IMCA

Guidelines for

The Design and Operation of Dynamically Positioned Vessels

International Marine Contractors Association

www.imca-int.com

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The International Marine Contractors Association (IMCA) is the international trade association representing offshore, marine and underwater engineering companies.

IMCA promotes improvements in quality, health, safety, environmental and technical standards through the publication of information notes, codes of practice and by other appropriate means.

Members are self-regulating through the adoption of IMCA guidelines as appropriate. They commit to act as responsible members by following relevant guidelines and being willing to be audited against compliance with them by their clients.

There are two core activities that relate to all members:

- Competence & Training
- Safety, Environment & Legislation

The Association is organised through four distinct divisions, each covering a specific area of members' interests: Diving, Marine, Offshore Survey, Remote Systems & ROV.

There are also five regional sections which facilitate work on issues affecting members in their local geographic area – Asia-Pacific, Central & North America, Europe & Africa, Middle East & India and South America.

IMCA M 103 Rev. 1

The original issue of these guidelines and its subsequent revisions have been prepared for IMCA (previously DPVOA), under the direction of its Marine Division Management Committee, by Chris Jenman of Global Maritime and, more recently, by the IMCA secretariat.

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Foreword

In 1991, IMCA's predecessor DPVOA (the DP Vessel Owners Association) first published *Guidelines for the design and operation of dynamically positioned vessels*, prepared by Global Maritime, with the reference 103 DPVOA. The guidelines represent a practical amalgamation of current regulations, operating procedures and good practice. They have been periodically reviewed and updated and are now published with the reference IMCA M 103 (DPVOA merged with AODC to form IMCA in 1995).

In 1994, the International Maritime Organization (IMO) Maritime Safety Committee approved its own *Guidelines for vessels with dynamic positioning systems* (Ref. 113 IMO/IMO MSC Circ.645), in conjunction with implementation of paragraph 4.12 of the 1989 MODU Code as amended. Later versions of these DPVOA/IMCA guidelines have reflected the IMO document. While the IMO guidelines apply to new vessels with dynamic positioning systems constructed on or after 1 July 1994, no distinction is made between new vessels and those constructed prior to 1994 within this IMCA document.

The latest revisions to the IMCA guidelines reflect:

- IMO acceptance of IMCA M 117 – *The training and experience for key DP personnel*;
- the increasing number of DP class 3 vessels constructed since 1998;
- changes and developments which have taken place including the increasing use of DGPS;
- the work in deepwater and the production of the ISO standard on station keeping;
- the supplement on two-vessel operations published separately by IMCA in 2001 (IMCA M 161) but now included as a section within this publication

An appendix on DP incident reporting has been included, together with references to other published material and the increasing practice of risk analysis.

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Appendices

Glossary of Terms and Abbreviations

Abandon dive	On a DSV an equivalent to red alert instructing dive control to recall the divers to the bell immediately and to bring the bell to the surface.
Advisory	DP operational status; failure of redundant equipment. This is mainly used aboard drilling vessels.
Artemis	Radio system used to measure vessel's position. System operates using a microwave frequency and measures the range and bearing of the vessel from a fixed station that is usually installed on a platform.
Back up DP	A DP control system, physically separate from the main DP control system that will be available in the event of a total failure of the main system.
Beacon	Acoustic pulse generating device on the seabed or structure whose signals are repeated at a regular interval and used by HPR to establish the vessel's position.
Blackout	Loss of all main electrical power to thrusters or DP control system. Loss of electrical power that prevents the DP control system operating is known as DP Blackout.
BOP	Blow-out preventer: Blackout prevention.
Capability plot	A theoretical polar plot of the vessel's capability for particular conditions of wind, waves and current from different directions. These can be determined for different thruster combinations and should be produced in accordance with IMCA M 140 – *Specification for DP capability plots.*
CCTV	Closed circuit television.
Common failure mode	A failure which affects two or more similar items of equipment which are essential for redundancy.
Controlled disconnection	Release in a planned and controlled manner of all physical connections linking the vessels/units involved in two-vessel operations and their physical separation.
DGPS	GPS plus a differential correction supplied by one or more receivers at a known fixed location, to increase the accuracy of the position fix.
DP	Dynamic positioning: automatic control of vessel's position and heading by the use of thrusters with respect to one or more position references. May also be used to mean dynamically positioned.
DP control location	Permanently manned location(s) onboard a DP vessel or unit where the DPO is able to monitor the performance of the DP system and where the DPO is able to interface with the DP system, intervening as necessary.
DP hazard observation	Set of circumstances identified which have had the potential to escalate to 'near-miss' status or more serious.
DP class notation	Notation used by classification societies, such as Det Norske Veritas (DNV), for DP vessels based upon IMO equipment class principles.
DP control system	The part of the DP system that calculates position and provides thruster commands.
DP downtime	Position keeping instability, loss of redundancy which would not warrant either a red or yellow alert, however loss of confidence has resulted in a stand down from operational status for investigation, rectifications, trials etc.
DP incident	Loss of automatic control, loss of position or any incident which has resulted in or should have resulted in a red alert.
DP near-miss	Occurrence which has had a detrimental effect on DP performance, reliability or redundancy but has not escalated into 'DP incident', 'undesired event' or 'downtime'.
DP system	All equipment that supports automatic position keeping control.

DP undesired event	Loss of position or other event which is unexpected/uncontrolled and has resulted in or should have resulted in a yellow alert.
DP vessel	Dynamically positioned vessel.
DPO	Operator of the DP control system.
DSV	Diving support vessel: a vessel from which divers are deployed.
Duplex DP	DP control system with full redundancy including smooth automatic changeover between the two DP control systems.
EDS	Emergency Disconnect Sequence.
Emergency disconnection	Unscheduled rapid shutdown and release of all physical connections to enable separation of vessels/units.
Equipment class	Classification outlined in IMO MSC Circ.645 for the equipment capability of DP vessels defined by their worst case failure modes.
ESD 1	Emergency shutdown and disconnect 1.
ESD 2	Emergency shutdown and disconnect 2.
FMEA	Failure mode and effects analysis.
Footprint	A graphic illustration of a set of real observations of a vessel's DP station keeping ability in particular environmental conditions.
FPSO	Floating production storage and offloading unit.
FPU	Floating production unit.
GPS	Global positioning system using satellites to establish a vessel's position, e.g. Navstar or GLONASS.
GPS relative	Differential and relative position system (note DGPS is used generally in this document but the same principles apply both for dual DGPS as dual DARPS or dual GPS).
Green status	Normal operational status; adequate DP equipment is on line to meet the required performance within the declared safe working limits.
HAZID	Hazard identification.
HAZOP	Hazardous operation.
HPR	Any hydroacoustic position reference system.
I/O	Input/output.
Independent joystick	A joystick that is independent of the DP control system.
Joystick	Positioning facility that uses a single lever for surge, sway and yaw control.
Laser-based system	Positioning and tracking system, such as Fanbeam and Cyscan, measuring distance and angle using reflected pulsed laser light
Limit alarms	Selectable values for position and heading excursions at which points an alarm will activate.
Loss of position	Movement(s) of vessel and/or unit from the intended or target position.
Manual control	Use of individual thruster controls or joystick with or without automatic heading control.
Operator	Any member of the vessel's complement involved with DP equipment for example DPO, master, duty engineer, chief engineer, electrician, taut wire operator, radio operator. This can also mean the organisation which operates vessels on behalf of the owners.
Permit to work	Authority to carry out certain operations under a system whereby these permits are approved and issued for a specific period of time and work during which the work would normally be completed.
Platform	Any structure that is fixed relative to the DP vessel.
Plough	Towed unit generally used to bury cables.
Pseudo	Prefix used when a position measurement system is interfaced to a DP control system as another position reference.

Radar-based system	Position reference system based on the measurement of radar signals reflected from passive transponders e.g. Radascan, RADius.
Radio position reference	Any position reference that transmits radio waves through the air for example Microfix, Syledis.
Red alert	DP emergency status: Position and/or heading loss have happened or are inevitable.
Redundancy	The ability of a component or system to maintain or restore its function, when a single failure has occurred. Redundancy can be achieved, for instance, by installation of multiple components, systems or alternate means of performing a function.
Responder	A transponder in which the interrogation is by an electronic pulse sent down a cable. This is generally fitted to an ROV and interrogated down the ROV's umbilical.
ROV	Remotely operated vehicle that operates subsea.
Safe working limits	The environmental limits that a vessel or company sets for safely working on DP taking into account specified equipment failures and limitations imposed by the current worksite.
Shallow water	A depth of water in which, depending upon the work being undertaken by the DP vessel, further considerations may be necessary.
SIMOPS	Simultaneous operations.
Simplex DP	DP control system with no redundancy.
Taut wire	Position reference using a tensioned wire vertically to a seabed weight or horizontally to an external fixed object nearby.
Telemetry	UHF communications system between an FPSO/FSU and a shuttle tanker that comprises a series of interlock checks along the cargo transfer process to allow cargo transfer to take place by establishing a green line. Interruption of the green line results in automatic shutdown.
Thruster	Any propulsion device used by the DP control system.
Transponder	Device on the seabed that responds to acoustic interrogation from the HPR on the vessel and gives vessel relative position.
Trencher	Subsea vehicle used for pipe or control line burial.
Triplex DP	Triple DP control system that is able to vote and reject one of the three systems if it is faulty.
Umbilical	Connection carrying life support and communication systems between a support vessel and a diving bell, an ROV or similar device (also diver's umbilical between diver and bell).
UPS	Uninterruptible power supply – unit to provide electricity continuously to DP control system in the event of a blackout of the vessel's main power.
Worst case failure	The worst case failure of a DP system is the failure that has been the basis of the design and proved by the FMEA. This usually relates to a number of thrusters and generators that can simultaneously fail and that are used in consequence analysis.
WSOG	Well specific operating guidelines.
Yellow alert	Degraded DP status for which the DP vessel has a pre-planned response to prepare for the risks associated with a DP red alert.

1 Principles for All DP Vessels

Section 1 is applicable to all DP vessels. The principles should be met in full by all DP vessels.

1.1 Basic Philosophy

i) For the purposes of these guidelines a fully operational DP system is defined as one that is able to reliably keep a vessel in position when working up to the rated environment, such that the maximum excursion from vessel motions (surge, sway and yaw) and position control system accuracy (DP footprint) is equal to, or less than, half the critical excursion for the work being carried out.

ii) The DP control system should provide adequate information to operators such that any change of status of the DP system due to weather, equipment malfunction or operator action should be clearly indicated at the permanently manned position where corrective action is possible and where the limitation, if any, can be understood by operators. The indication should be such that the operator is unlikely to make a mistake in assessing the severity and effect of the status change.

iii) Safe working limits should be determined for each geographical location, expected environmental condition/force and type of task to be performed. These limits need to consider every failure mode defined by the FMEA and the likely time to restore position control, recover the divers, disconnect a gangway or riser or otherwise move clear of an area to return to a safe situation. In the case of simultaneous or close operations, failures on the other vessels also need to be considered.

Note: A 'safe situation' means one where the work has or could immediately cease with no serious consequences from position loss and the vessel is left in a state where operations can readily resume once the disturbance is corrected.

It should be possible for the performance and health of a system to be effectively monitored by suitably trained and experienced personnel without the need to interrupt the control process. Changing between the various modes of position control should be simple, secure and demonstrably effective in meeting the points i), ii) and iii) above.

The above basic philosophy should be applied to all the types of work the vessel is designed to undertake with careful consideration of the consequences of position loss. If continuous working means that the vessel is likely to work in a degraded state the new 'safe working limits' and 'safe situation' should be agreed by formal risk assessment. If it is not normal to continue working in a degraded status, but because of the particular circumstances on board it is considered safe to continue, then this decision should also be made after an operational risk assessment involving the key personnel responsible for the work and station keeping before a decision is made.

To help vessel owners/operators and their clients achieve the above philosophy three equipment classes for DP vessels have been defined by IMO (Ref. 113 IMO – *Guidelines for vessels with dynamic positioning systems* (IMO MSC Circ.645)) which recommends that DP vessels built after 1 July 1994 be assigned an equipment class.

♦ **Equipment Class 1**

  Loss of position may occur in the event of a single fault.

♦ **Equipment Class 2**

  Loss of position is not to occur in the event of a single fault in any active component or system. Normally static components will not be considered to fail where adequate protection from damage is demonstrated, and reliability is to the satisfaction of the Administration. Single failure criteria include:

  – Any active component or system (generators, thrusters, switchboards, remote controlled valves, etc.);

  – Any normally static component (cables, pipes, manual valves, etc.) which is not properly documented with respect to protection and reliability.

♦ **Equipment Class 3**

  For this class a single failure includes:

- – Items listed above for class 2, and any normally static component is assumed to fail;
- – All components in any one watertight compartment, from fire or flooding;
- – All components in any one fire sub-division, from fire or flooding.

For equipment classes 2 and 3, a single inadvertent act should be considered as a single fault if such an act is reasonably probable.

To achieve a DP class notation with certain classification societies may require additional considerations such as an independent joystick which some societies require for class 2 or 3.

The decision on which class of vessel is adequate for a particular task or a series of tasks is addressed in section 2.1 of 113 IMO – *Guidelines for vessels with dynamic positioning systems* (IMO MSC Circ.645) which states:

> *The equipment class of the vessel required for a particular operation should be agreed between the owner of the vessel and the customer based on a risk analysis of the consequence of a loss of position. Else, the Administration or coastal State may decide the equipment class for the particular operation.*

This paragraph from the IMO MSC circular is repeated here because this principle should apply to all DP vessels irrespective of when they were built or what DP notation or class they have. The risk analysis that is called for need not be extensive: but it has to adequately reflect the consequences that a loss of position can reasonably cause or lead to.

The best time to carry out a risk analysis is when the work scope is known and experienced personnel from the vessel are available.

However it is clear that for a fundamental decision, such as whether to contract a DP equipment class 2 or a class 3 unit, the risk analysis has to be carried out at an early stage when perhaps much of the detail needed for the analysis is not available. The situation is also made more difficult because DP equipment class 2 vessels range from relatively simple vessels with good track records to sophisticated modern vessels that are almost DP equipment class 3. From DP incident data it is clear that the above differences between DP equipment class 2 and DP class 3 vessels are not as important as the training and experience of operators, the procedures on board, the vessel's power and thrust redundancy and the control systems.

Ideally the risk analysis should be carried out in a preliminary form as early as possible and reconsidered at various stages of the work, particularly if changes to the vessel and/or the work scope have been made during the development of the project. The subsequent risk analysis need not be a major exercise and in some cases may only involve key personnel on board the DP vessel. In all instances records are required of the analysis and the decisions made.

For vessels undertaking the same tasks many times a generic risk analysis could be adequate, provided a mechanism exists to check that the generic analysis applies and if it does not or there are differences that may affect the results, appropriate re-analysis is carried out.

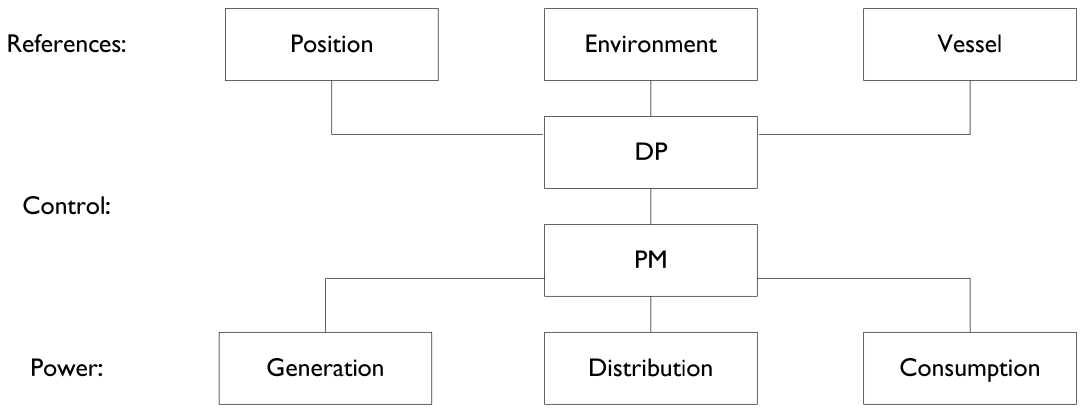
1.2 Scope of Dynamic Positioning

The DP system comprises all the equipment that directly and indirectly effects the position keeping ability of the unit.

The equipment that provides system reliability by redundancy has to be on line or immediately available so that;

- ♦ a sudden failure of one item or an inadvertent act will not cause an unexpected position excursion;
- ♦ the transfer of control or transfer of service between redundant equipment will be smooth, and;
- ♦ no unwanted thruster activity occurs.

The DP system comprises three areas: power, control and references. Power can be sub-divided into power generation, distribution and consumption (by propulsion systems). Control refers to a power management system (automatic or manual) and the position control system. References are essentially sensors giving position, environmental and vessel attitude information.



The DP control consoles should be located where operators can see the environmental conditions. If this is not practical, environmental condition as well as working area information should be supplied by CCTV.

The most important parts of the DP system are those which link several major items of equipment and, no matter how much redundancy is provided, some elements of control are likely to be common. Irrespective of the complexity of the vessel, common single point failures should be avoided wherever possible; if they cannot be avoided then they should fail safe and their effects taken into account when determining safe working limits (see 1.1 iii)).

For all DP vessels, all failure modes and their effects should be considered in a formal FMEA study (Ref. IMCA M 166 – *Guidance on failure mode and effects analysis*). The modes that should be considered are; first, the sudden loss of major items of equipment; second, the sudden or sequential loss of several items of equipment with a common link; and third, various control instability failures and their method of detection and isolation. Faults that can be hidden until another fault occurs should also be considered. For each fault the likely responses, based on the information available to the operator, should be assessed. Operator responses to the three types of failure mode mentioned above should be reflected in the operations manual for operational scenarios for which the vessel is intended.

For equipment class 2 or 3 a single inadvertent act should be considered as a single fault if that act is reasonably probable (Ref. 113 IMO – *Guidelines for vessels with dynamic positioning systems* (IMO MSC Circ.645)).

The FMEA should be updated if modifications are made that are likely to affect its conclusions. It should be a live document and so should be maintained and reviewed regularly (Ref. IMCA M 166 – *Guidance on failure modes and effect analysis* and IMCA M 178 – *FMEA management guide*).

1.3 Extent of Dynamic Positioning FMEA Proving Trials

DP vessels have to undergo FMEA proving trials, in addition to and after, dockside testing, commissioning and owner (customer) acceptance trials.

The DP system should be proven as far as is reasonably practicable in all the normal modes of operation expected during the life of the vessel.

When all normal modes of operation appear to be functioning correctly, failure modes should be simulated and the results of such tests documented, by a third party. Finally, performances should be demonstrated in both the intact and various failed conditions. (Moderate or rough weather is ideally required for these tests, but is not essential for acceptance of the DP capability and system stability.)

Such proving trials should be properly documented and the results made available to operators, owners, charterers, surveyors and responsible authorities, to obviate the necessity of repetition of some of the design related trials during the vessel's working life and as input into operational manuals and vessel familiarisation procedures.

1.4 System Capability Definition

The maximum continuous operational station keeping capability for the DP system should be calculated for the following cases:

i) All thrusters operational with maximum effective thrust;

ii) All thrusters, except the most effective thruster, operational with maximum effective thrust;

iii) The maximum number of thrusters and/or power units that could be operational after the worst single failure depending upon the class modes;

iv) The equivalent loading on all thrusters in the failed mode should not exceed the available power in iii) above.

The above should be presented in polar plot form for various current speeds, for example 1.0, 1.5 and 2.0 knots, co-incident with wind and associated wave loads from a fully developed sea. A realistic allowance should be made for losses from, for example, interaction, thruster tunnel length, high current, control system response, non-steady conditions and normal deck wind loading conditions when working. Other external forces should also be considered if appropriate (Ref. IMCA M 140 – *Specification for DP capability plots*).

The purpose of 1.4 i) is to be able to calculate predicted capability, and assess the practical working limits.

The purpose of 1.4 ii) as a single composite plot is to provide operators with a limit that cannot be exceeded if position is to be kept when the most effective thruster suddenly stops.

The purpose of 1.4 iii) is to provide operators with guidance on working limits which should be imposed for the most difficult or sensitive tasks where the consequences of a loss of position are particularly severe, for example, loss of life or injury to many people. Using this limit should mean that there will be a 'safe situation' (see 1.1 iii)) after the worst single failure.

The purpose of 1.4 iv) is to give operators information so that they can assess from available power and thrust usage whether safe working limits have been exceeded. This is generally known as consequence analysis because the consequence of a failure, when this warning is active, is a loss of position.

This theoretical exercise is to provide plots that are easily verified during proving trials and in the first year of DP operation. It is essential for the wave conditions used in the calculations be stated on all capability plots.

Capability plots do not show the excursions of a DP vessel. They show the likely environmental limits within which a DP vessel will effectively return to the wanted position when an excursion takes place from normal external disturbing forces. The excursions of a vessel depend on the environmental conditions, the control system tuning and the accuracy of the position references. In marginal conditions working within the defined safe working limits DP vessels should record the vessel's excursions and so develop a 'footprint' for the vessel in these conditions.

Online capability plots provided as an additional facility with a DP control system should be verified by full scale testing and are a useful tool in reassessing safe working limits but should not be used in isolation.

1.5 Operation, Training and Documentation

Every DP vessel should have an operations manual that is particular to that DP system and the operating practice of the owners or operators of the vessel. It should cover all the work for which the vessel is designed or likely to be used. It should include but not be limited to the following:

- Capability plots;
- Trials data;
- Working profiles and capabilities of equipment;
- DP status, alerts, emergency responses and procedures;
- Responsibilities and communications;

- Approach, setting up, checking and testing of the DP system;
- Reporting and recording;
- DP footprints;
- Manning.

All documents should be controlled and updated in accordance with the vessel's QA (ISM code) procedure.

In addition to the above general document, each work location, task or operation of the DP vessel may require a site- or well-specific document that further specifies additional constraints or procedures for a particular project if the general document will not suffice for example project safety plan, HAZOP/HAZID exercises, SIMOPS and close out documentation.

This site- or well-specific document would, for example, include plans for positioning and handling equipment, operating with other vessels or near platforms, or changing some of the operations manual normal procedures because of special circumstances.

The items covered would include the findings of any risk analysis carried out for that project or similar projects. The principle here is that each task is given individual consideration prior to its being performed and, unless it is a standard operation that is covered by the general manual, a suitable project specific procedure should be produced.

All personnel involved in the operation should be familiar with the above documentation.

For all DP vessels there are at least three DP alert status levels:

- Green — Normal operational status

  Adequate equipment is on line to meet the required performance within the declared safe working limits.
- Yellow — Degraded DP status

  In general it is the condition where one or more items of redundant DP equipment has failed, safe working limits are being exceeded or an excursion of heading or position is a possibility.
- Red — DP emergency status

  This is where there is a loss of position, or position loss is inevitable.

Note: For DP drilling it has become normal practice for there to be an intermediate alert between Green and Yellow. This is called 'Advisory' and is designed to provide an early warning that some condition exists that needs to be considered by the key DP personnel and all personnel involved with the permit to work system.

Reporting and recording on board a DP vessel should be comprehensive. Yellow alerts should be logged and the actions from any discussions as a result of the change of alert status be formally recorded onboard. Red alerts should be similarly treated and, in addition, they should also be reported as required by the company's system. For vessels engaged in sensitive DP operations data recorders that record all DP parameters including operator keystrokes should be seriously considered.

Note: DP incidents are reported on a voluntary basis to IMCA on a pro forma for analysis and included in the IMCA DP annual station keeping report so that the technical and safety lessons can be appreciated by the operators of all DP vessels. All DP incident information is made anonymous before its use in the database.

All checks, tests and trials should be noted so that equipment problems can be dealt with and operator errors are minimised. Documentation would typically cover the following:

- Vessel acceptance trials results (new or converted vessels);
- Annual trials for quality assurance of the DP system;
- Mobilisation checks for new charter, as required by charter party;
- DP bridge checklist for new location;

- ECR checklist for new location;
- Watch status checklists.

Such documentation should be updated in line with industry experience from time to time so that it remains valid.

The DP system should be technically well documented so that operators and maintenance engineers can fully understand all items of the equipment. It should also be included in the vessel's planned maintenance system.

When DP vessels are operating on DP close to one another, they are potentially subject to several forms of mutual interference. These include thruster wash (which may affect both hulls and taut wires), acoustic and radio position reference sensor signal interference and intermittent shelter from wind and sea. These factors should be considered when planning such operations and due allowance made for them. This may take the form of assuming less accurate position keeping tolerance than would normally be expected. Co-ordination or choice of position reference sensors and frequencies and careful choice of the relative positions of the vessels is essential. One DP vessel should be given the co-ordination responsibility. Checks with respect to each vessel's safety management system should be made (Ref. IMCA M 125 – *Safety interface document for a DP vessel working near an offshore platform*).

1.6 DP Equipment Characteristics

DP vessels differ in their level of complexity and redundancy and even within a DP equipment class or Class notation there can be significant differences. Irrespective of the vessel's equipment class there are basic equipment characteristics that apply to all DP systems and these are outlined in the following sub-sections. Further details are given for each type of vessel in later sections of these guidelines.

It is essential that all DP personnel know the consequences to be expected from the various failures that are known to be possible on the vessel on which they are employed (Ref. IMCA M 117 – *The training and experience of key DP personnel*). To assist operators with worst case failures for DP equipment class 2 and 3 vessels the DP control system for vessels built after 1 July 1994 should have a continuous analysis function checking that in terms of thruster and power the vessel can maintain position after the worst case failure. This calculation should be based on the thruster allocation logic only using the remaining thrusters after the agreed worst case failure mode for creating the required thrust and moment. The calculation should be based on the average thruster utilisation over the previous one minute. This calculation is generally known as consequence analysis. DPOs should never rely on this analysis alone and the subsequent warning to tell them there is a problem with thrust and/or power.

There are basic equipment characteristics that apply to all DP systems and these are outlined in the following sub-sections. Further details are given for each type of vessel in later sections of these guidelines.

1.6.1 Thrust Units

Speed of response, efficiency and interference should be considered for all thrust units and the arrangement should be made to give, as far as is possible, a balanced configuration even after the worst failure. It is essential to avoid a thruster control fault that results in full power or power in an unwanted direction which can destabilise the whole DP control system. Such problems are overcome by a fail safe design; that is, the thruster:

- fails as set;
- fails to zero thrust;
- trips the drive motor or engine.

While these safety features should be automatic it is nevertheless essential to provide an independent emergency stop for each thrust unit, suitably protected against inadvertent operation and operated from the DP control console or nearby. Thrust units should be as independent as possible in terms of location, cable runs, electrical and control power and cooling, to maximise the safe working limits. Each thrust unit should be independently monitored and alarmed. Sensors causing a thrust unit to trip should be minimum in number, i.e. tripping should only take place in situations where continued running will cause the unit to be damaged within a short space of time, e.g. 30 seconds. Sensors that initiate warning alarms should themselves be designed to cause an alarm on failure; sensors that trip important equipment, e.g. generators, pumps, motors and engines should not themselves fail such that an unwanted loss of important equipment is caused, i.e. they should fail safe.

1.6.2 Power Generation

The type, number and arrangement of power generation units, will have a direct bearing on the safe working limits of the DP system, because the effect of the failure of any one unit, or common sub-system, will be considered in the determination of safe working limits (see 1.1 iii)). This includes the number and type of engine shutdowns. The number of engine rooms and engines should be determined by the safety, reliability and availability required for the work as well as the time to completely shut down. Utilities supporting power generation systems, e.g. cooling water, ventilation, fuel oil, lubricating oil should be arranged so that their total failure is not more critical than failure of the equipment they support.

Safety systems that enable shut down of power generation automatically or manually should be designed to fail safe so that unwanted shut down does not take place from single faults. If the design philosophy is that a single fault also includes a fire in any one compartment (IMO DP equipment class 3) then the shut down control system should withstand fire damage or be separated so that in the worst case adequate power remains to meet the safe working limits.

1.6.3 Power Management

A system to prevent overload and blackout is essential on all DP vessels. A system for the prudent starting and stopping of diesel generators is also desirable, although on some vessels this management can be manual if there is ample time for operators to react and manage the power on line. On DP vessels that rely on automatic power management the system will need to be fast and reliable for the vessel to work efficiently and give the required priority to maintaining position.

Power management and position control are inseparable in that they both affect thrust for position keeping. It is essential to clearly define the interfaces and responsibilities for all operational modes of every vessel. DP vessels which use substantial amounts of power for equipment other than thrusters, for example, for cranes, fire pumps, drilling and hotel facilities, need to be able to shed or reduce load (phase back) to maintain power to thrusters. The speed, effectiveness and reliability of load shedding by a power management system are factors to take into account when determining safe working limits.

1.6.4 Power Distribution

A basic requirement for a DP vessel is to maintain power to thrusters for as long as possible, even in some alarm conditions, so that a safe situation with respect to position can be maintained until the work is terminated (see 1.1 iii)). This very often conflicts with the shut downs and protection systems normally installed on ships and rigs. Where emergency switchboards are provided as a classification society requirement, careful consideration should be given when using this switchboard for critical DP equipment: loss of the emergency switchboard should not prevent starting of main generators after a blackout.

The electrical power distribution to thrusters is usually the aspect of the DP system design which determines the worst case failure mode. For DP equipment class 3 vessels fire and flood subdivision should not make the design failure case worse.

Examples of single failures in power distribution include the following:

- undervoltage;
- underfrequency i.e. governor failure;
- earth faults;
- phase-phase short circuits;

- faults on a bus tie breaker;
- over/under excitation.

For DP equipment class 3 vessels the following additionally apply:

- fire or flood at the DP control station;
- fire or flood in a switchboard room;
- fire or flood along a common cable route;
- fire or flood in the emergency switchboard room;
- fire or flood in a main or auxiliary machinery space;
- fire or flood in the engine control room.

Note: Flood in the above context can be taken as water spray throughout the space if flooding is unrealistic.

The highest priority should always be given to clearing faults that risk the overall power and control networks, and maintaining enough power to give time to cease any operation and reach a safe situation.

1.6.5 Position Control

There are several options available for the automatic control of thrusters to keep a vessel in a fixed position. For nearly all DP vessels electronic computers and/or several microprocessors are used, hence these guidelines assume these control systems are installed. For designers considering other control technology the underlying principles can be determined from this section and applied in a similar way. For good performance of the position control system it is essential that a period of stabilisation is used after position is first established and after significant moves or heading changes which may affect the vessel model. The initial stabilisation period should be at least 20 minutes; subsequent periods of stabilisation should be determined by the circumstances and conditions.

There are numerous combinations of operator control facilities for thrusters, but most combine both an automatic and a manual remote system plus local control. Automatic DP control systems are generally supplied in single, dual or triple configurations with a back-up DP control system for DP equipment class 3 vessels. Manual systems are a combined lever or joystick, with or without automatic heading control. Joysticks can be completely independent of the computer(s) used for automatic position control, or an integral part of the automatic system in that they use the same I/O, network or cables to the thrusters. The minimum DP control facility is a single automatic control system with an integral joystick, which is adequate for some tasks.

Irrespective of the number of control systems and types of joystick certain essential features are required to ensure adequate reliability of each. These include the following:

- Secure power supplies with backup (usually batteries) provided in case of a mains failure;
- Independent emergency stop for each thruster, adequately protected against inadvertent operation and for DP equipment class 3, arranged so thrusters do not trip from fire or flood damage to the stop circuits;
- Separate output command signals for each thruster or sets of thrusters;
- Secure location with negligible risk of fire, flood or overheating;
- Comprehensive data display and alarms;
- Internal self checking;
- Independent I/Os for sensors.

The DP control console should ideally be located so that the DPO can see the controls, the external environment and the working operations of the vessel. Every reasonable effort should be made to compensate in the event that this is not fully achievable for example by CCTV.

DPO inputs to the system should require a confirming action before being accepted by the computer to prevent accidental changes being made by a single inadvertent act.

Power supplies for position control should be redundant, secure and so arranged that no short circuit, cable damage, earth fault, or automatic change over could result in the loss of position control.

The location of the secure power supplies should be chosen such that:

- they can be easily checked;
- they are unlikely to be misused or to fail from mechanical damage, fire, inadequate ventilation etc.

Where position references, environmental sensors and vessel sensors are powered by the position control system's secure supply, care should be taken to ensure adequate sensors remain after the worst power failure, for example failure of the UPS's inverter.

Control information should be displayed or be easily available to meet the principles outlined in 1.1 ii). For all DP vessels this should include the following:

- Thrust units status and power ordered and used;
- Power generation and distribution arrangement in use;
- Reference sensor status and performance;
- Position performance present and past;
- Alarm status and sensor trends.

The DP control should enable automatic position and heading changes to be made in any preselected direction at rates within the vessel's capability so that the new heading and/or position is quickly established without instability, or a position excursion, or overshoot above acceptable limits for the work.

1.6.6 Position References

The number and types of position references installed will be determined by the class notation sought or assigned. This may also depend upon the nature of the work to be performed as well as the environment in which they are required to operate. Care is needed to determine whether redundancy is completely provided by duplication of similar sensors which may have common failure modes.

All position references should be designed so that they cannot give an unchanging position when data is lost and the vessel is moving.

For example taut wires, whether horizontal or vertical, should be designed so that they cannot fail in a way which will provide a constant position signal to the DP control systems, because of a fouled wire, inadequate bottom weight or a faulty head sensor. To meet the requirements of 1.1 ii) such faults should be brought to the notice of the operator in the form of alarms and the sensor data rejected by the DP control system. Position references should be deselected, if they have not already been rejected, once they no longer reasonably contribute to the estimated position.

A DP vessel's HPR should be designed so that it cannot accept any signal that is not intended (by design or procedure) to be used for position information. The limits of performance of an acoustic position reference should be determined prior to work commencing so that the limits of movement of the vessel using the HPR, as deployed, are known. Seabed sensors that are tethered, or attached to vessel equipment, so that they could give a false steady position reference with the vessel moving, should be avoided whenever practicable, and this limitation considered when determining redundancy and safe working limits. The positioning of acoustic units in the hull should take into account the likely sources of noise that could interfere with the acoustic signals and result in the loss of position reference data. If two acoustic systems are installed their independence or dependence should be clearly established and this reflected in how they are treated by the DP control software.

Deploying more than one transponder does not make the acoustic position reference redundant if it is still subject to a common failure mode, for example thruster noise.

Short range radio position reference systems can suffer sudden failure from loss of line of sight or a fault at a remote station. They should be designed so that they cannot accept any signal that is not unique by design or procedure to the DP vessel on which they are being used. Precautions should be taken to avoid all failures or faults that cause the position data to 'freeze' irrespective of whether the vessel is stationary or not (Ref. 105 DPVOA – *Failure modes of the Artemis position reference system*; 118 DPVOA – *Failure modes of Artemis Mk IV position referencing system*; IMCA M 170 – *A review of marine laser positioning systems*; IMCA M 174 – *A review of the Artemis Mark V positioning system*; IMCA M 142 – *Position reference reliability study*).

The use of DGPS as more than one position reference depends on the level of independence achieved with respect to hardware and software, the number of satellites available, the antennae locations, the quality and number of differential corrections available and their effects if giving the same incorrect data. However when two separate DGPS inputs of position are used by the DP control system, their contribution to the estimated position together with other position references needs to be properly balanced. Here balanced means that two DGPSs (or GPS or GPS Relative) should never out-vote one or more other position references and operate the system such that a loss of position could result.

The DGPS input should also provide information on fix quality for use by the DP control systems (Ref. 128 DPVOA – *QRA for the use of a dual DGPS system for dynamic positioning* – and IMCA M 141 – *Guidelines of the use of DGPS as a position reference in DP control systems*).

When multiple position reference systems are selected to the DP control system, the operator should confirm that they are working correctly before selection. Once accepted by the DP control system information should be provided to assist the operator with decisions about individual reference system performance and malfunction. This can be provided in the form of warnings, alarms and trend graphs of standard deviation or equivalent. Sensors which fail or provide data outside pre-set limits should be automatically de-selected by the DP control system (Ref. IMCA M 142 – *Position reference reliability study*).

The use of pseudo signals to simulate a different position reference so that the DP control system can accept it, for example accepting the DGPS signal as an Artemis signal on the DP control where there is no available input for DGPS itself, should be avoided whenever possible. If such use is unavoidable all failure modes should be thoroughly tested.

1.6.7 Environmental Sensors

The position keeping performance and speed of response of the DP system can be improved by the incorporation of environmental sensors to provide feed forward to the DP control system. DP control systems should use wind sensors as a minimum. To provide an overall position keeping improvement the wind sensor(s) should be positioned such that they are not subject to vessel turbulence or interference for example from cranes, helicopters and platforms. Irrespective of the suitability of the location of the sensor, the wind feed forward input to position control should be so arranged that it will not cause a critical excursion when suddenly shielded or unshielded from the wind. It should also be noted that wind sensors may be subject to icing up in certain conditions. Where the vessel has more than one wind sensor every consideration should be made so that all wind sensors are available for use by the DP control system.

1.6.8 Vessel Sensors

Position keeping includes the control of the vessel's heading; gyro compasses are normally used for this purpose. Failure of heading input has a dramatic effect on position keeping and excursion, particularly if the heading data is lost to all position references or if the DP rotation centre is remote from the geometrical centre of the vessel. Provision of gyro compass redundancy and the ability of the DP system to detect failure, including a slow drift of the on-line unit, are factors to be taken into account when determining safe limits, particularly on mono-hulled vessels.

The other sensors that are required for accurate position keeping are the vertical or motion reference sensors. These devices, that measure roll and pitch and sometimes heave, should ideally be in separate spaces and located near the rotation centre of the vessel. If they are located some distance from the rotation centre then this should be corrected for in the DP software where this cannot be done on the sensor itself. The DP system requires this information to correct position reference sensors for X and Y offsets caused by vessel inclination and motion. Loss of these inputs degrades DP system performance particularly with some HPR systems in deep water (Ref. IMCA M 145 – *Review of three dual hydro acoustic position reference systems for deepwater drilling*). It is recommended that current control is used for sensors rather than voltage.

1.7 Weather Precautions

DPOs should pay particular attention to any indications of impending weather changes, in particular sudden shifts in wind force and direction, tidal change or local phenomena e.g. solitons (Ref. IMCA M 132 – *Summary of the proceedings of the 1995 IMCA Station Keeping Seminar, London* (including the paper Experience of Solitons while on DP in South China Sea)), to ensure that timely action is taken to reduce the possibility of a critical excursion or exceeding the safe working limits.

All reasonable precautions should be taken in accordance with good marine practice to ensure that forecasts of changing weather conditions are obtained and acted upon. These precautions should include:

- obtaining regular and frequent weather forecasts for the area of operations and use of facsimile facilities and charts;
- seeking information from other units in the vicinity about prevailing weather conditions in their areas;
- use of knowledge and experience to assess the prevailing conditions and likely trends;
- use of environmental information measured by the DP system and any trends in conditions which it can provide;
- use of onboard meteorological instruments, including barometer; barograph; wind sensors (both fixed and portable);
- other sources of weather information e.g. radar.

If the vessel is to work to windward (or up current) of a platform or obstruction the additional power that might be required to reach a safe situation should be considered when safe working limits are determined.

1.8 International, Government and Regulatory Organisation Requirements

Nothing in these guidelines should supersede the spirit or letter of any legislation that covers the authority and responsibilities of individuals on board DP vessels or representatives of owners/operators ashore.

Irrespective of the sea area in which a DP vessel is working, it is a fundamental necessity for the owner/operator of the vessel to define the responsibilities and authority of the various members of the vessel's complement via the master or OIM.

Care should be exercised at all time to ensure that the correct lights and shapes are displayed in accordance with the latest international regulations for preventing collisions at sea. By the present rules, whereas power driven and sailing vessels are required to keep out of the way of a vessel restricted in its ability to manoeuvre (for example a DP vessel engaged in underwater operations), a vessel engaged in fishing when underway, is required only 'so far as possible' to do so. The master of a vessel restricted in its ability to manoeuvre should give early warning that it is unable to manoeuvre to any vessel which appears to be on a collision course, using visual and sound signals.

The proper use of radar, automatic collision warning systems and automatic identification systems should not be overlooked.

In reduced visibility, decisions about the suitability of conditions for continued working should rest with the master of the vessel. A proper lookout should be kept which includes using the radar and making plots. All regulations for preventing collisions including sound signals should be observed and work terminated if the master considers that there may be requirements to take collision avoidance action.

A DP vessel that is connected to the seabed by equipment such as a riser or drill string may be construed as a fixed platform or installation by the relevant coastal state and hence carry the lights and shapes applicable for example quick flashing lights at each corner of a semi-submersible in the Gulf of Mexico and the Morse code U in the North Sea.

1.9 Training

Training of personnel using DP control equipment is essential (Ref. IMCA M 117 – *The training and experience of key DP personnel*). The extent of training and experience necessary for a particular vessel is a matter for the vessel owner and/or vessel management. Training may take the following forms:

- Onboard training under the supervision of an experienced operator when on DP but not when the vessel is operational, for example when the vessel is standing by;
- A shore based training course or courses;
- On board instruction about the particular systems of a vessel from experienced operators or equipment suppliers;
- A period of supervised operation while the vessel is working.

The amount of training and experience necessary for an operator to be a senior watchkeeper depends on the type of vessel and the risks associated with the operations to be carried out. Comprehensive records of the training and experience of key DP personnel should be maintained as part of competence assurance. These key personnel requiring DP training are generally the same for all DP vessels namely:

- DPOs and master/OIM;
- ECR engineers and chief engineer;
- Electrical and electronic engineers.

Note: For more information the IMCA guidance on competence assurance and assessment should be consulted (Ref: IMCA C 002 – Guidance document and competence tables (Marine Division) – *and IMCA C 003* – Guidance document and competence tables (Diving Division)*).*

In addition, personnel related to the specialist nature of the vessel's work for example ROV operators, toolpushers and crane drivers, need some basic instruction in the capabilities and limitations of working on DP (Ref. IMCA C 001 – *Guidance document and competence tables (all divisions)*).

2 Diving Support Vessels

2.1 Design Philosophy

In addition to the basic principles outlined in section 1 a DSV should meet the following:

- No known single failure mode should prevent the safe recovery of divers or cause a red alert.

The determination of safe working limits should consider the time necessary for divers to return to the bell on initiation of a yellow or red alert, the likely rate of loss of position and the increased position excursion after the worst case failure mode.

Safe working limits can vary depending on location and water depth; lower limits should apply when divers are working inside a steel jacket structure or habitat than when divers are working in open water over a pipeline.

2.2 Redundancy

2.2.1 General

Redundancy to reduce the effect of failure modes and improve safe working limits is expected on all DP DSVs. The following examples are to provide minimum requirements and information on the current practice on DP DSVs. The level of redundancy is a matter for owners and designers to optimise to achieve practical and economically viable safe working limits. DP DSVs are expected to be at least DP equipment class 2 (Ref. 113 IMO – *Guidelines for vessels with dynamic positioning systems* (IMO MSC Circ. 645)).

2.2.2 Thruster Units

The arrangement of thrust units should be such as to provide, as far as practicable, a good all around DP capability for intact and worst case failure situations, so the vessel is not unduly heading limited. In addition, consideration should be given to providing a balanced athwartships capability in the intact and worst case failure conditions. Crossover power facilities for thrusters should meet class requirements.

The thrusters should, as far as is practicable, be independent in location, cable routes and control power so that a power fault, fire or flood would not result in the loss of more than one thruster. If separation for fire and flood is not reasonably achievable the risk of fire and flood should be considered in high risk areas. The cabling for redundant equipment should avoid engine rooms, boiler rooms, machinery spaces and similar spaces. It is important that cables are not routed such that the designed worst case failure mode, for example a switchboard fault, is compromised, resulting in a more significant failure than the designed worst case failure mode.

2.2.3 Power Generation

The sudden unexpected failure of one diesel engine should always be a DP system design and operational consideration, as should a fire in one engine room. The latter failure however will normally involve a period of time during which divers could be recovered. It is unreasonable to consider a whole engine room and the power it generates to be instantly lost through a fire, if good detection is installed (Ref. IMCA M 119 Rev. 1 – *Fires in machinery spaces on DP vessels*). Vessels with independent engine rooms, capable of supplying enough thrust units to keep position with one shut down, have a lower risk of position loss and should therefore have higher allowable safe working limits. It is essential that smoke from a fire in one engine room cannot be drawn into the other engine room and impede operators or activate additional smoke alarms so as to make the fire appear worse than it is.

2.2.4 Power Management

For vessels with complex and redundant power generation and thruster systems with load shedding systems the power management has to be automatic, comprehensive and operate for all switchboard combinations. It has also to be redundant itself or fail safe so that no loss of power or thrust takes place on failure of the power management system. Designers should ensure that there is a clear interface between the blackout prevention control by the DP control system and that exercised by the power management or the individual thruster protection.

Communication between the two is not essential for control, but if this communication is to improve the speed of response to a power demand, failures of this communication should also be considered when determining safe working limits. The power management system should be redundant as far as its failure directly affects position keeping. If its failure modes do not result in loss of power to thrust units until a change of status takes place, redundancy is not essential.

The power management need only operate for the normal DP mode of operation, i.e. with a common switchboard (bus tie closed) provided this meets the requirements of sections 1.1 iii) and 2.2.5. If the vessel is designed to operate with the bus ties open while diving and closed for other work, then a power management system will be needed that can operate for each side, or section, of the switchboard independently.

2.2.5 Power Distribution

For diving support work using DP the power distribution arrangement should be set up so that a fault on any switchboard section separated by bus ties should not cause the loss of the whole switchboard. This should be the case for every working combination of generators and thrusters. To achieve this requirement the bus ties should be set and tested at regular intervals so that they split the bus before any tripping of generators has taken place on the healthy sections of the switchboard. If there is a realistic chance of the bus ties not opening or not opening fast enough then the switchboard should be split for the work.

2.2.6 Position Control

For dive support work using DP, the minimum control requirement is for two automatic and fully redundant control systems providing, on the loss of one, a smooth transfer to the other which would be unnoticed by divers working near the diving bell. In addition there should be a joystick facility for manoeuvring which can either be separate from or an integral part of the DP control system.

If fire or flood is assessed as a realistic failure mode within the DP control location then consideration should be given to separate DP control system equipment in a location independent of the main system (DP equipment class 3).

When locating equipment within the DP control area and its cabling, designers should consider both the risk of fire and its subsequent detection.

DP control computers, sensors and UPS units located remotely from the DP control console should be separated so that maximum protection is given to the redundant DP control system. If located together, the space requires a fire and temperature detection system. In tropical climates where the temperature is expected to rise significantly above ambient when ventilation alone is used, air conditioning may also be required.

At least one computer should be uninterrupted by the worst power loss fault possible and be able to continue operating with associated equipment for at least 30 minutes. It is prudent to provide an independent UPS for each DP control system, with independent battery back up for each and no cross connection.

2.2.7 Position References

For diving work at least three references should be on line and at least two should be of a different type. Two DGPSs using different correction stations may be usable but could still be subject to common failure in the satellite section of the system. Re-plumbing a taut wire, when it is one of the three position references, does not constitute a violation of the above requirements, if such action is completed as quickly as is safe and practicable and the station keeping was stable when the taut wire was deselected prior to re-plumbing. Power supplies to position references should not be common and cable routes should be separated. Furthermore no single factor should affect more than one reference so as to cause a common failure mode (see section 2.5 for shallow water).

The three position references selected for use should reflect the circumstances such as deep water, shallow water, open water, close proximity to a fixed or moored platform or simultaneous DP operations. See section 2.7 for diving within anchor patterns.

The DP control system should be able to identify a fault in a position reference, alert operators, and reject the suspect sensor.

2.2.8 Environmental Sensors

At least two wind sensors in different locations, with separate supplies and cable routes, should be provided. If a third unit is installed it should be in a different location or in the better of the two locations for the other wind sensors. If the wind sensors are at significantly different heights they should be corrected so that operators can compare them easily.

Whenever possible all wind sensors should be selected. If the wind sensors can be shielded by the platform to the detriment of DP control system performance, repositioning of the wind sensors should be considered.

The DP control should be able to identify a faulty unit and alert operators before a position change takes place.

2.2.9 Vessel Sensors

At least two vertical reference sensors should be provided. If a third unit is installed it should be in a separate location with a separate power supply. Three gyro compasses should be provided particularly for mono-hulled vessels, because of the critical nature of heading control. The DP control system should be able to identify a faulty unit and alert operators before a heading and/or position degradation takes place. Vessel sensors should be physically separated so that the redundant units are unlikely to suffer from the same fire, flood or mechanical damage event.

The design and arrangement of these sensors should ensure that the independence of the position references is not compromised if one of them fails because all position references are using the same vertical reference sensor and/or gyro compass.

2.3 Communications

(Ref. IMCA M 175 – *Guidance on operational communications: Part 1 – Bridge and dive control*).

2.3.1 Voice Communications

Voice communication by a priority system or dedicated channel should be available between dive control and the DP control location. In addition there should be a dedicated system between the control centres of the vessel for its various working scenarios. This system should include DP control, ECR, dive control, ROV control, crane control and other control stations as applicable. There should be a back up to this system which in most cases would be a common internal telephone network. These communications should be checked as part of the location checks made during the initial DP stabilisation period (see sub-section 1.6.5).

Good liaison between the dive control position and the DP control is essential (Ref. IMCA M 175 – *Guidance on operational communications: Part 1 – Bridge and dive control*) and an open hands-free line with priority is a desirable facility. Each watchkeeper should inform the other about any change in operational circumstances, either existing or planned. The following lists give an indication of the type of information which should be passed.

i) Dive control to DP control:
   - Bell status
   - Diver status
   - Intention to use and use of water jetting equipment
   - Possibility of divers, bell or equipment blanking or moving acoustic reference signals
   - Requests to move the vessel
   - Intention to release high volume compressed air subsea
   - Status of all down-lines
   - Any situation which is unusual or may need a change to agreed procedures.

ii) DP control to dive control:
   - Intention to move vessel or change heading
   - Changes in operational status affecting position control
   - Any situation which is unusual or may need a change to agreed procedures
   - Any forecast or actual significant changes in weather
   - Vessel movements in the vicinity
   - Intention to handle down-lines of any description, including repositioning taut wire weight
   - Platform information relevant to operations.

iii) ECR to DP control:
   - Intention to start or continue work already approved under the permit to work system, and notification of completion. Advice of any electrical or mechanical system intervention which is operationally necessary and could directly or indirectly affect online DP equipment or make stand-by equipment unavailable
   - Intention to start and stop ancillary air/hydraulic units which may reduce pressure on DP or diving associated equipment
   - Intention to start and stop pumping overboard bilge or ballast water
   - Intention to start and stop any equipment which may affect the DP control system or power management
   - Intention to handle equipment which may affect the trim of the vessel
   - Fault or failures of equipment which may reduce DP capability and/or redundancy.

iv) DP control to ECR:
   - Request for additional generators or power
   - Vessel on location
   - Divers in water
   - Warning of moves that might require additional power
   - Increasing/decreasing weather conditions
   - Trim and list matters
   - Ballasting requirements
   - Major deck operations for example lifting
   - Request for location checklist to be started.

v) Platform to DP control:
   - Planned movements of other vessels and helicopters
   - Planned crane lifts or outside platform work which could interfere with the diving operation or position references
   - Intention to use underwater discharges
   - Planned blackouts in communications or power and hazardous operations (for example well-tests)
   - Weather information
   - Other subsea operations
   - Other operational or abandoned acoustic beacons or transponders which may be in the vicinity

– Mooring line adjustment (for moored platform) (see also section 2.7).

vi) DP control to platform:
- – Changes in status of divers
- – Changes in status of DP system
- – Intention to perform tasks involving the operation of any hazardous tools or equipment
- – Vessel movements for example closer to platform or to new work location, major change of heading.

vii) ROV control to DP control:
- – Request clearance to launch ROV
- – ROV in water
- – ROV at depth
- – Commence recovery of ROV
- – ROV on surface
- – Loss of control or communication with ROV.

viii) DP control to ROV control:
- – Clearance to launch ROV
- – Positions of taut wires and other down-lines
- – Positions of transponders
- – Details of obstructions
- – Movements of the vessel and heading changes
- – DP alert status.

For further information on ROV intervention during diving operations consult IMCA D 010 – *Diving operations from vessels operating in dynamically positioned mode* – and AODC 032 Rev. 1 *– Remotely operated vehicle intervention during diving operations*.

Sections v) and vi) above assume the vessel is within 500m of an offshore platform or within an area under the jurisdiction of a designated marine controller.

2.4 DP Alert Status System

2.4.1 Visual and Audible Characteristics

A system of lights and audible alarms should be provided in dive control, saturation control, air diving control area, working area, ECR and, where applicable, the ROV or submersible control position, manually activated from, and repeated in, the DP control room. The lights should be:

- Steady green light to indicate vessel under automatic DP control, normal operational status and confirming the alert status system functional;
- Flashing yellow light to indicate degraded DP control;
- Flashing red light to indicate DP emergency.

In addition the distinctive alarm for the red alert should sound in the master/OIM's cabin, operations superintendent's cabin (if applicable) and the senior diving supervisor's cabin in conjunction with the flashing red light.

Provision of a means of acknowledging and silencing the audio and flashing functions of the signals from the receiving positions should be made.

When supporting divers on DP a clear procedure indicating the recommended responses to yellow and red alerts is required. The events that should trigger these alerts should be based upon a minimal number of standard operating status levels reflecting the capability of the DP system to maintain the vessel on station within safe working limits.

Examples are provided below.

2.4.2 Green

Normal operational status (green light). The vessel can be defined as in normal operational status when all the following conditions apply:

- Vessel under DP control and DP system operating normally with appropriate backup systems available;
- Thruster power and total power consumption is equal to or less than the maximum thrust and power that would be available after the worst single failure;
- Vessel's indicated position and heading are within predetermined limits and the worst single failure would not result in safe working limits being exceeded;
- Negligible risk of collision exists from other vessels.

2.4.3 Yellow

Degraded status (yellow alert). The vessel can be defined as being in a degraded status when any of the following conditions applies:

- A failure in a sub-system has occurred leaving the DP system in an operational state (possibly after reconfiguration) but with no suitable backup available, such that an additional fault would cause a loss of position;
- Vessel's position keeping performance is deteriorating and/or unstable;
- Vessel's indicated position deviates beyond limits determined by risk analysis or HAZOP without simple explanation;
- Risk of collision exists from another vessel;
- Weather conditions are judged to be becoming unsuitable for DP diving;
- Any other condition or circumstance affecting the operation of the vessel which could reduce the status from normal.

2.4.4 Red

Emergency status (red alert). A vessel can be defined as in emergency status if either of the following conditions applies:

- System failure results in an inability to maintain position or heading control;
- Any external condition exists, including imminent collision, preventing the vessel maintaining position.

Onboard this alert is often referred to as 'abandon dive'.

2.4.5 DP Alert Responses

The following diving operational responses would be expected to the change of alert status initiated by the DP operator:

- Green Normal Operational Status

Full DP diving operations can be undertaken.

- Yellow Degraded Status

The diving supervisor should instruct the divers to suspend operations and move to a safe location. The DPO, after consultation with the diving supervisor, should decide if any further action is necessary. If the diving supervisor is unable to get clear advice from the DPO he will instruct divers to return to the bell and obtain a seal or to return to the surface as appropriate.

Note: *Flexibility has been provided in this alert response (1994 revision) so that (a) this alert is sounded early rather than late, (b) discussion can take place between senior personnel and (c) the safety of diving operations is improved.*

- Red Emergency status

The diving supervisor should instruct the divers to return immediately to the bell (or deployment device as appropriate) and obtain a seal. The bell should be recovered as soon as possible after due consideration of hazards involved in the recovery (for example fouling of mooring lines or jacket members).

Key DP personnel should use all reasonable means available to limit the loss of position while the divers are being recovered.

2.5 Shallow Water

2.5.1 Vessel Draught

The master of the DP vessel should determine the appropriate clearance the vessel needs between the seabed and the keel or lowest thruster taking into account the weather forecast, heights of the tides, vessel motion and the presence of subsea obstructions. Consideration should also be given to the clearance that is required by the divers' deployment device. The above factors will determine the shallow water limits of a DP DSV.

Where water depth that limits the direction of escape is close by, care should be exercised to monitor the tide and determine the safe routes to deeper water.

2.5.2 Vessel Capability

The vessel's capability plots may not accurately give the limiting environmental conditions for shallow water and operators should expect higher thruster and generator loads than for the same wind speed in deeper water and, as a consequence, termination of diving support operations earlier than might otherwise have been expected.

For vessels with a consequence analysis warning, the reduced capability should automatically be taken into account.

2.5.3 Position References

The major difference between deep and shallow water diving support operations is the distance the vessel is able to move whilst maintaining seabed based position references on line. This is further reduced if the accuracy of the position references is poor. Each of the vessel's position references should provide position information accurate to ±2% of the water depth. For example in 30m of water the information provided by the reference systems should have a standard deviation of ±0.6m.

There should always be at least three position reference systems on line of which one should be a radio or surface position reference. When working in water depths of less than 60m the scope (radius of operation) of each of the three position references should be equal to or greater than 30% of the water depth, and never less than 5m for example water depth =30m, radius of operation 9m.

In general terms, the shallower the water depth the smaller the scope for movement before seabed position reference sensors need relocation. In particular:

- the scope of vertical taut wires is greatly reduced depending on the height of the suspension point;
- acoustics are more susceptible to interference from the vessel;
- the peak natural excursion of the vessel can exceed the scope of a bottom position reference.

Surface reference systems, not being susceptible to water depth, may offer greater reliability. These may, however, have limitations, the acceptability of which should be assessed, for example the Artemis range may be too great for accurate bearing resolution (Ref. 105 DPVOA – *Failure modes of the Artemis position reference system*; 118 DPVOA – *Failure modes of Artemis Mk IV position referencing system*; IMCA M 174 – *A review of the Artemis Mark V positioning system*).

The standard deviation of the vessel's natural excursions should not exceed one third of the scope of any position reference.

For additional information please refer to IMCA D 010 – *Diving operations from vessels operating in dynamically positioned mode*.

2.6 Diving from DP Vessels Operating within an Anchor Pattern

2.6.1 Safety Principles

Diving within an anchor pattern restricts the movement of the vessel and may introduce additional hazards. Special consideration should be given to emergency and contingency procedures during the evaluation, planning and risk assessment of this type of operation.

The primary hazard to be considered when performing manned intervention from a DSV within an anchor pattern is that in the event of a DP failure or 'black ship' incident, when in the 'drift on' position, the DSV could drift across the mooring catenary.

The environmental forces should be monitored by the DP operator from his console and if the resultant forces conclude that the vessel may drift towards the anchor lines the diving supervisor should be notified so that he can consider and plan diver recovery.

2.6.2 Mooring Line Identification

When supporting divers from a position inside the mooring pattern of another vessel, drill rig or offshore installation, it is essential that anchor positions are confirmed by the other vessel, drill rig or installation and the position of the mooring lines by two independent means, one of which may be by calculation.

If a vessel returns to the same location, it is necessary to recheck these positions.

2.6.3 Mooring Line Adjustments

If the risk assessment has indicated that a mooring line can be safely lowered to the seabed, it is still necessary for the position of the line to be identified, for example, by verifying that the tension has been lowered at the installation, or by ROV inspection, etc.

The other vessel, rig or installation must not move or adjust mooring line tension or position during the diving operation. If necessary the OIM should inform the vessel master of any environmental changes or proposed draught changes that will affect the catenaries of mooring lines. This should invoke management of change procedures.

The DPO must be able to monitor the other vessel, rig or installation from which the mooring lines are deployed at all times, either with radar or by radio. Diving operations should be stopped immediately if communications to the installation are lost.

2.6.4 Permit-to-Work and Reporting Procedures

A reporting procedure should be established between the vessel master and the OIM to provide relevant information, such as the operation of other vessels in the area. There should also be an interface between the permit-to-dive procedure on the vessel and the permit-to-work system on the other vessel, rig or installation concerning mooring line adjustment or any other activity that might adversely affect the diving operation.

2.6.5 Minimum Operating Clearance

A horizontal clearance of at least 50m should normally be maintained between a suspended mooring line and a deployed bell or basket. This nominal distance of 50m in a 'drift on' situation would, in most circumstances, be inappropriate. The appropriate minimum operating clearance should, in such cases, be determined from the outcome of a risk assessment which may include a drift trial.

If the master, the OIM, the diving superintendent, the diving supervisor and the client agree that a clearance of less than 50m is essential for executing the work, the following should be adhered to:

- the position of the mooring line should be plotted, and remain traceable throughout the operation. This can be achieved with an ROV-mounted transponder or other suitable means;
- the time spent with the bell in water with a clearance of less than 50m should be minimised;
- twin bell systems should not to be deployed simultaneously within the anchor pattern.

Emergency provision for the loss of the bell needs to be considered during the evaluation, planning and risk assessment.

Movement at the touch-down point of the mooring line is inevitable, and can result in poor seabed visibility and entrapment of a diver and/or his umbilical. This should be addressed during the evaluation, planning and risk assessment.

2.6.6 Position References

Care should be taken to prevent vessel position reference taut wires from coming into contact with the mooring lines because this will result in the loss of the seabed position reference. If it is technically feasible, a radio or surface position reference should always be used.

2.6.7 Operational Plots

The thruster configuration diagram should include the position of mooring lines in an easy-to-assimilate form. The vessel should also have on-board diagrams showing the catenaries and touch-down points for various mooring-line tensions.

2.7 DP Diving Hazards

The following sub-sections highlight common DP diving hazards. Information on the operational aspects of diving from DP vessels can be found in IMCA D 010 – *Diving operations from vessels operating in dynamically positioned mode*. The degree of variation in both the complex characterisation of DSVs operating on DP and the types of subsea operations being carried out make it difficult to provide guidance that is all embracing. However for every vessel and project the following and similar hazards particular to the vessel should be considered and included in vessel onboard manuals and be part of any project or pre-operation risk analysis/HAZOP.

2.7.1 Down-Line Handling and Interference with DP Sensors

The handling of all down-lines from DP vessels requires special care; long horizontally slung objects can rotate while being lowered and come into contact with taut wires; and any down-line can snag a diver. Down-lines should only be handled by experienced personnel under supervision of the diving supervisor. Acoustic devices should only be moved by divers under the supervision of the diving supervisor and on the direct authority from DP control. Consideration should be given to the incorporation of a suitable weak link to secure down-lines subsea in order to minimise the risk to personnel and damage in the event of uncontrolled DP movements. After positive identification the diving supervisor should inform the DPOs of all secured down-lines in use.

2.7.2 Uncontrolled Movement

A DP vessel moving off station can cause failure of main lift wires, life-support and/or communication arrangements between the vessel and the diver deployment device. Operating and emergency procedures should be established to minimise these risks and adequate arrangements should be made for the provision of emergency life support, communications and relocation devices to allow a successful recovery. The deployment device should be positioned, whenever possible, above the level of potential underwater obstructions. Any restriction on the diver's mobility should be considered when determining safe working limits.

2.7.3 Operations Plot and Emergency Plans

A plot displaying the relative positions of the vessel, the diver's deployment device, air divers, the work site, and any known obstruction for example platform, other vessels, mooring wires, wellheads etc. together with vessel's heading and environmental data where appropriate at the DP and dive control position. The DP watchkeepers should ensure that this plot is regularly updated and that the planned emergency procedures have been agreed with the diving supervisor and that the relevant information for dive control to keep a similar plot is given to the diving supervisor.

2.7.4 Vessel Movement Limitations

A DP DSV under full and stable DP control may execute a change of position or heading without recalling the divers to the deployment device, provided the DPO and the diving supervisor are both satisfied of the following:

- the move can safely be executed;
- umbilicals are clear and will remain so during the move;
- divers understand the move and they are in a safe location;
- the divers can easily reach the deployment device;
- there will be three position references on line throughout the move;
- low speed is selected;
- a change of heading and position are not planned to be carried out simultaneously;
- the move can be stopped at any time;
- the move will not exceed the scope of any one of the three position references;
- the move will be stopped when any one position reference has to be repositioned;
- the DPO will verify the move input before execution;
- due account will be taken of the selected centre of rotation when heading is to be changed.

In addition if at any time the DPO has any doubt about the safety of the move being executed the DPO should instruct the dive supervisor to recall the divers to the deployment device and stop the move to re-assess the safety of proceeding.

2.7.5 DP Operations Close to Obstructions

Particular care should be exercised when operating on DP in close proximity to fixed objects such as subsea manifolds, production platforms, mooring buoys, wires and chains etc. When DP diving is undertaken in the vicinity of anchor wires and cables, the accuracy of their position as well as their excursion should be used to determine a safe working clearance for divers, the bell and bell wires.

Every effort should be made to check the vessel's co-ordinates to guard against a slow drift off position undetected by the DP control system.

2.7.6 Visual Reference Points

When close to fixed structures, the availability of a visual reference from the DP control position to provide an early additional indication of vessel movement is an advantage, and the DP vessel heading should be selected to make this feasible whenever possible. The master may order the termination of diving operations in reduced visibility when loss of visual reference to a structure or vessel is considered to be an unacceptable risk.

2.7.7 Surface Orientated Diving

Great care is needed in the planning and execution of shallow and surface orientated diving operations from a DP DSV to minimise the effect of thrusters on the divers. The effects of thruster wash or suction should be carefully considered and precautions taken to guard against them, particularly when the diver's deployment device or the divers pass the potential wash zone. These precautions could include appropriate thruster barred zones in the DP software to avoid any hazardous effects on the operation of the diver's deployment device or divers. The use of thrust diagrams when planning dives can also help. Inhibiting or deselecting certain thrusters may be necessary and the resulting reduction in the vessel's operational limitation should be taken into account. Divers' umbilical lengths and the manner of deploying them should be chosen so that divers and their umbilicals are physically monitored and restrained from going to positions where they or their equipment could come into contact with thrust units or be adversely affected by their wash (Ref. IMCA D 010 – *Diving operations from vessels operating in dynamically positioned mode*).

2.7.8 ROV Operations

If ROV and diver operations are being carried out simultaneously from the same vessel then the operational areas of each should be sufficiently separated to ensure that diving operations are not jeopardised and down-lines for the diving operations and position references are not interfered with.

2.8 Personnel Responsibilities and Capabilities

2.8.1 The Master/OIM

The master/OIM is ultimately responsible for the safety of the vessel and all personnel on board or working from it, and has ultimate authority to forbid the start or order the termination of diving and DP operations on grounds of safety to personnel or the vessel. The master cannot order the start of diving operations. The master also has the responsibility of ensuring the compatibility of the vessel's safety management system with that of any platform within whose jurisdiction it is working (Ref. IMCA M 125 – *Safety interface document for a DP vessel working near an offshore platform*).

2.8.2 The Operations Superintendent

The Operations Superintendent, where present, is responsible for the conduct of all operations carried out from the vessel. As such this superintendent has authority to forbid the start or order the termination of diving and DP operations for safety or other reasons. The superintendent may not order the start of diving or DP operations.

2.8.3 Diving Supervisor

The diving supervisor on duty is ultimately responsible for all aspects of diving safety including the condition and operation of all diving equipment for the dive. The supervisor is responsible to the diving superintendent (if one is appointed) for the effective and timely conduct of diving operations. The supervisor is the only person who may order the start of diving operations. The supervisor is also responsible for keeping the DPO advised of any change of status of the diving operation.

2.8.4 Diving Superintendent

In most circumstances (for example during 24-hour working), there will be a diving superintendent (or senior diving supervisor) who will be an experienced diving supervisor. This superintendent (or supervisor) will act as offshore project manager to co-ordinate the work of both shifts of divers and liaise with the vessel's master and client's representative. Functionally, the other diving supervisors will report to the superintendent (or senior diving supervisor) while retaining responsibility for the commencement, operation and termination of the dive which they are supervising.

2.8.5 The Client's Representative

The client's onboard representative should, in conjunction with the contractor's senior onboard representative, be responsible to the client for the proper performance of all work in accordance with the contract. The client's representative may request the start of DP or diving operations, and should have the authority to veto the start of, or order the termination of, diving or DP operations.

2.8.6 Project Liaison

In view of the additional safety factors involved in DP operations, it is essential that close liaison be maintained between the various authorities concerned. Some organisations may include additional supervisory roles, but the above four authorities should represent the minimum forum for planning meetings concerning DP supported diving operations.

2.8.7 Priorities

Priorities should be clearly established for dealing with a DP emergency. The authority of the master/OIM and diving superintendent are of fundamental importance at such times. They should co-operate closely on these priorities so that there is no room for doubt or dissension and so that the senior DPO and diving supervisor on duty at the time of an emergency act to the same priorities without undue hesitation. When determining priorities the following should be considered:

i) The safety of life is the first priority. The master has ultimate authority to assess and decide on courses of action in this respect. The advice of the diving superintendent should be taken into account;

ii) The safety of property is of lower priority. No effort should be made to safeguard property at the expense of safety to life, but the potential danger to life associated with certain threats to property should not be overlooked. The advice of the client's representative and offshore installation manager should be considered, where possible, with respect to the safety of offshore platforms and equipment.

2.8.8 Manning for DP Diving Operations

The requirements for numbers of qualified DPOs will vary. Every DP vessel engaged in diving operations should, however, meet the following minimum requirements:

i) The master/OIM of a DP DSV, when performing DP diving operations, should be appropriately trained for this type of DP operation. He should also be capable of assuming the role of a DPO.

ii) Two DPOs should be present in the DP control room whenever DP diving operations are being carried out. Each should be capable of operating the system without supervision. They are responsible for the vessel's marine operations and for keeping relevant control centres informed as required by section 2.3. One of them should hold an appropriate deck-officer's qualification to be in charge of the navigational watch.

iii) An appropriately trained technician, capable of minor fault finding and maintenance of the DP system, should be onboard at all times when DP operations are taking place.

iv) The period of time for which the watchkeeper, referred to in ii) above, continuously operates the DP control system should be limited to avoid loss of concentration. It is unlikely that continuous periods of longer than two hours would be satisfactory and in some circumstances this may need to be shortened.

v) Engine control rooms or engine rooms as appropriate should be adequately manned at all times when on DP supporting diving work, or within the 500m zone of an platform by a watchkeeping engineer familiar with the operation of the power plant and the functions of the power management system.

2.8.9 Training and Experience

The training and experience of key DP personnel should be as set out in IMCA M 117 – *The training and experience of key DP personnel.*

3 Drilling Vessels

3.1 Design Philosophy

In addition to the basic principles outlined in Section 1, a DP drilling vessel should also meet the following:

- No known single failure mode should risk position loss which could result in an uncontrolled release of hydrocarbons.
- The determination of safe working limits should consider the time required to secure the situation on the drill floor, for example to hang off drill string and operate the BOP emergency disconnect.
- Safe working limits can vary depending on the nature of the task within the drilling programme and the influence of current on the riser. These limits should reflect the risk associated with each task hence, for example, different limits for drilling, running casing and for well testing are acceptable. Safe working limits should be revised for periods of maintenance on machinery if this would cause a reduction in availability that would limit DP performance after a single failure.
- The time available for an emergency disconnection from the position of the rig in the existing and forecast environmental conditions should always be known and compared with the time for emergency disconnect with a suitable time margin for the response of the operators. The critical offset is the distance from the present set point to the position where the disconnection should be instigated for it to be successful. In shallow water this distance might be so small that disconnection may have to be instigated immediately there is a station keeping problem.

Note: All the above should be captured and summarised in a single well specific operating guidelines (WSOG) document, which should be a practical and all encompassing guide for the DPO and driller.

3.2 Redundancy

3.2.1 General

Redundancy to reduce the effect of failure modes and improve safe working limits is normal on all DP drilling units. The level of redundancy is a matter for owners and designers to optimise to achieve practical and economically viable safe working limits. DP drilling units are expected to be at least DP equipment class 2 on the basis that hydrocarbons are frequently present.

3.2.2 Thruster Units

Thruster units should be independent such that the risk of loss of more than one thruster unit is as low as reasonably possible. The safe working limits should include the failure of the most useful thruster and the loss of a switchboard or engine room from shut down, if the design intent is not to disconnect after the worst case single failure. If the vessel availability is to be high, then necessary repair and maintenance of thruster units should also be considered.

The arrangement of thruster units should be such as to provide, as far as practicable, a good all-around DP capability for intact and worst failure situations. In addition consideration should be given to providing a balanced athwartships capability in the intact and worst failure conditions.

This has been achieved on some mono-hulled vessels with three thrusters forward and aft, where the centre unit is capable of being powered from either switchboard. Cross-over power facilities for thrusters should meet class requirements. Other designs provide independence for each of the three thrusters.

If separation for fire and flood is not reasonably achievable the risk of fire and flood should be considered in high risk areas. The routing of cables for redundant equipment through engine rooms, boiler rooms, machinery spaces etc. should be avoided. It is important that cables are not routed such that the designed worst case failure mode, for example a switchboard fault, is compromised because failure in common cable routeing in an engine room would cause more (or more critical) thrust units to fail than the switchboard fault.

3.2.3 Power Generation

The sudden unexpected failure of one diesel engine or the diesel engines of one engine room should always be a design and operational consideration, as should a sudden demand for increased power from the drill floor. Provided blackout is prevented and another engine can be started and brought on line, before the position excursion has exceeded that defined in the WSOG for a yellow alert and the time limits defined in 3.1; then power redundancy does not have to be on line.

The reduced power available after an engine room fire should also be a design consideration, and the need for provision of separate engine rooms should be determined by the time necessary to achieve a 'safe situation' in comparison with the speed that a fire is likely to develop and be controlled.

Utilities such as fuel oil and cooling water required for power generation should be redundant, or have a passive capacity to support power generation for longer than the time to achieve a safe situation.

It is essential that if there are two or more engine rooms then smoke from a fire in one cannot be drawn into the other and confuse operators or activate additional smoke alarms so as to make the fire appear worse than it is.

3.2.4 Power Management

For vessels with complex and redundant power generation and with thruster systems with load shedding systems, the power management has to be automatic and comprehensive and operate for all switchboard and bus tie combinations. It has also to be redundant itself or fail safe so that no loss of power or thrust takes place on failure of the power management system. Designers should ensure that there is a clear interface between the blackout prevention control by the DP control system and that exercised by the power management or the individual thruster protection.

Communication between the two is not essential for control, but if this communication is to improve the speed of response to a power demand, failures of this communication should also be considered when determining safe working limits. The power management system should be redundant as far as its failure directly affects position keeping. If its failure modes do not result in loss of power to thruster units until a change of status takes place, redundancy is not essential.

The power management need only operate for the normal DP mode of operation, i.e. with a common switchboard (bus tie closed) provided this meets the requirements of 1.1 iii) and 3.2.5. If the vessel is designed to operate with the bus ties open while well testing and closed for drilling then the power management system will need to operate for each side, or section of the switchboard independently.

Where phase back and/or regenerated power can be fed back to the switchboards from drilling equipment the calculation of limits using this data should be secure and allow for single point failures.

3.2.5 Power Distribution

The power distribution should be so arranged that when undertaking the most sensitive operations (for example, non-shearable equipment in the BOP) no switchboard fault can cause a failure of such proportions that there is inadequate power to keep position until the well is safe. This should be the case for every working combination of generators and thrusters.

To achieve this requirement when normally operating with a common bus, the bus ties should be set and tested at regular intervals so that they split the bus before any tripping of generators has taken place on the healthy sections of the switchboard. If there is a realistic chance of the bus ties not opening or not opening fast enough to prevent a blackout then the switchboard should be split for the work.

Similarly no fire or flood in any vulnerable space should threaten electrical power or control cables which could cause a total loss of position control before a safe situation is reached. This should have been addressed if the vessel is intended to meet DP equipment class 3 requirements.

3.2.6 Position Control

For drilling using DP, the minimum control requirement is for two automatic and fully redundant control systems providing, on loss of one, a smooth transfer to the other which would be unnoticed by the drillers. In addition there should be a joystick facility for manoeuvring which can either be separate from/or an integral part of the DP control system.

The joystick should afford manual control of fore and aft, athwartships and rotational thrust with an optional automatic control of heading. The operators should be suitably experienced with this mode of position control and able to maintain the vessel's position adequately to always provide enough time for an emergency disconnection.

Both gyro compasses should be available to the joystick control system.

For use in the event of DP control unit failure a simple independent display of vessel position should be provided by, for example, the DGPS display.

For vessels that require a high availability, a triplex DP control system can be installed, and arranged so that, on failure of one system the duplex mode can continue, while the faulty unit is repaired without risk to the active duplex DP control system.

For vessels where the main DP control system (duplex or triplex) could reasonably be lost from a fire a backup DP control system should be provided. The location should enable control to be easily taken over well before the need to instigate an emergency disconnection (see 3.1).

3.2.7 Position References

When connected or installing the BOP at least three position references should be continuously on line. These position references should be configured to minimise the possibility of common mode failure. For shallow water (<500m) the expectation is for acoustics, DGPS and a taut wire. In deepwater where only acoustics and DGPS can provide the accuracy and update rate needed, two independent acoustic and DGPS inputs can be shown to be adequate (Ref. 128 DPVOA – *QRA for the use of a dual DGPS system for dynamic positioning* – and IMCA M 141 – *Guidelines on the use of DGPS as a position reference in DP control systems*), provided the DP control system treats them correctly with respect to their weight in any position estimate. Reference should also be made to IMCA M 160 – *Reliability of position reference systems for deepwater drilling*.

3.2.8 Environmental Sensors

At least two wind sensors in different locations, with separate supplies and cable routes, should be provided. If a third unit is installed it should be in a different location or in the better of the two locations for the other wind sensors. If the wind sensors are at very different heights they should be corrected so that operators can compare them easily. Whenever possible all wind sensors should be selected. The DP control should be able to identify a faulty unit and alert operators before a position change takes place.

3.2.9 Vessel Sensors

At least two vertical reference sensors should be provided. If a third unit is installed it should be in a separate location with a separate power supply. Three gyro compasses should be provided particularly for mono-hulled vessels because of the critical nature of heading control. The DP control should be able to identify a faulty unit and alert operators before a heading and/or position degradation takes place. Vessel sensors should be physically separated, so that the redundant units are unlikely to suffer from the same fire, flood or mechanical damage event.

The design and arrangement of these sensors should ensure that the independence of the position references is not compromised if one of them fails because all position references are using the same vertical reference sensor and/or gyro compass.

3.3 Communications

3.3.1 Voice Communication

Priority voice communications should be available to ensure immediate and clear transfer of information between all responsible parties. In particular, these should include:

- DP control position;
- Engine control room;
- Drill floor;
- ROV operator's shack;
- Drilling supervisors office.

All essential voice communications systems should be provided with redundancy, either through duplication or by provision of an alternative system. Terminals should be sited close to the normal operating positions of the personnel for whom they are provided. The equipment should be capable of single hand or foot control.

These communications should be checked as part of the location checklists made during initial DP control system stabilisation see 1.6.5.

Good liaison between the DP control position, the drill floor and the engine room is essential. Each watchkeeper should inform the others about any change in operational status, about to be made or planned.

For good and efficient communications with the drill floor an open, hands free line with priority is a desirable facility.

3.4 DP Alert Status System

3.4.1 Visual and Audible Characteristics

A system of lights and audible alarms, supplied by a UPS and with an indication of power being available, should be used in a similar manner to other DP operations with audible and visual indication in the above locations. The light should be as follows:-

- Steady green light to indicate vessel under automatic DP control, normal operational status and confirming the alert system functional;
- Flashing yellow light to indicate degraded DP control;
- Flashing red light to indicate DP emergency.

3.4.2 Green

Normal operational status (green light). The vessel can be defined as connecting or connected to the sea bed in normal operational status when the following conditions apply:

- Vessel under DP control and DP system operating normally with appropriate back up system available;
- Thruster power and total power consumption is less than the maximum thrust and power that would be needed after the worst case single failure to avoid exceeding yellow alert limits;

- Vessel's indicated position and heading are within predetermined limits;
- Negligible risk of collision exists from other vessels.

3.4.3 Advisory

For DP drilling it has become normal practice for there to be an intermediate alert between green and yellow. This is called 'advisory' and is designed to provide an early warning that some condition exists that needs to be considered by the key DP personnel and all personnel involved with the permit to work system. This alert is to be covered by the WSOG. It is communicated internally by phone or e-mail and is an agenda item at all management meetings. The advisory events do not rate a yellow alert because there is still adequate DP system redundancy in the current weather conditions. It, for example, would warn of high thrust and power consumption and/or increasing environmental conditions and/or the need to change position to reduce the riser angle.

3.4.4 Yellow

Degraded status (yellow alert). The vessel can be defined as being in a degraded status when any of the following conditions applies:

- A failure in a sub-system has occurred leaving the DP system in an operational state (possibly after reconfiguration) but with no suitable backup available, so that an additional fault would cause a loss of position;
- Vessel's position keeping performance is deteriorating and/or unstable.
- The flex joint angle has reached 2°;
- Vessel's indicated position deviates beyond limits determined during risk analysis or HAZOP without simple explanation;
- Risk of collision exists from another vessel;
- Weather conditions are judged to be becoming unsuitable for DP drilling.

Note: A loss of position, other than a large excursion, should not be taking place. This means that the DPO is certain that the position will be restored. A large excursion is one that is outside the DP footprint for the existing circumstances.

3.4.5 Red

Emergency status (red alert). A vessel can be defined as in 'emergency status' if any of the following conditions apply:

- System failure results in an inability to maintain position or heading control;
- Any external condition exists, including imminent collision, preventing the vessel maintaining position;
- There is no time available for position recovery;
- The critical offset is expected to be reached;
- Maximum permissible riser angle is exceeded.

Note: The measurement of the critical offset depends on the position references and the position being sought by the DP control system. If these are wrong the offset is wrong.

3.4.6 DP Alert Responses

The following drilling operational responses would be expected to the alert levels initiated by the DPO:

- Green — Normal operational status; no action;
- Advisory — All key personnel informed by agreed method(s) of communication for the situation to be discussed;
- Yellow — Degraded status; the drill floor should start preparing for a disconnection. The senior DPO and duty driller should confer and decide if any further

action is necessary before the more senior personnel assemble to discuss the situation formally.

Note: *The above response is very flexible, so that (a) the alert is sounded early rather than late; (b) discussions take place between the duty personnel followed by senior personnel as appropriate; and (c) the safety of drilling operations is improved.*

- Red Emergency status; emergency disconnect sequence to be initiated.

3.5 Operations

A riser management programme can assist operations particularly in deepwater where high subsea currents are likely. If such a facility is installed, steps need to be taken, when connected, to confirm the system is set up correctly and that there are no serious software bugs. The data should also be available for use with any DP data recorder so that incident analysis is possible.

An escape route for use in case of emergency should always be readily available. This should account for bathymetry and for any architecture on the seabed.

3.6 Personnel Responsibilities and Capabilities

3.6.1 The Master/OIM

The master/OIM is finally responsible for the safety of his vessel/platform and all personnel onboard or working from her. The master/OIM has ultimate authority in extreme circumstances, and after due consultation with the drilling supervisor, to forbid the start or order the termination of drilling operations on grounds of safety to personnel or the installation. The master/OIM also has the responsibility of ensuring the compatibility of his safety management system with that of any of the installation within whose jurisdiction the vessel is working (Ref. IMCA M 125 – *Safety interface document for a DP vessel working near an offshore platform*).

3.6.2 The Drilling Supervisor

The drilling supervisor should be in overall charge of the drilling operation and for the safety and integrity of the well being drilled. This supervisor has the authority to forbid the start or order the termination of drilling operations on grounds of drilling safety.

3.6.3 The Client's Representative

The client's onboard representative should, in conjunction with the contractor's senior onboard representative, be responsible to the client for the proper performance of all work in accordance with the contract. This representative may request the start of DP or drilling operations, and should have the authority to veto the start of, or order the termination of DP drilling operations.

3.6.4 Priorities

Priorities should be clearly established for dealing with a DP emergency. The authority of the master/OIM and drilling supervisor are of fundamental importance at such times. They should co-operate closely on these priorities so that there is no room for doubt or dissension and that the senior DPO and driller on duty at the time of an emergency act to the same priorities. Safety of life is the first priority and the master/OIM has ultimate authority to assess and decide on courses of action in this respect, but the advice of the drilling supervisor should be taken into account.

3.6.5 Training and Experience

The training and experience of key DP personnel should be as set out in IMCA M 117 – *The training and experience of key DP personnel*.

4 Floating Production Units

4.1 Design Philosophy

In addition to the basic principles outlined in section 1 a DP floating production unit (FPU or FPSO) should meet the following.

- Shut down and disconnection of the production riser(s) should be possible.
- No known single failure mode should risk position loss, such that an uncontrolled release of hydrocarbons is likely which may cause pollution and/or fire.
- The determination of safe working limits should consider the time required to secure the riser and the time to safely disconnect in an emergency.
- Safe working limits should be revised for periods of maintenance on machinery if this reduction in availability limits DP performance after a single point failure.
- Where thruster power is provided indirectly by produced gas, sudden loss of this fuel should not cause an unacceptable loss of thrust for DP.

4.2 Redundancy

4.2.1 General

Redundancy to reduce the effect of failure modes and improve safe working limits is encouraged on all DP FPUs/FPSOs. The following examples are to provide minimum standards and information on the current practice. The level of redundancy is a matter for owners and designers to optimise in order to achieve practical and economically viable safe working limits. DP FPUs/FPSOs are expected to be at least DP equipment class 2 (Ref. 113 IMO – *Guidelines for vessels with dynamic positioning systems* (IMO MSC Circ.645)).

4.2.2 Thruster Units

The arrangement of thruster units should be such as to provide, as far as practicable, a good all around DP capability for intact and worst case failure situations so the vessel is not unduly heading limited. In addition, consideration should be given to providing a balanced athwartship capability in the intact and worst case failure conditions.

This has been achieved on some mono-hulled vessels with three thrusters fore and aft, where the centre unit is capable of being powered from either switchboard. Cross-over power facilities for thrusters may be manual, but automatic transfer is faster and superior, provided the protection prevents fault transfer on change over.

The thrusters should, as far as is practicable, be independent in location, cable routes and control power so that a power fault, fire or flood would not result in the loss of more than one thruster. If separation for fire and flood is not reasonably achievable the risk of fire and flood should be considered and high risk areas, for example engine rooms, boiler rooms, machinery spaces, avoided by the cables of redundant equipment. It is important that cables are not routed such that the designed worst case failure mode, for example a switchboard fault, is compromised because failure in common cable routing in an engine room would cause more (or more critical) thrust units to fail than the switchboard fault.

The safe working limits should include the failure of the most useful thruster, if the design intent is not to disconnect after the loss of one thruster. If the vessel availability is to be high, then in addition an allowance for repair and maintenance of thruster units should also be considered.

4.2.3 Power Generation

The sudden unexpected failure of one diesel engine or the sudden failure of produced gas, if used for power generation, should always be given design and operational considerations, as should a sudden demand for increased power from the process plant. Power redundancy should always be on line for these events and for an engine room fire.

The need for the provision of separate engine rooms should be determined by the time necessary to achieve a 'safe situation' in comparison with the speed that a fire is likely to develop and be controlled. Utilities such as fuel oil and cooling water required for power generation should be redundant, or have a passive capacity to support power generation for longer than the time to achieve a safe situation.

It is essential that smoke from a fire in one engine room cannot be drawn into the another engine room and confuse operators or activate additional smoke alarms so as to make the fire appear worse than it is. There should be no automatic shut down of engine rooms.

4.2.4 Power Management

For vessels with complex and redundant power generation and thruster systems including load shedding systems, the power management should be automatic, comprehensive and operate for all switchboard and bus tie combinations. It would also need to be redundant itself or fail safe so that no loss of power or thrust takes place on failure of the power management system. Designers should ensure that there is a clear interface between the blackout prevention control by the DP control system and that exercised by the power management or the individual thruster protection.

Communication between the two is not essential for control, but if this communication is to improve the speed of response to a power demand, failures of this should also be considered when determining safe working limits. The power management system should be redundant in as far as its failure directly affects position keeping. If its failure modes do not result in loss of power to thrust units until a change of status takes place, redundancy is not essential.

The power management need only operate for the normal DP mode of operation, i.e. with a common switchboard (bus tie closed), provided this meets the requirements of sub-sections 1.1 iii) and 4.2.5 below. If the vessel is designed to operate with the bus ties open while producing and closed for other work, then the power management system will need to be able to operate for each side or section of the switchboard independently.

4.2.5 Power Distribution

The power distribution should be arranged so that, when producing, no switchboard fault can cause a failure of such proportions that there is inadequate power to keep position until the well is safe. This should be the case for every working combination of generators and thrusters. To achieve this requirement when normally operating with a common bus the bus ties should be set and tested at regular intervals so that they split the bus before any tripping of generators has taken place on the healthy sections of the switchboard. If there is a realistic chance of the bus ties not opening or not opening fast enough to prevent a blackout then the switchboard should be split for the work.

Similarly no fire or flood in any vulnerable space should risk electric power or control cables that could cause a total loss of position control before a safe situation is reached. This should have been addressed if the vessel is intended to meet DP equipment class 3 requirements.

4.2.6 Position Control

For production vessels using DP, the minimum control requirement is for two automatic and fully redundant control systems providing, on loss of one, a smooth transfer to the other which would be unnoticed. In addition there should be a joystick facility for manoeuvring which can either be separate from/or an integral part of the DP control system.

The joystick should afford manual control of fore and aft, athwartships and rotational thrust with an optional automatic control of heading. The operators should be suitably experienced with this mode of position control and can maintain the vessel's position adequately to always provide enough time for an emergency disconnection.

Both gyro compasses should be available to the joystick control system.

For use in the event of DP control unit failure a simple independent display of vessel position should be provided by, for example, the DGPS display.

For vessels that require a high availability, a triplex DP control system can be installed and arranged so that, on failure of one system, the duplex mode can continue while the faulty unit is repaired without risk to the active duplex DP control system.

For vessels where the main DP control system (duplex or triplex) could reasonably be lost from a fire a backup DP control system should be provided. The location should enable control to be easily taken over well before the need to instigate an emergency disconnection (see section 3.1).

4.2.7 Position References

At least three independent position sensors should be continuously available. These need not all work on different principles, but if two similar systems are to be considered as independent they should not be subject to common modes of failure. In deepwater where only acoustics and DGPS can provide the accuracy and update rate needed two inputs from each as independent as possible has been shown to be adequate (Ref. 128 DPVOA – *QRA for the use of a dual DGPS system for dynamic positioning* – and IMCA M 141 – *Guidelines on the use of DGPS as a position reference in DP control systems*) provided the DP control system treats them correctly with respect to their weight in any position estimate. The DP control system should not use riser angle as a position reference unless:

- the characteristics of the production riser(s) are accurately modelled;
- the lag in the position information is acceptable and accounted for in the computation of position; and
- the system has been thoroughly failure tested.

(Ref. IMCA M 160 – *Reliability of position reference systems for deepwater drilling.*)

4.2.8 Environmental Sensors

At least two wind sensors in different locations, with separate supplies and cable routes, should be provided. If a third unit is installed it should preferably be in a different location or if this is not possible in the better of the two locations for the other wind sensors. If the wind sensors are at very different heights they should be corrected so that operators can compare them easily. Whenever possible all wind sensors should be selected. The DP control should be able to identify a faulty unit and alert operators in good time.

4.2.9 Vessel Sensors

At least two vertical reference sensors should be provided. If a third unit is installed it should be in a separate location with a separate power supply. Three gyro compasses should be provided, particularly for mono-hulled vessels, because of the critical nature of heading control. The DP control should be able to identify a faulty unit and alert operators before a heading and/or position degradation takes place. Redundant vessel sensors should be physically separated, so that they are unlikely to suffer from the same fire, flood or mechanical damage event.

The design and arrangement of these sensors should ensure that the independence of the position references is not compromised if one of them fails because all position references are using the same vertical reference sensor and/or gyro compass.

4.3 Communication

4.3.1 Voice Communication

Priority voice communications should be available to ensure immediate and clear transfer of information between all responsible parties. In particular, these should include:

- DP control position;
- Engine control room;
- Production control room;
- ROV operator's shack;
- Production supervisor's office/OIM.

All essential voice communications systems should be provided with redundancy, either through duplication or by provision of an alternative system. Terminals should be sited close to the normal operating positions for which they are provided. The equipment should be capable of single hand or foot control.

These communication systems should be checked as part of the location checklists made during initial DP control system stabilisation (see section 1.6.5) and thereafter on a regular basis.

Good liaison between the DP control position, the production control room and the engine room is essential. Each watchkeeper should inform the others about any charge in operational status about to be made or planned.

For good and efficient communications with the production control room, an open hands-free line with priority is a desirable facility.

4.4 DP Alert Status System

4.4.1 Visual and Audible Characteristics

A system of lights and audible alarms should be used in a similar manner to other DP operations with audible and visual indication in the above locations. The light should be as follows:

- Steady green light to indicate vessel under automatic DP control, normal operational status and confirming the alert system functional;
- Flashing yellow light to indicate degraded DP control;
- Flashing red light to indicate DP emergency.

For each new well, a well specific plan should be produced, which provides more detailed responses for yellow and red DP alerts. Such plans take into account the various operations, the water depth and the riser(s) and disconnection systems. For some locations and complex DP systems it is advisable to adopt the advisory alert in addition to the standard three (see 3.4.1).

4.4.2 Green

Normal operational status (green light). The vessel can be defined as connecting or connected to the sea bed in normal operational status when the following conditions apply:

- Vessel under DP control and DP system operating normally with appropriate back up system available;
- Thruster power and total power consumption is equal to or less than the maximum thrust and power that would be needed after the worst case single failure, to avoid exceeding the yellow alert limits;
- Vessel's indicated position and heading are within predetermined limits;
- Negligible risk of collision exists from other vessels.

Note: No 'advisory' status is included as this is not the practice at present, but if required by any client a system similar to that used on drilling vessels could be used. On most floating production units an advisory alert would be an operational advantage.

4.4.3 Yellow

Degraded status (yellow alert). The vessel can be defined as being in a degraded status when any of the following conditions applies:

- A failure in a sub-system has occurred leaving the DP system in an operational state (possibly after reconfiguration) but with no suitable backup available, so that an additional fault would cause a loss of position;
- Vessel's position keeping performance is deteriorating and/or unstable;
- Vessel's indicated position deviates beyond limits determined during risk analysis or HAZOP without simple explanation;
- Risk of collision exists from another vessel;
- Weather conditions are becoming unsuitable for DP production operations.

Note: A loss of position, other than a large excursion, should not be taking place. This means that the DPO is certain that the position will be restored. A large excursion is one that is outside the DP footprint for the existing circumstances.

4.4.4 Red

Emergency status (red alert). A vessel can be defined as in 'emergency status' if any of the following conditions applies:

- System failure results in an inability to maintain position or heading control;
- Any external condition exists, including imminent collision, preventing the vessel maintaining position;
- There is no time available for position recovery;
- The critical offset is expected to be reached.

Note: The measurement of the critical offset depends on the position generated by the references and the wanted position being sought by the DP control system. If the references are generating an incorrect position then the offset is incorrect.

4.4.5 DP Alert Responses

The following floating production operational responses would be expected to the alert levels initiated by the DPO:

- Green — Normal operational status; no action
- Yellow — Degraded status; The production control should start preparing for a disconnection. The senior DPO and duty production supervisor should confer and decide by their standing orders if the OIM and production supervisor should be called.

  Note: The above response is very flexible so that (a) the alert is sounded early rather than late; (b) discussions take place between the duty personnel followed by senior personnel as appropriate; and (c) the safety of floating production operation is improved.
- Red — Emergency status; Emergency disconnect sequence to be initialled

4.5 Operations

Floating production (and the well shutdown) facilities are in many instances subject to the approval of a government department. DP floating production units should be able to shut down in any circumstances.

A riser management programme can assist operations particularly in deepwater where high subsea currents are likely. If such a facility is installed, moves need to be made when connected to confirm the system is set up correctly and there are no software bugs. The data should also be available for use with any DP data recorder so that post incident analysis is possible.

In case of emergency a plan for moving from the wellhead position should always be readily available. This should take account of the fact that, in the initial stages, the riser(s) will recoil and extend its full length beneath the vessel and that the vessel may move into shallower water.

4.6 Personnel Responsibilities and Capabilities

4.6.1 The Master/OIM

The master/OIM is ultimately responsible for the safety of the vessel/installation and all personnel onboard or working from it, and should have ultimate authority in extreme circumstances, and after due consultation with the production supervisor, to forbid the start or order the termination of production operations on grounds of safety to personnel or the installation. The master/OIM also has the responsibility of ensuring the compatibility of the unit's safety management system with that of any other installation or vessel within the master/OIM's area of authority (Ref. IMCA M 125 – *Safety interface document for a DP vessel working near an offshore platform*).

4.6.2 The Production Supervisor

The Production Supervisor should be in overall charge of the production facilities on the FPU and their operation and that of the associated subsea systems. The production supervisor has the authority to forbid the start up and order the shut down of all production facilities.

4.6.3 The Client's Representative

The client's onboard representative should, in conjunction with the contractor's senior onboard representative, be responsible to the client for the proper performance of all work in accordance with the contract. The client's representative may request the start of DP or floating production operations, and should have the authority to veto the start of, or order the termination of production operations.

4.6.4 Priorities

Priorities should be clearly established for dealing with a DP emergency. The authority of the master/OIM and production supervisor is of fundamental importance at such times. They should co-operate closely on these priorities, so that there is no room for doubt or dissension and that the senior DPO and production engineer on duty at the time of an emergency, act to the same priorities, without undue hesitation.

The safety of life is the first priority. The master/OIM has ultimate authority to assess and decide on courses of action in this respect, but the advice of the production supervisor should be taken into account.

4.6.5 Training and Experience

The training and experience of key DP personnel should be as set out in IMCA M 117 – *The training and experience of key DP personnel.*

5 Accommodation Vessels

5.1 Design Philosophy

In addition to the basic principles outlined in section 1 a DP accommodation vessel should meet the following:

No known single failure mode should risk position loss such that the gangway connecting the DP vessel to the offshore structure will be damaged or move in such a way as to injure personnel using the gangway. Personnel should have sufficient warning to safely evacuate the gangway.

The determination of safe working limits should consider the speed with which position could be lost relative to the time required for warning personnel on the gangway and in its immediate vicinity, evacuating personnel from the gangway and lifting and swinging it clear.

The maximum excursion expected in the prevailing conditions before recovery of position and the effect of this on the distance between the two structures and the time taken to recover position should be considered in the risk analysis.

Note: Pull off or excursion limiting anchors can be considered for accommodation vessels and the philosophy outlined under crane vessels (see section 6) is then applicable.

In order to reduce the risk of contact with the structure, the safe working limits can include disconnection and stand off for periods outside changes of shift.

5.2 Redundancy

5.2.1 General

Redundancy to reduce the effect of failure modes and improve safe working limits is encouraged on all DP accommodation vessels. The level of redundancy is a matter for owners and designers to optimise to achieve practical and economically viable safe working limits. DP accommodation vessels are expected to be at least DP equipment class 2 (Ref. 113 IMO – *Guidelines for vessels with dynamic positioning systems* (IMO MSC Circ.645)).

These vessels, by their employment, are normally close to other structures and therefore redundancy should be provided to meet the requirements of sections 1 and 5.1 and to retain the capability to perform their work in moderate weather conditions. If a DP accommodation vessel at an offshore installation wishes to work beyond the weather conditions such that, in the event of the worst case failure, the vessel would lose position, a risk analysis should be carried out to consider whether the gangway will lift and clear and whether the vessel will move away from the structure or towards it in various environmental conditions.

5.2.2 Thruster Units

The arrangement of thruster units should be such as to provide, as far as practicable, a good all around DP capability for intact and worst failure situations, so the vessel is not unduly heading limited. In addition consideration should be given to providing a balanced athwartships capability in the intact and worst failure conditions. All thrusters should be well tuned for the gangway motion to be kept well within alarm limits.

The thrusters should, as far as is practicable, be independent in location, cable routes and control power so that a power fault, fire or flood would not result in the loss of more than one thruster. If separation for fire and flood is not reasonably achievable the risk of fire and flood should be considered and as far as possible high risk areas for example engine rooms, boiler rooms, machinery spaces avoided by the cables of redundant equipment. It is important that cables are not routed such that the designed worst case failure mode, for example a switchboard fault, is compromised because failure in common cable routeing in an engine room would cause more (or more critical) thrust units to fail than the switchboard fault.

5.2.3 Power Generation

The sudden unexpected failure of one diesel engine should always be a design and operational consideration, as should a fire in one engine room. The latter however will normally involve a period of time during which the gangway can be raised and the vessel moved away from the installation. Vessels with independent engine rooms, capable of supplying enough thrust to keep position with one shut down, have a lower risk of position loss as a result of power loss and should therefore have higher allowable safe working limits. It is essential that smoke from a fire in one engine room cannot be drawn into the other engine room and confuse operators or activate additional smoke alarms, so as to make the fire appear worse than it is. If gas detection systems are needed for the platforms served, automatic shut down of engine rooms should be avoided and only alarms and manually initiated shut downs used.

5.2.4 Power Management

For vessels with complex and redundant power generation and thruster systems with load shedding systems the power management has to be automatic, comprehensive and operate for all switchboard and bus tie combinations. It has also to be redundant itself or fail safe so that no loss of power or thrust takes place on failure of the power management system. Designers should ensure that there is a clear interface between the blackout prevention control by the DP control system and that exercised by the power management or the individual thruster protection.

Communication between the two is not essential for control, but if this communication is to improve the speed of response to a power demand then failures of this communication should also be considered when determining safe working limits. The power management system should be redundant as far as its failure directly affects position keeping. If its failure modes do not result in loss of power to thrust units until a change of status takes place, redundancy is not essential.

The power management need only operate for the normal DP mode of operation, for example with a common switchboard (bus tie closed) provided this meets the requirements of sub-sections 1.1 iii) and 5.2.5. If the vessel is designed to operate with the bus ties open when close to structures in accommodation mode and closed for other work, then the power management system will need to operate for each side or section of the switchboard independently.

5.2.5 Power Distribution

The power distribution arrangement should be set up, for gangway connected work using DP, so that a fault on any switchboard section separated by bus ties does not cause the loss of the whole switchboard. This should be the case for every working combination of generators and thrusters. To achieve this requirement the bus ties should be set and tested at regular intervals, so that they split the bus before any tripping of generators has taken place on the healthy section of the switchboard. If there is a realistic chance of the bus ties not opening, or not opening fast enough, to prevent a blackout then the switchboard should be split for the work.

Similarly no fire or flood in any vulnerable space should hazard electrical power or control cables that could cause a total loss of position control before a safe situation is reached.

5.2.6 Position Control

For gangway connected work using DP close to a structure the minimum control requirement is two automatic, fully redundant control systems providing, on loss of one, a smooth transfer to the other which would be unnoticed by personnel crossing the gangway. In addition there should be a joystick facility for manoeuvring which can be separate or an integral part of the DP control system. The gangway should be visible from the DP control location either directly or via CCTV.

If fire or flood is a realistic failure mode within the DP control location then consideration should be given to a separate DP control system equipment location(s) independent of the main system (DP equipment class 3).

Such a fire risk is unlikely to come from within the DP control console space, especially if it is continuously manned when working. When locating equipment within the DP control area, designers should consider fire both above the deck and to cables below the deck.

DP control computers sensors and UPS units located remotely from the DP control console should be separated so that maximum protection is given to the redundant DP control system. If located together the space requires a fire and temperature detection system. In tropical climates where the temperature is expected to rise significantly above ambient when ventilation alone is used, air conditioning may also be required.

At least one computer should be uninterrupted by the worst power loss fault possible and be able to continue operating with associated equipment for at least 30 minutes. It is prudent to provide an independent UPS for each DP control system, with independent battery back-up and no cross connection. Such an arrangement does not increase safe working limits, but it can decrease the risk of a fault causing loss of the redundant DP control system.

5.2.7 Position References

Three position references should be on line, when the gangway is connected and two during approach. If a taut wire is one of the three position references, replumbing it does not contribute a violation of the above. However personnel should not normally be crossing the gangway when this is carried out and this action should be completed as quickly as is reasonably practicable. The power supplies to references should not be common nor should their cable routes. The DP control system should be able to identify a fault in a position reference, alert operators and change to other position references and/or reject the suspect sensor. When the gangway is connected, the point of interest is the gangway and a horizontal taut wire or radio reference (line of sight) near this location should always be considered, as should the use of gangway itself as a position reference. If the installation or structure on which the gangway is deployed is moored or tethered, then the position references used should all be referenced relative to the gangway deployment point, so that the surge, sway and yaw of the installation or structure does not degrade the DP control systems performance. Prior to such an operation the DP control system supplier should be contacted to check if any special settings of the DP control system are required to take into account the motion characteristics of the installation or structure on which the gangway is deployed.

5.2.8 Environmental Sensors

At least two wind sensors in different locations, with separate supplies and cable routes, should be provided. If a third unit is installed it should preferably be in a different location or if not in the better of the two locations for the other wind sensors. If the wind sensors are at very different heights they should be corrected so that operators can compare them. Whenever possible all wind sensors should be selected. The DP control should be able to identify a faulty unit and alert operators in good time. If the wind sensors can be shielded by the installation or structure to the detriment of DP control system performance, repositioning of the wind sensors should be considered.

5.2.9 Vessel Sensors

At least two vertical reference sensors should be provided; if a third unit is installed it should be separately located with a separate power supply. Three gyro compasses should be provided particularly for mono-hulled vessels because of the critical nature of heading control. The DP control should be able to identify a faulty unit and alert operators before a heading and/or position degradation takes place. Vessel sensors should be physically separated so that the redundant units are unlikely to suffer from the same fire, flood or mechanical damage event.

The design and arrangement of these sensors should ensure that the independence of the position references is not compromised if one of them fails because all the position references are using the same vertical reference sensor and/or gyro compass.

5.3 Communications

5.3.1 Voice Communication

Priority voice communications should be available to ensure immediate and clear transfer of information between all responsible parties. In particular, these should include:

- DP control position;
- Engine control room;
- Gangway control position;
- Platform control room.

All essential voice communications systems should be provided with redundancy, either through duplication or by provision of an alternative system. Terminals should be sited close to the normal operating positions of the personnel for whom they are provided. The equipment should be capable of single hand or foot control. The communication between the DP control position and gangway control position should be easy to use during the gangway landing operation.

5.3.2 DP Alert Status System

A system of alert status levels may also be used in a similar manner to other DP operations with audible and vessel indication in the three above locations.

- Steady green light to indicate gangway connection can be maintained to safe working conditions;
- Flashing yellow light to indicate vessel has suffered a failure or reached safe working limits such that one additional event would cause a red alert. Gangway alarm should be given and personnel evacuated from gangway area.

The decision on whether the unit should move clear of the fixed structure will depend on the existing circumstances. For example, in moderate weather or weather that would take the unit towards the structure the unit should move outside the 500m zone until green status is restored. A smaller move or no move at all could be adequate if environmental conditions would take the unit away from the structure.

- Flashing red light to indicate position is being lost or excursion is greater than the limits set out in 1.1 i) and 5.1. The gangway is at risk if not cleared immediately and a pre-determined sequence for achieving a 'safe situation' is about to be carried out.

5.3.3 Gangway Alerts

Independent of the DP control system there should be alerts for the gangway crossing.

Green status lights each end of the gangway indicate free passage.

Yellow flashing lights each end of the gangway and an audible warning indicate that pre-set gangway stroke limits have been reached (for example ±3.5m) and persons using the gangway should exit by the quickest route and clear the area around where the gangway is landed.

Red flashing lights each end of the gangway and an audible alarm indicate that higher pre-set gangway stroke limits have been reached (for example ±4.5m) and the gangway can be expected to auto lift.

5.4 Operations

Accommodation arrangements are usually subject to the approval of a government department and because of their usual location, next to permanent platforms, they also come under the responsibilities of the OIM on the permanent platform.

Decisions relating to the movements of the accommodation unit will normally be decided between those on the unit and the permanent platform. For emergency situations there should be pre-set arrangements so that action does not become delayed by prolonged communication. Emergency situations on the installation may require that the accommodation unit remains with the gangway connected, even though a yellow alert occurs at this time.

5.5 Personnel Responsibilities and Capabilities

5.5.1 The Master/OIM

The master/OIM is ultimately responsible for the safety of the vessel/installation and all personnel onboard or working from it and should have ultimate authority, in extreme circumstances, to lift the gangway and clear any nearby installation. The master should be appointed as, and assume the responsibilities and authorities of, the offshore installation manager while the vessel is operating under DP and is acting as an offshore installation. The master/OIM also has the responsibility of ensuring the compatibility of the vessel's safety management system with that of the installation he is serving (Ref. IMCA M 125 – *Safety interface document for a DP vessel working near an offshore platform*).

5.5.2 Manning for DP when Gangway is Connected

Every DP vessel engaged in DP when gangway connected to an offshore structure should meet the following requirements:

i) The master/OIM should be appropriately trained for this type of DP operation and experienced with the manoeuvring required to land the gangway. He should also be capable of assuming the role of DPO;

ii) Two DPOs should be present in the DP control room whenever DP is being used inside the 500m zone. Each should be capable of operating the system. One of them should hold an appropriate deck-officer's qualification to be in charge of a navigational watch;

iii) The period of time for which the watchkeeper, referred to in ii) above, continuously operates the DP control system should be limited to avoid loss of concentration. It is unlikely that continuous periods of longer than two hours would be satisfactory and in some circumstances this may need to be shortened;

iv) Engine control rooms or engine rooms as appropriate, should be adequately manned by trained personnel at all times when within 500m zone of an installation. This should include a watchkeeping engineer familiar with the operation of the power plant and the functions of the power management system;

v) An appropriately trained technician, capable of minor fault finding and maintenance on the DP system, should be on-board at all times when DP operations are taking place.

5.5.3 Training and Experience

The training and experience of key DP personnel should be as set out in IMCA M 117 – *The training and experience of key DP personnel.*

6 Crane Vessels

Crane vessels, to which the following apply, are large offshore units which install and or remove offshore platforms and modules.

6.1 Design Philosophy

In addition to the basic principles outlined in section 1 a DP crane vessel should meet the following:

No known single failure mode should cause an excursion or loss of position such that contact with a nearby structure is possible, whether such nearby structure is fixed or floating, moored or using DP.

The determination of safe working limits should consider:

- the clearance necessary in the normal operating (green light) situation, so that the failure case above is met with a margin of 10m (this margin shall not apply to the clearance between the crane and the lift but all reasonable steps should be made to maximise this clearance); and
- the exposure time that the crane barge and the DP control system are constrained by the lift fixed horizontally to the platform.

The use of a passive system of pre-laid anchors or external power, for example tugs, can help in meeting the demands imposed by the above philosophy. However it is essential that the response and response times of such an arrangement are taken into account. If tug propellers are left in operation while towing lines are connected they should be as reliable as any thruster of similar power source and free from failure modes that might cause a sudden unexpected towline force.

The DP control system design and operation should be suitable for the changes imposed by moving and placing lifts on fixed structures.

6.2 Redundancy

6.2.1 General

Redundancy to reduce the effect of failure modes and improve safe working limits is encouraged on all DP crane vessels. The following examples give information on the current practice for DP crane vessels. The level of redundancy is a matter for owners and designers to optimise, to achieve practical and economically viable safe working limits. DP crane vessels are expected to be at least DP equipment class 2 (Ref. 113 IMO – *Guidelines for vessels with dynamic positioning systems* (IMO MSC Circ.645)).

6.2.2 Thruster Units

The arrangement and size of thruster units and power should provide, so far as is practicable, a DP capability after the worst case failure that will enable the lift to be completed. The limiting condition will depend on the design but the DP capability plots should assume that the crane(s) are up as if carrying out a large lift over the stern.

The thrusters should, so far as is practicable, be independent in location, cable routes and control power so that a power fault, fire or flood would not result in the loss of more than one thruster. It is important that cables are not routed such that the designed worst case failure mode, for example a switchboard fault, is compromised because failure in common cable routing in an engine room would cause more (or more critical) thrust units to fail than the switchboard fault.

6.2.3 Power Generation

The sudden unexpected failure of one diesel engine should always be a design and operational consideration, as should a fire in one engine room. The latter failure however will normally involve a period of time during which some action can be taken for example clear the load or complete the lift. The power on line and available should include the power for the crane(s) and ballast system as part of the base load if these are supplied from the same generator plant as the DP system. In the event of the worst case failure, restoration of adequate power for DP and lifting, including by ballast, is a priority. Utilities such as fuel oil and cooling water required for power generation should be redundant, or have a passive capacity to support power generation for longer than it is likely to take to reach a safe situation. It is essential that smoke from a fire in one engine room cannot be drawn into the other engine room and confuse operators or activate additional smoke alarms so as to make the fire appear worse than it is.

6.2.4 Power Management

For vessels with complex and redundant power generation and thruster systems with load shedding systems the power management has to be automatic and comprehensive and operate for all switchboard and bus tie combinations. It has also to be redundant itself or fail safe so that no loss of power or thrust takes place on failure of the power management system. Designers should ensure that there is a clear interface between the blackout prevention control by the DP control system and that exercised by the power management or the individual thruster protection.

Communication between the two is not essential for control, but if this communication is to improve the speed of response to a power demand, failures of this communication should also be considered when determining safe working limits. The power management system should be redundant as far as a failure directly affects position keeping. If its failure modes do not result in loss of power to thruster units until a change of status takes place, redundancy is not essential.

The power management system need only operate for the normal DP mode of operation, i.e. with a common switchboard (bus tie closed) provided this meets the requirements of sub-sections 1.1 iii) and 6.2.6. If the vessel is designed to operate with the bus ties open while lifting and closed for other work then a power management system will be needed to operate for each side or section of the switchboard independently.

6.2.5 Power Distribution

The power distribution arrangement should be set up for lifting work on DP, so that a fault on any switchboard section separated by bus ties should not cause the loss of the whole switchboard. This should be the case for any working combination of generators and thrusters and include power distribution faults to the crane(s) if they are part of the same distribution as the thrusters. To achieve this requirement the bus ties should be set and tested at regular intervals so they split the bus before any tripping of generators has taken place from the healthy sections of the switchboard. If there is a realistic chance of the bus ties not opening, or not opening fast enough, to prevent a blackout, then the switchboard should be split for the work. Similarly, no fire or flood in any vulnerable space should hazard electrical power or control cables that could cause a total loss of position control before a safe situation is reached.

6.2.6 Position Control

For lifting work on DP the minimum control requirement is two automatic, fully redundant control systems providing, on the loss of one, a smooth transfer to the other which would be unnoticeable with respect to the lifting operations. In addition, there should be a joystick facility for manoeuvring, which can be separate or an integral part of the DP control system.

The joystick should afford manual control of fore and aft, athwartships and rotational thrust with an optional automatic control of heading. The operators should be suitably experienced with this mode of position control and can maintain the vessel's position adequately to always provide enough time for clearing the lift.

Both gyro compasses should be available to the joystick control system.

A simple independent display of vessel position should be provided by, for example, the DGPS display for use in the event of DP control unit failure.

Position control during the stabbing of loads should be very stable and the time that the crane vessel is connected to the structure, via the lift, should be as short as possible. To help facilitate this, rapid ballast control should be used in a way that will not cause any disturbance of the DP control system. In addition the DP control system supplier should provide operators with guidance on control system setting changes that are likely to be needed to avoid the instability that can be caused from the vessel stiffness change when the load is stabbed.

If fire or flood is a realistic failure mode within the DP control location then consideration should be given to a separate DP control system equipment location(s) independent of the main system (DP equipment class 3).

Such a fire risk is unlikely to come from within the DP control console space, especially if it is continuously manned when working. When locating equipment within the DP control area designers should consider fire both above the deck and to cables below the deck.

DP control computers sensors and UPS units located remotely from the DP control console should be separated so that maximum protection is given to the redundant DP control system. In tropical climates where the temperature is expected to rise significantly above ambient when ventilation alone is used, air conditioning may also be required.

At least one computer should be uninterrupted by the worst power loss fault possible and be able to continue operating with associated equipment for at least 30 minutes. It is prudent to provide an independent UPS for each DP control system, with independent battery back-up and no cross-connection. Such an arrangement does not increase safe working limits but it can decrease the risk of a fault causing loss of the redundant DP control system.

6.2.7 Position References

When a crane vessel is also gangway connected one point of interest is the gangway and the guidelines for accommodation units are also applicable (section 5). When lifting, the point of interest is the hook of the crane which is required to be dynamically positioned as the weight is loaded/transferred. Position references should be organised for this situation with respect to line of sight and movement, particularly if the loading is on to a floating unit that itself may change position and/or heading. At least two position references should be on line during approach and three when gangway connected and/or when lifting. Allowance should be made for cranes causing the loss of the line of sight for radio, radar or laser position references so four or five position references might be needed to be sure of always having three. The power supplies of references should not be common and cable routes should be separated. Furthermore no single factor should reduce the vessel to less than two position references. The DP control systems should be able to identify a fault in a position reference, alert operators and reject the suspect sensor.

6.2.8 Environmental Sensors

At least two wind sensors in different locations, with separate supplies and so far as practicable separate cable routes are necessary. The locations chosen should take into account the movement of cranes and turbulence caused by crane movement. If the wind sensors are at very different heights they should be corrected so that operators can compare them. Whenever possible all wind sensors should be selected. The DP control should be able to identify a faulty unit and alert operators before a position change takes place. If a third wind sensor is installed it should preferably be in a different position, or if not in the best of the two separate locations already provided.

6.2.9 Vessel Sensors

At least two vertical reference sensors should be provided, if a third unit is installed it should be separately located with a separate power supply. Three gyro compasses should be provided particularly for mono-hulled vessels because of the critical nature of heading control. The DP control should be able to identify a faulty unit and alert operators before a heading and/or position degradation takes place. Vessel sensors should be physically separated so that the redundant units are unlikely to suffer from the same fire, flood or mechanical damage event.

The design and arrangement of these sensors should ensure that the independence of the position references is not compromised if one of them fails because all the position references are using the same vertical reference sensor and/or gyro compass.

6.3 Communications

6.3.1 Voice Communication

Priority voice communications should be available to ensure immediate and clear transfer of information between all responsible parties. In particular these should include:

- DP control position for lifting;
- Back up DP control position if provided;
- Engine control room;
- Ballast control position;
- Deck (lifting) superintendent;
- Crane cab(s).

All essential voice communication systems should be provided with 100% redundancy, either through duplication or by provision of an alternative system. Terminals should be sited close to the normal operating positions of the personnel for whom they are provided. The equipment should be capable of single hand or foot control.

6.3.2 DP Alert Status System

A system of lights and audible alarms should be used in a similar manner to other DP operations with visible and audible indication in the locations mentioned above.

i) Steady green light to indicate full working can be undertaken to safe working limits.

ii) Flashing yellow light to indicate the vessel has suffered a failure or reached safe working limits such that any additional event would cause a red alert. Lifting operations should be terminated with the load being placed or lifted clear whichever is the safest option. If sufficient power for keeping position would be lost by using the crane, the priority for power should be decided by the circumstances.

Note: All realistic failure circumstances should be analysed by the project specific risk studies and included in the project procedures as necessary: this may also cause changes to the yellow alert criteria and responses. Gangway passage should be stopped and personnel kept clear of lifting and stand by for pre-arranged plan, if red alert takes place. A similar status alert should be sounded on the platform being attended, if manned.

iii) Flashing red light to indicate position is being lost or excursion is greater than the limits of 1.1 i) and damage to the lift and/or the installation being attended is possible. Personnel should move clear of the crane and the lift area and the platform should sound a pre-determined emergency signal. If the lift is clear, the crane vessel should move from the vicinity of the installation as soon as possible.

6.4 Operations

Lifting operations are usually subject to the approval of a marine surveyor and in addition the crane vessel will come under the responsibilities of the OIM on the permanent platform and safety interfaces should be checked (Ref. IMCA M 125 – *Safety interface document for a DP vessel working near an offshore platform*). The safe limits for an operation should carefully consider the weather forecast. Each lift, location and arrangement may need different safe working limits and weather forecast confidence.

Safe working limits and procedures should include approach and departure in normal and failed conditions and for all defined or calculated situations full scale testing should be considered to prove the procedures before close approach. Such care and precautions are necessary to reflect the enormous damage and loss of life possible from the impact of a large crane vessel with a manned offshore structure.

6.5 Personnel Responsibilities and Capabilities

6.5.1 The Master/OIM

The master/OIM is ultimately responsible for the safety of his vessel/installation and all personnel on board or working on the lifting works. The master/OIM has ultimate authority in extreme circumstances to instigate clearing of the lift and any gangway connection to a nearby structure and moving out of the area. The master/OIM also has the responsibility of ensuring the compatibility of the vessel's safety management system with that of the installation where it is working (Ref. IMCA M 125 – *Safety interface document for DP vessels working near an offshore platform*).

6.5.2 The Construction Superintendent

The construction superintendent should be in overall charge of the lifting operation and the safety and integrity of the lift and the personnel working on the lifting operation. He has the authority to forbid the start or order the termination of the lifting on grounds of safety.

6.5.3 The Client's Representative

The client's onboard representative should, in conjunction with the contractor's senior onboard representative, be responsible to the client for the proper performance of all work in accordance with the contract. He may request the start of the lifting operations and has the authority to veto the start of the operations but he can only request the termination of the operations because there is a point where it is safer to continue than abort.

6.5.4 Training and Experience

The training and experience of key DP personnel should be as set out in IMCA M 117 – *The training and experience of key DP personnel*.

6.5.5 Manning for DP During Heavy Lift Operations

The requirements for numbers of qualified DPOs will vary. Every DP vessel engaged in diving operations should, however, meet the following minimum requirements:

i) The master/OIM of a DP DSV, when performing DP diving operations, should be appropriately trained for this type of DP operation. He should also be capable of assuming the role of a DPO;

ii) Two DPOs should be present in the DP control room whenever DP diving operations are being carried out. Each should be capable of operating the system without supervision. They are responsible for the vessel's marine operations and for keeping relevant control centre informed as required by section 2.3. One of them should hold an appropriate deck-officer's qualification to be in charge of the navigational watch.

iii) An appropriately trained technician, capable of minor fault finding and maintenance of the DP system, should be onboard at all times when DP operations are taking place.

iv) The period of time for which the watchkeeper, referred to in ii) above, continuously operates the DP control system should be limited to avoid loss of concentration. It is unlikely that continuous periods of longer than two hours would be satisfactory and in some circumstances this may need to be shortened.

v) Engine control rooms or engine rooms as appropriate should be adequately manned at all times when on DP supporting diving work, or within 500m zone of an installation with a watchkeeping engineer familiar with the operation of the power plant and the functions of the power management system.

7 Shuttle Tankers

7.1 Design Philosophy

In the context of this document a shuttle tanker is taken to be any ship-shaped vessel designed to load, store and/or carry hydrocarbons at or from an offshore facility, which maintains position at that facility by means of full or partial DP.

In addition to the basic principles outlined in section 1, a DP tanker should meet the following:

No known single failure mode should cause an emergency disconnect or cause a position excursion which necessitates emergency release of the loading hose and/or mooring hawser, if used.

The determination of safe working limits should consider the maximum time required to shut down loading and prepare for a controlled release of the loading hose. This is based on the assumption that any DP failure mode, while complying with 1.1 iii), may necessitate a subsequent disconnection.

Safe working limits will vary depending on the type of loading operation and the proximity of offshore structures. It should not be assumed that a hawser connected operation with DP is necessarily safer than one which is only using DP.

Note: For further guidance in this area the UKOOA *Tandem Loading Guidelines* and section 10 of this document (Two-Vessel Operations) should be consulted.

7.2 Redundancy

7.2.1 General

Reliability is provided by thorough testing before loading and/or by providing equipment redundancy to meet the above requirements and to reduce the effect of failure modes and improve safe working limits. Where station keeping redundancy is provided by a mooring hawser this alone may determine normal safe working limits. The following examples provide minimum standards and information on current practice which should be used in HAZID/HAZOP and risk analysis as appropriate.

7.2.2 Thruster Units

DP tankers, which vary from DP equipment class 1 to DP equipment class 2 with twin main propellers and two or three tunnel thrusters, will to a certain extent 'weathervane'. The DP controller is configured to allow the vessel to move about a point some distance ahead of the bow and to keep the ship's head pointing into the weather and towards the loading point while maintaining a constant distance from the loading point. Heading and surge control are thus of paramount importance although the best heading may be naturally kept by the windvaning of the tanker. Generally, heading will be adjusted by one or more tunnel thrusters and constant distance from the loading point by the main propulsion.

In operations where the hawser connection is tensioned a single bow thruster has been found sufficient, but the maximum safe working limits are lower.

The guidance under sub-section 1.6.1 is very important because failure to full power of a single tunnel thruster or single main propeller can cause collision with the loading point or parting of the hawser.

The main propulsion, where used for maintaining position, should be failsafe so that the loading facility cannot be overrun. For example, maximum power might be limited and hydraulic power packs duplicated, with automatic changeover of pumps, should a fault occur in the on-line unit. A secondary means of control should be available, with a separate solenoid valve operated by separate control system with a secure power supply.

When station keeping is totally reliant on the DP system, thrust redundancy in both heading and surge should be provided. A twin drive facility geared to a single shaft and fixed pitch propeller could meet this requirement, provided that adequate redundancy is provided to ensure high reliability of the common control system.

Where rudders are used by DP control as an adjunct to the main propulsion to provide transverse thrust at the stern, they should be treated in a similar manner to thrusters with respect to redundancy. High lift rudders are an advantage provided operators appreciate their limitations.

7.2.3 Power Generation

In a hawser connected operation, the power generation equipment can be similar to that provided in a trading tanker, in that the main propeller(s) will be direct drive, while the bow thruster(s) will be motor driven by electrical power from auxiliary generators or shaft generators.

When station keeping is effectively reliant on DP alone, redundancy in power supplies to thrusters and propulsion units should be provided by a sufficient number of generators and switchboards. Redundancy should ensure that at least one transverse bow thruster and one fore and aft propulsion unit remain in operation after any single failure. When considering safe working limits, the power and station keeping capability should be assessed with the worst identified single failure, such that the critical excursion will not be reached before a controlled loading shut down and disconnection can take place.

Note: Disconnection may not be the safest option in case of a loss of all propulsion if there is a chance of the shuttle tanker drifting down weather towards another structure. In these cases remaining connected by the hawser might be safer.

7.2.4 Power Management

An automatic power management system is not essential but should be seriously considered if there are several combinations of generators possible to achieve the same purpose. Where power management systems are not installed, sufficient units should be on line at all times to account for peak loads on the tunnel thrusters and the DP control system should be able to take care of blackout prevention.

7.2.5 Position Control

In a hawser connected system, the requirement for position control is to keep the best heading and to keep a constant distance (or within a window) from the reference (loading) point or maintain a specific tension in the hawser.

Redundancy is not essential for the DP control system provided total failure does not risk rupture of the loading hose, i.e. a controlled disconnection is possible. Thus a single automatic control system with a joystick back up is adequate. This DP control system should have redundancy in power supplies and the joystick should be separate from the control computer. It should also be designed for the several loading conditions of the tanker if this involves large changes of draught and/or trim.

When a hawser is used the hawser characteristics together with the load imposed on the vessel should be an input into the DP control system and used as necessary to keep the station keeping stable. If the loading point can move significantly (for example FPSO/FPU stern from yaw motion) the DP control system should have the option to position without following the “noise” or this target position. Alarms should be provided when the set window of movement is exceeded.

7.2.6 Position References

A single position reference system is only sufficient:

- if any fault of this reference will not cause a drive off;
- if the DPOs are well trained and experienced to take over in manual control.

A hawser can provide a good visual reference if the DP control is located on the bow. The hawser can be tensioned up by use of a wanted position further astern to improve heading performance and reduce fishtailing.

When station keeping is effectively reliant on DP, at least two different position references should be used DGPS or GPS Relative with an Artemis or Fanbeam for example.

7.2.7 Environmental Sensors

Two wind sensors should be installed in different locations and each should be available to the DP control system. Irrespective of the suitability of the location of the sensors the wind feed forward input to position control should be so arranged that it will not cause a sudden change in position when selected or deselected to the control system, or when the sensor is suddenly shielded or unshielded from the wind. Whenever possible both wind sensors should be selected.

7.2.8 Vessel Sensors

The minimum requirement is for one gyro compass and one vertical reference sensor. However serious consideration should be given to having at least two with both being available by the DP system. Large changes of draught are normal in the loading phase, thus the DP control system should change the model to reflect draught changes. Draught sensors or draught calculations from DGPS provide this information and the DP control system should default to a manually set draught if there is some inconsistency with the inputs.

7.3 Communications

7.3.1 Voice Communications

Priority voice communications should be available to ensure clear and immediate transfer of information between all responsible parties. In particular these should include:

- DP control position;
- Engine control room;
- Cargo control room;
- Platform loading control.

All essential voice communications should be provided with 100% redundancy, either by duplication or by provision of an alternative system. Terminals should be sited close to the normal operating position of the personnel for whom they are provided. The equipment should be capable of single hand or foot control.

7.3.2 Telemetry

No loading should commence until a secure telemetry link has been established with the loading control room. This link is also be used to shut down the loading from the shuttle tanker in the event of a station keeping problem. Failure of this system should stop the loading. A dual system can be installed to reduce the frequency of unwanted shutdowns from faults.

7.3.3 DP Alert Status System

The ESD1 and ESD2 alarms are shown on the DP on these vessels and are preset with reference to the offtake station selected into the DP system. The activation of an ESD alarm will cause a procedure to commence or be progressed ultimately leading to shutdown of operations and disconnect from the loading station. These alarms should alert the DPO to activation of an ESD.

Although not common on board this type of vessel a system of lights and audible alarms could be used in a similar manner to other DP operations, but they should operate in conjunction with the field operators normal alert levels for loading emergencies and have visible and audible indication in the locations mentioned above viz.:

i) Steady green light to indicate normal loading can be undertaken to safe working limits;

ii) Flashing yellow light to indicate the vessel has suffered a failure or reached safe working limits such that an additional event would cause a red alert. In almost every foreseeable loading situation, such an alarm would initiate a precautionary loading shut down (ESD1. If the situation is found to be stable, and position able to be held in the prevailing environment, on DP mode or tensioned hawser mode then loading may continue subject to a frequent review of the situation;

iii) Flashing red light to indicate position is being lost or excursion is greater than the limits of sub-section 1.1 i), and damage to equipment, pollution and injury to personnel is likely. This signal should initiate the pre-determined sequence for emergency shut down (ESD2) and disconnection from the loading facility.

7.4 Operations

Offshore loading operations are usually subject to the approval of a government department, however, this typically is a basic approval of the connection and disconnection arrangements, loading rates, emergency procedures etc., and will not necessarily consider the DP aspect of the loading.

In addition to the usual DP modes the DPO(s) should be fully trained and experienced in the modes specific to this type of vessel and DP failures should also be considered, especially failure modes that require a change over to manual (hawser) control from a critical situation at short notice.

Where the hose is the only connection to the loading facility and the safety of the operation in terms of position keeping rests entirely on the DP system, the environmental limits for each loading facility should be prudently set. In setting these limits the maximum allowable excursion from the hose origin, the time for disconnection and the consequences of the worst single failure of the DP system should be taken into account.

The hours of use of the hawser and the loads experienced should be recorded and a change out of the hawser organised based on the utilisation and the experiences of premature hawser failure.

7.5 Personnel Responsibilities and Capabilities

7.5.1 The Master

The master is ultimately responsible for the safety of the vessel and all personnel on board or working from it and has ultimate authority, in extreme circumstances, to forbid the start or order the termination of loading operations. The master also has the responsibility of ensuring the compatibility of the vessel's safety management system with that of the installation from which it is loading (Ref. IMCA M 125 – *Safety interface document for a DP vessel working near an offshore platform*).

7.5.2 The Loading Supervisor (Platform)

The loading supervisor should be in overall charge of the loading operation from the platform side, and of the safety and integrity of the loading facility. The loading supervisor has authority to forbid the start or order the termination of loading operations on grounds of platform/loading facility safety.

7.5.3 Training and Experience

The training and experience of key DP personnel should be as set out in IMCA M 117 – *The training and experience of key DP personnel*. In addition the master and each DP watchkeeper should have received instruction in the principles and operation of the special features of the DP control system for offtake and have satisfactorily completed at least six loading operations on DP, understudying the role of a senior operator. During this period, they should have been given every reasonable opportunity to operate the DP system, both in normal and simulated emergency conditions. The time waiting on cargo readiness (outside the 10nm zone) should be used to perform approach and manoeuvring simulations to help train operators, particularly if they have not had recent practice in DP operations on relevant systems and manual control. Arrangements should be made for them to refresh their knowledge and experience before performing DP loading operations. The value of simulated operations and failures for this purpose should not be overlooked.

8 Pipelay Vessels

8.1 Design Philosophy

In addition to the basic principles outlined in section 1, a vessel maintaining position while providing a steady tension on a pipeline or umbilical should meet the following:

No known single failure mode should result in the sudden total loss of tension or unmanageable position instability.

The determination of safe working limits should consider the consequences of a sudden failure of the tension load from mechanical, or control, failure so that such a failure does not risk:

- injury to personnel working on or near the line;
- the vessel coming into contact with any nearby structure (surface or subsea) or vessel;
- lifting injury from crane operation from attendant vessel.

The safe working limits may additionally be determined by the limits of the heading capability after failure of thruster(s) furthest from the tensioned pipe when the environmental conditions are partly on the beam.

If divers are to be deployed while the pipeline is under tension, section 2 is also applicable and the pipeline tensioning systems should be able to withstand single point failures without exception and the vessel keep position irrespective of these failures.

If working close to live structures (surface or subsea) no known single failure should cause a loss of position such that contact with them is possible.

8.2 Redundancy

8.2.1 General

Redundancy to reduce the effect of failure modes and improve safe working limits is encouraged on all DP pipelay vessels. The level of redundancy is a matter for owners and designers to optimise to achieve practical and economically viable safe working limits. DP pipelay vessels are expected to be at least DP equipment class 2 (Ref. 113 IMO – *Guidelines for vessels with dynamic positioning systems* (IMO MSC Circ.645)) if they are expected to work close to offshore installations. If this is only achieved when thrust and power for pipe tension is ignored this should be made clear in all relevant DP documentation.

The following examples give information on the current practice of DP pipelay vessels working outside 500m from structures.

8.2.2 Thruster Units

The arrangement of thruster units should provide, as far as practicable, a good DP capability in the intact and the worst failure condition after subtraction of the mean tension required for working with the highest pipe tension load for which the vessel is designed.

The limiting condition will depend on the design, but the DP capability plots should assume the condition where the pipe is hung off at the stinger with a maximum load.

Thruster redundancy is not essential when the vessel is clear of structures (outside 500m), live pipelines and other vessels and the principles outlined in 8.1 are met. The level of redundancy for working limits is a commercial one.

The thrusters should, as far as is practicable, be independent in location, cable routes and control power so that a power fault, fire or flood would not result in the loss of more than one thruster. If separation for fire and flood is not reasonably achievable, the risk of fire and flood should be considered and as far as possible high risk areas for example engine rooms, boiler rooms, machinery spaces etc. avoided by the cables of redundant equipment. It is important that cables are not routed such that the designed worst case failure mode, for example a switchboard fault, is compromised because failure in common cable routeing in an engine room would cause more (or more critical) thrust units to fail than the switchboard fault.

8.2.3 Power Generation

The sudden unexpected failure of one diesel engine should always be a design and operational consideration. It is unlikely that another engine can be started and on line before the pipeline tension is lost. Hence a spinning reserve power equal to the largest generator on line should be available and connected. Vessels with independent engine rooms each capable of supplying enough thrust for the pipe tension and the station keeping with one engine room shut down have a lower risk of position loss and hence they should have higher allowable safe working limits.

8.2.4 Power Management

For vessels with complex and redundant power generation and with thruster systems with load shedding systems, the power management has to be automatic and comprehensive and operate for all switchboard and bus tie combinations. It has also to be redundant itself or fail safe so that no loss of power or thrust takes place on failure of the power management system. Designers should ensure that there is a clear interface between the blackout prevention control by the DP control system and that exercised by the power management or the individual thruster protection.

Communication between the two is not essential for control, but if this communication is to improve the speed of response to a power demand, failures of this communication should also be considered when determining safe working limits. The power management system should be redundant as far as its failure directly affects position keeping. If its failure modes do not result in loss of power to thruster units until a change of status takes place, redundancy is not essential.

8.2.5 Power Distribution

The power distribution arrangement should be set up, for pipelay work on DP, so that a fault on any switchboard section separated by bus ties should not cause the loss of the whole switchboard. This should be the case for every working combination of generators and thrusters. To achieve this requirement the bus ties should be set and tested at regular intervals so that they split the bus before any tripping of generators has taken place on the healthy sections of the switchboard.

8.2.6 Position Control

For pipelay using DP, the minimum control requirement is for two automatic and fully redundant control systems providing, on loss of one, a smooth transfer to the other which would be unnoticed by those in control of the firing line. In addition there should be a joystick facility for manoeuvring which can either be separate from/or an integral part of the DP control system.

In addition to the above, the DP control system should have special features to enable initiation, lay down and recovery of pipeline lengths. The vessel/pipeline combined model should help station keeping performance in steady and transitory conditions brought about by tensioners and winches operating normally and with anticipated failure modes.

It is essential that the tension input (feed forward) to the position control is accurate, redundant and reliable because such a disturbing force has a major impact on position control performance and stability. This also applies to any winch used to assist particular operations such as pipeline pull in.

8.2.7 Tension Control

The tension control equipment, for example tensioners, winches, hydraulics, motors and pumps, should be considered as part of the position control system, and designed with the same philosophy as the DP system itself and included in the DP FMEA.

8.2.8 Position References

The position references have two functions; these are to provide stable position information to the position control system and to provide sufficiently accurate data for the work being carried out. At least three independent position references should be available at all times. The third position reference is so that movement does not reduce the vessel to one position reference.

8.2.9 Environmental Sensors

Two wind sensors should be installed in different locations and each should be available to the DP control system. Irrespective of the suitability of the location of the sensors the wind feed forward input to position control should be so arranged that it will not cause a sudden change in position when selected or deselected to the control system, or when suddenly shielded or unshielded from the wind.

If the wind sensors are at very different heights they should be corrected so that operators can compare them easily. Whenever possible all wind sensors should be selected.

8.2.10 Vessel Sensors

At least two vertical reference sensors should be provided. If a third unit is installed it should be separately located with a separate power supply. Three gyro compasses should be provided particularly for mono-hulled vessels because of the critical nature of heading control. The DP control should be able to identify a faulty unit and alert operators before a heading and/or position degradation takes place. Vessel sensors should be physically separated so that the redundant units are unlikely to suffer from the same fire, flood or mechanical damage event.

The design and arrangement of these sensors should ensure that the independence of the position references is not compromised if one of them fails because all position references are using the same vertical reference sensor and/or gyro compass.

8.3 Communication

8.3.1 Voice Communication

A dedicated communication system should be provided between the operational centres of the vessel, for example DP bridge, ECR, tension control, crane, trencher/plough control if the vessel is involved with simultaneous pipeline burial.

This is in addition to more general systems such as internal telephones and portable radios.

8.3.2 DP Alert Status System

A system of lights and audible alarms should be used in a similar manner to other DP operations and suitable lights placed in the above spaces.

i) Steady green light to indicate full working can be undertaken to safe working limits;

ii) Flashing yellow light to indicate the vessel has suffered a failure or reached the safe working limits such that one additional event would cause a red alert. This situation is to inform all personnel of the status. The response will depend on the position of the vessel with respect to hazards and the perceived risk of continued work but if working with tensioners personnel should prepare for a rapid and unwanted pipe movement;

iii) Flashing red light to indicate position is being lost and damage to the pipe and associated equipment is possible.

8.4 Operations Close to Offshore Structures

If when working close to offshore hazards with high pipe tensions the power available for DP is reduced so that the worst case failure could cause an unacceptable loss of position a risk analysis should be carried out.

8.5 Personnel Responsibilities and Capabilities

8.5.1 The Master

The master of the vessel is ultimately responsible for the safety of the vessel and all personnel on board or working from it and has ultimate authority to forbid the start or order the termination of any work on the grounds of safety of personnel and/or the vessel. The master also has the responsibility of ensuring the compatibility of the vessel's safety management system with that of any installation within whose jurisdiction the vessel is working (Ref. IMCA M 125 – *Safety interface document for a DP vessel working near an offshore platform*).

8.5.2 Construction (or Pipelay) Superintendent

The construction superintendent is responsible for the safe execution of the work to the agreed procedures. The construction superintendent has the authority to forbid the start and order termination of the work on grounds of safety even if the circumstances and conditions are better than in the agreed procedures.

8.5.3 Training and Experience

The training and experience of key DP personnel should be as set out in IMCA M 117 – *The training and experience of key DP personnel*. In addition the master and each DP watchkeeper should have instruction in the principles and operation of the special features of the DP control system and tensions used for pipelay operations and emergency responses.

If operators have not had recent practice in DP operations on relevant systems, arrangements should be made for them to refresh their knowledge and experience before performing DP operations. The value of simulated operations and failures for this purpose should not be overlooked.

9 ROV Support Vessels

9.1 Design Philosophy

In addition to the basic principles outlined in section 1 a DP ROV support vessel should meet the following:

No known single failure mode should cause a position loss that could result in contact with another vessel, mooring line or offshore structure.

The determination of safe working limits should reflect the location in which the work is being carried out and the time to recover position as well as the relative size of the vessel and any nearby structure.

9.2 Redundancy

9.2.1 General

Redundancy to reduce the effect of failure modes and improve safe working limits is encouraged on all DP ROV support vessels. The following examples are to provide minimum standards and information on the current practice. The level of redundancy is a matter for owners and designers to optimise to achieve practical and economically viable safe working limits.

9.2.2 Thruster Units

Redundant thrust units are not required for ROV and survey work where loss of position does not risk personnel or offshore structures. Loss of the ROV is a commercial consideration only. For surveys within 500m of surface offshore structures thruster capability should be assessed as in section 1. This can result in the vessel only working in good weather or only working on the lee side of a structure.

9.2.3 Power Generation

If the safe working limits reflect the fact that the vessel can blackout and meet the requirements of sub-section 9.1 then there is no requirement for spare generators or separate engine rooms or automatic power management. Vessels with redundancy in some areas may increase their safe working limits and availability but there is little point in providing an uneven level of redundancy when single point failures are considered.

9.2.4 Position Control

The minimum DP control facility is a single automatic control system with a joystick and this is adequate for open water locations. The DP system is also likely to have autotracking facilities for some survey and ROV operations with a transponder on the ROV for tracking and recovery. Redundancy here is again a commercial decision. If the survey requires the vessel to work on automatic control in close proximity of structures then it is essential that the system cannot suddenly change track such as to risk collision with the structure in close proximity. It is also essential that thrust can be stopped and reversed to prevent collision even if the DP system has failed. An ROV support vessel should be free to work on any side of an offshore structure (windward or leeward side) provided the worst case failure does not leave the vessel without power to move outside the 500m zone.

9.2.5 Reference Sensors

One reference sensor of each type, for example position, wind, VRU and gyro, can successfully be used for DP control when clear of structures, particularly when the acoustic transponder on the ROV can be used if the position reference in use (usually DGPS) fails.

9.3 Communications

9.3.1 Voice Communication

Communications between DP control, engine control room/ROV shack and survey spread should be 100% redundant.

9.3.2 DP Alert Status System

A set of alerts similar to those used on other DP vessels should be utilised to assist operators as follows:

i) Steady green light to indicate full working can be undertaken to safe working limits;

ii) Flashing yellow light to indicate the vessel has suffered a failure and the ROV should be placed on the sea bed as an acoustic position reference;

iii) Flashing red light to indicate position is being lost.

9.3.3 Personnel, Training and Experience

In open water, for example outside the 500m zone around offshore installations, one familiar with the equipment on duty is adequate because there is little risk to the vessel or personnel from a loss of position.

For operations inside 500m, or taking more than two hours, two DPOs should be on duty, one of whom can be the master.

For DP operations within a 500m zone the level of training and experience necessary should be decided based on the circumstances and conditions as well as the length of time that the vessel will be working within this area.

In addition the relevant sections of IMCA M 117 – *The training and experience of key DP personnel* – should be used for guidance.

10 Two-Vessel Operations

In the context of this section 'two-vessel operations' refer to situations where a DP shuttle tanker undertakes cargo transfer operations in close proximity to another non-fixed structure at sea such as an FPSO or an FSU. There are three qualifying conditions for two-vessel operations:

- At least one of the vessels or structures is to be in full or partial DP.
- Vessels and structures involved are to be in close proximity to one another.
- Vessels and structures are to be subject to motions in at least one of the following axes; surge, sway or yaw.

Definitions are given at the end of this supplement.

In addition, although this section is written with shuttle tanker operations in mind, the principles and standards included may be applicable to other two-vessel operations.

There are a number of publications that are relevant to this type of two-vessel operation, the most relevant being the following:

- *'Offshore Loading Safety Guidelines with special relevance to harsh weather zones'* – OCIMF (Oil Companies' International Marine Forum), 1st edition – 1999
- *'Risk Minimisation Guidelines for Shuttle Tanker Operations Worldwide at Offshore Locations'* – INTERTANKO (International Association of Independent Tanker Owners), March 2000
- *'Quantified Frequency of Shuttle Tanker Collision During Offtake Operations'* – IMCA M 150, February 1999.
- *'Guidance on thruster assisted station keeping by FPSOs and Similar Turret-Moored Vessels'* – IMCA M 159, December 2000.
- *'Safety interface document for a DP vessel working near an offshore platform'* – IMCA M 125, July 1997.

In addition the reader's attention is drawn to sections 1 and 7 of this document, which provides guidelines on DP FPSOs and DP shuttle tankers.

It is recommended that the above publications and sections 1, 4 and 7 of this document are also referred to when considering two-vessel operations.

10.1 Design Philosophy

The design of all FPSOs/FSUs should take into account all the modes of offtake operations planned and their impact on the FPSO/FSU moorings, motions and station keeping controls. The methods used to examine these matters should include one or more of the following:

- Model tests of both vessels in co-incident wind waves and current in which connection, offtake and disconnection operations are planned;
- Model tests of representative non co-incident wind waves and current that represent the weather conditions in which connection, offtake and disconnection operations are planned;
- Mathematical modelling of both bodies in operational sea states in which offtake operations are planned. The model should enable the correct phase relationship of the first and second order motions and properly account for the response of the DP control system and/or taut hawser modes planned;
- Simulation of the combined motions together with changes of wind, waves, current and failure modes of thrusters and propellers of both vessels, as appropriate.

The design principle shall be that in all anticipated environmental conditions during which connection, cargo transfer and disconnection are planned there shall be a negligible risk of contact between the shuttle tanker and the FPSO/FSU. To demonstrate that the risk is negligible, all reasonably likely failure modes on the FPSO/FSU and the shuttle tanker must be considered.

An FMEA should be available for the systems that influence the station keeping of the FPSO/FSU if they are to be used during offtake, for example thrusters, rudders, main propellers, gyro compasses and position measuring equipment. An FMEA should also be available for the planned shuttle tankers. The combined failure modes of both vessels and their effects should be considered.

After the above work the consequences of design worst case combined failure modes of the two-vessel operation should be established together with the safe environmental limits and the motions (surge, sway and yaw) which it is considered safe to carry out offtake operations and safely disconnect and depart.

The shuttle tanker and the FPSO/FSU should each have facilities to effect an emergency disconnection in a manner that is safe for both the shuttle tanker and the FPSO/FSU (see section 10.3.3 on telemetry).

Consideration should be given to the positioning configuration of the FPSO/FSU and the shuttle tanker; the most conventional being tandem loading, where the offtake point on the FPSO/FSU is on the stern and where there is a bow loading system on the tanker. Tandem loading may involve relative and/or absolute positioning, stern follow, independent positioning or various combinations. There are other positioning configurations where the shuttle tanker and FPSO/FSU are bow to bow and where the offtake point on the FPSO/FSU and the loading point on the shuttle tanker are at the midships manifold.

10.2 Redundancy

Redundancy levels for the FPSO/FSU and the shuttle tanker should be in accordance with the relevant sections on redundancy in sections 1, 4 and 7 of this document.

The contents of this supplement should be considered in conjunction with these relevant sections and should be referred to when establishing standards of redundancy.

10.2.1 DP FPSOs/FSUs

The redundancy guidance in section 4 of this document for DP units should be used as the basis for establishing appropriate levels of redundancy. Section 4 gives guidance on redundancy for the following:

- thruster units;
- power generation;
- power management;
- power distribution;
- position control;
- position references;
- environmental sensors;
- vessel sensors.

Refer to section 1.3 for guidance on communications systems redundancy.

In general, the level of redundancy on the DP FPSO/FSU should be established so that no single failure should result in an unmanageable situation.

Additionally the following operational situations should be considered when establishing appropriate levels of redundancy.

FPSOs and FSUs can be positioned on location using only DP or by a mooring arrangement. Those that are positioned by DP control are not necessarily free to weathervane due to seabed connections, such as risers and turret arrangements. Generally, heading changes are possible but these may be initiated by the FPSO or FSU rather than being free. Offtake operations from these FPSOs/FSUs are generally carried out in the tandem mode.

Consideration should also be given to heading changes of the FPSO/FSU. It may be that the FPSO/FSU can only change heading in steps of a certain number of degrees dictated by the turret arrangement. The shuttle tanker will therefore have to move relative to these steps while maintaining the required physical separation distance and electronic communication.

Particular care should be taken in the selection of position reference systems used in the positioning of the shuttle tanker in close proximity to the FPSO/FSU during all phases of the offtake operation, including approach, offtake and departure. This is of particular importance with GPS Relative, through which the position of the shuttle tanker relative to the FPSO/FSU is determined by GPS data transmission between the two units. GPS Relative technology has developed to the extent that redundant hardware and software packages are now available which utilise positioning information from GPS satellites.

10.2.2 Moored FPSOs/FSUs

Some moored FPSOs and FSUs have some DP capability to assist in the station keeping. In such cases the guidance given in section 4 of this document should be referred to when establishing levels of redundancy. This section gives guidance on redundancy for the following:

- thruster units;
- power generation;
- power management;
- power distribution;
- position control;
- position references;
- environmental sensors;
- vessel sensors.

Other moored FPSOs and FSUs either have no thrust capability or have limited thruster assist capability. In all such cases, when establishing standards of redundancy, reference should be made to IMCA M 159 – *Guidance on thruster-assisted station keeping by FPSOs and similar turret-moored vessels* – which gives guidance on redundancy standards for equipment used in monitoring heading and for the transmission of heading information to the shuttle tanker, that is there should be two independent means of measuring heading and transmitting heading to the shuttle tanker.

In all cases, that is regardless of whether or not the FPSO/FSU has thruster assist, redundancy levels should be established, which ensure that an unmanageable situation does not result from any single failure on the FPSO/FSU, including the following:

- single mooring line failure;
- power generation or power distribution failure;
- thruster failure;
- gyro compass drift;
- position reference fault.

10.2.3 Single Point Installations

For the purposes of this section it is assumed that single point systems have a hawser and hose connection which allows the shuttle tanker freedom to weathervane through 360°. Levels of redundancy for single point installations should be established so that the following criteria are met, viz., that an unmanageable situation should not result from any single failure on the installation, including the following:

- single mooring line failure;
- position reference fault.

10.3 Communications

Specific reference should be made to IMCA M 125 – *Safety interface document for a DP vessel working near an offshore platform* – and to OCIMF's *'Offshore Safety Loading Guidelines'* when establishing appropriate levels of communication.

Communications should be established for the three following conditions:

- Routine operations;
- Control of change;
- Emergency situations.

10.3.1 Voice Communications

The objective is to provide continuous and effective voice communications between all vessels and structures involved in the two-vessel operation. This includes attendant tug/support vessels that are involved in the offtake operation. Compliance with the following guidelines will help to achieve that objective.

At least two independent methods of voice communications should be established between all vessels and structures involved in the two-vessel operation, so that loss of one method should not result in the loss of the other method. They may be referred to as a primary and a secondary system. All methods of communication should be tested before the start of operations and then checked at regular intervals during operations.

In all cases, voice communications terminals should be provided at all relevant locations and for all relevant phases of the two-vessel operation, for example in the bow house of a shuttle tanker, if fitted, in the wheelhouse and in the cargo control room of a shuttle tanker and in the production control room of a FPSO/FSU. Voice communications between the vessels and structures should be monitored continuously on the units involved in the operation, including, where appropriate, on attendant tug/support vessels. There should be adequate voice communications facilities to cater for all foreseeable emergency scenarios.

In all cases, the key personnel should have ready access to voice communications facilities to enable rapid contact to be made with the relevant person on the adjacent vessel or structure, both in normal operating mode and in emergency mode.

Typically, when in close proximity to one another, voice communications will be conducted by VHF and/or UHF. Hard line communications are also possible as a primary or secondary communications system. Satellite and ground based communications systems, such as are provided through mobile telephone networks, should not be used as a primary or secondary voice communications system.

Care should be taken when selecting operating and emergency frequencies to ensure, as far as possible, that interference from other users will not interrupt the continuous nature of either the primary or secondary system.

Prior agreement should be reached on the general subject matter of voice communication, the language to be used and the communications protocol.

It is recommended that voice communications on vessels and other structures are recorded so that they can be played back, if required, at a later date.

Consideration should be given to the loss of all voice communications systems. Appropriate emergency response procedures should be established. In the case of shuttle tanker operations this may result in shut down of cargo transfer.

10.3.2 DP Alert Status Levels

Communications systems should be in place for the transmission of information about station keeping performance.

Ideally, in the case of a DP shuttle tanker at a FPSO/FSU, there should be continuous two way transmissions between the tanker and the FPSO/FSU of information relating to:

- the station keeping performance of both units in surge, sway, yaw and heave;
- accelerations of these motions; and
- the physical separation distance between the two units.

Various methods can be used to achieve this standard.

A system for transmitting DP status levels between the DP shuttle tanker and the FPSO/FSU should be considered. Section 1.5 of this document contains an outline of a system that is based on green, yellow and red alert status levels. Consideration should be given to interfacing these alert status levels with the ESD system.

Operational limits should be established that take account of the above, in particular a minimum acceptable physical separation should be established, which, if breached, should result in a controlled shutdown, release and departure of the shuttle tanker from the FPSO/FSU.

10.3.3 Telemetry and Other Similar Data Links

In cases of cargo transfer, such as in shuttle tanker operations at FPSOs/FSUs, there should be appropriate means of communication that enable effective management of the flow of hydrocarbons. In this context flow management broadly refers to such aspects as permission to start cargo transfer, signal to stop and includes emergency shutdown. No hazardous events should result from activation of an emergency shutdown.

Although other systems might be suitable it is recommended that all hydrocarbon cargo transfers are managed through a telemetry system.

No cargo transfers should take place unless a secure telemetry link has been established and tested. Telemetry links should be capable of operating at all relevant control locations, in particular, on the shuttle tanker as well as on the FPSO/FSU.

It is recommended that two independent telemetry links are fitted between the vessels and structures involved so that the failure of one does not result in shutdown of cargo transfer. However, it is also recommended that in the event of total failure of the telemetry link, this should result in safe and secure shutdown of the cargo transfer.

It is recommended that care is taken on the siting of the aerials used in telemetry systems. Due to the large number of aerials on many shuttle tankers and other structures there is a possibility of radio interference and/or interruption of the transmissions which could result in unnecessary shutdown or disruption to the cargo process.

10.4 Operations

10.4.1 General

A verification process should be carried out for each discrete phase of the offtake and preparatory operations. The verification process should be a checklist or similar and should be completed at, say, 10nm, 3nm, 1000m and when entering the 500m zone. It is recommended that standard checklists are developed and used to record the results.

Wherever possible, the checklists should be jointly developed by the FPSO/FSU and the shuttle tanker. Results should be communicated between the two. This is important since a discrepancy on one unit may have significant consequences for the other unit.

Reference should be made to appendices 4 and 5 of the OCIMF publication *'Offshore Loading Safety Guidelines'*, where examples are given of standard checklists.

10.4.2 Legislation

Some governments, in whose territorial waters two-vessel operations are carried out, have introduced relevant regulations and guidance to duty holders and tanker operators on the management and conduct of the two-vessel operation. Companies involved should ensure that they take full account of such territorial requirements.

10.4.3 Tandem Loading Separation Distance

Tandem loading is a special case due to the close proximity of the two structures, the shuttle tanker and the FPSO or FSU. For shuttle tankers operating in this mode consideration should be given to fitting equipment to monitor, as a minimum, the separation distance.

Systems are available that utilise a separate independent computer for receiving information from, for example, the vessel sensors, positioning references, forward and transverse speed all as 'raw' data. The meaning of raw data in this context is data that is not relayed from the DP computer. Although using data from the same sensors as the DP computer it is fed directly to the independent computer. This independent computer can then be used to show the raw data on a separate VDU adjacent to the DP console, the purpose being that the raw data can be set with limits dependent on the operation with the parameters visible on screen. These limits would generally be set tighter than the alarm limits for the various DP functions. A change of vessel speed or the rate of change of the vessel position, for example, can then be noticed and alarmed at this console to give the DPO added time to assess and if necessary, take appropriate action.

10.4.4 Tandem Loading Software

Designers and operators should be aware of new generation tandem loading software that is designed to overcome shortcomings of first generation systems, which have the potential to result in overuse of shuttle tanker thrusters.

In the first generation systems the shuttle tanker has to continually adjust the separation distance to allow for surge in an attempt to keep the set distance, the sideways position to allow for sway and the heading and sideways thrust to allow for fishtailing. This in turn has the potential to result in overuse of thrusters, since the control system attempts to maintain tanker position relative to the FPSO/FSU.

Software systems have become available to overcome these shortcomings. These systems are designed to reduce excessive use of the shuttle tanker's propulsion systems as well as improving station keeping performance. This is done by introducing a deadband zone in surge, sway and yaw, which allows differences in these axes between the shuttle tanker and the FPSO/FSU before the DP shuttle tanker control system responds. The deadband zone is defined by comparisons between absolute and relative positions of the shuttle tanker and the FPSO/FSU.

10.5 Personnel Responsibilities and Capabilities

Reference should be made to sections 4 and 7 of this document for specific guidance on personnel responsibilities and capabilities.

10.5.1 Co-Operation and Understanding

There should be effective co-operation and understanding between the personnel involved in two-vessel operations. This can be achieved by ensuring that both sets of personnel are given adequate information and insight into all relevant aspects of the operation of other vessels and structures. In all operational cases the proposed two-vessel operation should be discussed beforehand by the appropriate personnel and a safety interface document should be prepared.

10.5.2 Master

In the case of a DP vessel the master is ultimately responsible for the operation and the safety of his vessel and for all personnel on board. He has the authority to terminate operations, if he deems that to do so will safeguard the vessel, personnel, hardware or the environment. He is also responsible for ensuring that there is effective integration of his vessel's normal operations and emergency response with the other vessels and structures involved in the two-vessel operation.

10.5.3 Offshore Installation Manager

In the case of most other structures, such as a FPSO/FSU, the person in command will be referred to as the offshore installation manager. He is ultimately responsible for the operation and safety of his installation and for all personnel on board. He has the authority to terminate operations, if he deems that to do so will safeguard the installation, personnel, hardware or the environment. He is also responsible for ensuring that there is effective integration of his installation's normal operations and emergency response with the other vessels and structures involved in the two-vessel operation.

10.5.4 DPOs/Bridge Watchkeepers

The following particular guidance should be considered in addition to the guidance given in this document.

For a two-vessel operation involving cargo transfer one vessel is normally tethered, for example a turret-moored FPSO/FSU and the other, shuttle tanker, operates on DP. It is not uncommon that due to a fault with the DP or to operational requirements it is necessary to change control mode from DP to manual control. Training in an environment similar to the proposed locations in simulated conditions is recommended. In the case of tandem loading shuttle tankers, this training should include time/power tests for main engine and/or thrusters. It is important that the DP operator has an understanding of the time taken for the vessel to gain momentum after a rapid increase in pitch or power although the pitch or power may be reduced quite quickly. The inertia may still propel the vessel forwards and an understanding of this and the time and distance required to stop is important.

The training should also include drift off patterns for the DP operated vessel at the installation location. There is always the possibility of a power loss prior to connection. For this possibility it should be proved that any field support vessel at the location has the capability to connect to and assist the drifting vessel.

DP Incident Reporting

Background

IMCA (and its predecessor DPVOA) has been collecting DP incident reports provided by members and publishing them as annual reports since 1991. During this time, the format of the IMCA report has changed little – using the categorisation of 'Loss of Position 1' (LOP1) for major loss of position, 'Loss of Position 2' (LOP2) for minor loss of position and 'Lost Time Incident' (LTI) for downtime as a result of loss of redundancy but where loss of position has not occurred.

The IMCA Marine Division Management Committee reviewed the system in 2005 and concurred that, since the system at that time could be considered to be somewhat subjective and that there could be some confusion as to when an incident should be reported to IMCA or not, it would be better to replace the reporting categories with those set out below. The aim of the change of format is to help people who are reporting incidents to have a better idea whether to report the incident and in which category it would fall and also to help those reading the annual report as it provides a wider range of incident types.

New Categorisations

The following new categories of DP incidents have been proposed and agreed by the IMCA Marine Division Management Committee. These categories should be used in conjunction with the revised IMCA Station Keeping Incident Form. These new categorisations will be used to replace the 'Loss of Position 1' and 'Loss of Position 2' incident categorisation currently used in the IMCA annual DP incident reports.

1 DP Incident

Loss of automatic DP control, loss of position or any other incident which has resulted in or should have resulted in a 'Red Alert' status.

2 DP Undesired Event

Loss of position keeping stability or other event which is unexpected/uncontrolled and has resulted in or should have resulted in a 'Yellow Alert' status.

3 DP Downtime

Position keeping problem or loss of redundancy which would not warrant either a 'Red' or 'Yellow' alert, but where loss of confidence in the DP has resulted in a stand-down from operational status for investigation, rectification, trials, etc.

4 DP Near-Miss

Occurrence which has had a detrimental effect on DP performance, reliability or redundancy but has not escalated into 'DP Incident', 'Undesired Event' or 'Downtime', such as:

- crane or load interfering with Artemis line of sight;
- scintillation.

5 DP Hazard Observation

Set of circumstances identified which have had the potential to escalate to 'Near-Miss' status or more serious, such as:

- Fanbeam laser target being placed in a position on handrails of a busy walkway where heavy traffic of personnel wearing PPE with retro reflective tape is identified;
- crane lift being swung close to Artemis line of sight.

This category should also capture relevant occurrences even when not operating in DP mode, such as:

- speed and latitude corrections supplied to all gyros from single DGPS by installation engineer;
- unexpected loss of essential DP components which would have had the potential to result in 'DP Incident', 'Undesired Event' or 'Downtime' if vessel had been operating in DP mode.

Guidance for Completing the IMCA Station Keeping Incident Form

Incident Types:

1 DP incident
2 DP undesired event
3 DP downtime
4 DP near-miss
5 DP hazard observation

- Incident types 1 and 2 are likely to result in type 3. Identify the option on the IMCA Station Keeping Incident Form which represents the greatest potential for harm. All sections of the form should be completed.

- For incident types 1, 2 and 3, please indicate 'initiating event', 'main cause' and 'secondary cause' where appropriate on the IMCA Station Keeping Incident Form, e.g.:

  i) 'Initiating event' – Additional thrust required due to increasing environmental conditions

  ii) 'Main cause' – Stoppage of thrusters

  iii) 'Secondary cause' – Operator error

- Incident types 4 & 5 can be reported to IMCA by e-mail and should only require a short description of events.

DP incident report forms are available from IMCA – www.imca-int.com