switchboards are very reliable but a better modification I believe is, in this case, to run independent 440/220 transformers to the thruster controls in line with the split of thruster high voltage supply.

Finally, I was delighted to hear from Mr Thorniley of the very searching survey and trials of the semisubmersible brought in to work in shallow water in the southern North Sea recently. I carried out that work. The vessel was very well appointed and its owners/operators, like all others, considered it perfect with respect to the DOE/NPD guidelines. It was not. I have carried out audits of several vessels and I have not found one that completely meets the single failure criteria. The fact that I may find a dozen critical single failures does not mean that the designers or owners have been negligent. It is that a fresh pair of eyes, specifically looking across the interfaces of the design packages, can see things easily that others have missed. This is a very good reason for an independent assessment. If a dozen critical failure possibilities are identified during a single survey it is likely that there are still two or three for the operators to find from experience. The essential points are, however, that the guidelines have been followed, i.e. an FMEA has been carried out and the risk of a catastrophe has been reduced, albeit not removed.

R. J. PAGE (Chevron Petroleum (UK) Limited): Anyone reading the papers might be led to think—incorrectly—that safety auditing only involved engineering matters. This is totally wrong; a team effort is required, as the Master has the ultimate responsibility for the safety of his ship and would be held responsible for every accident. The Master therefore must have a general knowledge of all systems on board his ship, to enable him to appreciate the situation if certain machinery units failed. The value of these meetings is in getting Masters and engineers to discuss common problems and act in unison.

The shipping industry and, in particular, some shipowners have been slow in laying down guidelines and checklists. This is a job for the industry, not the government, and the industry has only itself to blame if the government were to lay down regulations which the industry did not like.

The government should concentrate its efforts on collecting and promulgating information on failures and accidents so that everyone learns from past mistakes.

D. W. ROBINSON (Lloyd's Register of Shipping): I would like to make a comment about item (a) of the Audit described by Mr Barber and, in particular, the performance capability graph. In fact, items (a) and (f) are directly linked when the performance capability graph is considered. Whilst agreeing with the philosophy that operational data are better than theoretical values, there are considerable difficulties in time and quantification of meeting the wide range of possible limiting conditions. In fact, they may never be achieved. We would, and do, suggest that theoretical capabilities plots such as the one I illustrate in Fig. D1 are available and modified in the light of experience. Even this presents difficulties in quantifying objectively the environment in which the vessel is operating, i.e. wind speed, current velocity and direction and wave conditions.

I would like to take this opportunity to mention that Lloyd's Register of Shipping is currently talking to BP Shipping about full-scale measurements which we anticipate will take place this winter aboard *Iolair* to answer some of the questions raised. As well as the performance of the DP system, we will be making independent measurements of the environment to calibrate the theoretical model and define the most important variables.

An alternative approach to an assessment under operational conditions is a comparative assessment under standard environmental conditions, and Lloyd's Register has recently instigated Rule changes to award supplementary Performance Capability Ratings or PCRs, as they will doubtless become known. This type of comparative assessment is probably insufficient for the detailed audit described, but would be useful to complement the procedure.

C. J. PARKER (Secretary, The Nautical Institute): First I would like to congratulate the speakers on the way each has developed a rational and effective method of establishing whether or not a DP vessel will meet its performance expectations. I have never participated in a seminar such as this where

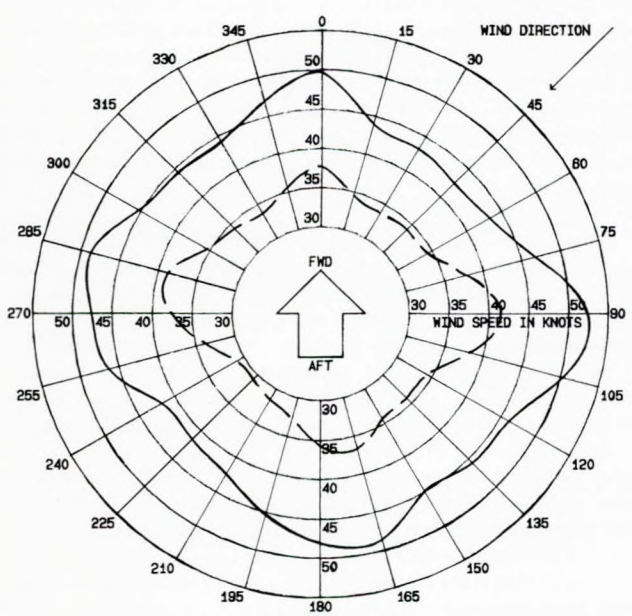
so much detailed attention has been given to the operation of a particular type of marine vehicle and I find this very heartening.

We have seen from the speakers and from some of the comments from the floor that their tests relate to designed criteria, power units, distribution networks, control systems etc. but are not co-related with the operating practices. While decisions are taken to hire and offhire vessels, there appears to be no commitment to employ those vessels within their design criteria. I understand that frequently DSVs are worked to the limits of weather windows and downtimes. Essential maintenance may not get done and test routines may be postponed. If this is so, what steps do the authors see as being necessary to prevent DSVs being worked beyond their design capabilities?

I. TURNER (Lloyd's Register of Shipping): I should like to congratulate Mr Daniel for a most interesting, informative and well presented paper. Whilst acknowledging that providing an adequate definition for DP is not an easy matter, the author gives what he considers to be a reasonable definition, namely: the objective being 'to hold a vessel in its desired position automatically without the use of physical restraint'. He further states that the word 'automatically' means that manoeuvring control must be achieved without manual input.

Clarification of this definition would be appreciated with regard to an independent manual back-up joystick control system.

No doubt the intention of the DOE Guidelines would be to consider joystick control as forming part of the DP system. However, the definition of what constitutes a DP system should, as far as is reasonably practicable, be free from ambiguity. This is particularly pertinent in the case of one DP control system manufacturer who considers the automatic features as forming the DP control system and refers to the joystick/rotate controller as 'manual control'. This sometimes leads to confusion with regard to information, data, alarms etc. to be provided for the 'manual' system.



——— All thrusters in operation – – – One inactive thruster

Current speed: 1 m/s.
Windspeed relates to hourly mean.
This plot is based on vessel design criteria and should be modified in the light of practical experience. Any modifications to be submitted to Lloyd's Register for approval.

FIG. D1 Dynamic positioning capability plot

To assist in clarifying the situation, and with a view to offering a broader definition of what constitutes a DP system, the author's attention is drawn to Lloyd's Register of Shipping's 'Rules for Ships with Installed Dynamic Positioning', from which the following extract is taken:

> 'For the purpose of these Rules dynamic positioning means the provision of a hydro-dynamic system with automatic and/or manual control capable of moving, manoeuvring and holding the desired heading and position of the ship during operation in the environmental conditions for which the ship is designed and/or classed.'

J. SIMPSON MNI: At present I work with the Marine Operations Department of Bechtel but formerly held command in DSVs for 7 years.

Although a pleasure to hear eminently sensible papers and reasoned discussions on the subject of dynamic positioning, the perspective of the subject when viewed from the cloistered comfort of the designer's chair or debating chamber is entirely different to the view from the wet and windy sharp end of operating a DSV. Direct responsibility for a DSV heaving about in the typical scenario of the marginal conditions that so often pertain, with a diver out on the end of his umbilical struggling with the crane hook while the crane jib points nicely at some highly vulnerable part of the very closely adjacent structure and the weather steadily deteriorates with 'only an hour or so to finish the job', concentrates the mind on system reliability wonderfully. The harsh, cold reality of the job of making a DSV work was not in any way highlighted by the debate and this in some small way I beg to remedy, and perhaps give some sense of urgency to problems that still confront dynamic positioning.

It is my experience that offshore vessels do tend to operate as fully integrated teams with generally excellent interdepartmental co-operation and a minimum of demarcation. This attitude is probably engendered by the strange and largely hazardous work habitually undertaken. The co-operation sought by one of the questioners I feel was that between manager/designer and the vessel's crew. Unfortunately, but traditionally, inbuilt into British shipping seems to be a mutual credibility gap separating operating crews and managers which means that the open and honest interchange of ideas that should flow both ways to mutual benefit is at best stilted, and at worst stifled. The rapid advance of high technology makes it imperative that this gap be closed, and in this respect the contribution of independent consultants and assessors, who gain access to vessels *and* management, may be a crucial one.

Another point raised, almost wistfully one felt, was that faults, near misses and incidents be publicized for the edification of all. With the present cut-throat state of the DSV market no company is voluntarily going to air its dirty washing in public to the instant glee of competitors, praiseworthy though the long term objective might be. Yet, is temporary corporate embarrassment really more important than a diver's life, because that is what we are addressing ultimately? Surely it is not beyond our wit to set up, confidentially if necessary, a data bank of object lessons learned with a suitably neutral body.

A major concern faced by every DSV Master is 'competitive edge'. The dive support market is highly competitive and if one's vessel does not perform then another, probably foreign flag, probably newer, probably better equipped and more sophisticated and almost certainly with better power-to-weight ratios will be waiting in the wings more than ready to take over. Pressures are very real and very intense to keep working a vessel up to and beyond the red line of environmental limits. Here I would beg to differ with one of the speakers in that some vessel's theoretical environment footprints, or operating capability envelopes, are very optimistically drawn and one has to cope not only with charterer's pressure to get the job done but also with the pressure of avoiding weather downtime

to maintain the vessel's advertised credibility. One can appreciate the commercial reasoning behind these pressures but the stresses they impose on men and machinery are obvious and detrimental. Owners/managers should accept the actual known limitations of their vessels and market them honestly. Charterers, having accepted that vessel, should also accept with good grace that only the Lord controls the weather, and not expect miracles from DSVs to compensate for His works, inconvenient though it sometimes may be to scheduling!

We have come a long way from the early days of single bow thruster, single stern thruster, single screw, single computer, single position reference system vessels, where redundancy meant a place in the dole queue. Divers no longer pick up their seabed acoustic transponder and walk in order to move the vessel.

However, the maturing of dynamic positioning and the tremendous technical advances made both above and below water have not eased the often hair-raising burden of diver and DSV operator, as might have been expected. Rather, these advances have given the industry the capability to perform ever more complex and mind-bending projects. The worries of DSV engineers have not eased either; quite the reverse. In many cases the increased workload imposed by complex and sophisticated equipment has not been fully appreciated by management; some vessels suffer inadequate engineering staff, both mechanical and electrical/electronic; almost all suffer lack of maintenance time in the working season—even when built into a contract it is usually deferred by management in the hope of picking up the spare days as a cash bonus or as a reserve against breakdown time.

Also unappreciated is the tremendous amount of machinery external to the engine rooms on DSVs, and these include cranes, deck winches, tuggers and more often than not a number of skid mounted power packs in temporary residence on deck, sometimes of dubious origin and questionable condition but nonetheless vital for the operations in hand and therefore needing maintenance. I once counted nine different *makes* of diesel engine on board at one time and I am sure that others can beat that.

Charterers also always demand that everyone be fully qualified, trained and experienced, no learners please! Hence DSV managers of all flags always offer 'fully experienced' crews. Yet the simple mathematics do not add up. On one hand there has been an unprecedented rapid increase in the number and sophistication of DSVs. On the other side of the equation, up until very recently, there has been no formal training facility and in many cases tight budgeting, which has not allowed for trainees to be carried on existing DSVs for on the spot experience.

The answer must be that out there are some DSVs with largely inexperienced crews in all ranks. DSV operations are now so complex and varied that the concept of 'walk on and watch it for a couple of days, you'll soon pick it up' can no longer be accepted with equanimity by any part of the industry.

Assessors are right to demand qualified and formally trained personnel and the training, or lack thereof, nettle needs to be firmly grasped by all concerned. Yet again the Norwegians seem to have stolen a march on us but it is heartening to see the Aberdeen facility appearing and I hope it will be used to capacity. Let us hope also that a suitable course combined with real field experience leads soon to recognition by the Department of Transport that there is a necessity to formalize a very loose situation. No manning loopholes for foreign flag operators in the British sector either please, thank you!!

Dynamic positioning as stated in the papers is here to stay, not only in dive support but other marine operations as well. If we in Britain are to capitalize on this newish development then we need fully to identify future vessel needs, design them with full redundancy and more than just a nod in the direction of single point failure, design them with more than adequate thruster power for their design limits and not, as so often happens with British offshore vessels, 'Just enough to cope', and initiate and insist on full crew training. Simple really; the only problems, of course, are convincing our accountants that it is really necessary, and our Government that encouragement for an active modern merchant fleet needs just a little more than lip service.

Authors' Replies

J. J. S. Daniel (Paper 2):

The answer to Mr Burnett's question, 'How can we operate safely and yet show a profit at the end of the day?', must lie in the definition of 'safely'. This involves a concept of 'acceptability of risk'. The objective must surely be to design systems and to train people to operate them, in such a way that the risk associated with them is acceptable.

How risk is measured and what is acceptable are both subjects about which much has been written and said. In practice, so far as DP is concerned, it is surely necessary to spend a small proportion of the total cost of operating DP vessels on training operators to a standard which will at least reduce, as far as can be reasonably expected, the risk of their making a mistake which could result in an accident, perhaps causing loss of life and high financial cost. Less than 10% of the annual salary of a DP operator, paid once in his career, would not seem an excessive investment and this is probably the sort of figure involved.

I am delighted to hear of Captain Jenman's work on mean times between failures of all DP components and feel sure that, if reasonably reliable, they will offer a major contribution to improving the reliability of DP through design.

I can also support his views concerning vessels not meeting the single design criteria. After 19 DP assessments, I too have never found one which completely meets these criteria. I would also stress the importance of carrying out comprehensive sea trials as well as design audits and equipment surveys. On an assessment I have carried out since the seminar, I discovered a software fault stemming from incorrect ship's drawings being used by the computer manufacturer which, under some conditions, caused a drive off. The ship had been operating for about 8 months on charter to several successive oil companies. At no time had this potentially catastrophic fault been discovered, nor could it have been by anything but rigorous sea trials.

I entirely endorse Mr Page's plea for the Master to have a general knowledge of all systems on board. It is to this end that the Aberdeen Technical College is about to offer DP operators and other DP courses and that The Nautical Institute is promoting a form of DP operator training and certification.

So far as checklists are concerned, I must express reservations. They are very valuable for specific systems; a good example would be cockpit checks for individual aircraft types. The more general their application, the more they leave to the interpretation of the user until they eventually become an *aide-mémoire*. Providing the user has proper understanding of the subject, they play an important role. Otherwise they are potentially dangerous.

Would that more details of failures and accidents or, better still, near misses were available. Life being what it is, I fear Government may not be the best vehicle for that collection and promulgation.

The answer to Mr Parker's question seems to me to be twofold. First, good design will reduce the impact of failures, whether they stem from fair wear and tear or poor maintenance, and it is therefore to be hoped that the latter will not cause catastrophic failures. Second, rigid application of the principle of

reducing operations when system redundancy is lost will result in considerable offhire time for ships where maintenance is not carried out diligently, as well as delays to charterer's programmes. Both these provide strong incentives for proper maintenance and will, hopefully. have an ultimate effect on the admittedly worrying present situation.

The definition of dynamic positioning offered in Mr Turner's question does not accord with my interpretation of the meaning of DP. DP to me, though I fully recognize not to everyone, assumes automatic positioning control. Historically it would appear that DP was originally applied to automatic systems and only extended to cover manual position control when the latter was offered for some roles for which automatic control was not yet adopted, such as supply ships. Nowadays common usage seems to exclude its use in this context, the trade name POSCON often being adopted instead.

So far as the intention of the Department of Energy Guidelines is concerned, they consider the DP system to be automatic and only look upon any 'independent' joystick control as an acceptable manual backup (subject to some pretty stringent requirements) for temporary use while the operation is being abandoned.

Where Captain Simpson's points are not covered by my earlier replies, I thoroughly support his observations.

S. W. Barber (Paper 3):

Mr Burnett has correctly identified 'hidden failures' as a cause for concern in the choice of a DP vessel for any specific operation. Unfortunately, no audit can guarantee to locate all, or even some, of the problem areas that a particular vessel may have. An audit is a coarse filter where the primary function should be a comparison between alternative vessels rather than an absolute judgement of one. In this respect commercial factors are also taken into account. Where various vessels are offered for an operation, a higher day rate may be justified if the vessel is better suited to that operation. Only an audit can determine that suitability.

I would endorse Captain Jenman's view of the vessel auditor as a fresh pair of eyes engaged in an overview of systems and interfaces. It is important that such a fresh view is taken in the light of each specific operation proposed. This is the point behind Captain Jenman's view of a modification initiated on one vessel. He is correct in his view that independent transformers to the thruster controls would be the best solution for any operation. However, the modification carried out was acceptable for the specific operation required of the vessel and had the advantage of being fast and simple to execute on that vessel.

Mr Page is right in his assertion that a good ship runs as a team headed by the Master. I would agree that the Master must have a full knowledge of all equipment and systems on board his ship. However, the purpose of an audit is to ensure that the vessel can perform its function as a platform from which the required operation can take place, and that the ships' company, headed by the Master, is fully capable of running that operation.

It is also the case that the marine aspects of the vessel and the intended operation must be investigated in tandem with the engineering aspects. However, usually the marine aspects do not involve such a detailed investigation unless the vessel is novel or the operation particularly unusual.

Mr Robinson's view of the difficulty in generating a real operational performance graph is well founded. It is impossible to generate data to cover the whole range of limiting conditions, both environmental and mechanical, that are encountered. A theoretical graph is the only possible basis. However, as pointed out by Captain Simpson, some theoretical graphs are very optimistic. I believe that such theoretical graphs are capable of basic point validation and should be so validated. Under any particular condition of weather and thruster configuration it is possible to turn the vessel's head away from the wind until position keeping ability is lost. That point, transposed to the theoretical graph, with a note as to sea state and assumed current, is of value as a check against the theoretical prediction.

Mr Parker has expressed concern over the use of vessels outside their design criteria. The establishing of these criteria is an important part of the audit. It is not in the interest of owner or charterer to push a vessel to the limit of its operational capability, unless that limit is clearly understood and no alternative vessel is available. I would also endorse Mr Parker's view that distinct periods for maintenance and testing are required. An auditor can only ensure that such routines are up to date at the time of the audit; during the operation itself, other judgements may be made.

It was with pleasure that I read Captain Simpson's contribution to the discussion. It is sound and eminently sensible, as would be expected from Captain Simpson's experience as a DSV Master. His description of the problems of operating a DSV in adverse weather and tight conditions, under pressure from owner and charterer, reveals the tremendous responsibility that is placed on the shoulders of the Master.

It should be the auditor's aim to identify the vessel's capability to a point where such pressures are not imposed because the limit of the vessel's operations are clearly understood. However, this is in reality unlikely ever to be the case and the industry owes a debt of gratitude to the Masters and crews of DP vessels for achieving the acceptance that dynamic positioning enjoys in the industry, under operational conditions where the capability of men and machines is often pushed to the limit and beyond.

R. I. Harper (Paper 4):

Mr Burnett raises a very difficult subject, when asking how hidden failures can be monitored. As I stated in my paper, and during the subsequent panel discussion, it is not practical to try and alarm all hidden failures; the alarms themselves could introduce additional faults and, of course, mean more complexity. A comprehensive failure modes and effects analysis (FMEA) should result in identification of most of the potential failures. At this stage an assessment must be made as to which of these are likely to remain hidden with critical consequences; these should be detected by monitoring devices and alarms. Other, less critical, hidden failures should be monitored by regular test procedures. Correctly formulated tests should show up both anticipated and unforeseen hidden failures, before any consequential effects materialize.

Within the dynamic positioning system itself, the computers have the ability to make a large number of very rapid checks of all interfaces, as well as carying out their own internal function checks. This ability should be utilized to maximum advantage for the detection of hidden failures.

Whilst appreciating Captain Jenman's concern in identifying critical single failures, I think we should be careful in assessing the significance of some of the single point failures found. The experience gained by the Consultancy and Technical Services division of Shell International Marine Limited is that, if the vessel is operated within its redundancy limitations (e.g. allowing for worst thruster failed or largest generating set failed), many of the critical single failures may become non-critical. This was our conclusion from the *Stadive* studies, and has

been confirmed by the many DSV surveys carried out by us during the last 2 years.

I fully endorse the comments from Mr Page and Captain Simpson on the necessity for teamwork, both onboard DSVs and between ship and shore. It may be of interest to them that a series of DP Seminars was held during the initial work-up time for the *Stadive*, which were attended by the Masters, chief engineers, control room operators, DP operators, electronics officers and shore-based staff concerned with DP operations. These were found exceedingly valuable, particularly in explaining to ship's staff the operating philosophy of the vessel, and in permitting feedback from the ship to the shore team. It was also the first opportunity many of the different disciplines on board had had to air their questions in front of each other.

Captain Simpson also refers to the competitive pressures which are the subject of Mr Parker's question. This relates to the responsibility of charterers of DSVs to ensure that adequate standards are maintained by operators, and that vessels are restricted to working within the limitations imposed by their designers and by qualified surveyors. In this respect, I would suggest that the UK Offshore Operators Association (UKOOA) is in the best position to monitor operations in British waters; their Diving Advisory Committee has sponsored the Guidance Notes and Checklist for Surveying Dynamically Positioned Diving Support Vessels, which has been adopted by all UKOOA members.