

**Guidelines for
The Design and Operation
of Dynamically Positioned
Vessels**



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

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IMCA M 103 Rev. 2

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Guidelines for the Design and Operation of Dynamically Positioned Vessels

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Executive Summary

This document is a major rewrite of IMCA M 103 – *Guidelines for the design and operation of dynamically positioned vessels* – which was last revised in 2007.

Specification for the rewrite was:

- ◆ rewrite the guidance which was last revised in 2007;
- ◆ consider the separation of the areas of design and operation into two sections. The section on design should be based on IMO Circular MSC 645;
- ◆ develop additional guidance for new vessel types;
- ◆ expand the guidance on training and experience of DP personnel and include guidance on manning and watchkeeping arrangements;
- ◆ reference existing guidance available from other organisations.

This document now includes generic design and operational guidance, as well as vessel type-specific guidance for seventeen representative vessel types that utilise dynamic positioning in support of the offshore oil & gas and offshore energy industries.

The design guidance focuses on the methods for creating fault-tolerant DP systems based on the principles of redundancy.

Operational guidance focuses on current good industry practice and draws from existing operational guidance from industry.

The vessel type-specific guidance focuses on the industrial mission of the vessel and the impact that this has on its design and operation. A brief description of the industrial mission is included for each vessel in order to better explain the technical and operational guidance and to give an indication of the risks associated with an inability to maintain position.

Abbreviations

AC	Alternating current
AGP	Advanced generator protection
AHT	Anchor handling tug
AHTS	Anchor handling tug supply
AHV	Anchor handling vessel
ALP	Articulated loading platform
AODC	Association of Offshore Diving Contractors
ASOG	Activity specific operating guidelines
AVR	Automatic voltage regulator
BOP	Blowout preventer
CAM	Critical activity mode
CCTV	Closed circuit television
CO ₂	Carbon dioxide
CPP	Controllable pitch propeller
CSD	Cutter suction dredger
DC	Direct current
DGNSS	Differential global navigation satellite system
DGPS	Differential global positioning system
DNV	Det Norske Veritas
DP	Dynamic positioning
DPO	Dynamic positioning operator
DSV	Diving support vessel
ECR	Engine control room
EPS	Early production system
ESD	Emergency shutdown
EWT	Extended well testing
F&G	Fire and gas
FFPV	Flexible fall pipe vessel
FMEA	Failure modes and effects analysis
FMECA	Failure modes, effects and criticality analysis
FPP	Fixed pitch propeller
FPSO	Floating production storage and offloading
FPU	Floating production unit
FPV	Fall pipe vessel
FSO	Floating storage and offloading
FSU	Floating storage unit
GOMO	Guidelines for Offshore Marine Operations
HEMP	Hazard effect management process
HMI	Human–machine interface
HV	High voltage
HVAC	Heating ventilation air conditioning
IEP	Integrated electric propulsion
IJS	Independent joystick

IMCA	International Marine Contractors Association
IMO	International Maritime Organization
JOM	Joint operations manual
MoC	Management of change
MODU	Mobile offshore drilling unit
MSC	Maritime Safety Committee
MTS	Marine Technology Society
MW	Mega watts
OCIMF	Oil Companies International Marine Forum
OIM	Offshore installation manager
OLS	Offshore loading system
OSV	Offshore supply vessel
PMS	Power management system
POB	Personnel onboard
PSV	Platform supply vessel
ROV	Remotely operated vehicle
SAL	Single anchor loading
SAP	Single anchor production
SRI	Subsea rock installation
SSDV	Side stone dumping vessel
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
STL	Submerged turret loading
TAM	Task appropriate mode
TCMS	Tripod catenary mooring system
TSHD	Trailing suction hopper dredger
UPS	Uninterruptible power supply
VMS	Vessel management system
WCF	Worst case failure
WCFDI	Worst case failure design intent
WSOG	Well specific operating guidelines

I Introduction

I.1 The History and Brief Summary of this Revision of IMCA M 103

This revision is a major rewrite of IMCA M 103, although some text is retained from previous revisions. This text supersedes all previous versions.

The design guidance in section 2 is applicable to all DP vessels. It provides guidance to achieve safety in DP vessel design through a fault-tolerant approach based on the principle of redundancy. For DP vessels, safety is measured by the ability to maintain position whilst in automatic DP control. This is a core principle of IMO MSC/Circ.645 and is applied throughout in this section.

All DP vessels of IMO DP class 2 and 3 or their classification society equivalent should, in all aspects of design – at new build time as well as when updates, modifications or large scale conversion works are being carried out, meet the guidance in IMO MSC/Circ.645 of fault tolerance based on redundancy providing station keeping reliability.

IMO DP class 1 vessels are not required to achieve that same level of fault tolerance since they are not required to have redundant systems or equipment and not required to maintain position after single point failure. These vessels may be susceptible to many single point failures that will result in the inability to maintain position.

Drawing on various industry design documents, this rewrite of IMCA M 103 seeks to achieve consistency across the DP sector.

Similarly, the operations guidance in section 3 applies to all DP vessels. It provides further guidance on a wide range of matters which are essential for ensuring that DP operations are carried out safely. Among other topics, section 3 contains guidance on recent developments in the industry to achieve safe DP operations through a detailed activity operational planning approach. Activity operational planning is based on the application of critical activity mode (CAM), task appropriate mode (TAM) and activity specific operating guidelines (ASOG), all of which are vessel-specific. Further guidance is available in [IMCA M 220 – Guidance on operational activity planning](#).

Vessel type specific guidance is set out in the Appendices.

2 Design Guidance

2.1 Introduction

The design guidance provided in this section focuses on the theory and practice of creating fault-tolerant systems based on redundancy.

2.2 Philosophy of the Guidelines

- i) For the purposes of these guidelines a fully operational DP system is able to reliably keep a vessel in position when working up to the rated environment.
- 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 limitations, 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 appropriate task to be performed. These limits need to consider every failure mode defined by the FMEA and the likely time to restore position control and 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 the inability to maintain position.

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 philosophy should be applied to all the tasks and operations the vessel is designed to undertake on DP with careful consideration of the consequences of the inability to maintain position.

2.3 DP Equipment Class

A dynamic positioning system (DP system) is defined by IMO MSC/Circ.645 – *Guidelines for vessels with dynamic positioning systems, 1994, (MSC.645)* as the complete installation necessary for dynamically positioning a vessel comprising the following sub-systems:

1. power system;
2. thruster system; and
3. DP control system.

MSC.645 defines three DP equipment classes:

1. For equipment class 1, loss of position may occur in the event of a single fault.
2. For equipment class 2, a 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.

3. For equipment class 3, a single failure includes:
 - items listed above for class 2, and any normally static component 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.

The guidelines require that a sufficient level of station keeping reliability is achieved by the use of fault-tolerant DP systems based on the principles of redundancy. *Redundancy* means 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 alternative means of performing a function.

2.4 Fundamental Principles of DP Vessel Design

Classification societies have incorporated the requirements of IMO MSC/Circ.645 within their rules and regulations for the design and construction of DP vessels.

Classification societies have adopted the failure modes and effects analysis (FMEA) as a means of demonstrating the fault tolerance of DP systems, as appropriate to the equipment class of DP, during their design approval process.

Any suitable power and propulsion technology may be used for the DP system; early engagement with prospective vendors is recommended to confirm the suitability of equipment for the intended application.

The majority of medium to large DP vessels have diesel–electric integrated electric propulsion (IEP) systems where all power for propulsion, hotel loads and industrial consumers is provided by an AC power generating and distribution system. IEP systems are also popular for smaller DP vessels. For a given power rating, low voltages result in higher currents than for a high voltage system therefore DP systems above a power of approximately 8MW to 10MW favour high voltage electrical systems.

Diesel–electric designs using DC power distribution are being reintroduced. Other technologies such as diesel-driven thrusters and diesel-hydraulic systems remain in use, particularly for smaller PSVs, barges and conversions of moored semi-submersibles.

Although the dominance of diesel–electric designs has resulted in most available guidance for DP systems being based on this technology, the basic principles of DP vessel design such as fault tolerance and redundancy are similar for all technologies.

Issues to be considered if designing a DP vessel include but are not limited to:

- ◆ the vessel's industrial mission and mission equipment;
- ◆ areas of operation, for example access to ports;
- ◆ personnel onboard (POB);
- ◆ deck load variations;
- ◆ permissible motions;
- ◆ survivability criteria.

These and other factors will dictate the physical characteristics of a vessel, such as displacement and hull form. Once the hull form and major dimensions have been established, the thrust required to maintain position in the anticipated environmental envelope can be established. It is at this point that the vessel's DP redundancy concept influences the design of the DP system.

2.5 The Influence of the Redundancy Concept on Machinery Rating

To achieve a DP system which meets the necessary fault tolerance (e.g. a single point failure criterion), equipment and machinery which is necessary for the DP system to function will be redundant in both number and capacity. In practice this means that machinery often operates at relatively low loads, meaning that engines spend much of their life operating at low loads; such low load operation reduces engine efficiency.

2.6 DP System Reliability

Equipment failures and a loss of redundancy may result in a vessel being unable to complete its mission until the redundancy of the DP system has been restored. Planned maintenance, condition monitoring and annual DP trials contribute to reliability in service. However, the most effective way to ensure good reliability is through design, for example by specifying high reliability components, carriage of critical spare parts and reducing the number of fault paths that lead to a loss of redundancy.

One of the most important elements to ensure DP system reliability is to provide software assurance for software used in DP systems and any systems (such as vessel management systems, power management systems and engine control units) which are necessary for the DP system to operate. Such software should be the subject of a software conformity assessment. Software conformity and controls should be maintained throughout the life of the DP system, including updates and configuration changes. No changes should be permitted to be made to software without first being reviewed in a management of change (MoC) procedure which considers how the DP system software assurance could be affected.

2.7 Key Elements of Fault-Tolerant Design

The key elements of a fault-tolerant system designed to prevent vulnerability to a failure are:

- ◆ performance;
- ◆ protection;
- ◆ detection.

Performance: Equipment intended to provide redundancy should be capable of its rated capacity or that which is assumed to be available in the event of a failure. Lack of performance is a potential hidden failure and therefore means should be developed to assure confidence that redundant systems will be capable of the required performance on demand.

Protection: Protection can be a combination of automatic systems, operator competency assurance and procedural barriers designed to prevent faults transferring between sub-systems of the DP system, with the result that there is a vulnerability to common cause failures.

Detection: Detection methods should indicate when an essential system is no longer available or no longer has the capacity to carry out its function effectively.

2.8 Power Plant Configuration

The size of the vessel and power generation demand strongly influences the power plant design. In an IEP installation the fault current (short circuit current flowing into a fault from the generators and other sources) will dictate the 'fault withstand rating' of the main switchboards.

2.9 DP System Approval

These guidelines are based on an assumption that DP vessels are designed and built in accordance with applicable classification society and flag administration requirements. These rules and requirements only provide minimum requirements for the reliability and safety of vessels, equipment, persons and the environment.

Flag administration requirements will incorporate applicable IMO requirements for those vessels within the scope of the IMO Conventions and where such IMO requirements have been ratified and/or adopted by the flag state. For vessels outside of these Conventions the flag administration will apply its own national requirements which may or may not be equivalent to those of the IMO. Additionally, coastal state administrations have requirements for vessels operating within their waters, regardless of vessel flag.

Classification societies and flag administrations may accept or require that certain equipment is designed, manufactured and tested in accordance with suitable standards published by bodies such as the International Organisation for Standardization (ISO) and the International Electrotechnical Commission (IEC). These standards are based on certain assumptions, such as intended operating environments and intended modes of use, and it is therefore important to establish the suitability of any standards proposed for equipment certification before their acceptance.

The boundary and interfaces between class and flag administration requirements need to be understood as failure to manage these boundaries and interfaces risks failing to meet all necessary requirements.

Classification societies will review a DP system design, they will then survey vessels and their machinery and equipment during construction and sea trials. Providing that the design is compliant with applicable rules and the surveys are satisfactory then the DP system will receive class approval. There will be a similar process to ensure compliance with applicable flag administration requirements. This may be undertaken by the flag administration itself or by a suitably authorised recognised organisation.

2.10 Power Plants Designed to operate as a Common Power System (Closed Bus Ties)

Power systems based on running generators in parallel generally become more robust as the number of connected generators increases, this makes it more difficult for a faulty generator to influence the bus voltage and frequency. Failure data from various sources confirms that in a majority of cases failure of a generator does not lead to total power plant failure. There may be some failure modes which could result in a blackout or loss of all thrusters such as fuel, short circuit and excitation control faults.

If the electrical system is divided into two or more segregated systems using open bus ties then a loss of electrical power in one section should not lead to a loss of electrical power in any of the other sections, making it unlikely that the vessel will suffer a total black out or lose all thrusters.

Alternatively, electrical systems can operate as a single power bus with their bus ties closed. For a closed bus tie configuration to achieve the same level of overall reliability as an open bus tie configuration it is often necessary to connect additional generators and to shed load in the event of loss of generating capacity (such as a generators trip) or if one part of the power system is lost.

Both potential modes of operation have advantages and disadvantages which are summarised in Table I.

	Open bus tie	Closed bus tie
Continuity of vessel DP operations	Good	Good
Station keeping integrity	Good	Good provided no critical failure modes occur
Flexibility for maintenance	Poor if all generators need to be connected at all times	Good
Fuel efficiency	Poor if all generators need to be connected at all times	Good
Emissions	Poor if all generators need to be connected at all times	Better than open bus tie systems

Table I – Configuration comparison

The vulnerabilities of common power closed bus tie systems can be mitigated by using advanced generator protection (AGP) systems which identify and isolate a range of generator faults not covered by standard protection arrangements. AGP systems can improve the station keeping integrity of closed bus tie power systems but do not address all potential failure modes or common failure modes.

Identifying and assessing the necessary protective functions requires specific expertise at the design stage, comprehensive commissioning, safe and effective verification.

DP vessel closed bus tie operation was one factor which led to the development of the concepts of critical activity mode (CAM) and task appropriate mode (TAM). CAM requires that the power plant be set up in the configuration that provides the highest level of station keeping integrity. *IMCA M 220 – Guidance on operational activity planning* – provides additional information.

Some, but not all, class societies provide guidance for systems intended to operate in closed bus tie configuration to comply with their rules for DP systems.

The FMEA for a diesel–electric DP class 2 or DP class 3 vessel operating with closed bus ties should consider the following supplemental studies:

- ◆ harmonic distortion in the intact case and after the worst case failure of harmonic cancellation features;
- ◆ transient voltage studies;
- ◆ extended protection co-ordination studies covering all protective functions in the DP system, not only those in the electrical protection system.

2.11 Testing the DP System

Testing the DP system is an on-going process and begins with analysing the redundancy concept on paper before any hardware or software is available. This is achieved using a FMEA. *IMCA M 166 – Guidance on failure modes and effects analyses (FMEAs)* – provides more information on this subject.

The key processes in testing the redundancy concept are:

- ◆ predict – the FMEA needs to be able to predict the failure modes;
- ◆ prove – the DP FMEA proving trials needs to demonstrate that the FMEA correctly describes the redundancy concept including confirmation that the FMEA is representative of the as-built configuration;
- ◆ protect – the redundant systems within the DP system have the performance, protective functions and detection features to defend the redundancy concept against failure modes.

DP vessels have to undergo FMEA proving trials, these are additional to commissioning and owner 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 are functioning correctly, failure modes should be demonstrated and the results documented by a third party. Performances should be demonstrated in both the intact and various failed conditions. Moderate or rough weather is ideal for these tests, but is not essential for acceptance of the DP capability and system stability. These proving trials should be properly documented and the results made available to operators, owners, charterers, surveyors and responsible authorities, to remove the necessity of repetition of design related trials during the vessel's working life and as input into operational manuals and vessel familiarisation procedures.

2.12 Defending the Redundancy Concept in Operation

Redundant systems only remain fault-tolerant if properly maintained and tested.

Part of the FMEA process is to identify the protective functions, equipment performance and detection functions upon which the redundancy concept depends. *IMCA M 166 – Guidance on failure modes and effects analyses (FMEAs)*, *IMCA M 190 – Guidance for developing and conducting annual DP trials programmes for DP vessels* – and *IMCA M 191 – Guidelines for annual DP trials for DP mobile offshore drilling units* – provide guidance on how to ensure the redundancy concept is intact.

Other testing intervals may be determined by the requirement for a five-yearly survey to align with classification societies' survey periods, and/or equipment manufacturers' recommended test and maintenance intervals.

If the redundancy concept requires a reconfiguration of thruster power supplies following a power bus failure, then the risk of automatic changeover functions transferring a fault from one redundant group to another should be minimised. Changeover mechanisms should be subject to FMEA.

2.13 Compartmentalisation

In DP class 3 vessels, redundant groups are to be separated by A60 fire subdivisions; watertight separation is required where there is a credible risk of flooding. Some classification society rules refer to the damaged stability waterline to define the point below which watertight separation is required. Separation requirements for the DP control system include the provision of a separate DP control room containing at least one backup DP control system that mirrors the main DP control system and which can be engaged manually.

DP class 2 has no requirement for protection against the effects of fire and flooding beyond that required by classification society rules and flag administration requirements. However installing generators and thrusters into segregated compartments, even if not to the same extent as DP class 3, can provide greater resilience against fire and flooding.

2.14 Auxiliary Systems

Auxiliary systems including, but not limited to, fuel oil, lubricating oil, hydraulic oil, sea water cooling, fresh water cooling, HVAC and compressed air are subject to classification society rules and applicable statutory requirements. They are to maintain the DP systems level of fault tolerance and redundancy required for the DP equipment class.

Further guidance on designing auxiliary systems to maintain the fault tolerance required by the DP equipment class and a sample redundancy concept for a DP equipment class 3 vessel is provided in [IMCA M 225 – Example redundancy concept and annual DP trials for a DP class 3 construction vessel](#).

2.15 Power Generation

2.15.1 Engines

The load response of modern diesel generator engines is strongly influenced by emissions legislation. The step load capability of some engines has fallen to the point where a load step change of 25% can result in under frequency. Under certain conditions this slow response to load changes could result in engine shutdown or auxiliary system disturbances.

When selecting engines for a DP vessel it is important that their suitability for this application is considered, taking into account:

- ◆ limits to time on standby;
- ◆ requirement for pre-lubrication or slow turning before starting;
- ◆ responsiveness to load change.

If these limiting factors are understood then they can be managed by system design changes or procedures.

Engines and their control systems should meet classification society rules. Engines which are approved by a classification society are subject to design approval and surveys during manufacture, installation and sea trials. They will then be subject to periodical survey through the life of the ship. Those classification societies who are members of IACS have harmonised requirements for engine type testing. Whilst this is a rigorous approval process it looks at the engine as a single entity. Classification societies have different approaches to evaluating engine performance as part of a complex system.

2.15.2 Alternators

Alternators and their control systems should meet class rules. Many high voltage (HV) alternators are rated for three short circuit events; if the classification society requires high voltage short circuit and earth fault testing then this may need careful management to avoid warranty infringement.

2.15.3 Governors

In a conventional diesel–electric power plant the engine governors are responsible for active power sharing (kW) and bus frequency control which may be trimmed by the power management system or linked by one or more load sharing lines. Designing the power system to run in uncorrected speed droop can minimise potential common point fault propagation paths, accuracy and stability in this mode of operation are well within the capability of modern digital governors. The use of electronic governors with a backup mechanical governor was once considered to offer benefits, however experience in DP vessels suggests that backup mechanical devices caused more incidents than they prevented.

2.15.4 Automatic Voltage Regulators (AVRs)

AVRs regulate control bus voltage and reactive power sharing (kVAr). Operating the AVRs in uncorrected droop generally provides the greatest degree of independence. Failure of AVRs has been the cause of a significant number of blackouts. Care should be taken to ensure the AVR's do not introduce fault commonality.

AVRs may have an external control power supply and another supply derived from the generator voltage transformer (VT) or permanent magnet generators. The external supply is typically only used during start up but should be treated as part of the overall redundancy concept to limit the potential for fault propagation.

2.15.5 Synchronising

Each generator should be provided with an independent method of automatic synchronising which has an independent check sync facility. Manual synchronising facilities should be provided in line with classification society requirements but care should be taken that these do not introduce unacceptable levels of commonality. For example, a centralised manual synchronising station could bring signals from different redundant groups together.

Where the redundancy concept is based on running machinery there should be no need to synchronise generators following a generator failure in order to maintain position. However the synchronisers should be capable of connecting a generator during the voltage and frequency variations that follow the loss of a generator to mitigate the risk that surviving generators might not being capable of their rated capacity.

2.15.6 Power Plant Protection

In both open and closed bus ties configurations it is beneficial for the protection systems to be capable of positively identifying the source of a fault and to limit any necessary isolation to a single consumer. In a closed bus power system it is essential that the protection system can limit any necessary fault isolation to one redundant group, typically by opening the bus ties rapidly enough to prevent a loss of other redundant groups.

Protection systems for closed bus tie configurations are required to manage a large number of fault scenarios. There may be failure effects for which there is no specific or easily implemented protective function. Proving that the power plant is sufficiently robust by analysis and testing can be time consuming and complex. The requirement to consider environmental factors such as fire and flooding in DP class 3 designs adds further complexity.

There are two types of protection:

- ◆ selective protection which positively identifies the source of a fault and isolates it from the power system;

- ◆ non-selective protection which cannot positively identify the source of the fault and simply disconnects circuits to remove exposure to the fault condition.

Selective protection includes:

- ◆ short circuit;
- ◆ earth fault.

Selectivity in short circuit protection may be achieved by time grading or by using differential or directional protection.

Non-selective protection includes:

- ◆ over and under-voltage;
- ◆ over and under-frequency;
- ◆ overload (where the entire plant is overloaded);
- ◆ over-speed;
- ◆ over and under-excitation;
- ◆ reverse power;
- ◆ current and voltage unbalance.

Non-selective protection can be used in open bus tie DP systems and should as a minimum isolate the fault to one part of the power system, ideally to the faulty consumer. The protection arrangement should open the bus ties before tripping any generators or consumers. Selective over-excitation protection is available based on similar principles to those used in advanced generator protection systems.

Since DP vessel power plants are usually arranged to have very low earth fault currents (high resistance or not-intentionally earthed) there may be no immediate need to disconnect an earth fault.

2.16 Power Distribution

2.16.1 Power System Concepts

Power system concepts for diesel–electric DP vessels are mostly radial designs. Each redundant power system is divided into a series of voltage distribution levels connected by transformers to suit the requirements of consumers.

Power storage can be added to the electrical distribution systems to even out cyclic variations in power demand, allowing generators to operate at constant power.

Systems may use either AC or DC power distribution. DC power systems are becoming more common. In these systems the output of AC generators is rectified to DC and fed to a DC distribution system. Advantages include:

- ◆ reduced fuel consumption and emissions as allowing the engines to run at variable speeds means they can be optimised for efficiency at given load points;
- ◆ fault currents can be controlled electronically;

However, such systems do require more power conversion equipment. The main switchboards may be operated as isolated power systems, as a linear bus or a closed ring. The arrangement of DC for control power may vary in design. Isolated power systems are preferred although cross connected systems may be used.

There could be a large number of potential fault propagation paths associated with power, protection and control lines crossing the boundaries between redundant groups; this should be analysed in the FMEA.

2.16.2 Bus Ties

DP equipment class 3 requires two bus tie circuit breakers between each redundant machinery group so that a fire or flood damaged tie line can be automatically isolated. This is also found on some DP equipment class 2 designs. These bus ties often operate as master–slave pairs, creating potential fault propagation paths. These fault paths and effects can be predicted using computer modelling, such as the modelling required to analyse the fault tolerance of DP equipment class 3 vessels operating with closed bus ties. In all cases it is better to focus on preventing this failure mode than ensuring the power plant can ride through its consequences.

2.16.3 Harmonics and Filters

Harmonic distortion can cause power systems to malfunction. Harmonic filters may be used to reduce the levels of harmonic distortion and improve low power factors. These filters often incorporate HV capacitors, short circuit of which can cause severe voltage dips.

Applying capacitance to power systems can cause system resonance which can result in the development of severe over-voltage. Harmonic studies should encompass a suitable frequency spectrum to allow evaluation of such resonant conditions.

Studies supporting the DP system FMEA should consider the implications for the electrical and power systems if there is a failure of harmonic filters, where such harmonic filters have been provided based on the outcome of a harmonic study. Where the FMEA considers that loss of harmonic filters could result in an unacceptable risk of interruptions to power systems then suitable risk mitigation measures will be required.

2.17 Power Management and Blackout Recovery

2.17.1 Power Management System (PMS)

The power management system (PMS) is an essential protective system and a common point connecting segregated power systems. The PMS plays a critical role in the ability of the power plant to respond to load changes and can control load demands so as to avoid disturbances in the power system. If a DP vessel is operated with sufficient spinning reserve then there will be a large margin for load acceptance and rejection and as such the system will have a higher degree of resilience to load fluctuations.

In some designs the PMS functions are limited to generator management and blackout recovery, such an approach removes many of the concerns regarding the PMS being a common failure point.

2.17.2 PMS Hardware

Power management systems should utilise distributed control systems with redundant data communications links and should include a power feed from an uninterruptible power supply (UPS). The UPS for each PMS should have a primary supply from the same redundant power system which it controls as well as a supply from the emergency switchboard. The UPS should include a manual selector switch to transfer onto the emergency switchboard supply.

Redundant groups of machinery and equipment should be provided with their own PMS which may be further subdivided to control generators and switchboards. The PMS for each redundant group should be capable of managing that power system independently both when isolated from other groups and when connected with other groups in a closed bus tie configuration. The interface between the PMS for different groups should use a master–master philosophy in preference to master–slave arrangements.

PMS operator stations and field stations should be provided in a manner that is consistent with the redundancy concept.

2.17.3 Load Shedding and Blackout Prevention

The traditional means of preventing an overload and consequential blackout caused by loss of generating capacity was to operate the power plant with sufficient spinning reserve to cope with a loss of generating capacity. However, the poor load step response of some modern engines and large industrial consumers makes this impractical and other measures, such as load shedding, are required. Some reasons that increasing loads may occur include:

- ◆ changes in the environmental conditions (gusts, squalls, solitons, etc.);
- ◆ executing a change of position or heading;
- ◆ demand from industrial consumers;
- ◆ use of the DP joystick;
- ◆ drive off associated with position jump;
- ◆ a run-away thruster.

These changes happen relatively slowly relative to the sampling frequency of the DP control system, therefore a plant overload can be prevented by shedding load.

The most effective form of load shedding is provided by variable speed drive control systems for thrusters and other rotating machinery, also known as phase-back. This may be required to supplement engine load acceptance capability and needs to be tuned and tested under realistic conditions. Priorities for electrical phase-back in the event of demand exceeding supply should be derived from the FMEA.

If operating in uncorrected droop mode then bus frequency is an indicator of plant loading with load shedding responding to falling frequency. The load-shedding system can be tuned to maintain nominal full load frequency. Frequency based phase-back of industrial consumers may be used to co-ordinate phase-back, ensuring that industrial consumers shed load before the thrusters. Unlike a Kw based load shedding strategy this allows for generators which are not capable of their rated capacity for technical reasons (such as fuel starvation) to contribute whatever power they can. A Kw based load shedding system uses an assumed engine capacity which may be inaccurate, although such a system can be a useful backup to a frequency based system provided that it does not introduce commonality between redundant groups.

Controllable pitch propellers (CPPs) are relatively slow to shed load and have a relatively high base load (at low loads a significant amount of power is required just to turn the propeller). Thruster tripping was a popular means of load shedding on vessels with CPP thrusters, however if fixed pitch, variable speed thrusters are used the higher efficiency of such thrusters at low loads favours retaining the maximum number of thrusters following a failure. Where thrusters use CPPs then it may be better to operate fewer thrusters at higher efficiency.

DP control systems incorporate a load limitation function which prevents overloading the power plant, so reducing the possibility of a black out. An alarm indicates when this function is active, in which case measures should be taken to increase generating capacity or reduce the load. In most DP vessels this is done automatically by the PMS however some systems cannot react quickly enough to overloads caused by a loss of generating capacity (rather than load increase).

A protection study should be undertaken to evaluate and, if necessary, address issues associated with sequential/multiple voltage dips and fault currents being applied to more than one redundant group. This study should include operating scenarios where the vessel operates with its bus ties open.

2.17.4 Blackout Detection and Recovery

Blackout detection should be robust: false detection of blackout could create a blackout. Detection should be based on several independent sources such as voltage transducers, blackout relays and generator circuit breaker status.

Tripping of generator circuit breakers or other circuits on detection of blackout should be left to dedicated blackout protection relays.

Blackout recovery systems should be designed to start all available generators on detection of blackout. All DP essential consumers supporting thrusters and generators should be capable of making themselves ready for DP operation automatically, without the need for supervisory control. Connection to the main power supply can be triggered by detection of the main power being available. Thrusters, main propellers and rudders used for DP should be made as independent as possible, autonomous thrusters can be designed to make themselves ready for DP system operation as soon as they detect that power is available.

For vessels operating with bus ties closed there may be advantages in arranging for the bus ties to be closed again during blackout recovery but care is necessary in the design to prevent re-closing onto a fault.

2.18 Thrusters, Main Propellers and Rudders

Unlike some other parts of the DP system, thrusters and their control systems can fail in such a way as to cause a drive-off. Such failures can be compounded by load shedding measures. If a large thruster fails to full thrust when there is insufficient spinning reserve, the power management system may command a phasing back of thruster rpm or reduce pitch for all thrusters. As the faulty thruster cannot respond to the command to reduce load the effect is to exaggerate the drive-off as the healthy thrusters are no longer able to oppose the faulty unit.

Unlike thrusters provided with hydro-mechanical CPP mechanisms, fixed pitch propeller (FPP) thrusters driven by variable frequency drives very rarely fail to full thrust. DP rules and guidelines generally require thrusters not to fail in such a way which results in an uncontrolled increase in thrust or change in thrust direction. Fail safe conditions are taken to be:

- ◆ fail as set;
- ◆ fail to zero thrust;
- ◆ drive motor trips.

Although almost all thrusters now exhibit a failsafe response to the type of faults simulated during DP FMEA proving trials, the extent to which thrusters and their local control systems are truly fail safe is not well established. Very few thruster control systems have a completely independent protection system monitoring the performance of the thruster. An unambiguous alarm should be given for a command/feedback deviation and not for a wire-break. The very low incidence of failures to full thrust in FPP thrusters tends to place this issue well down on the list of DP failure modes to be addressed.

Although it would be relatively simple to develop independent monitoring and protection systems for thrusters it is important not to reduce reliability by introducing a system which can spuriously trip one or more thrusters. *IMCA M 216 – Thruster integrity management guidance* – provides further guidance by presenting and describing a thruster integrity management system for thruster units installed on a new build and existing vessels.

2.19 Vessel Management Systems (VMS)

2.19.1 System Concept

Vessel management systems are essentially remote control, monitoring and alarm systems for the vessel which include a range of automatic functions and which may incorporate the PMS. In a centralised VMS all field connections are brought to a single point, typically in the engine control room. A centralised VMS may be appropriate for smaller less complex DP vessels but for larger DP vessels such as MODUs and construction vessels the use of distributed VMSs is now almost universal. A distributed VMS offers many advantages including:

- ◆ reduced control cabling;
- ◆ reduced failure effect;
- ◆ diversity of control locations;
- ◆ ease with which system can be split to match the redundancy concept.

In a distributed VMS the software which controls equipment is in field stations positioned close to the equipment, reducing the length of cable runs. Each field station is connected to two separate communications networks using network hubs or switches. These switches connect together to form the network 'backbone'. Operator stations provide the human-machine interface (HMI) and are connected to the network in the same way as the field stations.

2.19.2 Redundancy Requirements

The data communications network for a VMS is generally designed to be dual redundant. The networks should be provided with a high degree of mechanical protection, particularly in areas of higher risk. In DP equipment class 3 designs there are requirements for physical separation and appropriate fire protection, including watertight integrity being maintained between the cable routes for each network. Some classification societies require similar physical separation for DP equipment class 2 designs. The use of Industrial Ethernet as a communications protocol is almost universal, typically utilising fibre optic connections which offer advantages if compared to copper wire in terms of:

- ◆ externally coupled noise immunity;
- ◆ bandwidth;
- ◆ preventing the transfer of electrical faults including those created by the effects of fire and flooding.

Although triple redundant systems can be used, evidence suggests that those few incidents that have defeated the redundancy of dual networks would also have defeated triple redundant systems. The emphasis should therefore be to protect dual redundant networks against internal and external common cause failures rather than adding additional communications redundancy.

Vessel downtime associated with failure of Ethernet links can be addressed by carrying critical spares such as network switches and interface cards and by including spare fibre optic links in the backbones which are already terminated and ready for use.

2.20 DP Control Systems

2.20.1 Operating Principles

DP control systems operate on the same basic control system principles as any other control system. Where significant differences exist, it is in the type and range of protection functions provided, the means of detecting faulty position and sensor data and the means of dealing with internal faults.

The system should indicate the operating mode which has been selected at all times during DP operation.

2.20.2 Thruster Interface

DP control systems can be distinguished by their thruster interfaces. On smaller vessels, the trend is to provide an individual analogue interface to the local thruster control system with command, feedback and 'ready for DP' signals. Larger vessels tend to have a network interface to the thrusters.

2.20.3 Redundancy Requirements

The minimum requirement for DP equipment class 2 is to have one duplex DP controller at the main DP station. In this type of system, one controller is in command at any one time. Command is transferred to the standby controller on detection of a critical fault.

The minimum requirement for DP equipment class 3 vessels is a duplex controller at the main DP station and a simplex controller at the backup DP station with suitable physical separation between them (typically A60 bulkhead). The backup DP station may also be a duplex unit to limit the possibility for non-productive time associated with failure of a simplex unit.

Various functions monitor the health of both the online and offline controller and provide alarms if redundancy is lost. As the DP control system is a relatively small part of the cost of a large DP vessel some owners elect to have a dual redundant (sometimes referred to as triplex) controller.

A dual redundant triplex DP control system is often selected as it is possible for the DP system to maintain the required single failure fault tolerance if one of the controllers fails. Provided the system limitations are fully understood and proper testing is carried out to confirm the system retains the required fault tolerance, it is possible for a vessel to return to work with some element of a triplex DP control system unavailable.

2.20.4 Thruster Control Mode Selection

The means by which control over the thrusters is changed from manual to DP to independent joystick (IJS) is a potential weak point in any DP system. No failure of the selector system should prevent manual control.

The control selector forms a common point between all thrusters. The design should ensure that a failure cannot cause the control mode to transfer from auto DP to another mode. For DP equipment class 3 vessels it is important to ensure no single failure of the control selector switch should cause control to transfer unexpectedly to the backup DP system. This can be achieved by having a separate digital communications interface from the control selector to each thruster field station.

Accidental change of mode continues to be a cause of DP incidents. Locating buttons with critical functions close to less critical functions increases the risk of a critical button being accidentally pushed. Good ergonomic design should position critical push buttons where they are unlikely to be operated inadvertently.

2.20.5 Intelligent Consequence Analysis

A consequence analyser is a class requirement in all DP equipment class 2 and DP equipment class 3 DP control systems.

A consequence analyser provides a warning if the vessel is not able to maintain position and heading after a predefined worst case failure has occurred during current operations and weather conditions. Additionally, the consequence analyser should perform calculations to verify that in the event of a single fault there is sufficient thrust available to maintain position and heading.

There is a risk that the consequence analyser will not offer the required protection if it is not correctly specified. Early engagement with the DP control system provider is recommended to ensure that the intelligent consequence analyser is correctly specified.

2.20.6 External Interfaces

Erroneous signals from position references, vessel sensors and other interfaces should be rejected before they can affect the DP control system. These connections are sometimes referred to as 'external interfaces' and can include:

- ◆ external force compensation for pipelayers, towline tension, etc.;
- ◆ draught gauges;
- ◆ connections for industrial power management;
- ◆ connections to survey suites.

All external interfaces should be designed to fail safe or have sufficient redundancy and fault detection to tolerate failures using the fault tolerance criteria required by the vessel's DP equipment class. Guidance on the interfacing of ESD and F&G systems is provided in section 2.21.

2.20.7 Position Reference Systems and Vessel Sensors

DP equipment class 2 vessels require at least three position reference systems based on two different measurement principles. IMO MSC/Circ.645 requires that these position references should be suitable for the type of operations the vessel will undertake. For DP equipment class 3, at least one position reference must be assigned to the backup DP system.

The vessel's industrial mission often dictates the type of position references that can be used. For vessel sensors, there is no requirement for diversity or differentiation however it is good practice to specify some diversity in the form of different manufacturers or measurement principles to reduce the risk of common mode failures. Such diversity in position reference systems is not always sufficient to ensure incident free DP operations. Differentiation can be introduced into signals provided by position references of the same type to reduce the risk of common mode failures. Satellite based and hydroacoustic position references may be used in conjunction with inertial navigation systems to provide improved position reliability.

The power supplies for the DP control system should be designed so that at least one reference system remains online in the event of a single failure. This may be relaxed when the vessel has more than three position references, provided not more than one of those selected for DP can fail. Antennas and external sensors such as anemometers should be provided with lightning arresters which are fitted to antenna leads and vulnerable connections.

2.20.8 Independent Joystick (IJS)

The IJS, with auto heading control, can be used to control the vessel through its independent connection to the thrusters if the DP control system fails. The IJS should be powered from an uninterruptable source of power independent of the DP control system. It should be arranged to allow rapid transfer of control from the DP control system. Consideration should be given to provide an independent means for the operator to monitor vessel position.

2.20.9 Control Station Design and Ergonomics

Control station design should apply best ergonomic practices to facilitate the tasks the operator is intended to perform. The control station should be positioned such that adjacent surface structures, vessels, appropriate working areas and vessel operations are visible from the control station. The DPO should be able to effectively monitor vessel positioning performance, position relative to loading facilities and adjacent vessels (where applicable) and the status of ballast and loading operations.

The DP control station should be positioned such that the DPO is provided with as large an arc of external visibility as is compatible with the requirements for physical protection of the control station. CCTV images of working areas may be used where provision of direct visibility is not possible.

The following information should be displayed at the control station as applicable:

- ◆ position reference system status and configuration;
- ◆ survey data for surface and seabed features, overlaid with the vessel outline and ROV position;
- ◆ a similar display positioned to be visible from the independent joystick control position in the event of a failure of automatic control;
- ◆ CCTV images of working areas not visible from the control position, overside, back decks and cranes and adjacent vessels or structures when in close proximity;
- ◆ ROV, diver and crane camera images as appropriate;
- ◆ status of industrial mission systems (for example, pipelay, dredge, rock placement, cable lay and repair and crane systems);
- ◆ positions and tracks of other vessels operating in the vicinity;
- ◆ gangway status, crane position and loads, vessel draught, ballast system status;
- ◆ riser monitoring information;

- ◆ for accommodation vessels, a plot showing the outline of the adjacent facility, overlaid with the accommodation vessel outline and gangway position; the outlines should represent the area where any contact would first occur following an inability to maintain position;
- ◆ vessel position footprint in relation to the tanker loading facility, and the permitted sectors for operation (defined limits for position and heading);
- ◆ telemetry data (where available) from the tanker loading facility, including relative position information, ESD status and mooring hawser tension;
- ◆ vessel draught, cargo loading and ballast system status;
- ◆ CCTV images of manifolds, mooring systems and the separation distance from the offshore tanker loading facility.

Independent communication facilities to monitor and communicate with simultaneous activities/locations should be provided where appropriate.

2.20.10 Project Survey Systems

Position reference equipment and sensors may provide data to the DP system and the project survey system. In such cases consideration should be given to installing separate equipment for both applications rather than sharing common data. If this is not possible then the systems should be designed to protect the integrity of the data required by the DP control system, and prevent an accidental loss of data through human interface. See [IMCA S 009 – Guidelines for the shared use of DGPS for DP and survey operations](#) – and [IMCA S 010 – The shared use of sensors for DP and survey operations](#).

2.21 Safety Systems

2.21.1 Emergency Shutdown (ESD)

ESD systems are fitted to drilling vessels and other DP vessels engaged in activities where there is a risk of explosion from hydrocarbon gas release. These systems can automatically shut down energy sources and ventilation on detection of gas or fire as well as retaining manual shutdown operability. These systems have been a significant cause of DP incidents due to poor hardware and software design. The 2009 IMO MODU Code recognises the special circumstances of DP vessels and states in section 6.5:

6.5.1 In view of exceptional conditions in which the explosion hazard may extend outside the above-mentioned zones, special arrangements should be provided to facilitate the selective disconnection or shutdown of:

- 1. ventilation systems, except fans necessary for supplying combustion air to prime movers for the production of electrical power;*
- 2. main generator prime movers, including the ventilation systems for these;*
- 3. emergency generator prime movers.*

6.5.2 In the case of units using dynamic positioning systems as a sole means of position keeping, special consideration may be given to the selective disconnection or shutdown of machinery and equipment associated with maintaining the operability of the dynamic positioning system in order to preserve the integrity of the well.

6.5.3 Disconnection or shutdown should be possible from at least two strategic locations, one of which should be outside hazardous areas.

6.5.4 Shutdown systems that are provided to comply with paragraph 6.5.1 should be so designed that the risk of unintentional stoppages caused by malfunction in a shutdown system and the risk of inadvertent operation of a shutdown are minimized.

This allows the shutdown facility to be designed to selectively shut down machinery in a way which allows the incident to be addressed whilst retaining sufficient DP capability to maintain position.

ESD systems should be operable in an advisory mode (in which the system will not take executive action) when hazardous effects management processes (HEMP) favour this. They should be designed using the following principles;

- ◆ Individual shutdown buttons should be provided for each redundant machinery group, interfaced to dedicated field stations for that redundant group. There should not be a single overall ESD button;
- ◆ There should be no cascade function from a higher level to lower levels;
- ◆ The ESD system should not compromise the redundancy concept;
- ◆ ESD field stations should be provided in numbers and locations which match the split in the redundancy concept.

2.21.2 Fire and Gas Detection

Fire detection systems are to be fitted to all DP vessels in accordance with IMO, flag and classification society requirements. Gas detection systems are fitted to vessels engaged in operations where there is a risk of hydrocarbon gas release. Fire and gas detection systems can generally be operated in either advisory mode or active mode as HEMP dictate.

Detection systems and their sensors, interfaces and related hardware should be arranged to support the overall split in the redundancy concept and in accordance with the requirements of the vessel's DP class. Diversity in sensor supplier can enhance the robustness of the detection system.

2.21.3 Fixed Firefighting Systems

Fixed firefighting systems should be designed to minimise the risk of common point failures created by the pipework installation and controls and are to meet redundancy and segregation requirements of the vessel's DP equipment class.

The linking of ventilation stops to the opening of doors on the cabinets for CO₂ system pilot bottles should be avoided, except where such arrangements do not compromise the vessel's redundancy concept.

2.22 Protection Against the Effects of Fire and Flooding

2.22.1 Requirements for Physical Separation

One of the main differences between DP class 3 and DP class 2 is the requirement to consider the effect of the loss of all the equipment within one fire subdivision and/or watertight compartment to the effects of fire or flooding.

DP class 3 requires physical separation between redundant groups, the separation is to have a specific fire and watertight rating.

For DP class 2 vessels some degree of physical separation between redundant groups is recommended however this is not mandatory and should not necessarily be to full DP class 3 specifications.

2.22.2 Fault Propagation out of Compartments

Fault propagation out of compartments by way of cables and pipework can occur. Control power supplies from UPSs are particularly vulnerable and often cross the boundaries between redundant groups. UPSs should be designed to withstand a fault current and continue to operate selectively or without an unacceptable voltage dip.

3 Operational Guidance

3.1 Introduction

3.1.1 Purpose

This section is intended to provide owners, operators, masters, crews and other stakeholders involved in the operation of DP vessels with guidance for operating in DP mode safely.

An inability to maintain position may result in risks to safety of persons and the environment. Whilst all DP operations have some degree of risk it should be recognised that the severity of risk associated with an inability to maintain position will vary according to the activity being undertaken.

The appendices of this document provide detailed guidance for seventeen different DP vessel types, considering three perspectives:

- ◆ industrial mission;
- ◆ vessel type specific design guidance which is additional to the generic design guidance provided in section 2;
- ◆ vessel type guidance to achieve safe DP operation.

The operational guidance provided in this section of the document is generic and applicable to all DP vessels and all operating scenarios.

3.2 DP Operating Rules, Regulations and Guidance

3.2.1 Overview

The DP sector is subject to a variety of rules, regulations and guidance. Those rules, regulations and guidance documents relating to vessel and equipment design and construction are considered in section 2.

The principal regulatory document governing DP operations is IMO MSC/Circ.645 – *Guidelines for vessels with dynamic positioning systems*. This provides guidance on some operating requirements in addition to vessel and equipment design requirements. IMO MSC/Circ.645 applies risk based principles and establishes that DP vessels should be considered in terms of DP equipment class.

Despite there being a considerable volume of rules and regulations for vessel and equipment design and construction, DP operations are largely managed by self-regulation.

3.2.2 IMCA DP Guidance

IMCA publishes industry guidance documents designed to promote good practice and support self-regulation.

A list of IMCA DP referenced guidance documents is given in Appendix 19. Documents are available on the IMCA website at www.imca-int.com.

3.2.3 MTS DP Committee DP Guidance

The DP Committee of the Marine Technology Society (MTS) has published a series of DP guidance documents.

All MTS DP Committee guidance documents are available from the MTS DP Committee website at www.dynamic-positioning.com. MTS DP Committee guidance documents referenced in this document are listed in Appendix 19.

3.2.4 Classification Societies' DP Guidance and Recommended Practice

Classification societies require all vessels within their registers to meet the applicable regulations and rules for the design and construction of ships and equipment. Ships meeting particular requirements can be assigned a class notation signifying certain special features. Classification societies may also publish guidance and recommendations to support their rules and may also provide operational guidance.

3.2.5 Charterers' Requirements for DP Operations

DP vessels generally operate under charter. Each vessel charterer (for example, an oil company) will have its own expectations and requirements for DP vessels. Most charterers reference guidance documents published by third parties such as IMCA in their charter requirements in addition to their own requirements for audit, inspection and operation of DP vessels.

3.2.6 Governments' Requirements for DP Operations

Flag administration requirements will incorporate applicable IMO requirements for those vessels within the scope of the IMO Conventions and where such IMO requirements have been ratified and/or adopted by the flag state. For vessels outside of these Conventions the flag administration will apply its own national requirements which may or may not be equivalent to those of the IMO. Additionally, coastal state administrations have requirements for vessels operating within their waters, regardless of vessel flag.

Owners and operators of DP vessels are to be aware of the requirements of those coastal states which their vessels operate within.

3.3 DP Documentation

3.3.1 Overview

DP vessels should be provided with appropriate, up to date, DP documentation. This documentation should be available to all relevant members of the vessel crew as well as to shore based technical management and superintendents. Documents onboard should be written in a language which can be understood by the crew.

Except where stated otherwise, documents may be electronic or hard copy or both. Where electronic documents are used then they should be retrievable at all times.

These documents should include but are not limited to the vessel-specific DP FMEA, proving trials report, annual DP trials programmes and reports and the vessel's DP operations manual. Any superseded documents should be removed from circulation.

Independent third party DP practitioners will generally perform a significant role in developing the necessary DP documentation; it is recommended that vessel crews are involved in this process.

The DP documentation should include operational requirements and data, such as:

- ◆ the safe and effective management of the vessel in DP;
- ◆ the technical suitability of the vessel for each DP activity it is required to carry out;
- ◆ the configuration for the critical activity mode of operation (CAM) and the task appropriate mode (TAM);
- ◆ the vessel's station keeping capabilities following worst case failure;
- ◆ compliance with appropriate standards and guidelines;
- ◆ training and familiarisation material to vessel crews.

3.3.2 Recommended Documentation

The documents in Table 2 should be kept onboard and in addition, where feasible, at the shore based centres of technical and operational management. Where a periodicity for document storage is recommended this is not to be taken as superseding any applicable regulatory requirements for the minimum storage period for such documents.

No.	Document	Guidance
1	DP system FMEA	To be kept up to date and incorporate all modifications and additions since the original study, if not in the document itself then by other traceable means. Modifications and additions should be covered by an MoC process.
2	DP FMEA proving trials	To be conducted to prove the initial DP FMEA and any modifications and additions to the DP system and when a complete test of the DP system is to be carried out. Findings should be addressed in accordance with their criticality.
3	Annual DP trials	Should be carried out within three months before or after each anniversary date of the initial DP FMEA proving trial. This may be changed to align with new DP FMEA proving trials following a major upgrade or conversion. All previous annual DP trials reports should be retained onboard.
4	DP capability plots	These should be hard copy plots of the vessel's calculated capability to maintain position in various operational scenarios. They should be readily available at the DP control location.
5	DP footprint plots	These are plots of the vessel's real station keeping performance in various thruster and vessel configurations and in different environmental conditions. They determine the limits of the vessel's position keeping ability in various thruster and vessel configurations and in different environmental conditions (for comparison with DP capability plots). These plots should also be readily available at the DP control location.
6	Service reports concerning the DP system	Any open items should be highlighted, tracked and recorded when closed out.
7	Details of all DP related modifications and additions	Records of all DP related modifications and additions complete with interface and testing information. New and modified software should be subjected to a thorough validation process, and recorded.
8	Vessel audit reports and DP audits and inspection reports	Complete history of all audit reports, DP audits and inspection reports, including findings and close outs. Any open items should be highlighted, tracked and recorded when closed out.
9	DP operations manual	Vessel-specific DP operations manual, to be readily accessible at the DP control location. It is recommended that owner/operators develop a standardised DP operations manual table of contents for vessels in their fleet. Modifications and amendments to the DP operations manual should be subject to MoC processes. Further guidance is given in IMCA M 109 – A guide to DP-related documentation for DP vessels .
10	DP incident reports	Records of all DP station keeping and other DP related incidents, including investigation records and close outs should be retained onboard permanently.
11	DP mobilisation/DP field arrival/trials procedures (bridge and engine room)	Records of DP mobilisation trials and DP field arrival checklists should be retained onboard for the period set by the owner/operator. Where a checklist is related to a DP station keeping or DP related incident it should be retained onboard permanently.
12	DP location and watchkeeping checklists (bridge and engine room)	Records of all DP location and watchkeeping checklists should be retained onboard for the period set by the owner/operator. Where a checklist is related to a DP station keeping or DP related incident it should be retained onboard permanently.
13	DP drills and emergency response drills	Records of DP drills and emergency response drills should be retained onboard for a period set by the owner/operator.

No.	Document	Guidance
14	DP fault log	Records of all faults related to the DP system should be retained onboard permanently.
15	Data logging	Records should be retained onboard for the period set by the owner/operator and, where relating to a DP incident, permanently stored.
16	DP alarm printer readouts	Hard copy records of the DP alarm printer readout should be retained onboard for the period set by the owner/operator and, where relating to a DP incident, permanently stored.
17	DP familiarisation and competency records	All records relating to vessel-specific DP familiarisation and competency for key DP personnel including DPOs and technical DP personnel should be kept onboard permanently.
18	Resumés and vessel-specific work records of all key DP personnel	Resumés of all key DP personnel, copies of certification and qualifications, records of DP watchkeeping hours should be maintained onboard. Key DP personnel are responsible for maintaining their respective original certificates and DP logbooks which should be held onboard.

Table 2 – DP documentation

3.4 DP System Trials, Tests and Checks

3.4.1 General

All DP vessels should undergo trials, tests and checks to verify their operability, integrity and fault tolerance when operating in DP mode. These verification processes should be carried out at regular, pre-planned intervals and should consider the planned industrial missions and worst case failure of the vessel. The most rigorous testing occurs at DP FMEA proving trials, the content and range of subsequent trials, tests and checks is based on the vessel's DP FMEA and proving trials results.

Tests and checks should be carried out during project mobilisation, field and location arrival, watch handovers and pre-task times.

3.4.2 DP FMEA Proving Trials

It is recommended that all DP vessels, regardless of DP equipment class, are subject to DP FMEA proving trials at new build, after conversion and major modification.

The purpose of the DP FMEA proving trials is to establish the level of redundancy and fault tolerance provided by the DP system and to confirm the analysis in the FMEA.

DP FMEA proving trials should not be confused with commissioning trials, however, some tests required by both DP FMEA proving trials and commissioning trials may be conducted together. DP FMEA proving trials provide evidence of redundancy and fault tolerance whereas commissioning trials are conducted to demonstrate that systems and equipment meet the required functional specification.

During DP FMEA proving trials equipment is to be configured in accordance with the specification in the DP FMEA.

The DP FMEA and the proving trials should pay attention to the interfaces between the DP system and other systems, such as emergency shutdown systems (ESD), fire monitoring systems and pipe tensioner systems, which have the potential to affect the DP system. These interfaces and dependencies should be subjected to a systems engineering approach including FMEAs and proving trials.

The DP FMEA and proving trials should confirm the;

- ◆ worst case failure design intent (WCFDI);
- ◆ worst case failure (WCF).

In addition the DP FMEA and the proving trials should address the following;

- ◆ identify the subsystems and equipment and modes of operation;
- ◆ identify all potential failure modes and their causes;
- ◆ identify single point failures;
- ◆ identify potential hidden failures;
- ◆ identify potential configuration errors;
- ◆ evaluate the effects on the DP system of each failure mode.

Further and more detailed guidance on DP FMEAs and proving trials is provided in section 2 of this guidance document and in:

- ◆ [IMCA M 166](#) – *Guidance on failure modes and effects analyses (FMEAs)*;
- ◆ MTS DP committee – *DP operations guidance*, Parts 1 and 2; and MTS DP committee – *DP vessel design philosophy guidance*, Parts 1 and 2.

3.4.3 Annual DP Trials

All DP vessels should be subjected to annual testing of the DP system to demonstrate that the vessel remains fit for purpose for DP operations. The annual DP trials programme should be based on the vessel's DP FMEA proving trials.

DP trials may be conducted on an annual or incremental basis. Incremental trials are the norm for drilling vessels and are increasingly being applied to other DP vessel types. This is acceptable provided that the incremental testing programme includes all testing which would be required for an annual test within the defined twelve month period.

Where an annual DP trials is undertaken then it should be held on a specific occasion each year and within three months either side of the anniversary date of the initial DP FMEA proving trials. [IMCA M 190](#) and its executive summary, published separately as [IMCA M 190A](#), provide the basis for developing and conducting annual DP trials for vessels other than drilling vessels.

[IMCA M 191](#) provides guidance for the annual testing of drilling vessels, this is based on incremental testing throughout the year as opportunities arise.

[IMCA M 191](#) may be used as guidance for incremental testing for other DP vessel types provided that any particular requirements deemed necessary for testing other vessel types are incorporated into the testing programme.

The annual DP trial should test all functions on which the redundancy concept depends, including network testing, blackout recovery plans and ESD functions.

DP vessel owner/operators should ensure that an independent third party witnesses annual DP trials.

Actions identified during the annual DP trial should be tracked and closed out as promptly as possible.

The definitions of the findings from annual DP trials differ from those for DP FMEA proving trials, although they share the same A, B and C categories.

[IMCA M 190](#) recommends that findings from annual DP trials are categorised as follows;

1. Category A – for immediate attention;
2. Category B – for action when reasonably convenient;
3. Category C – for future attention/consideration.

IMCA M 190 provides examples of test results that are appropriate to the above findings categories.

The development, conduct and ownership of all annual DP trials is the responsibility of the vessel owner/operator.

3.4.4 DP Mobilisation Trials

DP mobilisation trials should demonstrate the operational integrity and performance of the vessel's DP system, confirming the vessel's redundancy concept and proving the vessel's ability to maintain position after suffering worst case failure. DP mobilisation trials should be carried out by the vessel prior to the start of operations for a new client.

3.4.5 DP Field Arrival Trials

These checks should be carried out on arrival at the field and conducted outside the 500 metre safety zone. The checks should be repeated when the vessel returns to the field after an absence of more than 24 hours.

The purpose of these checks is to ensure satisfactory operation of the DP system. The checks should include full functional checks of the operation of the thrusters, power generation, auto DP and independent joystick (IJS) and manual controls. The checks also ensure that the DP system is set up correctly and that the manning is adequate.

3.4.6 DP Location Set-up Checklist

These checks should be carried out at every working location and may be used as a routine checklist. Where the vessel is to visit a number of offshore installations on a voyage then these checks should be carried out every time the vessel changes from transit mode to auto DP mode.

The purpose of these checks is to ensure that the vessel's station keeping performance at the working location is satisfactory and, in particular, to ensure that the position reference systems are properly set up. The checks also provide a hard copy record of power and propulsion demands and DP control parameters.

Vessel heading should also be adopted at this time to ensure that thruster loads will be acceptable on the working heading and location. The initial stabilisation period should be at least 30 minutes, subsequent periods of stabilisation following moves and heading changes should be determined by the circumstances and conditions. The initial stabilisation period may be reduced to less than 30 minutes where it can be demonstrated that this will not have a detrimental effect on DP model and position keeping dependability, the risk profile of the activity should be considered.

3.4.7 Change of Watch Checklist

The change of watch checklist should include all checks necessary to confirm the status of essential DP equipment and to complete a routine check of the performance and settings of that equipment. The DP sections of this checklist should be completed again following any substantial reconfiguring of essential DP equipment during the watch. The oncoming DPO should verify the contents of this checklist prior to starting the DP watch.

3.4.8 DP Engine Room Checklist

Before the vessel approaches within 500 metres of the work site or when requested by the DPO on watch an engine room readiness for DP operations checklist should be completed by the engineer on watch. The purpose of this checklist is to ensure that the engine room systems and equipment are set up correctly for DP with the correct redundancy and the appropriate equipment and switchboard configuration. Appropriate DP checks are additionally to be incorporated within the engine room change of watch checklist.

3.4.9 500m Zone Safety Checklist

These checks should be carried out each time before the vessel comes within 500 metres of any offshore installation.

The purpose of these checks is to ensure satisfactory operation of the DP system. The checks should also confirm that the DP system is set up correctly and that the manning is adequate and that the vessel has communicated with the installation and been given permission to enter the 500m zone.

3.5 Risk Based Planning and Control

3.5.1 Introduction

Successful execution of DP operations and safe completion of the vessel's industrial mission relies on proper planning and control. This can be achieved by activity operational planning which comprises three different elements; critical activity mode (CAM), task appropriate mode (TAM) and activity specific operating guidelines (ASOG).

3.5.2 Critical Activity Mode (CAM)

The CAM defines the most fault-tolerant configuration for the DP system and associated equipment. CAM should be implemented for all critical activities undertaken by the vessel. For DP class 2 and 3 vessels the CAM will ensure that a single point failure does not exceed the vessel's identified worst case failure. Where it is permissible to operate with a lesser standard of fault tolerance then the CAM may be replaced by a TAM.

3.5.3 Task Appropriate Mode (TAM)

A TAM is a risk based operating mode in which the DP vessel may be configured and operated such that a single point failure could result in exceeding the vessel's identified worst case failure. A TAM may be applied where a risk assessment has demonstrated that the consequences of exceeding the vessel's identified worst case failure are acceptable.

3.5.4 Activity Specific Operating Guidelines (ASOG)

An ASOG defines the operational, environmental and equipment performance limits for the location and the specific activity the vessel is undertaking. The performance limits are established based on the level of risk. A DP vessel may have a number of different ASOGs, each applying to different locations, activities and levels of risk. The terms well specific operating guidelines (WSOG), field specific operating guidelines (FSOG) and location specific operating guidelines (LSOG) denote equivalent concepts as applied by specific offshore sectors.

3.5.5 CAM and TAM Examples

CAM and TAM refer to the system and equipment configurations of DP vessels. For example, CAM may require the DP vessel to operate with open bus ties whereas TAM may permit the vessel to operate with closed bus ties.

CAM may require a minimum of three independent position references based on different principles whereas TAM may accept two.

A DP MODU may operate in CAM where time to terminate an operation in an emergency is long, such as when non-shearable heavy wall drill pipe is passing through the BOP, but in TAM when time to terminate is short.

3.5.6 Activity Operational Planning Recommendations

CAM, TAM and ASOG are recommended for all DP vessels, regardless of DP class. The CAM, TAM and ASOG are the responsibility of the vessel owner/operator and are to be based on:

- ◆ a thorough knowledge of the DP system;
- ◆ the DP FMEA;
- ◆ the industrial mission;
- ◆ vessel location, and
- ◆ risk assessment.

A DP vessel will have one CAM and normally one TAM although some vessel owner/operator's decide not to operate in TAM. The owner/operator is responsible for the CAM and TAM, including determining the situations requiring CAM and where a TAM may be used, however the client will generally expect to have a say in the decision making process.

There are likely to be several ASOGs, each of which applies to a specific activity and location. The ASOGs are the responsibility of the owner/operator, however the client's views should be considered when an ASOG is to be used.

A CAM table uses only two columns:

- ◆ GREEN – normal;
- ◆ BLUE – advisory.

The same two-column table can be used for a TAM although the GREEN (normal) conditions will differ from the CAM.

	Green	Blue
Definition	Normal operations – all systems and equipment fully operational, DP verification processes completed and DP set up confirmed	Advisory status – where any of the GREEN conditions are not met
Response	For DP operations to commence and continue the conditions in the GREEN column must be met	Conduct risk assessment to determine whether to continue, change position or cease operations

Table 3 – Critical activity mode of operation – outline

An ASOG table uses all four columns:

- ◆ GREEN – normal;
- ◆ BLUE – advisory;
- ◆ YELLOW – degraded;
- ◆ RED – emergency.

	Green	Blue	Yellow	Red
Definition	Normal operations – all systems fully functional and operating within acceptable performance limits	Advisory status – approaching performance limits or reportable alarm status. Operations may continue whilst risks are being assessed. A failure has occurred that does not affect DP redundancy	Reduced status Pre-defined performance limits reached, component or system failure resulting in loss of redundancy	Emergency status – pre-defined operational or performance limits exceeded, component or system failure resulting in loss of control or position, internal or external emergency situation affecting the vessel
Response	For DP operations to commence and continue the conditions in the GREEN column must be met	Conduct risk assessment to determine whether to continue, change position or cease operations	Commence preparation to safely terminate operations. Specific guidance for vessel types is available in the appendices	Abandon operations. Take immediate action, i.e. initiate emergency disconnect sequence (EDS) to ensure the safety of people, the environment, the operation and the vessel

Table 4 – Activity specific operating guidelines – outline

3.5.7 Further Information

Further information and guidance is given in other documents, in particular:

- ◆ IMCA M 220 – *Guidance on operational activity planning*;
- ◆ MTS DP Committee – *DP operations guidance* Parts 1 and 2;
- ◆ DNV Recommended Practice RP-E-307, *Dynamic positioning systems – Operation guidance*.

3.6 DP Capability Analysis and DP Footprints

3.6.1 DP Capability Analysis

The capability of the DP vessel to maintain position in defined equipment configurations and environmental conditions should be known; particularly position keeping capability following its worst case failure.

A vessel's calculated DP capability is determined by using a DP capability analysis, the results of which should be produced in a wind envelope format. DP capability analyses should be prepared for all DP vessels, regardless of DP equipment class. Recommended configurations for DP capability analysis should include the following;

- ◆ fully intact in power generation and thrusters;
- ◆ loss of most effective thruster(s), after worst case failure;

They should be calculated for the intended area of operations and at current speeds of 0kts, 1kt and 2kts and any other expected current speed.

They may be calculated based on a balance of static forces, measuring thruster forces against environmental forces, however adding dynamic force interaction to the calculation will provide a more accurate result.

Detailed explanation and description of DP capability analysis are given in [IMCA M 140 – Specification for DP capability plots](#) – and also in *MTS DP committee – DP operations guidance, Part 2*.

3.6.2 DP Footprint Plots

The calculated position keeping capabilities which are provided by the DP capability analysis should be supplemented by real time measurements and observations. These real time observations and measurements are used to develop DP footprint plots.

DP footprint plots measure the vessel's real station keeping performance (accuracy) in specific equipment configurators and environmental conditions. They determine the vessel's actual position keeping ability in various thruster configurations and environmental conditions and can be used for comparison with DP capability plots.

A more detailed explanation and worked examples of DP Footprint plotting are given in *MTS DP operations guidance, Part 2*.

3.7 DP Training, Competence and Certification

3.7.1 Personnel

All key DP personnel should be trained and their competence assessed and verified as meeting defined requirements for the DP vessel on which they are serving. The owner/operator of the DP vessel is responsible for ensuring that crews are suitably trained and competent.

IMCA provides guidance in the form of a competence assurance and assessment framework, [IMCA C 002 – Guidance document and competence tables: Marine Division](#) – as well as guidance for the training and experience of key DP personnel. IMO MSC/Circ.645/738 – *Guidelines for DP operator training* – recommends that [IMCA M 117 – The training and experience of key DP personnel](#) – is applied to the training of personnel employed on DP vessels. More general advice on the content of training and experience for DP personnel is also provided in the IMO STCW Convention (STCW B-V/f).

In addition to external qualification and certification requirements, all key DP personnel should be required to complete a vessel-specific DP training and competency programme.

Other personnel should have an understanding of the DP operations which is appropriate to their position onboard.

3.8 DP Manning Levels

Manning levels for DP vessels when operating in DP should be considered separately from the vessel's safe manning certification issued by the flag administration. The owner/operator should ensure that manning levels when operating in DP mode are sufficient to meet the recommendations in industry guidance and as required by the charterer.

Good practice is for two DPOs to be on watch in the DP control room/bridge when the vessel is carrying out DP operations. An exception is supply vessels where a single fully certificated DPO may be acceptable. [182 MSF – International guidelines for the safe operation of dynamically positioned offshore supply vessels](#) – provides specific guidance for supply vessel operations.

It is also recommended that at least one engineer is on watch in the engine control room during DP operations.

Manning levels are covered in detail in [IMCA M 117 – The training and experience of key DP personnel](#).

3.9 DP Emergency and Contingency Planning

Plans should be in place to deal with DP and other emergencies which may affect the ability of the vessel to maintain position. These plans should be readily available to key DP personnel and tested at regular intervals.

Opportunities should be taken to carry out familiarisation of the system during annual DP trials when the emphasis turns from DP operations to ensuring DP fitness for purpose.

Lessons learnt from the vessel's own operational history should inform emergency training exercises, as should lessons from IMCA's DP incident reporting scheme. A structured programme of training for emergencies should be available for all DP vessel types and activities.

Emergency exercises should also consider failure modes identified in the vessel's DP FMEA. All key DP personnel onboard and shore based technical superintendents should be involved in the planning and delivery of DP emergency exercises.

All personnel onboard the DP vessel who are directly involved in the safety of DP operations should also be involved in emergency exercises as should personnel on adjacent installations.

Further detailed guidance on emergency exercises is to be found in [IMCA M 117](#).

3.10 Effective DP Communications

All DP vessels should be provided with appropriate communications systems and procedures which ensure effective communications between all parties involved in DP operations. This includes both communications between parties onboard the DP vessel as well as with nearby structures and vessels.

Communications should also be maintained during all foreseeable emergency situations; this should be tested and rehearsed regularly during emergency exercises by vessel crews and crews of nearby structures or vessels.

Guidance on communications systems is available in [IMCA M 205 – Guidance on operational communications](#) – and in MTS DP Committee – *DP Operations Guidance* Parts 1 and 2.

3.11 Recording, Reporting and Closing Out DP Incidents

All DP incidents should be recorded and reported in accordance with agreed practices and procedures. All DP incidents should be investigated by suitably qualified and competent personnel. The investigation should identify lessons learnt and make recommendations on actions to be taken to mitigate against the reoccurrence of the incident.

IMCA operates a DP incident reporting scheme which is open to IMCA members and non-members. Anonymised DP safety flashes are generated from reports received with permission of the originator.

Reports of DP incidents should be forwarded to IMCA using either the appropriate IMCA DP incident report form or a company-specific incident report form which describes the incident, the investigation, close outs and any follow up actions. IMCA provides two forms; one for DP vessels and one for thruster assisted vessels, DP tankers, FPSOs, FSUs, semi submersibles, flotels, etc. The forms are available from the IMCA website, www.imca-int.com. Details of the IMCA DP station keeping event reporting scheme are given in Appendix 18.

IMCA publishes an annual report which summarises the DP incidents reported and investigated throughout the previous year. The annual reports of DP incidents are available for IMCA members to download from www.imca-int.com.

In addition, charterers of DP vessels may require to be informed of DP incidents, with many charterers being actively involved in the investigation and close out processes.

Diving Support Vessels

AI-1 Industrial Mission

AI-1.1 Description and Role

The primary operational role of the vessel is diving wherever manual intervention is required for completion of tasks subsea. Diving support vessels may be equipped for support of surface-supplied dives (often referred to as air diving) or closed bell dives (often referred to as saturation diving).

Surface supplied divers are supplied with air via an umbilical and are exposed to the changes in ambient pressure between the surface and the working depth. Such dives require controlled decompression on return to the surface. Working depths are limited to 50m.

Closed bell divers use mixed gas in order to dive. Divers are maintained at a pressure equivalent to the assigned working depth when onboard the diving support vessel and transfer to the work site in a pressurised diving bell. Working depths are most frequently less than 200m in the offshore oil and gas industry.

Diving operations may take place in open water or in close proximity to fixed or floating structures, and within the anchor pattern of anchored units.

Diving operations are sensitive to vessel motions (due to the limitations of heave compensation systems for cranes and deployment devices) and water currents (due to limitations in DP capability and the diver's ability to work in strong currents).

Supporting saturation diving requires significantly more complex equipment than that required for air diving. Saturation diving systems tend to be a permanent part of a vessel's outfit, whereas air diving systems may be temporarily mobilised onboard any DP vessel meeting the required IMO DP equipment class.

Diving support vessels are usually fitted with a crane capable of supporting subsea activities and observation class ROVs for diver monitoring, and for survey/inspection.

The consequences of loss of vessel position are dependent upon the diver's ability to quickly return to the recovery device (diving bell or basket). If a diver is separated from their surface supplied life support then the consequences are potentially fatal. When operating in close proximity to fixed/floating structures then consequences of an inability to maintain position additionally include the potential for damage to the vessel/asset.

Due to the high potential risks of diving activities, flag administrations and coastal states may have specific requirements for the design and operation of diving support vessels.

AI-2 Design Guidance

AI-2.1 Design Considerations

Diving operations should be carried out from vessels complying with IMO DP equipment class 2 or 3.

The DP system should be designed to minimise the potential for human error to cause an inability to maintain position.

Diving systems should be designed such that no known single failure will result in an inability to safely recover divers.

The vessel should be capable of maintaining necessary life support systems for divers and should be able to provide a stable platform for diver deployments with minimum heave.

Diving systems are designed, installed and operated in compliance where appropriate with statutory requirements imposed by the coastal state and/or flag state of the vessel as well as the classification society and should be subject to FMEA (see [IMCA D 039 – FMEA guide for diving systems](#)).

Where a vessel is intended to be IMO DP equipment class 2 the effects of fire or flood should be minimised; where segregation of thruster and power systems into separate watertight and fire resistant spaces is not practicable then fire detection and suppression systems should be designed to ensure that in the event of fire there will be a sufficient period of time to recover divers (see [IMCA M 119 – Fires in machinery spaces on DP vessels](#)). Cabling for DP equipment should wherever practicable avoid Class A machinery spaces.

AI-2.2 DP Capability

The vessel should be capable of maintaining position in relation to the diver's worksite; a small DP footprint is often required when diver's bell/basket is deployed in close proximity to subsea structures, or when close approach to surface installations is required to facilitate diver access. The vessel response to incremental vessel moves or heading changes where requested should be smooth and predictable without overshoot.

The vessel should be capable of maintaining position for sufficient time after the worst case failure to safely recover divers in all anticipated operational and environmental conditions.

Position keeping capability plots should be developed for intact and worst case failure conditions.

AI-2.3 Control Systems

The primary DP control mode is to maintain position and heading in a fixed location. Other modes such as relative location and following a predetermined track should not be used during diving operations. Individual thruster controls which are independent of the DP system should be provided for use in emergency situations.

An independent joystick control system should be provided.

Blackout recovery should be fully automatic and should restore the power plant to operational condition. Consideration should be given to automatic restart of thrusters and recovery to full DP control.

AI-2.4 Reference Systems and Sensors

At least three independent position reference systems and three heading reference systems should be in use for diving operations.

Both surface and seabed referenced systems should be fitted providing a combination of both absolute and relative references.

At least two different measurement principles should be employed for the position reference systems at any time; three principles should be employed whenever possible. When operating close to a surface structure then at least one relative reference should be in use.

Power for the position references should be supplied from different redundancy groups to prevent the worst case single failure resulting in the loss of all position references.

Position reference systems should be resistant to interference from diving operations.

Hull transducers and seabed transponders used for acoustic systems should be positioned to minimise possible attenuation caused by bubbles in the water column.

Taut wires used in taut wire systems should be positioned to minimise the risk of contact with umbilicals which may cause wire deflection and to ensure that the clump weight and wire do not obstruct the diver deployment device and diver worksite.

Microwave and laser ranging devices which may be susceptible to interference should be located to minimise the risk of such interference.

The simultaneous use of two differential global navigation satellite systems (DGNSS) for position reference should be avoided but may be acceptable in open water if different methods for differential corrections are employed. If operating close to structures there is a risk that such structures could block GPS signals and cause instability. DGNSS equipment should be sourced from different manufacturers to avoid software induced common mode failures.

Reference systems and sensors used by the DP control system should be segregated from other users to preserve the integrity of data and prevent an accidental loss of data through human error.

AI-2.5 Power Systems

Provision of power for positioning and diving related systems may be independent, however it is more usual for a redundant diesel–electric power plant to provide power for all vessel systems.

The power management philosophy should consider the criticality of divers' life support, deployment and recovery systems and vessel operational power plant as well as dynamic positioning systems. The power management should ensure that control is maintained of all operationally and safety critical systems at all anticipated electrical loads and after worst case failure in power provision.

The unexpected loss of a generator should not result in a loss of capability in any system necessary for conduct of the diving operation.

AI-3 Operational Guidance

AI-3.1 Operational Considerations

For additional information please refer to [IMCA D 010 – Diving operations from vessels operating in dynamically positioned mode](#). The following should be considered:

- ◆ The time to terminate for diving operations, this is influenced by dive depth, environmental conditions and nature of diver's worksite;
- ◆ The power plant and thrusters are to be suitably configured prior to commencing diving operations;
- ◆ The most robust fault-tolerant switchboard configuration is most likely to be achieved by operating in open bus tie mode. The switchboard may be configured with closed bus ties provided that the FMEA and a thorough analysis have demonstrated that this provides an equivalent degree of fault tolerance to open bus tie mode;
- ◆ The integrity of seabed position references may be affected by diver activity;
- ◆ These reference systems (including associated clump weights) should be managed by the DPO in close co-operation with the diving supervisor to ensure that sufficient reference redundancy is maintained and that risk to divers and subsea infrastructure is minimised;
- ◆ The proximity of diver deployment and recovery devices to subsea hazards should be considered; vessel drift-off direction should be verified if there are risks of fouling umbilicals and deployment systems. Diver deployment devices should be positioned above the level of potential underwater obstructions where practicable;
- ◆ Environmental limits for the diving operations may be governed by the heave limits of deployment devices rather than by the vessel's ability to maintain position;
- ◆ The DPO should be provided with information identifying all secured down-lines and subsea lifts by the diving supervisor;

- ◆ Resetting or repositioning position reference systems during a dive should be avoided, however this may be permitted if it is not carried out simultaneously with a vessel change of heading or position and where it can be completed quickly and safely. Station keeping should be stable prior to deselecting the reference from DP;
- ◆ Seabed acoustic devices utilised by the DP system may only be moved by divers with the direct permission of the DPO and under the supervision of the diving supervisor;
- ◆ Relative position reference systems for the DP control system should only be used when the remote reference point is static. A relative system reference point may be fitted on a floating structure where minimal movement has been verified. Non-fixed reference points may be used to monitor and alert the DPO of movement of adjacent floating structures where the reference is not part of the DP system;
- ◆ In determining safe separation limits between the DP diving vessel and an adjacent fixed structure, the following is recommended:
 - i) the vessel position footprint under normal operating conditions should not exceed 50% of a defined critical excursion limit
 - ii) the critical position excursion limit should not exceed 50% of the separation distance between the vessel and adjacent structure
 - iii) minimum separation between any point of the DP diving vessel and the adjacent structure should normally not be less than 10m.

AI-3.2 Operational Planning

Where appropriate the following should be documented:

- ◆ Risk assessment for the loss of vessel position at all stages of the diving operation;
- ◆ Assessment of the potential drift-off rate and direction, in conjunction with an assessment of the time to terminate (time necessary to recover divers to a position above adjacent subsea obstructions);
- ◆ Configuration of DP related systems for the critical activity mode of operation (CAM);
- ◆ Activity specific operating guidelines (ASOG) to provide a decision support tool for the DPO in the event of loss of DP critical systems, and the procedures necessary to safely recover divers to the vessel;
- ◆ Permission to dive – to include the conduct of specific DP system checks, the obtaining of approval/permits from relevant personnel and the exchange of necessary information between vessel control positions and adjacent installation (if applicable);
- ◆ An operations plot at the DP and dive control positions displaying the relative positions of the vessel, the diver's deployment device, diver's work site, and any known obstructions;
- ◆ Diver umbilical length diagrams where a risk exists of divers or their umbilicals coming into contact with vessel thrusters. Umbilical lengths for the divers should prevent approach within 5m of the nearest thruster. The standby diver umbilical length should prevent approach closer than 3m to the nearest thruster so as to facilitate rescue of divers if required.

AI-3.3 Communications

Reference should also be made to [IMCA M 205 – Guidance on operational communications: Part B – Communications in bridge to dive control](#).

Voice communication by a priority system or dedicated channel should be available between the diving supervisor and the DPO.

Additionally, there should be a dedicated system for communication between all relevant operational and control centres on the vessel, such as:

- ◆ DP control;
- ◆ air dive control;
- ◆ saturation dive control;

- ◆ engine control;
- ◆ ROV control;
- ◆ crane cabin;
- ◆ deck foreman.

There should be a backup to these systems that is operable in a black out condition, both primary and backup communications should be checked as part of the permission to dive checks.

A communications matrix and example flowchart is provided in IMCA M 205 – *Guidance on operational communications*. This should be developed to ensure that all necessary information is shared appropriately; in particular between the DPO and the diving supervisor.

When the vessel is within 500m of an offshore installation or within an area under the management of a designated marine controller the following communications should be made where applicable:

DP control to installation control:

- ◆ requests for permission to enter safety exclusion zones;
- ◆ request for permits for diving;
- ◆ bell status (left surface/at surface);
- ◆ changes in DP alert status to yellow or red;
- ◆ intention to perform tasks involving the operation of any hazardous tools or equipment;
- ◆ intention to significantly change vessel position.

Installation 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);
- ◆ other subsea operations;
- ◆ weather information;
- ◆ other operational or abandoned acoustic beacons or transponders which may be in the vicinity;
- ◆ mooring line adjustment (for moored platform).

AI-3.4 DP Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in tabular format in the ASOG.

The red alert, accompanied by a distinctive alarm, should additionally sound in the master/OIM's cabin, operations superintendent's cabin (if applicable) and the senior diving supervisor's cabin (if applicable). A local means of acknowledging and silencing these alarms and flashing lights should be provided.

Guidance on DP status and responses is given below.

Normal status – GREEN light. Full DP diving operations can be undertaken.

- ◆ The DP system is operating as intended;
- ◆ Operational, environmental and equipment performance criteria as defined within the ASOG are all categorised as normal;

- ◆ The vessel could maintain position in the prevailing environmental conditions after the worst case failure.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;
- ◆ The DP system is no longer configured as required in the CAM/TAM;
- ◆ An advisory condition exists as defined in the ASOG;
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. The diving supervisor should instruct the divers to suspend operations and move to a safe location. The DPO, after consulting the diving supervisor, should decide if further action is necessary. If the diving supervisor is unable to get clear advice from the DPO then the divers should be instructed to return to the bell or deployment device and obtain a seal or to return to the surface as appropriate.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ The vessel's position keeping performance is deteriorating or unstable;
- ◆ The vessel would be unable to maintain position in the prevailing environmental conditions after the worst case failure;
- ◆ A 'yellow' condition exists as defined in the ASOG for abnormal operational, environmental and equipment performance conditions;
- ◆ Any other condition exists which may lead to a suspension of diving activities.

Emergency status – RED light with accompanying distinctive alarm. The diving supervisor should instruct the divers to return immediately to the bell (or deployment device as appropriate) and obtain a seal. The deployment device should be recovered as soon as possible after due consideration of hazards involved in the recovery. The DPO(s) should use all available means to limit the inability to maintain position while the divers are being recovered.

- ◆ A system failure or other condition has occurred resulting in an inability to maintain position or heading control or to safely conduct diving operations;
- ◆ A 'red' condition exists as defined in the ASOG for hazardous operational, environmental and equipment performance criteria;
- ◆ Any other emergency situation which warrants immediate recovery of divers to a safe position.

A1-3.5 Management of Changes to Position and Heading

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 that:

- ◆ The move can safely be executed;
- ◆ Umbilicals are clear and will remain so during the move;
- ◆ Divers understand the move and are in a safe location;
- ◆ Divers can reach the deployment device;
- ◆ Three position references on line throughout the move;
- ◆ The selected speed complies with that specified in the ASOG;
- ◆ A change of heading and position are not 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 verifies the move input before execution.

The selected centre of rotation should be considered when changing heading. If at any time the DPO has any cause to doubt the safety of the heading change then the diving supervisor should be instructed to recall the divers to the deployment device and the heading change suspended and re-assessed.

AI-3.6 Diving in Shallow Water

Shallow water may restrict the possible escape direction for the vessel: tidal rate and direction should be monitored and safe routes to deeper water should be determined.

The vessel's capability plots may not accurately give the limiting environmental conditions for shallow water. DPOs should expect higher thruster loads than for the same wind speed in deeper water; as a consequence, requiring earlier termination of diving operations.

In shallow water there will be less scope for movement before seabed position reference sensors need relocation.

- ◆ The scope of vertical taut wires is reduced in shallow water;
- ◆ A natural excursion of the vessel from its position and heading setpoints in shallow water may exceed the scope of a bottom position reference;
- ◆ Acoustics are more susceptible to interference from the vessel in shallow water.

When working in shallow water the radius of operation of each of the three position references should never be less than 5m. The vessel's natural excursions from its setpoint should never exceed a third of the radius of operation of its position references.

AI-3.7 Diving Within an Anchor Pattern

Diving within an anchor pattern will restrict the position and movement of the vessel and may introduce additional hazards. This should be risk assessed and suitable emergency and contingency procedures developed.

The principal hazard is that the vessel could drift across the mooring catenary if it is unable to maintain position or heading, risking the diver's deployment device.

The operational plot should show the position of mooring lines in an easy-to-assimilate form. The vessel should also have diagrams showing the catenaries and touch-down points for various mooring-line tensions and the position of the vessel and thrusters in relation to the catenary.

It is essential that anchor positions are confirmed by the moored vessel and that the position of mooring lines is verified by two independent means, one of which may be by calculation the other which is usually by ROV. These positions should be rechecked if a vessel returns to the location. The position of mooring lines still needs to be checked even if the risk assessment has indicated that they can be lowered to the seabed.

If an analysis of environmental forces indicates that the vessel could drift towards mooring catenary in the event of a DP failure the diving supervisor should be notified so that they can consider and plan for diver recovery.

The moored vessel should not adjust mooring line tension or position during the diving operation and should inform the diving vessel of any environmental or draught changes which may affect the mooring catenary. The permit to work systems of the moored vessel and diving support vessel should be co-ordinated to ensure that neither vessel undertakes an activity which could threaten the other vessel and any activities it is undertaking.

Communications should be maintained between the DPO and the moored vessel control room. Diving operations should be stopped immediately if communications are lost.

A horizontal clearance of at least 50m should normally be maintained between a suspended mooring line and the diver's deployment device except for 'drift on' situations where the minimum operating clearance should be determined using a risk assessment. A drift trial should be conducted where considered necessary.

If close approach to the mooring line is essential to execute work then:

- ◆ The mooring line position 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 be deployed simultaneously.

The risk of reference taut wires coming into contact with the mooring lines should be minimised and at least one surface position reference should be used where practicable.

AI-3.8 Surface Orientated Diving

The effect of thrusters on the divers should be minimised. The effects of thruster wash or suction should be considered and precautions taken to ensure that divers are safe, particularly when they or their deployment device pass through a potential wash zone. The use of thrust diagrams when planning dives should be considered.

The reduction in the vessel's operational capability if it is necessary to inhibit or de-select thrusters should be analysed.

The lengths and the manner of deployment of divers' umbilicals should be chosen to enable physical monitoring of divers and their umbilicals and to prevent them from coming into contact with thrusters.

AI-3.9 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 divers are not put at risk and that down-lines for the diving operations and position references are not interfered with. For further information on ROV intervention during diving operations consult [IMCA D 010 – Diving operations from vessels operating in dynamically positioned mode](#) – and [IMCA D 054/R 020 – Remotely operated vehicle intervention during diving operations](#).

AI-3.10 Responsibilities

The vessel master is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid the start or order the termination of diving and DP operations, including conditions where operational limits defined in ASOGs have not been exceeded, however the master cannot order the start of diving operations. Where practicable they are responsible for ensuring the compatibility of the vessel's safety management system with that of the installation where it is working – see [IMCA M 125 – Safety interface document for a DP vessel working near an offshore platform](#).

The diving supervisor is responsible for diving safety, including the condition and operation of diving equipment, and is the only person who is able to order the start of diving operations. The diving supervisor is responsible to the diving superintendent for the effective and timely conduct of diving operations and responsible for keeping the DPO advised of any change of status of the diving operation. The diving supervisor should respond to changes in DP alert status immediately as required by the ASOG.

The DPO is responsible for ensuring that the DP system is configured as specified in the CAM/TAM and for monitoring the vessel position. The DPO is responsible for changing the DP alert status with reference to the ASOG without delay should this become necessary and for carrying out the associated actions.

The diving superintendent should act as a project manager to co-ordinate the work of both shifts of divers and liaise with the vessel's master and client's representative. The diving supervisors report to the superintendent while retaining responsibility for the commencement, operation and termination of the dive which they are supervising.

The client's representative is responsible to the client for the proper performance of all work in accordance with the contract and should have the authority to forbid the start of, or require the termination of diving or DP operations.

Pipelay Vessels

A2-1 Industrial Mission

A2-1.1 Description and Role

The primary operational role of the vessel is seabed pipeline installation, this may utilise a variety of lay techniques for the installation of rigid or flexible pipes.

Depending on the lay system installed on the vessel, pipe may be loaded in port and then carried to the installation site or loaded offshore from barges or supply vessels. Spooled pipe will generally be loaded at a dedicated spool base.

When operating in close proximity to supply vessels or barges which are supplying pipes both vessels may operate on DP or the vessels may be moored together.

The pipelay vessel should be capable of maintaining position whilst maintaining the correct pipe tension.

Pipelay vessels are frequently fitted with a crane to support subsea activities and with ROVs to facilitate subsea intervention, survey and inspection.

The consequences of loss of vessel position may include damage to the product, pipelay equipment and injury to personnel. When operating in close proximity to support vessels or fixed/floating structures then consequences may also include significant damage to the vessel and adjacent structure.

A2-2 Design Guidance

A2-2.1 Design Considerations

DP pipelay vessels should comply with IMO equipment class 2 or 3.

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

The vessel should be capable of ensuring pipeline integrity during pipelay operations by maintaining pipe tension and catenary and should be able to provide a stable platform for the industrial mission.

The horizontal component of pipe tension directly affects the position control system.

A2-2.2 DP Capability

The vessel should be capable of following a pre-determined pipelay corridor facilitating the pipeline installation with continuous or incremental vessel moves at a smooth and predictable rate whilst maintaining the required pipe tension.

Where the consequences of an inability to maintain position and/or pipe tension are deemed to be critical, then the pipelay vessel should be capable of maintaining both position and pipe tension for sufficient time to safely suspend or abandon operations after the worst case failure in all anticipated operational and environmental conditions.

A sufficient reserve power is to be maintained when operating in open water to ensure that position and pipe tension can be maintained after worst case failure.

The thruster force required to counter any horizontal component of pipe tension acting upon the vessel is additional to the thruster force required to maintain position based solely on prevailing environmental conditions.

If large cargo barges are to be moored alongside for transfer of pipes the extra shape exposed to the environment plus weight of the barge will have a direct impact on the DP system and this possibility will need to be accounted for in the DP capability of the pipelay vessel.

The restrictions on vessel heading imposed by rigid pipelay operations may dictate operational limits. Flexible pipelay operations in open water are generally less heading dependent and a vessel heading may be chosen to minimise thruster load.

The DP system should be capable of rapidly adapting to changing external forces.

Position keeping capability plots should be developed for a variety of environmental and thruster failure conditions which include an allowance for the highest pipe tension for which the vessel is designed.

A2-2.3 Control Systems

The DP control system should enable initiation, lay down and recovery of pipeline lengths. A vessel/pipeline combined model should be used when it significantly differs from the basic vessel model. Station keeping performance should be stable in equilibrium conditions, and also in dynamic conditions brought about by tensioners and winches operating normally and following anticipated single failures.

DP control consequence analysis should take account of the requirement to maintain pipe tension for each analysed failure.

A2-2.4 Reference Systems and Sensors

At least three independent position reference systems and three heading reference systems should be in use for critical pipelay operations.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

In shallow water, or when working in close proximity to offshore installations, at least two different measurement principles should be employed for the reference systems.

In deep water and open water locations there may be a reliance on satellite based position references, satellite based systems should be sourced from different manufacturers to avoid software induced common cause failures. Independence should be provided by the separation of power supplies. Different methods for differential corrections should be employed. No single failure should result in the loss of more than one position reference system. Consideration should be given to using position reference systems in combination with inertial navigation systems to filter short term instability.

When engaged in cargo operations with another vessel operating on DP, relative position reference systems should only be used by one vessel where the other is the fixed reference.

A pipe tension sensor may be interfaced to the DP control system; in such cases it is essential that the tension input is accurate, has redundancy and is reliable. This also applies to any winch used to assist particular operations such as pipeline pull in. Where redundancy or fail safe cannot be demonstrated then manual input of pipe tension may be permissible.

A2-2.5 Power Systems

Provision of power for propulsion and pipelay systems may be independent, or a diesel–electric power plant may provide power for all vessel systems.

The power management philosophy should consider the criticality of pipelay, crane and ROV systems, as applicable, as well as dynamic positioning systems. The power management system should ensure that control is maintained of all operationally and safety critical systems at all anticipated electrical loads and after worst case failure in power provision.

The preferential load shedding philosophy should consider whether or not it is appropriate to favour vessel positioning systems over pipelay, crane or ROV systems when in open water.

To facilitate a controlled termination of pipelay operations in the event of a failure in vessel power, redundancy in power supply should be provided to pipelay tensioners, abandonment winches, spooling equipment and associated systems. Alternatively, the systems should fail safe in the event of loss of power supply in order to ensure no sudden loss in pipe tension.

A2-3 Operational Guidance

A2-3.1 Operational Considerations

The following should be considered when planning DP pipelay operations:

- ◆ Depending on the pipelaying mode utilised there may be a long time to terminate operations. Flexible pipes and umbilicals cannot be terminated midway through the lay operation without significant damage occurring to the product through cutting, however rigid pipes can be terminated at any point with the product end being capped and lowered to the seabed;
- ◆ If pipe tension and catenary are not maintained then damage to the product, pipelay equipment and injury to personnel may occur;
- ◆ Rapid changes in pipe tension may cause instability in position if not accurately modelled in the DP system;
- ◆ Significant propulsion power may be required to maintain a horizontal component of pipe tension; this may reduce the position keeping capability in response to environmental forces;
- ◆ Availability and diversity of position references may be limited in open water and deep water;
- ◆ The pipelay activity may restrict choice of heading;
- ◆ Initiation and completion activities may be subject to more strict environmental and vessel motion limits than those for lay activities;
- ◆ The master and each DPO should be aware of the required tensions used for pipelay operations and the appropriate emergency responses;
- ◆ The pipelay supervisor should have instruction in the basic operation of the dynamic positioning system and the capabilities of the vessel in order to understand the potential vessel responses to requests for changes in position.

A2-3.2 Operational Planning

Where appropriate the following should be documented:

- ◆ Risk assessment for the loss of vessel position at all stages of the pipelay operation and for all associated activities;
- ◆ Configuration of DP systems for the critical activity mode of operation (CAM) or for the task appropriate mode (TAM) with specification as to which modes are required for each phase of the project;
- ◆ Activity specific operating guidelines (ASOG) to define operational, environmental and equipment performance limits applicable during the operation and provide guidance on actions in the event of these limits being exceeded.

A2-3.3 Communications

A dedicated system for communication between all relevant operational and control locations of the vessel should be provided, including:

- ◆ DP control;
- ◆ pipelay supervisor;
- ◆ pipelay control/reel operator;
- ◆ engine control;
- ◆ ROV control;
- ◆ trencher control;
- ◆ crane cabin;
- ◆ deck foreman.

There should be a backup to these systems that is operable in a black out condition, both primary and backup communications should be checked as part of the DP checklists.

A communications matrix and example flowchart is provided in [IMCA M 205 – Guidance on operational communications](#). This should be developed to ensure that all necessary information is shared appropriately; in particular between the DPO and the pipelay supervisor.

The pipelay supervisor's console should be located adjacent to the DP control console, if this is not possible then a 'normally open' communication link between the two control consoles should be provided.

A2-3.4 DP Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in tabular format in the ASOG.

Guidance on status and responses is given below.

Normal status – GREEN light. Full DP pipelay operations can be undertaken.

- ◆ The DP system is operating as intended;
- ◆ Operational, environmental and equipment performance criteria as defined within the ASOG are all categorised as normal;
- ◆ The vessel can maintain position in the prevailing environmental conditions after the worst case failure.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;
- ◆ The DP system is no longer configured as required in the CAM/TAM;
- ◆ An advisory condition exists as defined in the ASOG;
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. Personnel should suspend operations and prepare for a controlled abandonment of the product.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ The vessel's position keeping performance is deteriorating or unstable;

- ◆ The vessel would be unable to maintain position in the prevailing environmental conditions after the worst case failure;
- ◆ A 'yellow' condition exists as defined in the ASOG for abnormal operational, environmental and equipment performance conditions;
- ◆ Any other condition exists which may lead to a suspension of pipelay activities.

Emergency status – RED light with accompanying distinctive alarm. Procedures for emergency abandonment of the pipelay activity should be initiated.

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control, or to safely conduct pipelay operations;
- ◆ A 'red' condition exists as defined in the ASOG for hazardous operational, environmental and equipment performance criteria;
- ◆ Any other emergency situation which warrants immediate preparation for abandonment of the pipelay activity.

A2-3.5 Responsibilities

The vessel master is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid the start or order the termination of pipelay operations, including conditions where operational limits defined in ASOGs have not been exceeded. Where practicable they are responsible for ensuring the compatibility of the vessel's safety management system with that of the installation where it is working – see [IMCA M 125 – Safety interface document for a DP vessel working near an offshore platform](#).

The offshore construction manager is responsible for the safe execution of the work to the agreed procedures. They have the authority to order the commencement and termination of work but must respect the master's authority as outlined above.

The pipelay supervisor is responsible to the offshore construction manager for the safe execution of pipelay operations and co-ordinating the required assets and personnel. They are responsible for keeping the DPO advised of any change of status of the pipelay operation, communicating required vessel movements to the DPO and all necessary information required by the DPO to determine the required DP configuration. They should respond to changes in DP alert status immediately as required by the ASOG.

The DPO is responsible for ensuring that the DP system is configured as specified in the CAM/TAM and for monitoring vessel position. The DPO is responsible for changing the DP alert status with reference to the ASOG without delay should this become necessary and for carrying out the associated actions. They are to conduct vessel movements requested by the pipelay supervisor, however have the authority to suspend pipelay operations and stop the vessel if they consider this to be necessary for the safety of the vessel, environment or personnel.

ROV Support Vessels

A3-1 Industrial Mission

A3-1.1 Description and Role

The primary operational role of the vessel is the support of remotely operated vehicles (ROV) operations. These include a variety of vehicles from small 'eyeball' types through to complex vehicles for subsea intervention.

ROV support vessels provide a platform for the launch and recovery of ROVs and provide electrical power and maintenance facilities for the vehicles. ROV support vessels may be purpose built, or ROV operating facilities and systems may be mobilised on a temporary basis to a DP vessel with suitable deck space and capability.

Where multi-functional vessels operate ROVs to support an industrial mission then their DP capability will usually be determined by the needs of the primary industrial mission.

The working environment may include strong currents and large wave and wind forces. Operating limits may be determined by the vessel's ability to maintain position, or by vessel motion caused by the sea state since ROV launch and recovery systems have limitations for heave amplitude and rate.

When operating in DP the consequences of an inability to maintain position may include injury to personnel and damage to vessel/assets.

A3-2 Design Guidance

A3-2.1 Design Considerations

DP ROV support vessels can be IMO equipment class 1, 2 or 3. When required to work in close proximity to offshore installations they should be IMO DP equipment class 2 or 3. In open water the level of redundancy provided in the DP system is an operational consideration in order to protect the ROV and subsea assets from damage.

The vessel should provide a stable platform for ROV launch and recovery with suitable position keeping capability for the anticipated environmental conditions.

Consideration should be given to providing redundant power supplies to industrial mission specific equipment; vehicles and launch and recovery equipment.

A3-2.2 DP Capability

The ROV support vessel should be capable of maintaining a static position in relation to the seabed, or to follow a predetermined track.

Relative location DP operations may require rapid changes in vessel speed and direction; vessels with high thruster power and low inertial mass are more responsive to such changes. The DP system should be capable of starting and stopping the vessel smoothly and rapidly.

The vessel should be capable of safely suspending or abandoning operations after a worst case failure to restrict the inability to maintain position in the prevailing environmental conditions.

Position keeping capability plots should be developed for intact and worst case failure conditions.

A3-2.3 Control Systems

The DP control system should enable the vessel to maintain a position offset in relation to the ROV. Fixed location and relative location DP control modes are required.

For DP equipment class 1 vessels it is recommended that an independent joystick be provided, this is a requirement for DP equipment class 2 and 3.

A3-2.4 Reference Systems and Sensors

At least three independent position reference systems should be in use for critical activities where fault-tolerant operation is required.

When working in close proximity to surface structures at least two different measurement principles should be employed for reference systems, one of which should be a relative position reference system.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

A3-2.5 Power Systems

The provision of power to temporarily mobilised ROV systems may be independent of the vessel's power plant. Permanently installed ROV systems may be provided with power by a vessel common diesel-electric power plant.

Since ROV power demands may be low in comparison with the power demands of the propulsion system the power management for dynamic positioning may not be affected by ROV consumers. Redundant power supplies to ROV systems are advantageous to reduce the risk of preferential load shedding isolating power supplies to ROV systems.

Given that it may take a significant time to regain control of an ROV following loss of power to control and propulsion systems it is recommended that a secure power supply is provided. As a minimum, UPSs should be provided for control systems.

A3-3 Operational Guidance

A3-3.1 Operational Considerations

The following should be considered when planning DP ROV operations:

- ◆ ROV operations usually have a short time to terminate; providing there are no adjacent structures then loss of DP control may not have serious consequences for the vessel. Recovery of the ROV to surface may be protracted but should not be prevented by an inability to maintain position;
- ◆ In low risk operating conditions the DP system need not be configured to be fault-tolerant (TAM);
- ◆ Availability and diversity of position reference systems may be limited in open water and in relative location DP operations;
- ◆ Acoustic position reference systems are frequently used for tracking mobile ROV beacons, potential interference with DP position references should be minimised when using such systems. ROV beacons should be operated in responder mode where practicable;
- ◆ There may be a reliance on satellite based position references when in deep and/or open water where the risks associated with an inability to maintain position are low, this should be documented in the CAM/TAM;
- ◆ Use of the ROV beacon as a 'fixed' position reference to facilitate a constant offset between vessel and ROV should be avoided as this configuration necessitates the use of a single DP

reference and may result in high propulsion power demand if the speed or direction of travel of the ROV changes rapidly;

- ◆ Use of the ROV beacon as a 'fixed' position reference may be permissible when other references have failed and when the ROV has been instructed to fix its position through attachment to a seabed structure, or by setting down on the seabed;
- ◆ ROV launch and recovery operations may be subject to tighter environmental and vessel motion limits than during the ROV dive;
- ◆ It is generally acceptable for the vessel to adopt a heading which minimises vessel motion and/or thruster loads unless proximity to surface structures or the needs of ROV launch/recovery operations dictate otherwise.

A3-3.2 Operational Planning

Where appropriate the following should be documented:

- ◆ risk assessment for potential loss of vessel position;
- ◆ configuration of DP systems for the critical activity mode (CAM) or for the task appropriate mode (TAM) with guidance on selecting the appropriate mode;
- ◆ activity specific operating guidelines (ASOG) to define operational, environmental and equipment performance limits applicable when operating ROVs and provide guidance on actions in the event of these limits being exceeded.

A3-3.3 Communications

A dedicated system for communication between all relevant operational and control locations of the vessel should be provided, including:

- ◆ DP control;
- ◆ engine control;
- ◆ ROV control;
- ◆ deck launch/recovery control.

Provision of a 'normally open' communication link between DP control and ROV control is recommended.

There should be a backup to these systems that is operable in a black out condition, both primary and backup communications should be checked as part of the DP checklists.

A3-3.4 DP Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in tabular format in the ASOG.

Guidance on status and responses is given below.

Normal status – GREEN light. Full working can be undertaken.

- ◆ The DP system is operating as intended;
- ◆ Operational, environmental and equipment performance criteria as defined within the ASOG are all categorised as normal.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;
- ◆ The DP system is no longer configured as required in the CAM/TAM;

- ◆ An advisory condition exists as defined in the ASOG;
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. ROV operations should be suspended.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ A situation has developed or incident occurred that risks the vessel losing position;
- ◆ A 'yellow' condition exists as defined in the ASOG for abnormal operational, environmental and equipment performance conditions;
- ◆ Any other condition exists which may lead to a suspension of ROV activities.

Emergency status – RED light with accompanying distinctive alarm. Emergency recovery of the ROV to deck.

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control;
- ◆ A 'red' condition exists as defined in the ASOG for hazardous operational, environmental and equipment performance criteria;
- ◆ Any other emergency situation which requires immediate recovery of the ROV.

A3-3.5 Responsibilities

The vessel master is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid the start or order the termination of ROV operations, including in conditions where operational limits defined in ASOGs have not been exceeded. Where practicable they are responsible for ensuring the compatibility of the vessel's safety management system with that of the installation where it is working – see [IMCA M 125 – Safety interface document for a DP vessel working near an offshore platform](#).

The DPO is responsible for ensuring that the DP system is configured as specified in the CAM/TAM and for monitoring vessel position. The DPO is responsible for changing the DP alert status with reference to the ASOG without delay should this become necessary and for carrying out the associated actions. They have the authority to suspend ROV operations if they consider this to be necessary for the safety of the vessel, environment or personnel.

The ROV supervisor is responsible for the safe conduct of the ROV operation. They need to stay in close contact with the DP operator and should request permission before launching the ROV.

Crane Vessels

A4-1 Industrial Mission

A4-1.1 Description and Role

The primary operational role of the vessel is lifting offshore structures, including installation and subsequent decommissioning of offshore structures and modules.

DP crane vessels may be monohull or semi-submersible vessels provided with large capacity cranes or derricks.

Crane vessels may either transport the items intended for lifting or transfer the lift offshore between a transport vessel/barge and the installation location.

Large capacity crane vessels predominantly operate with the lifting hook above sea level or in shallow immersion due to the limited length of lifting wires and the effects of sea water on blocks and wires. Large mass structures for submerged seabed installation are generally installed by means of buoyancy lift.

Heavy lift crane operations are sensitive to wind speed and sea state.

Crane vessels may be either pure crane vessels or multi-purpose vessels, alternative functions may be operable in environmental conditions which would preclude lifting operations.

A motion compensated gangway may be provided to facilitate personnel transfer between the crane vessel and the installation/decommissioning site.

The ballast arrangements of crane vessels are to be capable of ensuring adequate stability and controlling trim and heel at all times during lifting.

Lifting operations are conducted in close proximity to other vessels or offshore structures and tugs and barges may be required to manoeuvre under the crane hook. Crane vessels regularly operate in close proximity to offshore structures when lifting.

The consequences of loss of vessel position may include injury to personnel, damage to the suspended load and to the adjacent offshore installation or support vessels, damage to the crane vessel and environmental pollution.

A4-2 Design Guidance

A4-2.1 Design Considerations

DP crane vessels should comply with IMO equipment class 2 or 3.

No known single failure should result in an uncontrolled contact occurring between the crane vessel, its lift, and the adjacent offshore structure or support vessel.

Systems and compartments critical to the industrial mission should be protected or provided with redundancy to ensure that any loss of DP capability occurring as a result of localised contact damage will not exceed the worst case failure.

Ballasting operations should not adversely affect DP station keeping, the potential effects of high ballast water flow rates during de-ballasting on vessel position keeping should be considered.

The ballast systems should be designed with the same redundancy philosophy as the DP system; and be subject to FMEA.

A4-2.2 DP Capability

The crane vessel should be capable of maintaining positioning during the load transfer to/from the crane, when in close proximity to another vessel or the installation location.

The vessel should have the capability to maintain position after worst case failure in all anticipated operational and environmental conditions within the time frame necessary to safely suspend or complete operations.

Positioning in shallow water may be achieved using a mooring system with thruster assistance, this is not considered to be dynamic positioning in the context of this guidance.

Position keeping capability plots should be developed for intact and worst case failure conditions, and should consider conditions where lifts are in progress. Where possible a specific plot for the planned lifting operation should be available.

A4-2.3 Control Systems

The DP control system primary mode is position keeping, other modes may be required if the vessel has an alternative mission activity.

The DP control modes consider external forces and transient conditions during heavy lift crane operations which have the potential to cause instability in position keeping:

- ◆ During load transfer the vessel will experience rapid changes in the DP control system environmental models caused by changes in draught, inertia and the wind profile of the combined vessel and lift. Alternative wind profiles and hydrodynamic models based on actual lift geometry and vessel draught should be incorporated within the control system;
- ◆ Vessel wind profile may change significantly when changing the crane jib position whether or not there is a suspended load therefore it is recommended that there is a dynamic wind profile model in the DP system based on crane position;
- ◆ During lifting there may be significant horizontal forces acting to displace the vessel position if the crane lifting wire is not vertical. Specialist DP control modes during such phases allowing the crane wire 'mooring' forces to dictate vessel position setpoint rather than the DP control system should be considered;
- ◆ Lifting induced pendulum motions may impose dynamic forces on the vessel; resonant conditions for such forces need to be avoided. Damping mechanisms may be provided in either the crane control system or the DP control system to ensure that pendulum motions decay following initiation and prevent resonance.

The DP system should be configured for automatic and rapid adaptation in response to the external forces and transient conditions described above. This may be based on rapid updating of the vessel or environmental computer model, or by calculated modification of controller gain settings. Alternatively the DP system manufacturer may provide instruction to operators as to the user input required to mitigate instability. Manual control during such transient conditions should be avoided.

It is recommended that the DP system should define a specific point of minimum motion, representing the priority for position keeping. This may be the crane hook position, or the vessel hull position at its closest approach to the adjacent vessel/structure.

Failure of control systems fitted to other vessel systems such as the ballast system should not affect the integrity of the DP control system.

A4-2.4 Reference Systems and Sensors

At least three independent position reference systems using a minimum of two measurement principles should be in use during lifting operations or when in close proximity to another vessel or structure.

At least three independent heading sensors for the DP system should be provided.

When working in close proximity to fixed structures then at least one relative position reference system should be used. If the adjacent structure is floating and a relative separation needs to be maintained then at least two of the position references used should be relative systems.

Reference systems should be selected so as to minimise possible degradation during load transfer, changes in draught and changes in position of the suspended load.

Power for position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

When the vessel is manoeuvring clear of other vessels or structures then a minimum of two position reference systems should be in use with a third immediately available.

At least three independent wind sensors should be provided, positioned to allow for local disruption of wind flow caused by crane and lift position, information should be corrected to a common height at the DP control station.

A4-2.5 Power Systems

Provision of power for propulsion may be independent from other significant consumers such as cranes. Where a common diesel–electric power configuration is adopted then DP systems need to be protected from faults in mission equipment and the power plant needs to be capable of responding to high transient loads.

Lifting equipment may have a high power demand in relation to propulsion power demand.

The power management philosophy should consider the criticality of lifting and ballasting systems as well as DP systems. Control is to be maintained of all operationally and safety critical systems at all anticipated loads and after the worst case failure in electrical power provision.

Regenerative breaking of thrusters or lifting equipment should not result in adverse effects to running generators following the highest regenerative load absorption.

A4-3 Operational Guidance

A4-3.1 Operational Considerations

The following should be considered when planning DP operations:

- ◆ Lifting operations prior to connection of rigging may be characterised by a short to medium time to terminate. Once rigging has been connected or lifting commenced there may be no possibility to safely terminate the lift before actual completion of the operation. This should be identified during operational planning and the duration of such activities minimised;
- ◆ Position instability may occur during periods of rapid load transfer;
- ◆ Lifting operations are subject to wind and wave limits. Wind forces may be high due to the size and shape of the vessel structure and lift, and may vary significantly depending on the position of the cranes;
- ◆ The risk that radar or laser range-finding position reference instruments may have the line of sight with their target obstructed by the lift should be analysed and mitigated;
- ◆ The risk that the signal from satellite derived position reference systems may be affected by the movement of the crane jib and or load should be analysed and mitigated;

- ◆ A vessel emergency escape route should always be planned.

A4-3.2 Operational Planning

Where appropriate the following should be documented:

- ◆ Risk assessment for the loss of vessel position at all stages of the operation and for all associated activities;
- ◆ Configuration of DP systems for the critical activity mode (CAM) or for the task appropriate mode (TAM) with specification as to which modes are required for each phase of the operation;
- ◆ Activity specific operating guidelines (ASOG) to define actions in the event of loss of DP critical systems, environmental and equipment performance limits. They should also provide guidance on required actions in the event of these limits being exceeded and how to determine whether it is safer to suspend or to complete the lifting operation in the event of specific failures.

A4-3.3 Communications

Reference should be made to [IMCA M 205 – Guidance on operational communications: Part C – Communications in lifting operations](#).

A dedicated system between all relevant operational and control locations of the vessel should be provided, including:

- ◆ DP control;
- ◆ engine control;
- ◆ ballast control;
- ◆ crane cabin;
- ◆ deck (lifting) superintendent;
- ◆ gangway control.

There should be a backup to these systems that is operable in a black out condition, both primary and backup communications should be checked as part of the DP checklists.

A4-3.4 DP Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in tabular format in the ASOG.

If working in close proximity to a manned structure then the audible alarm associated with an emergency status should be repeated on the structure to provide immediate warning of potential collision.

Guidance on status and responses is given below.

Normal status – GREEN light. Full DP lifting operations can be undertaken.

- ◆ The DP system is operating as intended;
- ◆ Operational, environmental and equipment performance criteria as defined within the ASOG are all categorised as normal;
- ◆ The vessel would be capable of maintaining position in the prevailing environmental conditions after the worst case failure.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;

- ◆ The DP system is no longer configured as required in the CAM/TAM;
- ◆ An advisory condition exists as defined in the ASOG;
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. Some condition exists which requires a suspension of the lifting operation. Gangway should be closed to traffic and support vessels/barges should move clear if possible.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ The vessel's position keeping performance is deteriorating or unstable;
- ◆ Weather conditions are (or are forecast) approaching the limits for the intended operation;
- ◆ A 'yellow' condition exists as defined in the ASOG for abnormal operational, environmental and equipment performance conditions;
- ◆ Any other condition exists which may lead to a suspension of the lift.

Emergency status – RED light with accompanying distinctive alarm. Procedures for emergency disconnection of the gangway and crane hook should be initiated. Vessel should move clear of the adjacent structure if possible.

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control or to safely conduct lifting operations;
- ◆ Weather conditions have exceeded the limits for the intended operation;
- ◆ A 'red' condition exists as defined in the ASOG for hazardous operational, environmental and equipment performance criteria;
- ◆ Any other emergency situation that warrants the most rapid suspension of lifting activities that is possible for the activity being undertaken.

A4-3.5 Responsibilities

In some cases lifting may only be safely terminated or suspended by completing the lift (see A4-3.1); in such cases agreed contingency plans and defined responsibilities for decision making once the lift commences are to be agreed by the vessel master and the offshore construction superintendent.

The vessel master is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid the start or order the suspension of lifting operations, including in conditions where operational limits defined in ASOGs have not been exceeded. Where practicable they are responsible for ensuring the compatibility of the vessel's safety management system with that of the installation where it is working – see *IMCA M 125 – Safety interface document for a DP vessel working near an offshore platform*.

The offshore construction superintendent is in overall charge of the lifting operation and is responsible for the safety and integrity of the lift and of personnel working on the lifting operation. They have the authority to order the start and termination of the lifting operation.

The DPO is responsible for ensuring that DP system is configured as specified in the CAM/TAM and for monitoring vessel position and that the vessel operates within limits defined in the ASOG. The DPO is responsible for changing the DP alert status with reference to the ASOG without delay should this become necessary and for carrying out the associated actions. They have the authority to suspend lifting operations if they consider this to be necessary for the safety of the vessel, environment or personnel.

The client's representative is responsible to the client for the proper performance of all work in accordance with the contract. This representative should have the authority to veto the start of operations and should have the authority to require the termination of lifting operations in a controlled manner.

Float-over Vessels

A5-1 Industrial Mission

A5-1.1 Description and Role

The primary role of the vessel is the load transfer of the topside structure from/to the vessel by means of ballasting or tidal assistance. This necessitates loadout/landing of the structure in a suitable port, and transit to/from the installation/removal location.

Float-over operations may be conducted by suitable heavy lift vessels.

Float-over operations are conducted onto or from host support structures such as fixed jackets and concrete bases.

DP float-over vessels may be monohull vessels which enter the inside of the host support structure, or multi-hull vessels which straddle the host structure.

Float-over operations are sensitive to wind speed and sea state. Relative vertical movement during the mating phase between the float-over vessel and host support structure should remain within defined, allowable limits. Whilst float-over operations may be conducted in any region they are most frequently employed in areas where benign environmental conditions can be expected.

The ballast arrangements of float-over vessels are to be capable of ensuring adequate stability and controlling trim and heel at all times during load transfer. The ballast capacity and pumping rate should be sufficient to minimise risk exposure during critical load transfer phases. Ballast compensation for the effects of flooding of a single compartment is desirable but may be difficult to achieve.

Specialist systems which may be fitted to facilitate load transfer include:

- ◆ Leg mating units (LMUs) or shock absorbers fitted at the interface between the topside structure and the host structure or vessel to dampen vertical and horizontal motions and assist with even load distribution;
- ◆ Rapid load transfer systems such as hydraulic jacks – these may operate in conjunction with the ballast system to facilitate rapid transfer of the topside structure to/from the host structure and establishment of a safe clearance between the structure and the vessel.

Fendering systems may be used to allow contact to be tolerated without compromising structural integrity where the vessel operates in close proximity to structures or other vessels.

A motion compensated gangway may be provided to facilitate personnel transfer between the float-over vessel and the installation/decommissioning site.

Float-over operations are conducted in close proximity to offshore structures and may be assisted by tugs and other vessels. High accuracy position keeping is required.

The consequences of loss of vessel position may include injury to personnel, damage to the vessel and its load and to the adjacent offshore installation or support vessels and environmental pollution.

A5-2 Design Guidance

A5-2.1 Design Considerations

Float-over vessels should comply with IMO equipment class 2 or 3.

No known single failure should result in:

- ◆ uncontrolled contact occurring between the float-over vessel and the host structure;
- ◆ unexpected change in draught, list or trim affecting stability or load transfer.

The potential consequences of contact occurring with the host structure should be risk assessed and appropriate risk mitigation measures identified. Systems and compartments should be protected to prevent the consequences of any localised contact damage exceeding those of the identified worst case failure.

If it is not possible to compensate for one compartment damaged at mating/de-mating draught, alternative arrangements should be made to reduce risk.

Ballasting operations should not adversely affect DP station keeping, the potential effects of high ballast water flow rates during de-ballasting on vessel position keeping should be considered.

The ballast systems should be designed with the same redundancy philosophy as the DP system and be subject to FMEA.

A5-2.2 DP Capability

The float-over vessel should be capable of maintaining positioning during the load transfer to/from the host structure and when in close proximity to other vessels or installations.

The vessel should have the capability to maintain position after worst case failure in all anticipated operational and environmental conditions within the time frame necessary to safely suspend or complete operations.

Positioning in shallow water may be achieved using a mooring system with thruster assistance; this is not considered to be dynamic positioning in the context of this guidance.

Position keeping capability plots should be developed for intact and worst case failure conditions, and should consider the windage of the load and conditions where float-over is in progress. Where possible a specific plot for the planned float-over operation should be available.

A5-2.3 Control Systems

The DP control system primary mode is position keeping, other modes may be required if the vessel has an alternative mission activity.

The DP control modes consider external forces and transient conditions (for example, those caused by mating cones and receptacles or load transfer damping systems) during float-over operations which have the potential to cause instability in position keeping.

The DP system should be configured for automatic and rapid adaptation in response to the external forces and transient conditions described above. This may be based on rapid updating of the vessel or environmental computer model, or by calculated modification of controller gain settings. Alternatively the DP system manufacturer may provide instruction to operators as to the user input required to mitigate instability. Manual control during such transient conditions should be avoided.

Failure of control systems fitted to other vessel systems such as the ballast system should not affect the integrity of the DP control system.

A5-2.4 Reference Systems and Sensors

When position keeping relative to a fixed or floating host structure then at least two of the position references in use should be relative systems.

At least three independent position reference systems using a minimum of two measurement principles should be in use during float-over operations or when in close proximity to another vessel or structure.

At least three independent heading sensors for the DP system should be provided.

Reference systems should be selected so as to minimise possible degradation during load transfer, changes in draught and changes in position of the load.

Power for position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

When the vessel is manoeuvring clear of other vessels or structures then a minimum of two position reference systems should be in use with a third immediately available.

At least three independent wind sensors should be provided, positioned to allow for local disruption of wind flow caused by the load, information should be corrected to a common height at the DP control station.

A5-2.5 Power Systems

Provision of power for propulsion may be independent from other significant consumers. Where a common diesel–electric configuration is adopted then DP systems need to be protected from faults in mission equipment and the power plant needs to be capable of responding to high transient loads.

The power management philosophy should consider the criticality of ballasting systems and equipment essential for load transfer as well as dynamic positioning systems to ensure that control is maintained of all operationally and safety critical systems at all anticipated loads and after the worst case failure in electrical power provision.

A5-3 Operational Guidance

A5-3.1 Operational Considerations

The following should be considered when planning DP operations:

- ◆ Float-over operations prior to mating and commencement of load transfer may be characterised by a short time to terminate. Once load transfer has commenced there may be no possibility to safely terminate the float-over before actual completion of the operation. This should be identified during operational planning and the duration of such activities minimised;
- ◆ Position instability may occur during periods of rapid load transfer;
- ◆ Due to the critical nature of vertical motion, consideration should be given to the detection of possible movements of fresh water (freshets) that could cause draught to change;
- ◆ The minimum float-over clearance will be determined based on vessel draught, environmental conditions and maximum motion amplitudes at the mating points;
- ◆ Where fenders are fitted to distribute contact load the effects of moderate horizontal forces experienced through such contact loads should be anticipated;
- ◆ Lifting operations are subject to wind and wave limits. Wind forces may be high due to the size and shape of the load, and may vary significantly depending on the position of vessel equipment such as cranes;
- ◆ The risk that radar or laser range-finding position reference instruments may have the line of sight with their target obstructed by the lift should be analysed and mitigated;
- ◆ A vessel emergency escape route should always be planned.

A5-3.2 Operational Planning

Where appropriate the following should be documented:

- ◆ Risk assessment for the loss of vessel position at all stages of the operation and for all associated activities;
- ◆ A comprehensive installation/removal manual to identify all aspects of the operations in detail, to cover all likely contingencies and specify exactly how the float-over will be conducted;
- ◆ Configuration of DP systems for the critical activity mode of operation (CAM) or for the task appropriate mode (TAM) with specification as to which modes are required for each phase of the operation;
- ◆ Activity specific operating guidelines (ASOG) to define actions in the event of loss of DP critical systems, environmental and equipment performance limits. They should also provide guidance on required actions in the event of these limits being exceeded and how to determine whether it is safer to suspend or to complete the float-over operation in the event of specific failures.

A5-3.3 Communications

A dedicated system for communication between all relevant operating and control locations of the vessel should be provided, including:

- ◆ DP control;
- ◆ engine control;
- ◆ ballast control;
- ◆ offshore construction superintendent;
- ◆ gangway control.

There should be a backup to these systems that is operable in a black out condition, both primary and backup communications should be checked as part of the DP checklists.

A5-3.4 DP Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in tabular format in the ASOG.

Guidance on status and responses is given below.

Normal status – GREEN light. Planned operations can be undertaken.

- ◆ The DP system is operating as intended;
- ◆ Operational, environmental and equipment performance criteria as defined within the ASOG are all categorised as normal;
- ◆ The vessel would be capable of maintaining position in the prevailing environmental conditions after the worst case failure.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;
- ◆ The DP system is no longer configured as required in the CAM/TAM;
- ◆ An advisory condition exists as defined in the ASOG;
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. Some condition exists which requires a suspension of the operation. Gangway should be closed to traffic. Support vessels should move clear if possible.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ The vessel's position keeping performance is deteriorating or unstable;

- ◆ Weather conditions are (or are forecast) approaching the limits for the intended operation;
- ◆ A 'yellow' condition exists as defined in the ASOG for abnormal operational, environmental and equipment performance conditions;
- ◆ Any other condition exists which may lead to a suspension of the operation.

Emergency status – RED light with accompanying distinctive alarm. Procedures for emergency disconnection of the gangway should be initiated. Vessel should move clear of the host structure if possible.

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control or to safely conduct operations;
- ◆ Weather conditions or motion limits have exceeded the limits for the intended operation;
- ◆ A 'red' condition exists as defined in the ASOG for hazardous operational, environmental and equipment performance criteria;
- ◆ Any other emergency situation that warrants the most rapid termination that is possible for the activity being undertaken.

A5-3.5 Responsibilities

In some cases transfer of float-over may only be safely terminated or suspended by completing the operation (see A5-3.1); in such cases agreed contingency plans and defined responsibilities for decision making once the operation commences are to be agreed by the vessel master and the offshore construction superintendent.

The vessel master is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid the start or order the suspension of operations, including in conditions where operational limits defined in ASOGs have not been exceeded. They are responsible for ensuring the compatibility of the vessel's safety management system with that of the installation where it is working – see [IMCA M 125 – Safety interface document for a DP vessel working near an offshore platform](#).

The offshore construction superintendent is in overall charge of the operation and is responsible for the safety and integrity of the operation and of the personnel involved in the operation. They have the authority to order the start and termination of the operation.

The DPO is responsible for ensuring that the DP system is configured as specified in the CAM/TAM and for monitoring vessel position and that the vessel operates within limits defined in the ASOG. The DPO is responsible for changing the DP alert status with reference to the ASOG without delay should this become necessary and for carrying out the associated actions. They have the authority to suspend float-over operations if they consider this to be necessary for the safety of the vessel, environment or personnel.

The client's representative is responsible to the client for the proper performance of all work in accordance with the contract. This representative should have the authority to veto the start of operations and should have the authority to require the termination of float-over operations in a controlled manner by direct communication with the master or offshore construction superintendent.

Accommodation Vessels

A6-1 Industrial Mission

A6-1.1 Description and Role

The primary operational role of the vessel is to provide accommodation for a workforce engaged on an adjacent facility.

Accommodation vessels are required where sufficient accommodation is not available at the facility or where the facility lacks the necessary safety or evacuation equipment.

Accommodation vessels may be utilised where it is unsafe to provide accommodation on a facility due to the proximity of process hazards.

Accommodation vessels operate in close proximity to offshore facilities and other vessels.

Personnel transfer arrangements between the accommodation vessel and the facility may consist of gangways, boat landings and helicopter decks. For the purpose of this guidance it is assumed that personnel transfer is conducted by means of a gangway with the accommodation vessel being in close proximity to the facility it is supporting. The gangway may utilise active motion compensation.

Accommodation vessels may be fitted with a crane to transfer equipment and provisions from a support vessel. They may also be provided with workshops or equipment to facilitate maintenance and work tasks on the facility.

The accommodation vessel may provide temporary services to the adjacent facility such as power, water or firefighting services.

The consequences of loss of vessel position may include injury to personnel, damage to the vessel and to the adjacent offshore installation or support vessels and environmental pollution.

A6-2 Design Guidance

A6-2.1 Design Considerations

Accommodation vessels should comply with IMO DP equipment class 2 or 3.

No known single failure should result in an uncontrolled movement of the gangway which endangers personnel.

The DP system is to prevent contact with the facility, however the potential consequences of contact occurring with the host structure should be risk assessed and appropriate risk mitigation measures identified. Systems and compartments should be designed to prevent the consequences of localised contact damage exceeding those of the identified worst case failure.

The risk of fire in accommodation areas should be considered and control stations and equipment critical for DP operations should be protected from potential accommodation fires.

Ventilation systems for machinery spaces should ensure that machinery can remain in operation and prevent gas ingestion in the event of gas alarm actuation on an adjacent facility.

The gangway active systems should be designed with the same redundancy philosophy as the DP system and subject to FMEA.

A6-2.2 DP Capability

The accommodation vessel should be capable of maintaining position during personnel transfer and when in close proximity to the adjacent offshore facility. The allowable excursion from the vessel's position setpoint should not exceed the gangway warning limits.

Positioning may be achieved using a mooring system with thruster assistance; this is not considered to be dynamic positioning in the context of this guidance.

The vessel should have the capability to maintain position and heading after worst case failure in all anticipated operational and environmental conditions within the time frame necessary to safely suspend or complete personnel transfers.

Position keeping capability plots should be developed for intact and worst case failure conditions.

A6-2.3 Control Systems

The DP control system primary mode is high precision position keeping.

The DP system should be able to define the gangway as the point of minimum motion which represents the priority for position keeping and centre of rotation. Automatic alarms and lifting systems which facilitate rapid evacuation and protect the gangway if position is lost should be provided.

No changes to DP position, heading or centre of rotation are to be executed whilst personnel gangway lights are green or flashing amber (see A6-3.4).

A6-2.4 Reference Systems and Sensors

At least three independent position reference systems based on at least two different measurement principles should be used when transferring personnel or when in close proximity to a facility.

If a seabed reference system needs to be relocated then two position references may be temporarily allowed providing the vessel is stationary with no DP system instability and the gangway is closed to traffic until three references are back in use.

Reference systems should be selected so as to minimise possible interference from adjacent facilities.

Power for position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

When the vessel is manoeuvring clear of other vessels or structures then a minimum of two position reference systems should be in use with a third immediately available.

When position keeping relative to a facility that has small position excursions then at least two independent relative position reference systems should be available in conjunction with absolute systems.

If the combined position excursions of the vessel and facility may exceed the operating limits of the gangway then the accommodation vessel should use relative reference systems only, allowing the vessel to follow facility movements, at least three relative reference systems should be provided.

Relative position reference systems should be located as close to the gangway as possible so as to minimise the effects of errors in heading references and reference system offsets on the gangway position.

If the gangway is used as a position reference for the DP system then the integrity of the position reference information should be subject to FMEA.

At least three independent heading sensors should be provided.

A6-2.5 Power Systems

Provision of power for positioning systems may be independent however it is more usual for a redundant diesel–electric power plant to provide power to all vessel systems. Hotel load will be relatively low and may be included in a load shedding philosophy for blackout prevention.

The criticality of power supplies to cranes and/or cargo pumps (where fitted) is to be derived from the FMEA.

A6-3 Operational Guidance

A6-3.1 Operational Considerations

The following should be considered when planning DP operations:

- ◆ Personnel transfer from an accommodation vessel is usually characterised by a short time to terminate. If the accommodation vessel is providing services such as fuel, water or power to the facility then the time for a controlled disconnection could be longer. If leaving personnel on the facility is not acceptable then the time to terminate should consider the time needed to recall all personnel via the gangway when determining operational configuration and limits;
- ◆ Accommodation arrangements are subject to coastal state administration approval. When positioned alongside a facility then the facility OIM may have responsibility for some aspects of the accommodation arrangements;
- ◆ Decisions relating to accommodation vessel movements should be made in co-operation between those on the vessel and the facility. Emergency arrangements should be agreed and documented in the ASOG to prevent actions during an emergency being delayed by prolonged communication. Some emergency situations on the facility may require that the accommodation vessel remains with the gangway connected during a DP yellow alert;
- ◆ Where permitted the accommodation vessel should move clear of the facility between personnel transfers to minimise exposure to risks associated with an inability to maintain position;
- ◆ The risk that radar or laser range-finding position reference instruments may have the line of sight with their target obstructed by personnel/equipment should be analysed and mitigated;
- ◆ Where position keeping is required relative to a floating facility an assessment of the facility's allowable position footprint and rate of movement should be completed to confirm that this does not exceed the capabilities of the accommodation vessel DP system and its gangway;
- ◆ A vessel emergency escape route should always be planned.

A6-3.2 Operational Planning

Where appropriate the following should be documented:

- ◆ Risk assessment of the loss of vessel position during personnel transfer and for all other activities to be undertaken;
- ◆ Configuration of DP systems for the critical activity mode of operation (CAM) or for the task appropriate mode (TAM) with specification as to which modes are required for each phase of the operation;
- ◆ Activity specific operating guidelines (ASOG) to define actions in the event of loss of DP critical systems as well as defining environmental and equipment performance limits and guidance on required actions in the event of these limits being exceeded.

A6-3.3 Communications

A dedicated system for communication between all relevant operating and control locations of the vessel should be provided, including:

- ◆ DP control;
- ◆ engine control;
- ◆ gangway control;
- ◆ crane cabin;
- ◆ offshore facility control room.

There should be a backup to these systems that is operable in a black out condition, both primary and backup communications should be checked as part of the DP checklists.

A6-3.4 DP Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in tabular format in the ASOG.

Guidance on status and responses is given below.

Normal status – GREEN light. Planned operations can be undertaken within agreed safe limits.

- ◆ The DP system is operating as intended;
- ◆ Operational, environmental and equipment performance criteria as defined within the ASOG are all categorised as normal;
- ◆ The vessel would be capable of maintaining position in the prevailing environmental conditions after the worst case failure.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed. Consideration should be given to recalling personnel from the offshore facility if it would not be safe for them to remain there in the event of the gangway being disconnected.

- ◆ Operational, environmental or equipment performance limits are being approached;
- ◆ The DP system is no longer configured as required in the CAM/TAM;
- ◆ An advisory condition exists as defined in the ASOG;
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. Personnel should suspend operations in a safe manner; preparations should be made for a controlled disconnection of the gangway and any services supplied to the facility. Personnel should be recalled from the offshore facility if it would not be safe for them to remain there when the gangway is disconnected.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ The vessel's position keeping performance is deteriorating or unstable;
- ◆ The vessel would be unable to maintain position in the prevailing environmental conditions after the worst case failure;
- ◆ A 'yellow' condition exists as defined in the ASOG for abnormal operational, environmental and equipment performance conditions;
- ◆ Any other condition exists which may lead to the lifting of the gangway.

Emergency status – RED light with accompanying distinctive alarm. The gangway should be immediately cleared as it is likely to auto-lift.

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control, or personnel transfer has become unsafe;
- ◆ A 'red' condition exists as defined in the ASOG for hazardous operational, environmental and equipment performance criteria;

- ◆ Any other emergency situation which warrants immediate preparation for moving clear of the adjacent facility.

Independent of any DP alert an alert system should be fitted for the gangway crossing:

- ◆ Green status lights each end of the gangway to indicate free passage;
- ◆ Yellow lights each end of the gangway and an audible warning to indicate that gangway stroke warning limits have been reached and persons using the gangway should exit by the quickest route and clear the area where the gangway is landed;
- ◆ Red lights each end of the gangway and an audible alarm to indicate that the gangway is closed and should not be crossed;
- ◆ Consideration should be given to interfacing the gangway alert with the DP alert system so that the DPO can manually activate the gangway warning system if necessary.

Where it is possible to execute a change of position or heading without disconnecting the gangway then the gangway alert system should indicate a red light status and the DPO is to ensure that there are no persons using the gangway before any change in centre of rotation, DP position or heading is implemented.

A6-3.5 Responsibilities

The master and the facility OIM should co-operate closely in responding to emergency situations. Their respective authority and responsibilities should be agreed and understood by both parties. The master has authority over the accommodation vessel but needs to consider the requirements of the facility OIM and the safety of personnel on the facility.

The vessel master is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid the start or order the suspension of personnel transfer operations, including in conditions where operational limits defined in ASOGs have not been exceeded. They are responsible for ensuring the compatibility of the vessel's safety management system with that of the installation where it is working – see [IMCA M 125 – Safety interface document for a DP vessel working near an offshore platform](#).

The DPO is responsible for ensuring that DP system is configured as specified in the CAM/TAM and for monitoring vessel position and that the vessel operates within limits defined in the ASOG. The DPO is responsible for changing the DP alert status with reference to the ASOG without delay should this become necessary and for carrying out the associated actions. They have the authority to suspend personnel transfer operations if they consider this to be necessary for the safety of the vessel, environment or personnel.

Drilling Vessels

A7-1 Industrial Mission

A7-1.1 Description and Role

The primary operational role of the vessel is drilling wells into oil or gas reservoirs, or scientific drilling activities.

Drilling vessels may also be utilised for maintenance or completion activities on existing wells and are frequently provided with ROVs to facilitate subsea intervention, survey and inspection.

The DP operational requirement is to maintain the drilling vessel in a static position over the well site for the duration of the drilling operation. The drilling vessel may need to temporarily offset its position clear of subsea infrastructure to conduct tasks where dropped objects may pose a risk.

Drilling vessels, generally known as mobile offshore drilling units (MODU) may be self-elevating/ bottom standing, moored or dynamically positioned (DP); DP vessels have advantages in being able to transit independently, relocate rapidly between wells and operate in the greatest water depths.

Drilling vessels frequently operate in locations subjected to strong sea currents and large wave and wind forces.

DP drilling operations are generally conducted in open water away from fixed surface structures, but can also be conducted near fixed and floating surface structures. DP Drilling activities will be required to operate in close proximity to other vessels, for example offshore support vessels and/or ROV, construction, and seismic vessels.

The consequences of loss of vessel position may include injury to personnel, damage to the vessel and to the drilling riser, wellhead, adjacent offshore installations and support vessels as well as environmental pollution.

A7-2 Design Guidance

A7-2.1 Design Considerations

DP drilling vessels should comply with IMO equipment class 2 or 3.

It is recommended that power and propulsion systems are designed to allow components to be isolated for maintenance or repair without compromising DP redundancy.

Thruster systems which can be maintained or replaced without the vessel dry docking are advantageous.

A7-2.2 DP Capability

The drilling vessel should be capable of maintaining the riser angle within prescribed limits for prolonged durations. A relaxed position and heading footprint may be acceptable for drilling operations, however high accuracy will be required for simultaneous operations with other vessels in close proximity. Use of relative position references may be necessary for OSVs and SIMOP vessels working in close proximity of the drilling vessel.

The vessel should be capable of maintaining position for sufficient time to safely suspend operations following the worst case failure in all anticipated operational and environmental conditions.

Choice of vessel heading may be determined by a requirement to maintain correct wind flow over the vessel or to minimise vessel motion.

The DP system should be capable of rapidly adapting to changing external forces.

Position keeping capability plots should be developed for intact single thruster failure and worst case failure conditions and include an allowance for the anticipated forces from riser drag in the water column.

A7-2.3 Control Systems

The primary DP control mode is to maintain position and heading in a fixed location.

No single failures or operator inadvertent act should result in a greater effect on position keeping than the worst case failure identified for the DP system.

Emergency shutdown (ESD) system operation may result in loss of power and propulsion equipment leading to an inability to maintain position. The philosophy of ESD systems should be described in terms of cause and effect and equipment essential for maintaining position and emergency response should be protected from external shutdown so far as is practicable. ESD systems should be aligned with the vessel redundancy concept and protected from erroneous operation.

A7-2.4 Reference Systems and Sensors

Reference should also be made to IMCA M 160 – *Reliability of position reference systems for deepwater drilling*.

At least three independent position reference systems should be in use for critical activities and three heading reference systems should be in use for heading sensitive operations.

Reference systems should use a minimum of two different measurement principles.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

In deep water and open water locations there may be a reliance on satellite based position references, satellite based systems should be sourced from different manufacturers to avoid software induced common cause failures. Independence should be provided by the separation of power supplies. Different methods for differential corrections should be employed. No single failure should result in the loss of more than one position reference system. Consideration should be given to using position reference systems in combination with inertial navigation systems to filter short term instability.

A riser monitoring system may be interfaced to the DP control system. In such cases it is essential that the integrity of such information is confirmed prior to its use in the DP system and verified during operation, as sudden failure may have an impact on position control performance and stability.

Intrinsically safe equipment may be required where risks exist from flammable vapours.

Wind sensors should be positioned to allow for local disruption of wind flow caused by the drilling derrick, information should be corrected to a common height at the DP control station.

A7-2.5 Power Systems

Provision of power for propulsion may be independent from other significant consumers. Where a common diesel–electric configuration is adopted then DP systems need to be protected from faults in mission equipment and the power plant needs to be capable of responding to high transient loads.

Drilling systems and other industrial mission equipment may have a high power demand in relation to propulsion power demand.

The power management philosophy should consider the criticality of mission systems such as drilling systems, heave compensation, winches and ballasting systems as well as dynamic positioning systems to ensure that control is maintained of all operationally and safety critical systems at all anticipated loads and after the worst case failure in electrical power provision.

Power supplies necessary to facilitate a controlled disconnection of the riser system should be redundant and protected from the effects of emergency shutdown operation (ESD).

Redundant power supply arrangements should be provided for riser heave compensation, BOP control and riser and well monitoring systems to facilitate a controlled termination of the drilling operation in the event of a failure in vessel power.

A7-3 Operational Guidance

A7-3.1 Operational Considerations

The following should be considered when planning DP operations:

- ◆ Drilling operations often have a short time to terminate, however this is sensitive to the nature of the specific operation being undertaken, for example if a non-shearable is passing through the wellhead then time to terminate will be longer. The time taken to restart operations may be long following an emergency disconnect;
- ◆ The power demands of drilling activities may cause high transient loads;
- ◆ Wind forces on the vessel may be high due to the size and shape of the vessel structure;
- ◆ Vessel heading may be determined by the requirement for wind flow over the vessel to mitigate potential effects of gas release;
- ◆ Changes in riser flex joint angles as well as to position relative to the seabed need to be considered when monitoring vessel position;
- ◆ A vessel emergency escape route should always be planned. This should take account of bathymetry and seabed structures.

A7-3.2 Operational Planning

Where appropriate the following should be documented:

- ◆ Risk assessment for the loss of vessel position at all stages of the operation and for all associated activities, including SIMOPs;
- ◆ Configuration of DP systems for the critical activity mode of operation (CAM) or for the task appropriate mode (TAM) with specification as to which modes are required for each phase of the operation;
- ◆ Activity specific operating guidelines (ASOG) or well specific operating guidelines (WSOG) to define actions in the event of loss of DP critical system as well as defining environmental and equipment performance limits and guidance on required actions in the event of these limits being exceeded, such as those conditions which require the riser to be disconnected.

A7-3.3 Communications

A dedicated system for communication between all relevant operational and control locations of the vessel should be provided, including:

- ◆ DP control;
- ◆ engine control;
- ◆ ROV control;

- ◆ drill floor/drilling control;
- ◆ drilling supervisor.

Provision of a 'normally open' communication link between DP control and drilling control is recommended.

There should be a backup to these systems that is operable in a black out condition, both primary and backup communications should be checked as part of the DP checklists.

A7-3.4 DP Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in tabular format in the ASOG/WSOG.

Guidance on status and responses is given below.

Normal status – GREEN light. Full DP drilling operations can be undertaken.

- ◆ The DP system is operating as intended;
- ◆ Operational, environmental and equipment performance criteria as defined within the ASOG/WSOG are all categorised as normal;
- ◆ Riser angle is within allowable limits;
- ◆ The vessel would be capable of maintaining position in the prevailing environmental conditions after the worst case failure, or risk assessment has determined that rate of loss of position would be acceptable and would allow safe suspension of activities.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;
- ◆ The DP system is no longer configured as required in the CAM/TAM;
- ◆ An advisory condition exists as defined in the ASOG/WSOG
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. Some condition exists which requires that drilling operations are suspended, preparations should be made to disconnect from the well.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ The vessel's position keeping performance is deteriorating or unstable;
- ◆ The vessel would be unable to maintain position in the prevailing environmental conditions after the worst case failure;
- ◆ A 'yellow' condition exists as defined in the ASOG/WSOG for abnormal operational, environmental and equipment performance conditions;
- ◆ Riser flex joint angle has reached the defined alarm limit;
- ◆ Any other condition exists which may lead to a suspension of drilling activities.

Emergency status – RED light with accompanying distinctive alarm. Damage to the riser and associated equipment is possible; the well should be shut in and emergency disconnection should be initiated.

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control or to safely conduct drilling operations;
- ◆ A 'red' condition exists as defined in the ASOG/WSOG for hazardous operational, environmental and equipment performance criteria;

- ◆ Maximum permissible riser angle has been exceeded;
- ◆ Any other emergency situation that warrants immediate disconnection and escape.

A7-3.5 Responsibilities

The master or OIM (as applicable) and the drilling superintendent should co-operate closely in responding to emergency situations. Their respective authority and responsibilities should be agreed and understood by both parties. The master/OIM has authority over the vessel but needs to be cognisant of the needs of the drilling superintendent and ensure that any actions consider potential safety implications arising from their influence on drilling activities.

The MODU master or OIM is responsible for the safety of the vessel and all personnel onboard. This includes the authority to forbid the start or order the suspension of drilling operations, including in conditions where operational limits defined in the ASOG/WSOG have not been exceeded.

The DPO is responsible for ensuring that the DP system is configured as specified in the CAM/TAM and for monitoring vessel position and that the vessel operates within limits defined in the ASOG/WSOG. The DPO is responsible for changing the DP status with reference to the ASOG/WSOG without delay should this become necessary and for carrying out the associated actions. They have the authority to suspend drilling operations if they consider this to be necessary for the safety of the vessel, environment or personnel. They should ensure that potential degradation in position keeping ability is communicated immediately to the master and to the drilling superintendent/supervisor.

The drilling superintendent is responsible for the safety and integrity of the well. The drilling superintendent has the authority to forbid the start or order the termination of drilling operations on grounds of drilling safety. They are responsible for providing unambiguous communication to the DPO to confirm the status of the drilling operation.

The client's representative is responsible to the client for the proper performance of all work in accordance with the contract. This representative should have the authority to veto the start of operations and should have the authority to require the termination of drilling operations in a controlled manner by direct communication with the master or drilling superintendent.

FPSO Vessels

A8-1 Industrial Mission

A8-1.1 Description and Role

The term FPSO is an acronym for floating production storage and offloading; these terms describe the industrial mission of the vessel.

Production is the onboard processing, separation and treatment of crude oil, gases and water from subsea wells connected to the FPSO by risers.

Storage is the storage provided onboard for the processed crude oil or gasses. These products may be transferred to shuttle tankers for shipment to shore-based facilities, removing the need for export pipelines.

The two mission activities of the FPSO may be separated and carried out by floating production units (FPU) with no storage and floating storage and offloading vessels (FSOs) which have no production facilities. Such vessels are considered to be within the scope of guidance offered for FPSOs for the purposes of these guidelines.

FPSOs may be moored or dynamically positioned. DP FPSOs are favoured for short term use associated with extended well testing (EWT) for proving the commercial viability of a well. DP FPSOs may also be used as early production systems (EPS) to bring production online quickly whilst installation of permanent facilities progresses. EPS generally produce from more than one well, increasing the risks associated with an inability to maintain position.

FPSOs are frequently provided with ROVs to facilitate subsea intervention, riser connection, survey and inspection.

FPSOs frequently operate in locations subjected to strong sea currents and large wave and wind forces.

Operations are generally conducted in open water away from fixed surface structures, however they will be required to operate in close proximity to other vessels, for example supply vessels and shuttle tankers.

The consequences of loss of vessel position may include injury to personnel, damage to the vessel, the riser, and support vessels as well as environmental pollution.

Refer to [IMCA M 159](#) – *Guidance on thruster-assisted station keeping by FPSOs and similar turret-moored vessels*.

A8-2 Design Guidance

A8-2.1 Design Considerations

DP FPSOs should comply with IMO equipment class 2 or 3.

It is recommended that power and propulsion systems are designed to allow components to be isolated for maintenance or repair without compromising redundancy or fault tolerance.

Fire and watertight separation of redundant elements of the DP system is recommended for DP equipment class 2 (it is required for DP equipment class 3). Power and data cables for the DP equipment should not be routed through machinery spaces (other than those within which the equipment is installed) or other high fire risk spaces.

The design intent should clearly identify those conditions which require the riser to be disconnected.

The vessel should be provided with sufficient redundancy to continue operations in a safe and efficient manner when equipment is under maintenance or when high probability failures occur.

The riser should be protected from damage as far as is reasonably practicable and production units should be able to shut down safely in any environmental or fault condition.

A8-2.2 DP Capability

The FPSO should be capable of maintaining the riser angle within prescribed limits for prolonged durations. A relaxed position and heading footprint may be acceptable for operations, however high accuracy will be required for simultaneous operations with other vessels in close proximity. Use of relative position references may be necessary for SIMOP vessels.

The vessel should be capable of maintaining position for sufficient time to safely suspend operations following the worst case failure in all anticipated operational and environmental condition.

Choice of vessel heading may be determined by a requirement to maintain correct wind flow over the vessel or to minimise vessel motion; hence thrusters should be capable of maintaining position when environmental forces are experienced on the vessel beam.

The DP system should be capable of rapidly adapting to changing external forces.

Position keeping capability plots should be developed for intact single thruster failure and worst case failure conditions and include an allowance for the anticipated forces from riser drag in the water column and the external forces associated with taut hawsers during offloading operations.

A8-2.3 Control Systems

The primary DP control mode is to maintain position and heading in a fixed location or weathervane.

The weathervane mode should allow the vessel to rotate around a fixed or moving terminal point in response to changes in wind, current and wave forces. In this mode neither the heading nor the position of the vessel is fixed; heading is controlled to point towards the terminal point whilst position is controlled to follow a setpoint circle around the terminal point. The terminal point is usually the riser turret.

Emergency shutdown (ESD) system operation may result in loss of power and propulsion equipment leading to an inability to maintain position. The philosophy of ESD systems should be described in terms of cause and effect and equipment essential for maintaining position and emergency response should be protected from external shutdown so far as is practicable. ESD systems should be aligned with the vessel redundancy concept and protected from erroneous operation.

A8-2.4 Reference Systems and Sensors

At least three independent position reference systems should be in use for critical activities and three heading reference systems should be provided.

Reference systems should use a minimum of two different measurement principles, it is recommended to use three different measurement principles.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

In deep water and open water locations there may be a reliance on satellite based position references, satellite based systems should be sourced from different manufacturers to avoid software induced common cause failures. Independence should be provided by the separation of power supplies. Different methods for differential corrections should be employed. No single

failure should result in the loss of more than one position reference system. Consideration should be given to using inertial navigation systems to filter short term instability.

Position references should be selected which support both auto position and weathervane modes of DP control.

Hawser tensions related to the external forces applied by a shuttle tanker during offloading may be interfaced to the DP system to enable the thrusters to compensate effectively. A riser monitoring system may also be interfaced to the DP control system. In such cases it is essential that the integrity of such information is confirmed prior to its use in the DP system, as sudden failure may have an impact on position control performance and stability.

Intrinsically safe equipment may be required where risks exist from flammable vapours.

Wind sensors should be positioned to allow for local disruption of wind flow caused by the vessel design, information should be corrected to a common height at the DP control station.

A8-2.5 Power Systems

Provision of power for propulsion may be independent from other significant consumers. Where a common diesel–electric configuration is adopted then DP systems need to be protected from faults in mission equipment and the power plant needs to be capable of responding to high transient loads.

Where hydrocarbons produced onboard are used to fuel power generating equipment then the reliability of such fuel sources should be analysed in the FMEA. Sufficient generating capacity which is independent of such fuel sources should be operating to ensure that position can be maintained after process plant shutdown.

The power management philosophy should consider the criticality of mission systems such as production systems, winches and ballasting systems as well as dynamic positioning systems to ensure that control is maintained of all operational and safety critical systems at all anticipated loads and after the worst case failure in electrical power provision.

Power supplies necessary to facilitate a controlled disconnection of the riser system should be redundant and protected from the effects of emergency shutdown operation (ESD).

A8-3 Operational Guidance

A8-3.1 Operational Considerations

The following should be considered when planning DP operations:

- ◆ Production and offloading operations often have a short time to terminate. The time taken to restart operations may be long following an emergency disconnection of the riser turret. Such emergency disconnection may also result in the loss of the well;
- ◆ Weathervane mode of control may demand high athwartship thrust if a rapid change in heading occurs in response to external forces; operators should be aware of the circumstances where change of mode to auto position is preferable;
- ◆ The power demands of drilling activities may cause high transient loads;
- ◆ Wind forces on the vessel may be high due to the size and shape of the vessel structure;
- ◆ Vessel heading may be determined by the requirement for wind flow over the vessel to mitigate potential effects of gas release;
- ◆ Changes in riser flex joint angles as well as to position relative to the seabed need to be considered when monitoring vessel position;
- ◆ A plan for emergency disconnection and escape from the wellhead position should be readily available. This should consider that in the initial stages of disconnect the riser will recoil and

extend its full length beneath the vessel, this should be considered when developing the ASOG/WSOG;

- ◆ Offloading operations to conventional shuttle tankers (not utilising dynamic positioning) may result in high hawser loads which will affect FPSO position keeping;
- ◆ Control of position and communications with the shuttle tanker during offloading operations requires careful planning; weathervaning of the FPSO may not be appropriate during such operations unless the shuttle tanker is capable of following the changes in position and heading (see Appendix 9 relating to shuttle tanker operations).

A8-3.2 Operational Planning

Where appropriate the following should be documented:

- ◆ Risk assessment for the loss of vessel position at all stages of the operation and for all associated activities, including SIMOPs;
- ◆ Configuration of DP systems for the critical activity mode of operation (CAM) or for the task appropriate mode (TAM) with specification as to which modes are required for each phase of the operation;
- ◆ Activity specific operating guidelines (ASOG) to define actions in the event of loss of DP critical system as well as defining environmental and equipment performance limits and guidance on required actions in the event of these limits being exceeded. Well specific operational guidelines may be appropriate;
- ◆ An interface document between offshore loading facility and shuttle tanker (may take the form of a joint operations manual (JOM)).

A8-3.3 Communications

A dedicated system for communication between all relevant operational and control locations of the vessel should be provided, including:

- ◆ DP control;
- ◆ engine control;
- ◆ ROV control;
- ◆ production control;
- ◆ production supervisor

There should be a backup to these systems that is operable in a black out condition, both primary and backup communications should be checked as part of the DP checklists.

A8-3.4 DP Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in tabular format in the ASOG.

Guidance on status and responses is given below.

Normal status – GREEN light. Planned operations can be undertaken within agreed safe limits.

- ◆ The DP system is operating as intended;
- ◆ Operational, environmental and equipment performance criteria as defined within the ASOG are all categorised as normal;
- ◆ Riser angle is within allowable limits;
- ◆ The vessel would be capable of maintaining position in the prevailing environmental conditions after the worst case failure, or risk assessment has determined that the rate of loss of position

would be acceptable and would allow for safe suspension of production and disconnection from the riser.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;
- ◆ The DP system is no longer configured as required in the CAM;
- ◆ An advisory condition exists as defined in the ASOG;
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. Some condition exists which requires that production is suspended, preparations should be made to disconnect from the riser.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ The vessel's position keeping performance is deteriorating or unstable (but an inability to maintain position other than a large excursion is not occurring);
- ◆ The vessel would be unable to maintain position in the prevailing environmental conditions after the worst case failure;
- ◆ A 'yellow' condition exists as defined in the ASOG for abnormal operational, environmental and equipment performance conditions;
- ◆ Riser angle has reached the defined alarm limit;
- ◆ Any other condition exists which may lead to a suspension of production.

Emergency status – RED light with accompanying distinctive alarm. Damage to the riser and associated equipment is possible; production should be shut in and emergency disconnection should be initiated.

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control;
- ◆ A 'red' condition exists as defined in the ASOG for hazardous operational, environmental and equipment performance criteria;
- ◆ Maximum permissible riser angle has been exceeded;
- ◆ Any other emergency situation that warrants immediate shutdown of production and disconnection from the riser.

A8-3.5 Responsibilities

The master/OIM (as applicable) and the production supervisor should co-operate closely in responding to emergency situations. Their respective authority and responsibilities should be agreed and understood by both parties. The master/OIM has authority over the vessel but needs to be cognisant of the needs of the production supervisor and ensure that any actions taken consider potential safety implications for production activities.

The vessel master/OIM is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid connection of the riser or commencement of production, including in conditions where operational limits defined in ASOG/WSOG have not been exceeded.

The master/OIM has the authority to terminate offloading operations on the grounds of safety and to forbid the approach of a shuttle tanker or other vessel within 500m of the FPSO.

The production supervisor is responsible for the safety of the riser and well. They have the authority to forbid the start of, or order the termination of production on grounds of safety.

The control room production engineer is responsible to the production supervisor. They are also responsible for providing unambiguous communication to the DPO to confirm the status of the production facilities.

The DPO is responsible for ensuring that the DP system is configured as specified in the CAM and for monitoring vessel position and that the vessel operates within limits defined in the ASOG. The DPO is responsible for changing the DP alert status with reference to the ASOG without delay should this become necessary and for carrying out the associated actions. They have the authority to suspend production operations if they consider this to be necessary for the safety of the vessel, environment or personnel. They should ensure that potential degradation in position keeping is communicated immediately to the master and to the production supervisor.

The client's representative is responsible to the client for the proper performance of all work in accordance with the contract. This representative should have the authority to veto the start of operations and should have the authority to require the termination of production operations in a controlled manner by direct communication with the master or production supervisor.

Shuttle Tankers

A9-1 Industrial Mission

A9-1.1 Description and Role

The role of the vessel is offshore loading of crude oil and condensates from production facilities followed by transporting these products to onshore terminals, providing an alternative to a fixed pipeline.

Offshore production facilities may produce directly into a shuttle tanker, or may have storage facilities which are periodically discharged to a shuttle tanker.

Shuttle tankers may also be used for lightening of larger tankers.

Shuttle tanker offshore loading operations may take place in any water depth which can accommodate the vessel's draught.

For offshore loading the tanker should be capable of maintaining position relative to the loading facility and be suitably equipped to connect to the loading system safely. The tanker should be able to enter designated discharge ports without undue restrictions and be capable of self-discharging.

Offshore loading facilities include (but may not be limited to):

- ◆ surface single point systems (including articulated loading platform (ALP)) and single buoy mooring (SBM);
- ◆ sub-surface single point systems including offshore loading system (OLS), submerged turret loading (STL), tripod catenary mooring system (TCMS), single anchor production (SAP) and single anchor loading (SAL);
- ◆ surface production and storage systems (including floating storage unit (FSU) systems and floating production storage and offloading (FPSO) systems).

The favoured approach for the shuttle tanker is directly into the prevailing environmental forces. However tankers may approach single point systems from any direction.

Surface production and storage systems will have a restricted approach sector for the shuttle tanker due to the arrangement of their offloading equipment. They may be spread moored in a fixed orientation, or may be turret moored and free to rotate.

Shuttle tanker offshore loading operations may be carried out as follows:

- ◆ Conventional (non-DP) tankers operating in benign environments may utilise a taut mooring hawser from the offshore loading facility to the bow of the shuttle tanker. Tug assistance may be provided for connection of the mooring hawser and to provide heading control in combination with tension in the mooring hawser. Refer to: *Tandem Mooring and Offloading Guidelines for Conventional Tankers at F(P)SO Facilities* 1st Edition – OCIMF (2009);
- ◆ DP equipped tankers utilising DP to maintain a position relative to the offshore loading facility. Refer to [IMCA M 159 – Guidance on thruster-assisted station keeping by FPSOs and similar turret-moored vessels](#);
- ◆ Tankers which use a combination of thrusters with tug and/or mooring assistance; such systems are not considered to be dynamically positioned within the context of this guidance.

The guidance contained in this document is only applicable to DP vessels.

The consequences of loss of vessel position may include injury to personnel, damage to the vessel and to adjacent offshore installations as well as environmental pollution.

A9-2 Design Guidance

A9-2.1 Design Considerations

DP shuttle tankers should comply with IMO DP equipment class 2 or 3.

No known single failure should result in an uncontrolled disconnection or cause a position excursion which requires an emergency disconnection.

A DP equipment class 1 vessel which uses a taut mooring hawser as a form of redundancy in position control should not be considered as equivalent to a non-mooring hawser class 2 vessel.

DP shuttle tankers may be purpose-built vessels or may be converted from an existing tanker with the addition of specialised thruster systems and offshore loading systems.

Thruster and main propulsion arrangements should provide sufficient dynamic positioning capability and transit speed to satisfy the requirements of the specific application.

The intended offshore loading arrangements will influence the complexity of the design:

- ◆ surface single point systems may only require simple deck-mounted winches and manifold connections for handling hawser and loading hose;
- ◆ sub-surface single point systems may require a complex underwater coupling for the loading system though they can be designed for hook-up via bow loading facilities;
- ◆ surface production and storage systems generally require bow loading facilities for manifold connection and hawser connection.

The potential consequences of uncontrolled contact between the shuttle tanker and the offshore loading facility should be assessed. A loading system ESD which automatically closes manifold valves and should disconnect hoses is recommended.

DP shuttle tankers may utilise external systems (such as tug assistance, hawser tension, etc.) to assist with position keeping. Any analysis of the risks of an inability to maintain position should also consider these systems. If operating with loading facilities which are also operating on DP, or which are free to rotate, the combined system of loading facility and shuttle tanker should be considered in analysis of failures risking an inability to maintain position.

A9-2.2 DP Capability

The shuttle tanker should be capable of maintaining position within designated sector and range limits relative to the loading point, and within defined environmental operating limits.

The required DP capability of the shuttle tanker is determined by:

- ◆ the type of offshore loading facility to which the tanker is intended to interface;
- ◆ the positioning strategy adopted for the offloading operation;
- ◆ the positioning accuracy required during the approach, connection and offshore loading;
- ◆ the defined limiting environmental conditions for wind speed, wave height and surface current.

The type of offshore loading facility will influence the vessel's positioning strategy and the required positioning accuracy. Weathervaning restrictions may exist.

The DP system should be capable of rapidly adapting to changing external forces.

Surface single point systems may not require a high DP capability if DP is only used for approach and connection and where the single point system's moorings are sufficiently strong to also act as a mooring for the shuttle tanker once a hawser is connected.

Sub-surface single point systems may require that the DP system be capable of very accurate positioning during connection and loading.

The required position keeping capability and means of position keeping will usually be specified by the field operator.

Position keeping capability plots should be developed for intact condition and worst-case failure conditions. The capability plots should consider ballast and fully loaded conditions.

A9-2.3 Control Systems

Shuttle tanker DP control modes may be specific to the offloading facility to which the tanker is intended to interface.

DP control systems required to maintain position relative to a moving reference position should be capable of filtering the motion associated with the position reference so as to reduce thruster power demand by allowing a range of motion before a new setpoint is required.

DP shuttle tankers subjected to external forces associated with offshore loading facility mooring systems should be programmed with facility-specific data to ensure stability in position keeping and to avoid overloading the facility mooring system. Such data may include, but not be limited to, maximum mooring system tensions, maximum hawser tensions, gain and damping effects of the mooring system. This is particularly important when connected to sub-surface single point loading systems which may have mooring restoring forces acting through 360°.

DP control system hydrodynamic, wind profile and thruster efficiency models should be developed for a variety of vessel draughts to enable accurate positioning throughout the loading operation. The models should adjust to changes in vessel draught automatically.

A9-2.4 Reference Systems and Sensors

Position reference systems appropriate to the DP equipment class should be in use for offshore loading operations. The available systems should allow the DP operator to select a different measurement principle for each reference in use.

Position references should support both auto position and weathervane modes of DP control where necessary.

Three independent heading sensors should be in use for critical activities.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

Where the loading facility is free to move then at least two relative position reference systems should be provided in conjunction with an absolute position reference system. Where a combination of fixed and relative position reference systems are used and the relative target is free to move then specialist DP control software is required to compensate this movement in the position calculation.

Potential for interference to reference systems from obstructions, false targets or environmental conditions should be analysed and references chosen which minimise such interference.

Intrinsically safe equipment may be required where risks exist from flammable vapours.

For sub-surface loading facilities acoustic position reference systems may be employed to provide a relative reference. Absolute references with a limited scope, such as taut wire, will not generally be suitable.

Wind sensors should be positioned to allow for local disruption of wind flow caused by the vessel's shape and structure and should be corrected to a common height at the DP control station.

If a mooring hawser is to be used during DP operations then a hawser tension sensor should be interfaced to the DP system to enable the thrusters to compensate effectively; this should be subject to FMEA.

The vessel draught sensors should be interfaced to the DP system.

A9-2.5 Power Systems

Where a diesel–electric power configuration is adopted then DP systems need to be protected from faults in other equipment and the power plant needs to be capable of responding to high transient loads. If the main propulsion system forms part of the DP arrangement then a variable pitch propeller to facilitate rapid changes in thrust should be used and redundancy requirements may dictate a twin screw arrangement.

Whilst vessel positioning systems should always be prioritised over other consumers the power management philosophy should consider the criticality of other onboard equipment and ensure that control is maintained of all operationally and safety critical systems at all anticipated loads and after the worst case failure in electrical power provision.

Relatively high transverse thrust is required at the bow of the DP shuttle tanker in order to facilitate accurate positioning of the bow during approach to the mooring facility and for heading/yaw control on DP.

A9-3 Operational Guidance

A9-3.1 Reference Documents

Detailed operational guidance for shuttle tankers is available in the following documents:

- ◆ *IMCA M 159 – Guidance on thruster-assisted station keeping by FPSOs and similar turret-moored vessels*
- ◆ Oil & Gas UK publication OP060 – *Tandem Loading Guidelines*;
- ◆ Oil Companies' International Marine Forum (OCIMF) – *Offshore Loading Safety Guidelines with special relevance to harsh weather zones*.

A9-3.2 Operational Considerations

The following should be considered when planning DP operations:

- ◆ Offshore loading operations are usually characterised by a short time to terminate. ESD systems should allow a quick termination of loading and disconnection of hoses and hawser.
- ◆ Fixed orientation surface production and storage facilities (spread moored) will limit the shuttle tanker's ability to use a weathervane mode. A non-optimal heading may require high athwartship thrust to maintain position, and risks high hawser tensions;
- ◆ A weathervaning mode of positioning may be used by shuttle tankers loading from rotating surface production and storage facilities (turret moored) however specialist DP control modes will be required due to the movement of the reference loading point. Differences in draught and wind profile between the shuttle tanker and the facility may necessitate each adopting different weathervane headings as they may react differently to changes in wind and current;
- ◆ Shuttle tankers adopting a weathervane mode are generally in a drift-off position in the event of positioning system failure;
- ◆ Where the heading of a surface production and storage facility can be controlled, such changes should be carefully managed, with procedures and communications for heading changes being agreed and clearly documented;
- ◆ Using tug assistance in conjunction with DP control is problematic as the forces applied by the tug may be unknown to the DP system and tug towing forces may be subject to a variety of single point failures;
- ◆ Weather working limits for connecting and loading phases are usually defined by the field operator. Hose connection is generally the most weather sensitive operation;
- ◆ In areas subjected to rapid current changes then the actions of the DPO in responding to such changes should be defined and recorded in appropriate procedures;

- ◆ If the shuttle tanker experiences a total black out whilst moored to the loading facility an emergency disconnect of the mooring hawser may not always be desirable. Decision support should accompany the ASOG;
- ◆ Shuttle tanker DPOs require specific training to ensure familiarity with the vessel operations, DP control modes, manual vessel control, ESD procedures and means of disconnection and vessel escape in the event of DP system failure. Training in an environment similar to the proposed working locations with simulated conditions is recommended. The training should also include drift off patterns for the DP vessel at the installation location.

A9-3.3 Operational Planning

Where appropriate the following should be documented:

- ◆ Risk assessment for the loss of vessel position at all stages of the offtake operation;
- ◆ Interface document between offshore loading facility and shuttle tanker (may take the form of a joint operations manual (JOM));
- ◆ Configuration of DP systems for the critical activity mode of operation (CAM) or for the task appropriate mode (TAM) with specification as to which modes are required for each phase of the operation;
- ◆ Activity specific operating guidelines (ASOG) to define actions in the event of loss of a critical DP system as well as defining environmental and equipment performance limits and guidance on required actions in the event of these limits being exceeded. These should include the minimum acceptable physical separation between shuttle tanker and loading facility which should initiate a controlled shutdown, release and departure of the shuttle tanker from the facility if it cannot be maintained. The procedure for such controlled shutdown should include the conditions for operation of automatic systems, the manual interventions required and the interfaces between alert systems and the ESD.

A9-3.4 Communications

A dedicated system for communication between the operational/control centres of the shuttle tanker, and between the shuttle tanker and the loading facility, should be provided. Such locations may consist of:

- ◆ DP control console;
- ◆ engine control room;
- ◆ cargo/ballast control;
- ◆ offshore loading facility control room;
- ◆ hold-back tug's bridge (if applicable).

There should be a backup to these systems that is operable in a black out condition, both primary and backup communications should be checked as part of the DP checklists.

A9-3.5 DP Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in tabular format in the ASOG.

If a DP emergency status alarm is activated on the shuttle tanker, consideration should be given to repeating the alarm onboard the loading facility and/or adjacent manned structures to give immediate warning of a potential inability to maintain position.

Guidance on status and responses is given below.

Normal status – GREEN light. Planned operations can be undertaken within agreed safe limits.

- ◆ The DP system is operating as intended;

- ◆ Operational, environmental and equipment performance criteria as defined within the ASOG are all categorised as normal;
- ◆ The vessel could maintain position in the prevailing environmental conditions after the worst case failure;
- ◆ Telemetry/ESD systems necessary for offshore loading are operating normally.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;
- ◆ An advisory condition exists as defined in the ASOG;
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. Suspension of the loading operation may be required (ESD1) and relevant preparations should be made.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ The vessel's position keeping performance is deteriorating or unstable;
- ◆ The vessel would be unable to maintain position in the prevailing environmental conditions after the worst case failure;
- ◆ A 'yellow' condition exists as defined in the ASOG for abnormal operational, environmental and equipment performance conditions;
- ◆ Any other condition exists which may lead to a suspension of loading activities.

Emergency status – RED light with accompanying distinctive alarm. Procedures should be followed for emergency shutdown, disconnection and escape (ESD2).

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control or to safely conduct the loading operation;
- ◆ A 'red' condition exists as defined in the ASOG for hazardous operational, environmental and equipment performance criteria;
- ◆ Any other emergency situation exists that warrants immediate shutdown of loading and possible disconnection and escape.

A9-3.6 Responsibilities

Effective co-operation and understanding between all personnel involved in offshore loading operations should be achieved by providing personnel with adequate information about all relevant aspects of the operation. In all cases the proposed operation should be discussed beforehand by the appropriate personnel and an interface document should be prepared.

The master of the shuttle tanker is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid commencement of loading, including in conditions where operational limits defined in ASOGs have not been exceeded. The master is responsible for ensuring that there is effective integration of the vessel's normal operations and emergency response with the other vessels and structures involved in the operation.

The OIM of a surface production and storage facility is responsible for the operation and safety of their installation and for all personnel onboard. They are also responsible for co-ordinating all activities within the 500m safety exclusion zone and have the authority to terminate operations if it is deemed that to do so will safeguard the installation, personnel, hardware or the environment. They are also responsible for ensuring that there is effective integration of their installation's normal operations and emergency response with the other vessels and structures with which the facility interacts.

The shuttle tanker DPO is responsible for ensuring that the vessel operates within the limits specified by the ASOG and that the vessel remains in a safe position in relation to any adjacent structure or other hazard. They are responsible for implementing a change in the DP status without delay should the situation dictate and to carry out the required actions in response to that change.

Trenching Vessels

A10-1 Industrial Mission

A10-1.1 Description and Role

The primary role of the vessel is the cutting of trenches in the seabed for subsea cables and pipelines. The purpose of trenching is to bury these cables or pipelines below the seabed to protect them from hazards associated with mechanical damage and the effects of water flow.

Trenching may be conducted prior to the lay of the pipeline or cable (pre-lay), at the same time as the lay, or post-lay.

Trenching techniques include:

- ◆ ploughing – a trench is formed by towing a plough;
- ◆ jetting – the seabed is liquefied using high pressure water jets allowing an existing pipeline or cable to sink into the seabed, or the liquefied material is pumped or ducted away to form an open trench;
- ◆ mechanical cutting – rotating cutting tools cut or erode seabed materials to form a trench;
- ◆ dredging – dredging vessels such as cutter suction dredgers, bucket dredgers or trailing suction hopper dredgers remove seabed materials in advance of pipeline or cable installation.

With the exception of dredging, trenching techniques do not normally remove material from the worksite.

Trenchers may be either self-propelled or towed by the trenching vessel. The towing force required depends upon the type of trencher used and the nature of the seabed.

The trenching vessel should be capable of track-keeping whilst maintaining the correct tension in the trencher towline (where applicable).

In addition to trenching operations in open water there may be occasions where trenching is required in close proximity to fixed or floating structures or in close proximity to the shore where cables and pipelines make landfall.

Multi-purpose vessels are frequently fitted with a crane and/or A-frame to facilitate launch and recovery of trenchers. Towing winches may be required where high tensions in trencher towline are required. ROVs may be provided to support trenching activities and for seabed survey and inspection.

The consequences of loss of vessel position may include injury to personnel, damage to the vessel, pipelines, cables adjacent offshore installations as well as environmental pollution.

A10-2 Design Guidance

A10-2.1 Design Considerations

DP trenching vessels can be IMO equipment class 1, 2 or 3. Where the risks associated with an inability to maintain position are deemed critical, dynamic positioning systems should be IMO DP equipment class 2 or 3, and should not be affected by failures in industrial mission equipment. In open water the level of redundancy provided in the DP system is an operational consideration in order to protect the trencher and subsea assets from damage.

DP trenching vessels may be purpose built or multi-purpose vessels provided with a temporarily installed trenching system. The capability and equipment required by multi-purpose vessels will be determined by the trenching technique to be employed, the size, weight and launching arrangements of the trencher, the towing force required, and the water depth and environmental conditions.

Particular requirements for small draught vessels operating in shallow water should be assessed. The potential for contact between the vessel hull and the seabed should be anticipated, and precautions taken to protect hull, thrust units, rudders and seawater cooling intakes from the consequences of such contact.

The potential risks to the vessel associated with contacting the trenching device during launch and recovery should be assessed. Critical systems should be protected from the consequences of such contact.

The vessel should provide a stable platform for trenching device launch and recovery with suitable position keeping capability for the anticipated environmental conditions.

Consideration should be given to providing redundant power supplies to industrial mission specific equipment; vehicles and launch and recovery equipment.

A10-2.2 DP Capability

The vessel should be capable of following a pre-determined trenching corridor facilitating the trenching operation with continuous or incremental vessel moves at a smooth and predictable rate whilst maintaining the required tow tension (where applicable).

Position keeping accuracy requirements are dependent upon the nature of the trenching operation; self-propelled trenching machines are independent of the vessel position in terms of track accuracy. Plough trench accuracy is affected more by plough deflection caused by changing seabed density than moderate vessel track error.

Where the consequences of an inability to maintain position and/or tow tension are deemed to be critical, then the DP trenching vessel should be capable of maintaining position but not necessarily maintaining tow tension for sufficient time to safely suspend or abandon operations after the worst case failure in all anticipated operational and environmental conditions.

The thruster force required to counter any horizontal component of tow tension acting upon the vessel is additional to the thruster force required to maintain position based solely on prevailing environmental conditions. Trenching operations using self-propelled trenching machines in open water are less heading dependent, allowing the vessel heading to be chosen to minimise thruster load.

The restrictions on vessel heading imposed by trenching operations may dictate operational limits. Operations in open water are generally less heading dependent and a vessel heading may be chosen to minimise thruster load.

The DP system should be capable of rapidly adapting to changing external forces, for example variations in towing tension.

High power from the main propulsion in the surge axis may be required where significant towing forces are anticipated.

Position keeping capability plots should be developed for a variety of environmental and thruster failure conditions which include an allowance for the highest towing tension for which the vessel is designed.

A10-2.3 Control Systems

The DP control system should have features to maintain position and heading in a fixed location, relative location and following a predetermined track.

For DP equipment class 1 vessels it is recommended that an independent joystick be provided; this is a requirement for DP equipment class 2 and 3.

Where high towline tensions are anticipated then the DP control system is to be capable of maintaining position under both constant tension and variable tension conditions.

A10-2.4 Reference Systems and Sensors

At least three independent position reference systems should be in use for critical trenching operations and three heading reference systems in use for heading sensitive operations.

Acoustic systems may be required to monitor subsea vehicles/equipment as well as to act as a position reference system.

For DP equipment class 2 or 3 vessels, power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

In shallow water, or when working in close proximity to offshore installations, at least two different measurement principles should be employed for the reference systems. Consideration should be given to potential interference with seabed reference systems such as taut wire or acoustics due to strong currents, noise or suspended particles in the water column caused by the trenching operation.

In deep water and open water locations there may be a reliance on satellite based position references; satellite based systems should be sourced from different manufacturers to avoid software induced common cause failures. Independence should be provided by the separation of power supplies. Different methods for differential corrections should be employed. No single failure should result in the loss of more than one position reference system. Consideration should be given to using position reference systems in combination with inertial navigation systems to filter short term instability.

Use of acoustic beacons fitted to a self-propelled trencher machine as a relative position reference system should be avoided unless absolute reference systems are also utilised in the position calculation.

A towline tension sensor may be interfaced to the DP control system, in such cases it is essential that the tension input is accurate, redundant and reliable. This also applies to any winch used to assist particular operations. Where redundancy or fail safe cannot be demonstrated then manual input of towline tension should be considered and rapid changes in tension avoided.

A10-2.5 Power Systems

Provision of power for propulsion and trencher systems may be independent from each other or a common diesel–electric power plant.

The power management philosophy should consider the relative importance of trencher, crane and ROV systems (as appropriate) as well as dynamic positioning systems. The importance of maintaining power to trencher systems will be dependent upon the nature of the trenching operation and likelihood of damage occurring to existing cables or pipelines.

If no redundancy in power supply is provided to trenching equipment, then such systems should fail safe in the event of loss of power in order to ensure no damage can occur to existing cables or pipelines.

A10-3 Operational Guidance

A10-3.1 Operational Considerations

The following should be considered when planning DP operations:

- ◆ Depending on the technique adopted, trenching may be characterised by a relatively long time to terminate. Where trenching of an existing cable or pipeline is taking place then intervention may be required using a crane or ROV to recover the trenching machine safely;
- ◆ Environmental limits may be lower for launch and recovery of trenching devices than they are for actual trenching operations;
- ◆ Significant propulsion power may be required to maintain towline tension; this may reduce the position keeping capability in response to environmental forces;
- ◆ Availability and diversity of position references may be limited in open water and deep water when the vessel is moving during the trenching operation;
- ◆ The trenching activity may restrict choice of heading;
- ◆ Landfall and shallow water activities may be subject to more strict environmental and vessel motion limits than those for deep water and open water activities;
- ◆ Safe under-keel clearance requires careful consideration in shallow water. In addition to conventional grounding risks, thruster efficiency may be reduced and vessel pitching and rolling may reduce under-keel clearance significantly;
- ◆ Seabed position reference systems may be subject to interference or may have very limited scope in shallow water;
- ◆ Rapid changes in tow tension may cause instability in position if not accurately modelled in the DP system;
- ◆ Accurate positioning of non-self-propelled trenching equipment may be difficult if any elasticity exists in the towline system; the trenching equipment may move ahead uncontrollably when a softer seabed is encountered or may be diverted from the intended track under the influence of localised changes in seabed density. These considerations are important when operating close to other seabed infrastructure;
- ◆ The master and DPOs should be aware of the required tensions used for trenching operations and the appropriate emergency responses;
- ◆ The trenching supervisor should have instruction in the basic operation of the dynamic positioning system and the capabilities of the vessel in order to understand the potential vessel responses to requests for changes in position.

A10-3.2 Operational Planning

Where appropriate the following should be documented:

- ◆ Risk assessment for the loss of vessel position at all stages of the trenching operation and for all associated activities. This is to include the potential for changes in towline tension causing an inability to maintain position;
- ◆ Configuration for the critical activity mode of operation (CAM) or for the task appropriate mode (TAM) with specification as to which modes are required for each phase of the project;
- ◆ Activity specific operating guidelines (ASOG) to define the operational, environmental and equipment performance limits that apply during the trenching operation and give guidance on required actions in the event of these limits being exceeded.

A10-3.3 Communications

A dedicated system for communication between the operational/control centres of the trenching vessel should be provided. Such locations may consist of:

- ◆ DP control;
- ◆ engine control;
- ◆ ROV control;
- ◆ trencher control;
- ◆ crane cabin.

There should be a backup to these systems that is operable in a black out condition, both primary and backup communications should be checked as part of the DP checklists.

A10-3.4 DP Alert Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in the ASOG.

Guidance on status and responses is given below.

Normal status – GREEN light. Planned operations can be undertaken within agreed safe limits.

- ◆ The DP system is operating correctly and is configured in accordance with agreed CAM/TAM;
- ◆ Operational, environmental and equipment performance criteria as defined within the ASOG are all categorised as normal;
- ◆ The vessel would be capable of maintaining position in the prevailing environmental conditions after the worst case failure.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;
- ◆ The DP system is no longer configured as required in the CAM/TAM;
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. Personnel should suspend operations in a safe manner; preparations should be made for a controlled recovery of the trencher.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ The vessel's position keeping performance is deteriorating or unstable;
- ◆ The vessel would be unable to maintain position in the prevailing environmental conditions after the worst case failure;
- ◆ A 'yellow' condition exists as defined in the ASOG for abnormal operational, environmental and equipment performance conditions;
- ◆ Any other condition exists which may lead to a suspension of trenching operations.

Emergency status – RED light with accompanying distinctive alarm. Damage to the trenching equipment, cable or pipeline is possible; procedures for emergency recovery or abandonment of the trenching equipment should be initiated where a significant risk exists to the cable or pipeline.

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control, or to safely conduct operations;
- ◆ A 'red' condition exists as defined in the ASOG for hazardous operational, environmental and equipment performance criteria;
- ◆ Any other emergency situation which warrants immediate preparation for abandonment of the operation.

A10-3.5 Responsibilities

The vessel master is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid the start or order the termination of trenching operations, including in conditions where operational limits defined in ASOGs have not been exceeded.

If present, the offshore construction manager is responsible for the safe execution of the work to the agreed procedures. They have the authority to order the commencement and termination of work but must respect the master's authority as outlined above.

The trenching supervisor is responsible to the offshore construction manager for the safe execution of trenching operations and co-ordinating the required assets and personnel. They are responsible for keeping the DPO advised of any change of status of the trenching operation, communicating required vessel movements to the DPO and all necessary information required by the DPO to determine the required DP configuration. They should respond to changes in DP alert status immediately as required by the ASOG.

The DPO is responsible for ensuring that DP system is configured as specified in the CAM/TAM and for monitoring vessel position. The DPO is responsible for changing the DP alert status with reference to the ASOG without delay should this become necessary and for carrying out the associated actions. They are to conduct vessel movements requested by the trenching supervisor but, however, have the authority to suspend trenching operations and stop the vessel if they consider this to be necessary for the safety of the vessel, environment or personnel.

Cable Lay/Repair Vessels

AI I-1 Industrial Mission

AI I-1.1 Description and Role

The cable lay vessel's operational role is the installation, burial and maintenance of submarine communication and power cables. Cable repair includes the recovery, cutting and splicing and redeployment of submarine cables.

Cable lay operations may comprise any of the following phases:

- ◆ Cable shore landing – requiring the vessel to approach close to the shore landing position and then floating or dragging of the cable ashore. The shore landing may be either trenched or a horizontally drilled pipe which crosses under the shoreline;
- ◆ Subsea lay – using tensioners to lower cable to the seabed at a controlled speed; lowering speed and cable catenary will be dictated by seabed contours, vessel speed and the requirements of the trencher (if in use);
- ◆ Cable trenching – required in waters where the cable is vulnerable; may utilise a towed plough or water jetting machine;
- ◆ Offshore cable jointing or pull-in to offshore structure – if the cable must be jointed offshore then specialist expertise and equipment is employed. If the cable is terminated at an offshore structure then pull-in procedures are used to pull the cable end into a purpose-built guide at the base of the structure;
- ◆ Cable inspection and testing – final survey of the cable to ensure trenching has been effective, or to bury exposed and vulnerable sections.

Cable repair operations generally comprise the following:

- ◆ Grappling for and cutting the cable – a towed cutting grapnel locates, cuts and lifts the first end of the cable;
- ◆ Buoying off the first end – carried out in preparation for subsequent recovery when making the final splice;
- ◆ Grappling for the second end – a towed grapnel is used to lift the cable second end in the region where repair is required;
- ◆ Jointing – once the damaged cable section is removed, a section of spare cable of a length at least twice the water depth is joined to the second end;
- ◆ Final splice – the buoyed first end is recovered and the final splice made to the inserted spare cable. The splice is then laid to the seabed in a long loop to maintain a minimum bend radius;
- ◆ Burial – required if the final splice loop is vulnerable to damage from marine activity or strong currents.

Trenching operations may require a significant bollard pull, for further information on the requirements for DP vessels engaged in trenching operations please refer to Appendix 10.

Operations may take place in any water depth such as shallow water close to shore for shore landing and in deep ocean waters for intercontinental connections.

Cable lay may be required in close proximity to inshore or offshore structures.

Vessels may be provided with trenchers for cable burial and ROVs to facilitate survey, inspection and intervention. Cranes or A-frames may be fitted for trencher and buoy deployment and recovery.

The consequences of loss of vessel position may include injury to personnel, damage to the vessel, cables, adjacent offshore installations as well as environmental pollution. Open water and deep water operations are generally tolerant of a large vessel position footprint.

A11-2 Design Guidance

A11-2.1 Design Considerations

DP cable lay vessels can be IMO equipment class 1, 2 or 3. Where the risks associated with an inability to maintain position are deemed critical, dynamic positioning systems should be IMO DP equipment class 2 or 3, and should not be affected by failures in industrial mission equipment. In open water the level of redundancy provided in the DP system is an operational consideration in order to protect assets from damage.

High capacity cable lay vessels are generally purpose-built due to the mission-specific requirements for a long cable deck and large storage baskets or carousels for long cable lengths. Low capacity cable lay and cable repair operations may utilise multi-purpose DP vessels with sufficient open deck space for the temporary mobilisation of cable lay/repair equipment.

In shallow water there is the potential for contact between the vessel hull and the seabed. Precautions should be taken to protect hull, thrust units, rudders and seawater cooling intakes from the consequences of such contact. The ability for the vessel to sit on the seabed between tides when engaged in shore landings may be advantageous.

The potential risks to the vessel associated with contacting the trenching devices and ROVs during launch and recovery should be assessed. Critical systems should be protected from the consequences of such contact.

The vessel should provide a stable platform for trenching device and ROV launch and recovery (where applicable) with suitable position keeping capability for the anticipated environmental conditions.

A11-2.2 DP Capability

The vessel should be capable of following a pre-determined cable lay corridor facilitating the lay operation with continuous or incremental vessel moves at a smooth and predictable rate whilst maintaining the required cable catenary and tow tension (where applicable).

Position keeping accuracy requirements are dependent upon the nature of the operation; certain open water and deep water operations may tolerate a large vessel footprint.

Where the consequences of an inability to maintain position are deemed to be critical, then the vessel should be capable of maintaining position for sufficient time to safely suspend or abandon operations after the worst case failure in all anticipated operational and environmental conditions.

The thruster force required to counter any horizontal component of tow and/or cable tension acting upon the vessel is additional to the thruster force required to maintain position based solely on prevailing environmental conditions.

The restrictions on vessel heading imposed by lay operations may dictate operational limits. Operations in open water are generally less heading dependent and a vessel heading may be chosen to minimise thruster load.

The DP system should be capable of rapidly adapting to changing external forces.

Position keeping capability plots should be developed for a variety of environmental and thruster failure conditions which include an allowance for the highest towing tension for which the vessel is designed.

A11-2.3 Control Systems

The DP control system should have features to maintain position and heading in a fixed location, relative location and following a predetermined track.

For DP equipment class 1 vessels it is recommended that an independent joystick be provided, this is a requirement for DP equipment class 2 and 3.

Synchronisation of vessel movement is required with the cable lay operation (speed of lay is controlled by the cable tensioners) to maintain correct cable tension and catenary. This may utilise automated or manual speed management, if automated then the control system should be either fault-tolerant, or designed to fail in a safe manner.

A11-2.4 Reference Systems and Sensors

At least three independent position reference systems should be in use for critical cable laying operations and three heading reference systems in use for heading sensitive operations.

Acoustic systems may be required to monitor subsea vehicles/equipment as well as to act as a position reference system.

For DP equipment class 2 or 3 vessels, power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

In shallow water, or when working in close proximity to offshore installations, at least two different measurement principles should be employed for the reference systems. Consideration should be given to potential interference with seabed reference systems such as taut wire or acoustics due to strong currents, noise or suspended particles in the water column.

In deep water and open water locations where an inability to maintain position is not deemed critical there may be a reliance on satellite based position references.

A11-2.5 Power Systems

Provision of power for propulsion and cable lay and other mission systems may be independent from each other or a common diesel–electric power plant provided.

The power management philosophy should consider the relative importance of cable lay, trencher, crane and ROV systems (as appropriate) as well as dynamic positioning systems. The importance of maintaining power to trencher systems will be dependent upon the nature of the trenching operation and likelihood of damage occurring to existing cables or pipelines.

If no redundancy in power supply is provided to cable lay equipment, then such systems should fail safe in the event of loss of power in order to ensure no damage can occur to the cable.

A11-3 Operational Guidance

A11-3.1 Operational Considerations

The following should be considered when planning DP operations:

- ◆ Cable lay operations may be characterised by a short time to terminate where the cable can be cut and abandoned for future recovery. Time to restart after such abandonment may be significant;
- ◆ Time to terminate may be long if the cable is not cut, or cannot be cut part way through the lay;
- ◆ Cable lay and repair operations may tolerate a large vessel position footprint in open water and deep water;

- ◆ Significant propulsion power may be required to maintain a towline tension if trenching in conjunction with cable laying; this may reduce the position keeping capability in response to environmental forces;
- ◆ Availability and diversity of position references may be limited in open water and deep water, and when the vessel is moving during cable lay;
- ◆ Choice of heading may be restricted during cable lay;
- ◆ Shore landing and shallow water activities may be subject to more strict environmental and vessel motion limits than those for deep water and open water activities;
- ◆ Safe under-keel clearance requires careful consideration in shallow water. In addition to conventional grounding risks, thruster efficiency may be reduced and vessel pitching and rolling may reduce under-keel clearance significantly;
- ◆ Seabed position reference systems may be subject to interference or may have very limited scope in shallow water;
- ◆ Synchronisation between vessel speed and cable lay speed is required to maintain correct cable lay tension and catenary;
- ◆ The master and DPO should be aware of the procedures for cable lay and repair to the extent necessary to understand the requirements for vessel speed, cable tensions and trencher towline tensions;
- ◆ The cable lay supervisor should have instruction in the basic operation of the dynamic positioning system and the capabilities of the vessel in order that they understand the potential vessel responses to requests for changes in position.

A11-3.2 Operational Planning

Where appropriate the following should be documented:

- ◆ Risk assessment of the loss of vessel position at all stages of the cable lay operation;
- ◆ Configuration for the critical activity mode of operation (CAM) or for the task appropriate mode (TAM) with specification as to which modes are required for each phase of the project;
- ◆ Activity specific operating guidelines (ASOG) to define the operational, environmental and equipment performance limits that apply during the cable lay or repair operation and to give guidance on required actions in the event of these limits being exceeded.

A11-3.3 Communications

A dedicated system for communication between the operational/control centres of the cable lay vessel should be provided. Such locations may consist of:

- ◆ DP control;
- ◆ engine control;
- ◆ cable lay supervisor;
- ◆ ROV control;
- ◆ trencher control;
- ◆ crane cabin.

There should be a backup to these systems that is operable in a black out condition, both primary and backup communications should be checked as part of the DP checklists.

A11-3.4 DP Alert Status

For critical phases of the cable lay/repair operation a system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in the ASOG.

Guidance on status and responses is given below.

Normal status – GREEN light. Planned operations can be undertaken within agreed safe limits.

- ◆ The DP system is operating correctly and is configured in accordance with agreed CAM/TAM;
- ◆ Operational, environmental and equipment performance criteria as defined within the ASOG are all categorised as normal;
- ◆ The vessel would be capable of maintaining position in the prevailing environmental conditions after the worst case failure.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;
- ◆ The DP system is no longer configured as required in the CAM/TAM;
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. Personnel should suspend operations in a safe manner; preparations should be made for a controlled abandonment of the cable or the movement of the vessel to a safe position.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ The vessel's position keeping performance is deteriorating or unstable;
- ◆ The vessel would be unable to maintain position in the prevailing environmental conditions after the worst case failure;
- ◆ A 'yellow' condition exists as defined in the ASOG for abnormal operational, environmental and equipment performance conditions;
- ◆ Any other condition exists which may lead to a suspension of cable lay operations.

Emergency status – RED light with accompanying distinctive alarm. Damage to the cable or contact between vessel and an adjacent structure is possible; procedures for emergency abandonment of the cable should be initiated.

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control, posing a risk to vessel or cable;
- ◆ A 'red' condition exists as defined in the ASOG for hazardous operational, environmental and equipment performance criteria;
- ◆ Any other emergency situation which warrants immediate preparation for abandonment of the operation.

A11-3.5 Responsibilities

The vessel master is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid the start or order the termination of cable laying operations, including in conditions where operational limits defined in ASOGs have not been exceeded.

If present, the offshore construction manager is responsible for the safe execution of the work to the agreed procedures. They have the authority to order the commencement and termination of work but must respect the master's authority as outlined above.

The cable lay supervisor is responsible to the offshore construction manager for the safe execution of cable lay and repair operations and co-ordinating the required assets and personnel. They are responsible for keeping the DPO advised of any change of status of the cable lay or repair operation, communicating required vessel movements to the DPO and all necessary information required by the DPO to determine the required DP configuration. They should respond to changes in DP alert status immediately as required by the ASOG.

The DPO is responsible for ensuring that the DP system is configured as specified in the CAM/TAM and for monitoring vessel position. The DPO is responsible for changing the DP alert status with reference to the ASOG without delay should this become necessary and for carrying out the associated actions. They are to conduct vessel movements requested by the cable lay supervisor, however have the authority to suspend operations and stop the vessel if they consider this to be necessary for the safety of the vessel, environment or personnel.

Jack-up Vessels

A12-1 Industrial Mission

A12-1.1 Description and Role

The jack-up vessel's primary operational role is to provide a stable platform in terms of wave-induced motions as well as static position keeping in order to conduct an offshore mission activity.

Jack-up vessels may be monohull ship-shaped or barge-shaped vessels. Three or more retractable legs lift the hull above the influence of wave forces and support the weight of the vessel. The operational elevation depends upon the requirements of the mission activity.

Jack-up vessels utilise DP for approach and positioning prior to lowering and pinning of the legs.

Jack-up vessels are also called self-elevating vessels, their mission activities include:

- ◆ wind farm installation;
- ◆ drilling of oil and gas wells;
- ◆ well maintenance;
- ◆ offshore construction and decommissioning;
- ◆ accommodation.

Touch-down is the moment that the first leg makes contact with the seabed and represents the commencement of transfer of position control from the DP system to the legs. Lift-off is the moment the last leg is retracted from the seabed and represents the completion of transfer of position control from legs to the DP system.

A gangway may be fitted to facilitate personnel transfers.

Large capacity cranes are frequently fitted to support the mission activity. Other industrial mission equipment varies according to the vessel activity.

DP operations are frequently conducted in close proximity to other vessels or offshore structures prior to the lowering of the legs. High accuracy position keeping is required.

The consequences of loss of vessel position may include injury to personnel, damage to the vessel and/or adjacent offshore installations, as well as environmental pollution. Overstress of the leg structure is a significant risk during the transitions between DP and leg support if the DP system does not maintain position in relation to the seabed.

A12-2 Design Guidance

A12-2.1 Design Considerations

DP jack up vessels should comply with IMO equipment class 2 or 3.

No known single failure should result in the jack-up vessel legs becoming overstressed by the force of vessel thrusters, or uncontrolled contact occurring between the jack-up vessel and an adjacent surface or seabed structure.

The potential for damage to occur to the vessel as a result of contact between the vessel and an adjacent surface structure should be assessed and critical systems structurally protected from the consequences of such contact.

The leg design will affect the hydrodynamic response of the vessel as the legs are extended. A design which minimises these hydrodynamic effects is advantageous.

Leg jacking speed affects the exposure time to risks associated with touch-down and lift-off; higher speeds are preferred during these critical phases.

A12-2.2 DP Capability

The vessel should be capable of high accuracy positioning during the critical phases of load transfer to/from the legs and when in close proximity to the installation.

The vessel should be capable of maintaining position after worst case failure in all anticipated operational and environmental conditions long enough to safely suspend or complete operations.

Position keeping capability plots should be developed for a variety of environmental and thruster failure conditions which include an allowance for the highest towing tension for which the vessel is designed.

A12-2.3 Control Systems

The primary DP control system mode is high precision position keeping.

Specialist DP control systems may be used to minimise risk during transition from DP positioning to leg support of the vessel.

The load transfer to and from the legs during self-elevation represents a period of significant change in the DP control system vessel and environmental models. The following should be considered:

- ◆ Deploying legs towards the seabed will affect the vessel's wind and hydrodynamic profile;
- ◆ Significant thruster forces may result if there is a position error at the time of touchdown; the DP environmental model may escalate thruster forces to try to regain setpoint;
- ◆ If the thrusters remain in operation following touchdown to alleviate the stress on the legs caused by current forces on the hull then the required thrust will reduce as hull submerged area reduces during elevation;
- ◆ DP compensation for prevailing sea currents during re-floating in order to prevent drift off as at lift off requires an accurate input of the current vector prior to hull immersion. DP manufacturers may calculate a system current based on exposure to such currents over a specified time period; rapid immersion and transfer to DP does not facilitate this 'learning' process.

Since the transient phase of elevation may cause instability in position keeping and stresses on the vessel legs the DP system should be configured for automatic and rapid adaptation; alternatively the DP system manufacturer should provide instruction on the user inputs required to mitigate such instability. This may require the DPO to freeze current during touch-down, or manual input of current prior to lift-off. Manual control for the duration of such transient conditions should be avoided.

A power management system should maintain power to both DP and jacking systems and be effective for all switchboard operational configurations. Failure of the power management system should not immediately impair the vessel's ability to maintain position under equilibrium conditions.

A12-2.4 Reference Systems and Sensors

At least three independent position reference systems employing at least two different measurement principles should be used during touch-down and lift-off, and when in close proximity to surface or seabed structures.

Reference systems should minimise the risk of degradation during touch-down, changes in draught and changes in deployment depth of legs. These risks include attenuation of acoustic systems' reception, variation in relative line-of-sight measurements as hull elevation varies and protruding legs interfering with satellite systems.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

When manoeuvring clear of other vessels or structures following lift-off then a minimum of two position reference systems should be in use with a third immediately available.

At least three independent heading sensors for the DP system should be provided due to the critical nature of heading control.

At least three independent wind sensors should be provided, these should be installed in different locations to allow for local disruption of wind flow caused by leg position. Where wind sensors are mounted at different heights then information at the DP control station should be corrected to a common height.

Additional sensors may be required for specialist jack-up DP modes to address the problems outlined in section A12-2.3:

- ◆ Sea current vector sensors – to facilitate thruster compensation for the prevailing current following lift-off;
- ◆ Leg position sensors – to facilitate automatic modification of wind and hydrodynamic profile in the DP control system;
- ◆ Leg touch-down sensors – to facilitate an automatic freeze of DP model integral for environment compensation and avoid over-stressing the legs.

A12-2.5 Power Systems

Propulsion thrusters, crane and leg jacking systems may all constitute high power consumers. Propulsion power may be independent from the other significant consumers. Where a common diesel–electric power plant is provided it should be arranged to protect the DP system from the effects of faults in mission equipment.

The power management philosophy should consider the criticality of other onboard equipment and ensure that control is maintained of all operationally and safety critical systems at all anticipated loads and after the worst case failure in electrical power provision.

A12-3 Operational Guidance

A12-3.1 Reference Documents

Operational guidance for jack-up vessels is also available in the following document:

- ◆ [IMCA M 223](#) – *Guidance for the positioning of dynamically positioned (DP) jack-up vessels on and off the seabed.*

A12-3.2 Operational Considerations

The following should be considered when planning DP operations:

- ◆ Jacking operations may be subject to strict wind, wave and sea current limits. Wind forces may be high due to the size and shape of the vessel structure, and may vary significantly depending on the position of legs and cranes;
- ◆ Position instability may occur during transfer from hull buoyancy to leg support and vice versa;
- ◆ The legs may be over stressed following touch-down if thruster forces are too high;
- ◆ Transit speed will be limited if legs protrude below the vessel hull in transit; drag due to water flow may overstress the leg structure;
- ◆ Some types of position reference system may be degraded during specific phases of the jacking operation, this should be risk assessed prior to starting elevation;

- ◆ An emergency vessel escape route should always be planned;
- ◆ The joystick may be used following lift-off if position keeping is unstable;
- ◆ Significant changes in vessel stability occur due to the change in position of the centre of gravity of the legs during the jacking process;
- ◆ Seabed stability and topography should be assessed prior to any project; general feasibility studies, including checks for punch-through resistance and fatigue may be required;
- ◆ The master and each DPO should be aware of the hazards associated with touch-down and lift-off, and the appropriate emergency responses following failures;
- ◆ The leg jacking control operator should have instruction in the basic operation of the DP system and the vessel's capabilities so as to understand the potential vessel responses during periods of touch-down and lift-off.

A12-3.3 Operational Planning

Where appropriate the following should be documented:

- ◆ Risk assessment of the loss of vessel position at all stages of the operation and for all associated activities, all realistic failures should be analysed by a project specific risk assessment and project procedures developed as necessary;
- ◆ Configuration for the critical activity mode of operation (CAM) or for the task appropriate mode (TAM) with specification as to which modes are required for each phase of the operation;
- ◆ Activity specific operating guidelines (ASOG) to define the operational, environmental and equipment performance limits that apply during the jacking operation and give guidance on required actions in the event of these limits being exceeded.

A12-3.4 Communications

A dedicated system for communication between the operational/control centres of the vessel should be provided. Such locations may consist of:

- ◆ DP control;
- ◆ engine control;
- ◆ leg jacking control;
- ◆ crane cabin;
- ◆ adjacent installation control room (if applicable).

There should be a backup to these systems that is operable in a black out condition, both primary and backup communications should be checked as part of the DP checklists.

A12-3.5 DP Alert Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in the ASOG.

Guidance on status and responses is given below.

Normal status – GREEN light. Planned operations can be undertaken within agreed safe limits.

- ◆ The DP system is operating correctly and is configured in accordance with agreed CAM/TAM;
- ◆ Operational, environmental and equipment performance criteria as defined within the ASOG are all categorised as normal;
- ◆ The vessel would be capable of maintaining position in the prevailing environmental conditions after the worst case failure.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;
- ◆ The DP system is no longer configured as required in the CAM/TAM;
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. Personnel should suspend operations in a safe manner; preparations should be made for abandoning the approach to the jacking position. Under certain circumstances following touch-down it may be deemed safer to continue with the jacking operation rather than attempt to lift-off and escape.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ The vessel's position keeping performance is deteriorating or unstable;
- ◆ The vessel would be unable to maintain position in the prevailing environmental conditions after the worst case failure;
- ◆ A 'yellow' condition exists as defined in the ASOG for abnormal operational, environmental and equipment performance conditions;
- ◆ Any other condition exists which may lead to a suspension of approach or jacking.

Emergency status – RED light with accompanying distinctive alarm. Damage to the legs or contact with the adjacent structure is possible; procedures for emergency jacking to stabilise position, or escape into open/deeper water should be initiated.

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control, or to safely conduct operations;
- ◆ A 'red' condition exists as defined in the ASOG for hazardous operational, environmental and equipment performance criteria;
- ◆ Any other emergency situation which warrants immediate action.

A12-3.6 Responsibilities

The vessel master is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid the start or order the termination of jack-up operations, including in conditions where operational limits defined in the ASOG has not been exceeded. They are also responsible for ensuring the compatibility of the vessel's safety management system with that of any installations with which it will work.

If present, the offshore construction manager is responsible for the safe execution of the work to the agreed procedures. They have the authority to order the commencement and termination of work but must respect the master's authority as outlined above.

The client's onboard representative is responsible for ensuring the performance of the work is in accordance with the contract, they should have the authority to veto the start of operations by direct communication with the master or offshore construction manager.

The DPO is responsible for ensuring that the DP system is configured as specified in the CAM/TAM and for monitoring vessel position. The DPO is responsible for changing the DP alert status with reference to the ASOG without delay should this become necessary and for carrying out the associated actions. They have the authority to suspend operations and stop the vessel if they consider this to be necessary for the safety of the vessel, environment or personnel.

Offshore Supply Vessels (OSV)

A13-1 Industrial Mission

A13-1.1 Description and Role

The offshore supply vessel's (OSV) operational role is the transfer of deck, dry-bulk or liquid cargoes and equipment offshore to fixed or floating vessels and installations.

OSVs primarily support offshore accommodation, drilling and production facilities and construction and pipelay vessels.

OSVs traditionally maintained position using manual controls during cargo transfer, as station keeping accuracy was usually not critical. However dynamic positioning improves station keeping accuracy and reduces the risk of human error during protracted operations.

OSVs have a large open deck area, and bulk storage tanks below decks. Specialist cargo transfer equipment is used for transfer of bulk powder and liquid cargoes. Deck cargoes are transferred by the receiving facility's cranes.

OSVs may be provided with equipment to fulfil additional industrial roles including deck cranes, anchor handling and towing winches, oil recovery systems, firefighting monitors and ROV systems however the primary role will be offshore supply.

Mission activities include transit to and from the shore supply base and loading/discharging at that base. DP is only utilised during the offshore cargo transfer activities.

Environmental limits may relate to DP position keeping capability, or to vessel motions caused by the sea state.

The consequences of loss of vessel position may not be significant if the vessel is working in a blow-off position without hoses connected to the receiving installation/vessel, in such a position however there would be potential pollution if hoses were connected. If the inability to maintain position results in contact with the receiving installation/vessel then the consequences can be serious in terms of safety of people, the vessel, installation and environmental pollution.

A13-2 Design Guidance

A13-2.1 Design Considerations

DP OSVs may be IMO equipment class 1, 2 or 3. When required to work in close proximity to offshore installations where the consequences of an inability to maintain position are high, all systems necessary for dynamic positioning should be fault-tolerant, i.e. IMO DP equipment class 2 or 3. No known single failure should result in the vessel coming into contact with an adjacent offshore structure, mooring line or other vessel.

The proposed size of the OSV requires careful consideration. Larger vessels may have greater cargo capacity, better station keeping capability and lower vessel motions in response to the sea state; however these benefits should be balanced against the potentially greater consequences of contact with the adjacent vessel due to the increased mass, and against any vessel size restrictions imposed by the associated port.

As OSVs spend only a small proportion of their operational time on DP, operational windows for maintenance of DP equipment are frequent, and vessels make regular port calls allowing rapid receipt of spares and technical support.

A13-2.2 DP Capability

The DP vessel is required to maintain a static position in relation to the receiving installation/vessel. The environmental envelope for station keeping capability is determined by the expected environmental conditions and acceptable vessel downtime resulting from these environmental conditions.

The vessel should be capable of a controlled termination of operations following a single worst case failure.

Except for the approach to the receiving installation/vessel operations are not heading dependent and a heading which minimises vessel motion and/or thruster load can be adopted.

Position keeping capability plots should be developed for intact and worst case failure conditions.

[182 MSF](#) – *International guidelines for the safe operation of dynamically positioned offshore supply vessels* – describes three capability classes for OSVs along with recommendations for where each should be employed.

A13-2.3 Control Systems

The DP control system should have features to maintain position and heading in a fixed and relative location.

For DP equipment class 1 vessels it is recommended that an independent joystick be provided, this is a requirement for DP equipment class 2 and 3.

A13-2.4 Reference Systems and Sensors

At least three independent position reference systems should be provided, when in close proximity to structures and installations they should employ at least two different measurement principles.

At least two relative position reference systems should be provided when working alongside floating structures/vessels.

OSVs are commonly provided with two satellite based position references. Where interference from adjacent structures may prevent such systems working then alternative reference systems should be provided to prevent position errors caused by such interference.

Contractual requirements and risk assessment will influence the number and type of position references required for specific locations. Additional guidelines may be found in [182 MSF](#).

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

The DP control system should incorporate a feed forward signal to compensate for potential reaction forces from firefighting monitors (where fitted) if it is intended to operate the vessel in DP whilst using the monitors, otherwise station keeping may become unstable.

A13-2.5 Power Systems

An OSV will typically spend only a small proportion of its time on DP; the majority of time being spent in transit; the desire to maximise efficiency for all operational activities may influence the choice of power plant.

Provision of power for propulsion and other systems may be independent from each other, use power take off shaft generators or utilise a common diesel–electric power plant. Where a common diesel–electric power plant is used then this is to be arranged to protect the DP system from the effects of faults in mission equipment.

OSVs may have heavy industrial consumers associated with bulk and liquid cargo transfers. The power management philosophy should consider the criticality of onboard equipment and

ensure that control is maintained of all operationally and safety critical systems at all anticipated loads and after the worst case failure in electrical power provision.

A13-3 Operational Guidance

A13-3.1 Reference Documents

Detailed operational guidance for offshore supply vessels is available in the following documents:

- ◆ [182 MSF](#) – *International guidelines for the safe operation of dynamically positioned offshore supply vessels*;
- ◆ Marine Safety Forum, et al – *Guidelines for Offshore Marine Operations (GOMO)*.

A13-3.2 Operational Considerations

The following should be considered when planning DP operations:

- ◆ Supply operations are frequently characterised by a very short time to terminate however this will increase if hoses are connected;
- ◆ Vessel operational limits should be determined by risk assessment;
- ◆ The capability, environmental limits and reliability required from the DP system will be influenced by the risk assessment for an inability to maintain position;
- ◆ Operational limits in excess of the vessel's capability following worst case failure may be allowable if the time to terminate is very short, there is a clear escape route in a blow-off position and where the risk assessment demonstrates a tolerable risk.

A13-3.3 Communications

A robust and reliable system for communication between the vessel control centres and personnel involved in cargo operations should be provided, including for:

- ◆ DP control;
- ◆ engine control;
- ◆ OSV deck;
- ◆ receiving installation/vessel; control room/bridge;
- ◆ receiving installation/vessel; crane driver;

Communications should be tested as part of the DP checklist.

A13-3.4 DP Alert Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in the ASOG.

Guidance on status and responses is given below.

Normal status – GREEN light. Supply operations can be undertaken within agreed safe limits.

- ◆ The DP system is operating correctly;
- ◆ Operational, environmental and equipment performance criteria are all categorised as normal.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;

- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. Supply operations should be suspended.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position
- ◆ A situation has developed or incident occurred that risks the vessel losing position;
- ◆ Operational, environmental and equipment performance limits have been reached;
- ◆ Any other condition exists which may lead to a suspension of activities.

Emergency status – RED light with accompanying distinctive alarm. If connected emergency disconnection of hoses should be initiated and vessel should terminate operations.

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control;
- ◆ Operational, environmental and equipment performance limits have been exceeded;
- ◆ Any other emergency situation which requires immediate departure of the OSV.

A13-3.5 Responsibilities

The vessel master is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid the start or order the termination of supply operations, including in conditions where operational limits have not been exceeded.

The DPO is responsible for ensuring that the vessel operates within the agreed limits and that the vessel remains in a safe position in relation to adjacent structures or other hazards. They are responsible for implementing a change in the DP alert status without delay should the situation dictate and for carrying out the associated actions.

Anchor Handling Vessels (AHV)

A14-1 Industrial Mission

A14-1.1 Description and Role

The anchor handling vessel's (AHV) operational role is the deployment and recovery of anchors for floating offshore facilities. Considerable caution needs to be exercised when utilising DP for anchor handling to compensate for outboard tension caused by the anchor line. AHVs may also be called anchor handling tugs (AHTs).

AHVs may also undertake other activities:

- ◆ Towing floating facilities to their intended location prior to running anchors and towing cargo barges to offshore construction sites; towing activities do not generally utilise DP;
- ◆ Hold-back activities such as acting as a brake during shuttle tanker approaches to offloading facilities, shuttle tanker heading control using taut towlines and weathervaning FPSOs when operations require a constant heading. Such activities may utilise DP;
- ◆ offshore supply operations in the same manner as OSVs. Such vessels are categorised as anchor handling tug supply vessels (AHTSs). Supply operations frequently use DP for position keeping.

AHTs or AHTSs may be provided with A-frames, oil recovery systems, firefighting monitors and ROV systems to undertake additional industrial missions however the primary role remains anchor handling.

AHVs are characterised by an open deck area aft, with separate winches for anchor handling work wires and towing wires located abaft the accommodation.

AHVs often operate in areas susceptible to strong currents and large wave and wind forces, environmental limits may relate to DP position keeping capability, or to vessel motions caused by the sea state.

Anchor handling activities take place in both shallow and deep water – maximum depth of water for anchor handling activities is limited by the capability of AHVs and the anchoring equipment.

The consequences of loss of vessel position are dependent on the nature of the operation being conducted. The most critical activities occur when operating in close proximity to another vessel or installation. An inability to maintain position during heading control operations may be a significant risk if maintaining heading is critical for parallel activities; such risks may be mitigated by the use of more than one AHT.

A14-2 Design Guidance

A14-2.1 Design Considerations

DP AHVs may be DP equipment class 1, 2 or 3. When required to work in close proximity to offshore installations where the consequences of an inability to maintain position are high, all systems necessary for dynamic positioning should be fault-tolerant, i.e. IMO DP equipment class 2 or 3. No known single failure should result in the vessel coming into contact with an adjacent offshore structure, mooring line or other vessel.

A14-2.2 DP Capability

The vessel is required to maintain a static position during DP operations. When there is a requirement to maintain a tension in anchor handling or tow wire then the vessel must be capable of delivering sufficient thrust to maintain tension and vessel position simultaneously.

The vessel should be capable of a controlled termination of operations following a single worst case failure however where a large proportion of available thrust is in use to maintain wire tension it may be impractical to require that equilibrium conditions are maintained after worst case failure. A risk assessment should determine whether an inability to maintain position is acceptable or whether release of line tension is preferable in order to maintain position and heading.

The thruster force required to counter any horizontal component of tow/catenary tension acting upon the vessel is additional to the thruster force required to maintain position based solely on prevailing environmental conditions.

High power from the main propulsion in the surge axis are a characteristic of AHVs.

Position keeping capability plots should be developed for a variety of environmental and thruster failure conditions which include an allowance for the highest tow/catenary tension for which the vessel is designed when in DP mode.

A14-2.3 Control Systems

The DP control system should have features to maintain position and heading in a fixed location, relative location and following a predetermined track.

Where high towline tensions are anticipated then the DP control system is to be capable of maintaining position under both constant tension and variable tension conditions.

For DP equipment class 1 vessels it is recommended that an independent joystick be provided, this is a requirement for DP equipment class 2 and 3.

A14-2.4 Reference Systems and Sensors

At least three independent position reference systems should be provided, when in close proximity to structures and installations they should employ at least two different measurement principles.

At least two relative position reference systems should be provided when working alongside floating structures/vessels.

Tension sensors for anchor handling and towing winches should be interfaced to the DP system where such tensions are likely to affect position keeping.

External force inputs to DP are to be accurate and reliable; sudden failure may have an impact on position keeping performance and stability.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

The DP control system should incorporate a feed forward signal to compensate for potential reaction forces from firefighting monitors (where fitted) if it is intended to operate the vessel in DP whilst using the monitors, otherwise station keeping may become unstable.

A14-2.5 Power Systems

Power systems on AHVs are intended to maximise bollard pull in the surge axis. Flexible power system designs may be used to provide economical operation for activities where high bollard pull is not required.

AHVs may have heavy industrial consumers associated with the anchor handling and towing winches. Consideration should be given to incorporating power management/blackout prevention

that will shed or phase-back such industrial consumers in favour of the thrusters in the event of insufficient power being available to maintain position.

A14-3 Operational Guidance

A14-3.1 Reference Documents

Operational guidance for anchor handling vessels is also available in the following document:

- ◆ Marine Safety Forum, et al – *Guidelines for Offshore Marine Operations (GOMO)*.

A14-3.2 Operational Considerations

The following should be considered when planning DP operations:

- ◆ Anchor handling operations are most frequently characterised by a short time to terminate as winch loads can be released quickly, the consequences of rapid termination will vary according to the stage of the operation in progress;
- ◆ Vessel operational limits should be determined by risk assessment;
- ◆ The capability, environmental limits and reliability required from the DP system will be influenced by the risk assessment for an inability to maintain position;
- ◆ Operational limits in excess of the vessel's capability following worst case failure may be allowable if the time to terminate is very short, there is a clear escape route in a blow-off position and where the risk assessment demonstrates a tolerable risk;
- ◆ In most mission activities tow tension may be reduced to assist position keeping however the criticality of towing tension should be understood and if necessary operational limits adopted to ensure tow tension can be maintained after worst case failure.

A14-3.3 Communications

A reliable and robust dedicated communication system should be available between each vessel engaged in anchor handling operations and the co-ordinating unit.

A telemetry link to monitoring vessels and anchor positions may be installed to simplify communications and enhance situational awareness.

A robust and reliable system for communication between the vessel control centres and personnel involved in operations should be provided, including for:

- ◆ DP control;
- ◆ engine control;
- ◆ towing winch control;
- ◆ AHT deck;

Communications should be tested as part of the DP checklist.

A14-3.4 DP Alert Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in the ASOG.

Guidance on status and responses is given below.

Normal status – GREEN light. Planned operations can be undertaken within agreed safe limits.

- ◆ The DP system is operating correctly;

- ◆ Operational, environmental and equipment performance criteria are all categorised as normal.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. Anchor handling operations should be suspended.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ A situation has developed or incident occurred that risks the vessel losing position;
- ◆ Operational, environmental and equipment performance limits have been reached;
- ◆ Any other condition exists which may lead to a suspension of activities.

Emergency status – RED light with accompanying distinctive alarm. Emergency actions may vary depending on nature of operation being performed.

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control;
- ◆ Operational, environmental and equipment performance limits have been exceeded;
- ◆ Any other emergency situation exists.

A14-3.5 Responsibilities

The vessel master is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid the start or order the termination of anchor handling operations, including in conditions where operational limits have not been exceeded.

The DPO is responsible for ensuring that the vessel operates within the agreed limits and that the vessel remains in a safe position in relation to adjacent structures or other hazards. They are responsible for implementing a change in the DP alert status without delay should the situation dictate and for carrying out the associated actions.

Well Stimulation Vessels

A15-1 Industrial Mission

A15-1.1 Description and Role

The vessel's operational role is to facilitate oil or gas well intervention to restore or enhance productivity. Stimulation may comprise hydraulic fracturing treatment or matrix treatment.

Well stimulation vessels have facilities for chemicals storage, blending and pumping. High pressure hoses are generally fitted on reels on the stern of the vessel for connection to the well bore.

Well stimulation operations are usually conducted by connecting to the well through a Christmas tree on surface installation, requiring the vessel to be positioned in close proximity to the installation for prolonged periods.

Environmental limits may be determined by the DP position keeping capability, or by vessel motions caused by the sea state.

The consequences of loss of vessel position depend upon the location of the vessel in relation to surface structures and whether the vessel is connected to the well. Pollution from well stimulation acids may result if hoses are damaged. Injury to personnel and severe damage to the vessel or surface structure may occur in the event of an inability to maintain position leading to collision.

A15-2 Design Guidance

A15-2.1 Design Considerations

Well stimulation vessels should comply with IMO DP equipment class 2 or 3.

Well stimulation vessels may be purpose built or converted vessels. OSVs may be temporarily fitted with well stimulation equipment; in such cases the well stimulation consumers will be independent of vessel power.

As well stimulation hoses are usually fitted on the stern and the preferred vessel position when working alongside a surface structure is blow-off the vessel will be required to operate stern-on to prevailing seas. It is therefore advantageous for the vessel stern design to be suited to stern seas to minimise vessel motion.

A15-2.2 DP Capability

The primary DP mode is static position keeping. Heading will, where practicable, be in line with the environmental forces to minimise thrust in the sway axis.

The vessel should be capable of a controlled termination of operations following worst case failure.

Position keeping capability plots should be developed for intact and worst case failure conditions.

A15-2.3 Control Systems

The DP control system should have features to maintain position and heading in a fixed location.

The power management systems should ensure that power and vessel propulsion systems are capable of rapidly changing load when operating in DP.

A15-2.4 Reference Systems and Sensors

At least three independent position reference systems should be provided; when in close proximity to structures and installations they should employ at least two different measurement principles.

At least two relative position reference systems should be provided when working alongside floating structures/vessels. Where relative reference systems are susceptible to interference (for example from cranes, structures and environmental conditions) then the potential for loss of position references should be risk assessed and suitable alternatives provided.

Well stimulation vessels are commonly provided with two satellite based position references. Where interference from adjacent structures may prevent such systems working then alternative reference systems should be provided to prevent position errors caused by such interference.

Contractual requirements and risk assessment will influence the number and type of position references required for specific locations.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

A15-2.5 Power Systems

Provision of power for propulsion may be independent from other significant consumers. Where a common diesel–electric configuration is adopted then DP systems need to be protected from faults in mission equipment and the power plant needs to be capable of responding to high transient loads.

The power management philosophy should consider the criticality of onboard equipment and ensure that control is maintained of all operationally and safety critical systems at all anticipated loads and after the worst case failure in electrical power provision.

A15-3 Operational Guidance

A15-3.1 Operational Considerations

The following should be considered when planning DP operations:

- ◆ Well stimulation operations usually have a short time to terminate. Hoses will generally be provided with emergency quick releases however time to restart after a quick release may be significant. A controlled termination of pumping and disconnection of hoses will generally require assistance from the adjacent installation;
- ◆ The vessel should be capable of a controlled termination of operations following a single worst case failure. A risk assessment should determine the environmental operating limits for the vessel and the acceptable position excursion limit;
- ◆ Availability and diversity of position reference systems should be suitable for the specific operational location.

A15-3.2 Operational Planning

Where appropriate the following should be documented:

- ◆ Risk assessment of the loss of vessel position at all stages of operations;
- ◆ Interface document between the installation and the well stimulation vessel;
- ◆ Configuration for the critical activity mode of operation (CAM) giving guidance to the crew for the most robust fault-tolerant configuration of DP critical systems. Task appropriate configuration (TAM) for operations where an inability to maintain position may constitute a lesser risk;

- ◆ Activity-specific operational guidelines (ASOG) defining the operational, environmental and equipment performance limits that apply during well stimulation operations, including details of actions to be taken in the event of any of the defined limits being exceeded;
- ◆ Operational limits, including the minimum acceptable separation between the well stimulation vessel and adjacent installations, allowable environmental limits for weather side and leeward working, and position excursion limits whilst on DP.

A15-3.3 Communications

A dedicated communication system should be provided between the vessel control stations and key well stimulation and working areas, including:

- ◆ DP control;
- ◆ engine control;
- ◆ well stimulation control;
- ◆ installation control room.

There should be a backup to these systems that is operable in a black out condition, both primary and backup communications should be checked as part of the DP checklists.

A15-3.4 DP Alert Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in the ASOG.

Guidance on status and responses is given below.

Normal status – GREEN light. Planned operations can be undertaken within agreed safe limits.

- ◆ The DP system is operating correctly and is configured in accordance with agreed CAM/TAM;
- ◆ Operational, environmental and equipment performance criteria as defined within the ASOG are all categorised as normal;
- ◆ The vessel would be capable of maintaining position in the prevailing environmental conditions after the worst case failure.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;
- ◆ The DP system is no longer configured as required in the CAM/TAM;
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. Personnel should suspend operations in a safe manner; preparations should be made for a controlled disconnection of the well stimulation hoses.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ The vessel's position keeping performance is deteriorating or unstable;
- ◆ The vessel would be unable to maintain position in the prevailing environmental conditions after the worst case failure;
- ◆ A 'yellow' condition exists as defined in the ASOG for abnormal operational, environmental and equipment performance conditions;
- ◆ Any other condition exists which may lead to a suspension of activities.

Emergency status – RED light with accompanying distinctive alarm. Emergency disconnection of the well stimulation hoses and departure from the installation safety zone.

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control;
- ◆ A 'red' condition exists as defined in the ASOG for hazardous operational, environmental and equipment performance criteria;
- ◆ Any other emergency situation which warrants immediate departure from the adjacent installation.

A15-3.5 Responsibilities

The vessel master is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid the start or order the termination of well stimulation operations, including in conditions where operational limits have not been exceeded.

The DPO is responsible for ensuring that the vessel operates within the agreed limits and that the vessel remains in a safe position in relation to adjacent structures or other hazards. They are responsible for implementing a change in the DP alert status without delay should the situation dictate and for carrying out the associated actions.

The well stimulation supervisor is responsible for the safe execution of well stimulation operations and for co-ordinating communications between the vessel and installations with which the vessel is working. They are responsible for implementing a controlled or emergency shutdown and release of well stimulation hoses upon communication of a change of DP status (unless emergency shutdown control has been delegated to the DP).

Rock Placement Vessels

A16-I Industrial Mission

A16-I.1 Description and Role

The vessel's operational role is the subsea installation of rocks or aggregates.

Rock placement vessels may also be referred to as rock dumping vessels or subsea rock installation (SRI) vessels.

Rock placement may be required to facilitate:

- ◆ Seabed preparation – stabilisation or levelling of the seabed prior to pipeline, gravity base or jack-up installation;
- ◆ Scour protection – where water flow can erode the supporting seabed;
- ◆ Subsea infrastructure protection – where activities such as fishing or anchoring, or risks of dropped objects could damage subsea assets;
- ◆ Subsea infrastructure stabilisation – where external or internal forces could result in movement of a subsea pipeline;
- ◆ Thermal insulation – to minimise temperature gradients between subsea pipelines and the environment.

DP rock placement vessels fall into two categories:

- ◆ Side stone dumping vessels (SSDV) operate up to around 50m water depth. Rock is discharged over the side and falls freely to the seabed;
- ◆ Fall pipe vessels (FPV) operate in deeper water up to around 2500m. Rock is discharged via a large bore rigid or flexible pipe to a position immediately above the installation site. Flexible fall pipe vessels (FFPV) may control the position of the lower end of the pipe using an ROV.

Rock placement vessels require storage for large amounts of bulk rock or aggregate. Discharging equipment such as conveyor belts, cranes or diggers remove the rocks and aggregates from the storage hold to the discharge hopper or chute.

Operations are mainly in open water, but it may also be necessary to operate in close proximity to surface structures.

Rock placement facilities may be fitted to a multi-purpose vessel to support a single mission activity.

Rock placement vessels are usually required to position themselves directly above the rock installation site. If a lateral offset is required due to the proximity of a surface obstruction then a limited reach may be obtained by means of a subsea rock installation (SRI) fitted with a laterally supported inclined chute. Flexible fall pipe vessels in deep water may also be able to obtain a lateral offset of the fall pipe by means of the fall pipe ROV.

Vessels may operate in locations subjected to strong currents and large wave and wind forces. Operational limits may be defined by:

- ◆ DP capability in the prevailing environmental conditions;
- ◆ The current flow rate: strong currents may cause a wide dispersal of rock dropped from a SSDV or damage the fall pipe of a FPV;
- ◆ Heave motions of FFPVs: vertical acceleration may damage the fall pipe or cause the fall pipe ROV to come into contact with the seabed or seabed infrastructure.

The consequences of an inability to maintain position in open water are generally low unless equipment vulnerable to damage from rock dumping is located in close proximity to the installation site. When operating in close proximity to surface structures then consequences may also include injury to personnel and significant damage to vessel/asset arising from a collision.

A16-2 Design Guidance

A16-2.1 Design Considerations

Rock placement vessels may be IMO DP class 1, 2 or 3. When required to work in close proximity to offshore surface structures and/or where an inability to maintain position poses a risk of collision then they should be IMO DP equipment class 2 or 3. If environmental forces will cause the vessel to drift off in the event of propulsion failure then this may be considered as risk mitigation in a risk assessment.

Where vessel operations will only be exposed to low consequences if position is not maintained then the level of redundancy is an operational consideration.

For vessels at risk of contacting adjacent structures, critical DP systems and equipment should be protected from the consequences of such contact. Water ingress into a single compartment following contact should not result in sufficient change in trim or list to cause uncontrolled loss of equipment or rock cargo overboard.

In DP equipment class 2 and 3 vessels, fault-tolerant or fail safe designs should also be considered for fall pipe deployment equipment, fall pipe heave compensation and fall pipe ROVs where risks associated with failure cannot be mitigated by operational procedures. Consideration should also be given to providing redundant power supplies for certain industrial mission equipment such as fall pipe ROVs and fall pipe deployment and recovery equipment.

Thruster and main propulsion arrangements should provide sufficient dynamic positioning capability for the anticipated environmental conditions and suitable transit speed, taking into consideration the rock cargo capacity of the vessel and transit speed requirements.

Increased cargo capacity will reduce the number of times the vessel is required to load cargo but will increase the potential momentum forces which may pose a risk to adjacent structures if position is lost.

DP rock placement vessels may be converted from existing bulk cargo carriers or other offshore support vessel types, but are generally built specifically for rock placement operations.

The vessel should provide a stable platform for the safe operation of rock discharging equipment with suitable position keeping capability for the anticipated environmental forces in the geographic area of operation.

A16-2.2 DP Capability

The DP vessel may be required to maintain a static position in relation to the seabed, or to follow a predetermined track when performing inspection or survey. FFPVs should be capable of maintaining a position relative to the fall pipe ROV where the ROV is used to follow the intended installation route.

Relative location DP operations may require a rapid change in vessel speed and direction; as rock placement vessels are likely to have a high inertial mass, thruster power should be effective for starting and stopping vessel moves smoothly and rapidly.

Capability following worst case failure may not be an important consideration if the time to terminate the operation is very short.

SSDVs need to be capable of maintaining a heading parallel to the installation track. For FFPVs operations are not heading-dependent except where approaching and in close proximity to surface structures and a heading to minimise thruster loads may be adopted.

Position keeping capability plots should be developed for intact and worst case failure conditions.

A16-2.3 Control Systems

The DP control system should have features to maintain position and heading in a fixed location, relative location and following a predetermined track. Desirable features of the DP control system include those to enable the vessel to maintain a constant position offset in relation to the fall pipe ROV.

Where the drag of the fall pipe in the water column is significant then these forces should be modelled in the DP control system.

Where vessel draught is expected to change significantly during the rock installation process the DP control system hydrodynamic, wind profile and thruster efficiency models should be developed for a variety of vessel draughts to enable accurate positioning throughout the operation. Where possible these models should be utilised automatically as draught changes.

The power management systems should ensure that power and vessel propulsion systems are capable of rapidly changing load when starting and stopping position moves.

High transient loads of industrial mission equipment should be anticipated and should not reduce the power which is available for dynamic positioning.

Automation and control systems fitted for other vessel systems such as the ballast system and rock installation equipment should be independent from the DP control system and designed so that failure or incorrect operation of such systems cannot affect DP system integrity.

For DP equipment class 1 vessels it is recommended that an independent joystick be provided; this is a requirement for DP equipment class 2 and 3.

A16-2.4 Reference Systems and Sensors

At least three independent position reference systems should be provided for critical activities and when in close proximity to structures and installations. When in close proximity to structures or installations they should employ at least two different measurement principles, one of which should be a relative reference between the vessel and adjacent installation/structure.

The availability and diversity of position reference systems in open water when engaged in a follow-target mode may be limited.

Where relative reference systems are susceptible to interference (for example from cranes, structures and environmental conditions) then the potential for loss of position references should be risk assessed and suitable alternatives provided.

The use of the fall pipe ROV acoustic beacon as a 'fixed' position reference to facilitate a constant offset between vessel and ROV should be avoided as this would necessitate the use of a single reference in the DP system and risk unexpected high vessel power demand in the event of rapid ROV changes in speed or direction.

In deep water or when engaged in relative location DP mode in open water a reliance on satellite based position references may be acceptable if the risk associated with an inability to maintain position is low. Such allowable configurations should be clearly documented in the CAM/TAM.

Acoustic position reference systems are frequently used to track mobile ROV beacons, the number of beacons interrogated and frequencies used should be selected so as to minimise the potential for interference with DP position references. The potential for acoustic noise associated with rock installation operations to interfere with acoustic position references should be minimised by appropriate placement of sensors.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

A16-2.5 Power Systems

Rock placement system power demands are generally not significant in relation to propulsion power demand.

Provision of power for propulsion and rock placement systems may be independent from each other, utilise power take off shaft generators or utilise a common diesel–electric power plant.

In order to facilitate a controlled termination of the rock placement operation in the event of a failure in vessel power, consideration should be given to provision of redundancy in the power supply to fall pipe recovery systems. Alternatively, the systems should fail safe in the event of loss of power supply in order to ensure no sudden dropping of the fall pipe or rock cargo.

The power management philosophy should consider the criticality of onboard equipment and ensure that control is maintained of all operationally and safety critical systems at all anticipated loads and after the worst case failure in electrical power provision.

A16-3 Operational Guidance

A16-3.1 Operational Considerations

The following should be considered when planning DP operations:

- ◆ Rock placement operations generally have a very short time to terminate. Providing the vessel and fall pipe ROV are clear of adjacent structures then a loss of DP control leading to an inability to maintain position may not have serious consequences. Recovery of the fall pipe may be protracted but can usually be achieved;
- ◆ In low risk, open water operations it may not be necessary for the DP system to be configured to be fault-tolerant (TAM);
- ◆ In open water operations the vessel will generally be able to adopt a heading to minimise vessel motions or thruster load;
- ◆ DPOs should understand the effects of significant changes in draught on the DP control system;
- ◆ The effects of currents in the water column between the vessel and the seabed installation site may impose different forces on the fall pipe at different depths; these forces may impact vessel position keeping, or with flexible fall pipes may result in the vessel being significantly offset from the position of the fall pipe discharge. Significant current shear forces may result in distortions in a flexible fall pipe causing blockages of rock materials;
- ◆ Environmental limits may be dictated by vessel motion rather than position keeping capability;
- ◆ When rock placement is required in close proximity to a surface obstruction then techniques should be adopted that allow a safe separation to be maintained between the vessel and the obstruction; depending on the water depth, lateral chutes or flexible fall pipes may allow the vessel to maintain an offset from the installation location. Vessel approach closer than 10m to the obstruction should be avoided, except where suitable mitigating measures determined by risk assessment have been implemented (such as installation of fenders).

A16-3.2 Operational Planning

Where a loss in vessel position poses a hazard to personnel, to the vessel or to the environment the following should be documented (where appropriate):

- ◆ Risk assessment of the loss of vessel position;
- ◆ Configuration for the critical activity mode of operation (CAM) giving guidance to the crew for the most robust fault-tolerant configuration of DP critical systems. Task appropriate configuration (TAM) for operations where an inability to maintain position may constitute a lesser risk;

- ◆ Activity-specific operational guidelines (ASOG) defining the operational, environmental and equipment performance limits that apply during operations, including details of actions to be taken in the event of any of the defined limits being exceeded

A16-3.3 Communications

A dedicated communication system should be provided between the operational/control centres of the vessel, including:

- ◆ DP control;
- ◆ engine control;
- ◆ rock placement control;
- ◆ ROV control.

Where DP and ROV control stations are remote from each other provision of a 'normally open' communication link is beneficial.

There should be a backup to these systems that is operable in a black out condition, both primary and backup communications should be checked as part of the DP checklists.

A16-3.4 DP Alert Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in the ASOG.

Guidance on status and responses is given below.

Normal status – GREEN light. Full working can be undertaken within agreed safe limits.

- ◆ The DP system is operating correctly and is configured in accordance with agreed CAM/TAM;
- ◆ Operational, environmental and equipment performance criteria as defined within the ASOG are all categorised as normal.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;
- ◆ The DP system is no longer configured as required in the CAM/TAM;
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. Rock installation operations should be suspended.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ A situation has developed or incident occurred that risks the vessel losing position;
- ◆ A 'yellow' condition exists as defined in the ASOG for abnormal operational, environmental and equipment performance conditions;
- ◆ Any other condition exists which may lead to a suspension of operations.

Emergency status – RED light with accompanying distinctive alarm. Emergency termination of rock installation and recovery of fall pipe and ROV to deck.

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control;
- ◆ A 'red' condition exists as defined in the ASOG for hazardous operational, environmental and equipment performance criteria;

- ◆ Any other emergency situation which requires immediate departure from the worksite.

A16-3.5 Responsibilities

The vessel master is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid the start or order the termination of rock placement operations, including in conditions where operational limits defined in ASOGs have not been exceeded.

If present, the offshore construction manager is responsible for the safe execution of the work to the agreed procedures. They have the authority to order the commencement and termination of work but must respect the master's authority as outlined above.

The ROV supervisor is responsible for the safe conduct of the ROV and rock placement operation. They should stay in close contact with the DPO and must request permission before deploying the fall pipe/ROV.

The DPO is responsible for ensuring that the DP system is configured as specified in the CAM/TAM and for monitoring vessel position. The DPO is responsible for changing the DP alert status with reference to the ASOG without delay should this become necessary and for carrying out the associated actions. They have the authority to suspend operations and stop the vessel if they consider this to be necessary for the safety of the vessel, environment or personnel.

Dredging Vessels

A17-1 Industrial Mission

A17-1.1 Description and Role

The vessel's role is the removal of seabed material.

Additional mission activities may include:

- ◆ seabed survey;
- ◆ transportation of dredged material;
- ◆ self-discharging of dredged material.

Dredging is conducted for the purpose of:

- ◆ pre-trenching (for pipeline or cable burial in the seabed);
- ◆ seabed levelling (such as may be required prior to installation of subsea infrastructure);
- ◆ increasing water depth (such as within navigable channels and harbours);
- ◆ land reclamation (where dredged material may be used for beach nourishment or reclamation);
- ◆ commercial extraction (such as minerals or aggregates from the seabed);
- ◆ environmental purposes (such as removal of contaminants from the seabed).

Dredgers may be propelled or non-propelled. DP dredgers are self-propelled utilising thrusters and propellers as the sole means of position keeping during dredging activities.

Dredging techniques may be broadly categorised into two groups:

- ◆ Hydraulic – material is pumped in suspension in water from the seabed;
- ◆ Mechanical – material is physically lifted from the seabed by means of buckets or grabs.

Hydraulic techniques require the seabed to be broken up to facilitate its removal in suspension, although light sands and gravel material is already loose and may be lifted by pump suction alone (e.g. trailing suction hopper dredgers (TSHD)). Denser materials may be dislodged by high pressure water jetting. Very dense material or rock can be broken up using cutting tools (e.g. cutter suction dredgers (CSD)). Dredging pumps may either be located on the vessel with a suction pipe extending to the seabed or submerged.

Mechanical techniques break up the seabed as part of the removal process, however very dense materials may require advance cutting or blasting. Mechanical buckets may be linked in a powered, endless chain extending to the seabed (bucket ladder dredge). Single grabs may be suspended from a crane (clamshell dredge) or mounted on a hydraulic excavator arm which reaches the seabed (backhoe dredge).

Dredged material may be contained within the dredging vessel (hopper dredger) for transport, transferred to hopper barges or pumped through a pipeline to a remote location.

Self-discharge of dredged material may be achieved either by liquefaction and pumping through a discharge pipeline or nozzle, or by gravity dumping through hopper bottom doors.

Dynamic positioning is generally only used by larger hydraulic seagoing dredgers which are required to be constantly moving. Mechanical cutting techniques often impose high reaction forces, in such cases dynamic positioning is not a suitably rigid positioning technique and anchors or spud poles tend to be used which can better counter high reaction force on the cutting tool.

Dredging is most frequently employed in shallow waters; the majority of applications do not require deep water dredging. Depth limits for hydraulic dredging are dictated by the maximum length of the vessel's suction pipes and the lifting capacity of the dredge pumps, based on the density of material to be lifted. Submerged dredging pumps can improve production and increase operational depth limits. Mechanical dredging depth limits relate to the maximum reach of mechanical tools below the water surface.

Except for harbour maintenance, dredging operations are predominantly conducted clear of adjacent surface structures. Discharge of material from hopper barges may require close approach to the shoreline. Material transshipment may require close approach to other vessels/barges.

Dredging vessels should be capable of following a predetermined track at constant speed whilst maintaining the correct dredging tool depth, speed will be determined by the seabed soil conditions.

The consequence of loss of vessel position in open water may be damage to the dredging tools. When operating in close proximity to the shore or offshore fixed/floating structures then consequences may also include significant damage to the vessel and any adjacent structure.

A17-2 Design Guidance

A17-2.1 Design Considerations

DP dredgers can be IMO DP equipment class 1, 2 or 3. Where the risks associated with an inability to maintain position are deemed critical then dynamic positioning systems should be IMO DP equipment class 2 or 3.

Dredging vessels are purpose-built to accommodate the equipment, storage facilities and discharging equipment required for the intended dredging technique.

High manoeuvrability and shallow draught are advantageous when operating close to the shoreline. High transit speeds may be advantageous where discharge locations are remote from dredging locations.

In shallow water the potential for contact between the vessel hull and the seabed should be considered, and precautions taken to protect hull, thrust units, rudders and seawater cooling intakes from the consequences of such contact.

Hull design should minimise vessel motions, heave and roll can result in damage to dredging machinery and may also lead to errors in dredging depths. Heave compensation systems may be fitted to maintain a constant dredging tool depth.

A17-2.2 DP Capability

The vessel should be capable of directing the dredging tool along a predetermined track or corridor, using continuous or incremental vessel moves with constant speed.

The vessel should be capable of accurate track-keeping at a variety of speeds. This is to be sufficient to operate with the maximum anticipated environmental forces on the beam. Capability following specified failures is usually a commercial consideration however the vessel should be capable of a controlled termination of operations.

Reaction forces from cutting equipment or pressure differential forces associated with hydraulic suction may act to displace the vessel from position. Where position keeping is critical the DP system should be capable of responding effectively to rapid variations in dredging forces in addition to countering environmental forces acting on the vessel.

Dredging tool position and depth may have a higher priority than vessel position during dredging and may be controlled independently of the vessel position (within specified limits). Vessel position may be a high priority when discharging close to a shoreline or other vessel.

Position keeping capability plots should be developed for a variety of environmental and thruster failure conditions which include an allowance for the highest dredging forces for which the vessel is designed.

A17-2.3 Control Systems

A common thruster control system may be fitted which will allow automatic or manual control of each axis of vessel movement when dredging at slow speed, when stopped during discharging, or when in transit.

The DP control system should have features to maintain position and heading in a fixed location and following a predetermined track. Relative position mode may be required for certain applications.

The DP control system hydrodynamic, wind profile and thruster efficiency models should be developed for a variety of vessel draughts to enable accurate positioning throughout the operation. Where possible these models should be utilised automatically as draught changes.

The power management systems should ensure that power and vessel propulsion systems are capable of rapidly changing load when necessary.

High transient loads of industrial mission equipment should be anticipated and should not reduce the power which is available for dynamic positioning.

Automation and control systems fitted for other vessel systems such as the dredging and ballast systems should be independent from the DP control system to prevent failure or incorrect operation of such systems affecting DP system integrity.

A17-2.4 Reference Systems and Sensors

At least three independent position reference systems should be in use for IMO equipment class 2 or 3 designs where position keeping is safety-critical, employing at least two different measurement principles. Power for the position references in fault tolerant DP systems should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

Where dredging is conducted in close proximity to offshore surface structures then at least one relative reference should be in use with the adjacent structure. Where relative reference systems are susceptible to interference (for example from cranes, structures and environmental conditions) then the potential for loss of position references should be risk assessed and suitable alternatives provided.

In shallow water noise, strong currents and suspended particles in the water column may cause interference to seabed reference systems. Acoustic systems are vulnerable to interference from noise associated with the dredging operation, however they may be used to monitor the position of subsea equipment.

In open water locations where the risks associated with an inability to maintain position are low there may be a reliance on satellite based position references; availability and diversity of position references may be limited in open water.

Sensors providing data relating to horizontal dredging forces acting on the vessel may be interfaced to the DP control system. Where loss of such data may impact position keeping performance, sensors should be robust, accurate and reliable and consideration should be given to providing redundancy. Where reliability or fail safe conditions cannot be demonstrated, then manual input or force inputs based on theoretical calculation may be considered.

A17-2.5 Power Systems

Provision of power for propulsion and dredging systems may be independent from each other, utilise power take off shaft generators or utilise a common diesel–electric power plant.

Power demands for dredging equipment may be significantly greater than the power requirements of positioning systems, and may be subject to large fluctuations. The DP system should be protected from adverse effects on power supply stability associated with rapid load changes on the power plant.

The power management philosophy should consider the criticality of onboard equipment and ensure that control is maintained of all operationally and safety critical systems at all anticipated loads and after the worst case failure in electrical power provision.

A17-3 Operational Guidance

A17-3.1 Operational Considerations

The following should be considered when planning DP operations:

- ◆ Depending on the technique adopted, dredging is usually characterised by a short time to terminate; dredging equipment can be lifted clear of the seabed and the vessel can move to a safe location immediately;
- ◆ Depending on the effectiveness of heave compensation equipment, environmental limits may be lower for equipment deployment and recovery than they are for dredging operations;
- ◆ Vessel motions may adversely affect dredging accuracy and cause damage to the seabed if dredging tools are rigidly connected to the vessel. Heave compensation may not be fully effective as mitigation; the DPO should be aware of how a change of heading and/or track will affect heave, roll and heel;
- ◆ Significant propulsion power may be required to overcome dredging forces. Dredging forces will tend to dampen position excursions, but may reduce the vessel's ability to maintain a constant dredging speed;
- ◆ Choice of heading may be restricted depending on the dredging technique employed;
- ◆ Very shallow water activities may be subject to stricter environmental and vessel motion limits than those for deeper water;
- ◆ Under-keel clearance requires careful consideration in shallow water due to the risks to thrusters and cooling systems. Thruster efficiency may be reduced and vessel pitching and rolling may reduce under-keel clearance significantly;
- ◆ The vessel may experience rapid changes in dredging forces acting on the vessel during constant speed dredging due to the changing nature of the seabed resulting in thruster power demand fluctuations;
- ◆ Accurate positioning of dredging tools on the seabed may be difficult if the seabed is not of uniform density or is uneven. The vessel may be required to rapidly adjust track to compensate for deflection in position of the dredging tool. These considerations are important when operating close to surface and seabed infrastructure;
- ◆ The master and each DPO should understand the principles and operation of any special features of the DP control system. They should be aware of the likely forces exerted on the vessel by the dredging operation and the procedure for emergency termination of operations.

A17-3.2 Operational Planning

Where a loss in vessel position poses a hazard to personnel, to the vessel or to the environment the following should be documented (where appropriate):

- ◆ Risk assessment of the loss of vessel position;
Activity-specific operational guidelines (ASOG) defining the operational, environmental and equipment performance limits that apply during operations, including details of actions to be taken in the event of any of the defined limits being exceeded

A17-3.3 Communications

A dedicated and reliable communication system should be provided between the operational control centres of the vessel, including:

- ◆ DPO (navigating officer);
- ◆ dredge operator;
- ◆ engine control;
- ◆ shore discharge personnel.

There should be a backup to these systems that is operable in a black out condition, both primary and backup communications should be checked as part of the DP checklists.

A17-3.4 DP Alert Status

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in the ASOG.

Guidance on status and responses is given below.

Normal status – GREEN light. Full working can be undertaken within agreed safe limits.

- ◆ The DP system is operating correctly;
- ◆ Operational, environmental and equipment performance criteria are all categorised as normal.

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- ◆ Operational, environmental or equipment performance limits are being approached;
- ◆ A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status -YELLOW light. Dredging/discharging operations should be suspended.

- ◆ A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- ◆ A situation has developed or incident occurred that risks the vessel losing position;
- ◆ Operational, environmental and equipment performance limits have been reached;
- ◆ Any other condition exists which may lead to a suspension of activities.

Emergency status – RED light with accompanying distinctive alarm. Emergency lifting of dredging tools/emergency disconnection from discharge pipeline and escape.

- ◆ A system failure or other condition has occurred that results in an inability to maintain position or heading control;
- ◆ Operational, environmental and equipment performance limits have been exceeded;
- ◆ Any other emergency situation which requires immediate suspension of dredging.

A17-3.5 Responsibilities

The vessel master is responsible for the safety of the vessel and all personnel onboard or working from it. This includes the authority to forbid the start or order the termination of dredging operations, including in conditions where operational limits defined in ASOGs have not been exceeded.

If present, the offshore construction manager is responsible for the safe execution of the work to the agreed procedures. They have the authority to order the commencement and termination of work but must respect the master's authority as outlined above.

The dredge operator is responsible for the safe and efficient operation of dredging equipment. They are responsible for communicating required vessel movements to the DPO and updating the DPO with the status of the dredging operation.

The DPO is responsible for ensuring that the DP system is correctly configured, monitoring vessel position and responding to position/movement requests made by the dredge operator. The DPO is responsible for changing the DP alert status with reference to the ASOG without delay should this become necessary and for carrying out the associated actions. They have the authority to suspend operations and stop the vessel if they consider this to be necessary for the safety of the vessel, environment or personnel.

DP Station Keeping Event Reporting

Background

IMCA has been collecting DP station keeping event reports and publishing them as annual review reports since 1991. During this time, the format of the IMCA report has changed little although attempts have been made to encourage more reporting of DP station keeping events. In 2005 for instance the IMCA Marine Division Management Committee reviewed the system and decided it would be better to replace the existing three reporting categories with five. The intention of including the two additional categories of 'DP Near-Miss' and 'DP Hazard Observation' was to allow for the reporting of more minor occurrences and to improve understanding about when to report a station keeping event and in which category it would fall.

2016 Review

A further review of the scheme was conducted in 2016. The main focus of the review was to encourage participation, including the reporting of minor DP events that might lead to more serious incidents and to ensure the DP industry has the information available to learn from DP station keeping events.

The review recognised that some DP events had been reported that constituted inclusion in the two additional categories mentioned above, these categories had never been used. It was therefore concluded that the scheme should have a maximum of three well defined categories and, so as to encourage the reporting of all events, not just incidents, the scheme would be renamed 'The IMCA DP station keeping event reporting scheme'.

The three categories are listed below:

- ◆ DP incident – A major system failure or human factor which has resulted in total loss of DP capability;
- ◆ DP undesired event – A system failure or human factor which has caused a loss of redundancy and/or compromised DP capability;
- ◆ DP observation – An event that has not resulted in a loss of redundancy or compromised DP operational capability but is still deemed worthy of reporting.

The scheme's reporting form will be revised to incorporate the three categories above and will include clear instruction for completion. The annual review of DP station keeping events will be maintained and improved by formulating the initiating event and causes into a table that can be highlighted to the reader. It is recognised that DP station keeping events provide the ideal opportunity for key DP personnel to learn. IMCA will publish DP station keeping learning opportunities through a series of regular DP safety flashes.

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

Referenced Guidance Documents

Readers should ensure they have the most up to date version of the relevant reference document.

Reference	Title
Incident report DPd	IMCA station keeping incident reporting form for DP vessels
Incident report DPo	IMCA station keeping incident reporting form for thruster-assisted vessels/FPSOs/FSUs/ DP tankers/EWTs/semis/flotels, etc.
IMCA C 002	Guidance on competence assurance and assessment: Marine Division
IMCA D 010	Diving operations from vessels operating in dynamically positioned mode
IMCA D 039	FMEA guide for diving systems
IMCA D 054/IMCA R 020	Remotely operated vehicle intervention during diving operations
IMCA M 109	A guide to DP-related documentation for DP vessels
IMCA M 117	The training and experience of key DP personnel
IMCA M 119	Fires in machinery spaces on DP vessels
IMCA M 125	Safety interface document for a DP vessel working near an offshore platform
IMCA M 125	Safety interface document for a DP vessel working near an offshore platform – Word checklist
IMCA M 140	Specification for DP capability plots
IMCA M 159	Guidance on thruster-assisted station keeping by FPSOs and similar turret-moored vessels
IMCA M 160	Reliability of position reference systems for deepwater drilling
IMCA M 166	Guidance on failure modes and effects analyses (FMEAs)
IMCA M 178	FMEA management guide
I82 MSF	International guidelines for the safe operation of dynamically positioned offshore supply vessels
IMCA M 190	Guidance for developing and conducting annual DP trials programmes for DP vessels
IMCA M 190A	Guidance for developing and conducting annual DP trials programmes for DP vessels: Executive summary
IMCA M 191	Guidelines for annual DP trials for DP mobile offshore drilling units
IMCA M 205	Guidance on operational communications
IMCA M 212	Example of an annual DP trials report
IMCA M 216	Thruster integrity management guidance
IMCA M 217	Offshore vessel high voltage safety
IMCA M 219	Example specification for a DP FMEA for a new DP vessel
IMCA M 220	Guidance on operational activity planning
IMCA M 223	Guidance for the positioning of dynamically positioned (DP) jack-up vessels on and off the seabed
IMCA M 225	Example redundancy concept and annual DP trials for a DP class 3 construction vessel
IMCA S 009	Guidelines for the shared use of DGPS for DP and survey operations
IMCA S 010	The shared use of sensors for DP and survey operations
MTS DP Committee	DP operations guidance Parts 1 and 2, Appendices 1, 2 and 3
MTS DP Committee	DP vessel design philosophy guidance, Parts 1 and 2
DNV Recommended Practice RP-E-307	Dynamic positioning systems – Operation guidance
OCIMF	Offloading Guidelines for Conventional Tankers at F(P)SO Facilities, 1st Edition