Dynamic Positioning Committee
Marine Technology Society

Guidelines on Testing of DP Systems

MTS Dynamic Positioning Committee
Subcommittee for Guidelines on Testing of DP Systems

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Mission Statement

The goal of the subcommittee is to develop and keep current a set of guidelines on testing of DP systems that will help illuminate the many issues to be considered in thorough testing of DP systems. This sharing of knowledge is expected to help improve the reliability and performance of DP vessels.

This will be a comprehensive document that includes available industry experience. It is recognized and intended that test designers select items from the guidelines to compile a suitable test plan for their particular vessel’s equipment suite and vessel application.

The guideline will contain sections with information about

- System design, specification, and FAT
- Commissioning and initial testing
- Routine and non routine testing during working life

It is a fundamental issue that the guidelines will be updated and that they will be available on the DP Committee website for use by interested parties. Updates will include changes to reflect

- Information learned about DP Incidents
- Technology changes
- Class, regulatory and industry standards
- Information volunteered to the sub committee that would improve competence of testing

Specification and Design

DP System

1. Conceptual Design Scope and boundaries DP application features DP Class issues

2. Order

3. Initial design
4. Design reviews

a. Functional Design Specification (FDS)
b. Human factors

    i. HMI
    ii. Arrangement of equipment and working area

FMEA

1. Scope and standards
2. As design aid

Factory Acceptance Testing of Equipment

1. General FAT issues

Preface

The Factory Acceptance Test (FAT) is a major project milestone where the vendor demonstrates that the system design and manufacturing meets the contract or PO specifications. Generally a substantial financial payment to the vendor is triggered by a successful FAT, therefore the FAT must be conducted formally and be witnessed by the vessel owner, with a formal record of discrepancies and non conformities and how they are to be handled. Often the Class and or client(s) also witness the FAT's for critical equipment.

Unfortunately some vendors are often poorly prepared for FAT, and the FAT is often rushed though in order to ship the equipment as soon as possible. But a poor FAT can delay observation of Non Conformities until after the equipment is installed when less time is available to correct the problems without consequences to the project schedule, and when there is sometimes less flexibility of technical solution.

This document is an overview of what the vessel owner inspectors should consider with respect to equipment FATs.

Contract/PO

Include the requirement for a FAT and

- that the FAT must be witnessed by the vessel owner
- the equipment should be fully pretested by the vendor before the witnessed FAT
- that the FAT include all equipment being supplied by the vendor
- that the FAT procedure is to be presented to the vessel owner for approval at least two weeks before the witnessed FAT

Pre FAT

- Vendor should prepare and submit a FAT procedure well in advance of the FAT. This procedure should be reviewed and approved by the vessel owner and in some cases by the Class and client. We should attempt to include testing of as much functionality as is practical in the factory, and check of all interfaces to other equipment and systems. Where possible the procedure should show pass/fail criteria or desired results for each item.
- Vendor should also provide a schedule for the FAT showing all timing and sequence of testing; this is an aid in planning the attendance of witnesses.
- Prior to FAT all design approvals should be complete, both the vessel owner and Class. This is to remove technical ambiguity from the FAT and prevent commercial disputes over work that continues after FAT.
- Vendor should prepare a test facility that can be effectively used to conduct the FAT

testing, including calibrated test equipment and any special test equipment.

- • Vendor should compile a document set that can support the testing and serve as a reference for the test results
    - contract/specification and copies of all references called out in the specification
    - all drawings for the project, including drawings received from other vendors that describe interfaces
    - drawing of the test set up
    - documentation on buy out equipment
    - QA/QC documentation
- Vendor is to pretest the system before witness test. Failure to do this can result in a lot of wasted time for the vessel owner and other witness, the standard practice for some vendors is not to pre-test so emphasis is required to avoid this default.
- Vendor is to arrange for and schedule attendance of a Class surveyor if the job requires Class approval of the equipment.

FAT

- Attendance by vendor, by the vessel owner, by Class (contract/PO), shipyard and client personnel. Depending on the scope of testing personnel of several technical disciplines and third party experts (software, FMEA, etc) may attend parts of the FAT.
- • Inspection of the equipment is an important step that can be done at any convenient point. The inspection is generally
  - Review the specification line by line while checking the equipment or drawings for compliance with the specification, including any change orders.
  - Review each standard or regulation referenced in the specification line by line while checking the equipment or drawings for compliance with the specification, including any change orders. Standards for example, API, IEEE-45, USCG, etc.
  - Inspect for workmanship
  - Inspect for problems that can occur during installation or use of the equipment, for example, lifting points/SWL, safe access to components for maintenance, etc.
- Test of the equipment per the vendor’s approved procedure; these should include functionality testing and any Class and regulatory testing.
- Ad hoc testing may be required to define any major non conformities revealed by testing

Post Testing Activities

- Check of documentation
  - draft manuals
  - confirm that the vendor has records and hardware traceability to support construction of a adequate data book
  - confirm vendor's schedule for completing the manuals and data book
- Check that all third party design reviews are complete and approved.
- Many specifications include multiple deliverables in a system, but often the FAT focuses on one or a few major items. You should at least inspect ALL items that are deliverables to be sure that they exist and that they meet the specification.

Punch Lists

- All discrepancies and non conformities of the system are to be registered on a Non Conformities List, including a "time to complete" column, for example, *before shipment, before CAT*. Items incomplete, or not available for inspection or FAT are to be included on the Non Conformities List.
- The Non Conformities List should be issued to the vendor at the end of FAT for discussion to confirm agreement with the "time to complete".
- The Non Conformities List helps to prioritize and focus work to complete the system with minimum impact on the project critical path. It needs to be followed up with the vendor periodically to insure continued attention.
- Substantial non conformities can influence the vendor's eligibility to receive the full FAT progress payment. Project management should review this on a case by case basis.

2. Test issues

- Note the software and firmware versions in the equipment to be tested

Commissioning and Initial Trials

1. Introduction

Typically, the term “DP System” is first thought of as the “computer control and display system” from which the position of a DP’d vessel is monitored and controlled. In actuality a “DP System”, whether for a relatively small workboat or an extremely large deepwater drilling unit, is comprised of a number of independent systems, delivered by many independent manufacturers. Some of the components of a typical “DP System” are as follows: several different types of position reference systems; a computer controller and display system; a thruster system; a power plant; and a power distribution system. Further break down of these various systems will lead to even more complexity. For example, just some of the components of the power plant include prime movers, power generating equipment, a cooling system, a fuel system, air intake and exhaust systems, as well as various monitoring and safety shut down systems. Typically, a single manufacturer does not produce all of these components, although one manufacturer may supply many of them as part of a package. Accordingly, to ensure that the “DP System” will adequately perform its function, all of the various aspects of the total system must be tested and verified. This means, coordinating and managing test procedures from a large number of different manufacturers.

Utilization

The purpose of this document is to create a comprehensive knowledge base that will give guidance and recommendations for the acceptance testing of a new DP system. This document will focus on generic tests and the overall goals and objectives of testing, and not on the mechanics of conducting the tests.

The documentation for a modern DP System should include a description of the hardware and functionality delivered, typically referred to as a “Functional Design Specification”. There should be an “Operations and Maintenance” manual for all major components of the DP System, as well as an “Operator’s Manual” that gives specific and detailed guidance and instructions to the operator as to the operation of the DP System under all foreseeable vessel operating conditions. In addition, all Class 2 or 3 DP Systems should have a Failure Mode and Effect Analysis covering all systems that are required for DP position keeping.

It is envisioned that these guidelines be used in conjunction with other system documentation as review benchmarks to ensure that proposed test programs are adequate, comprehensive and accurate enough to confirm that the delivered DP System is acceptable. Accordingly, as a first step, all of the system documentation should be reviewed in light of these Guidelines and verified with the existing system for content and accuracy. With this proven knowledge base as a foundation, it is then a straightforward matter to review and verify all proposed testing.

Development

The “total” DP system is broken down by component and functionality. Each component is then described as to various methods of operation and analyzed as to what and how its particular functions should be tested. In a similar manner, specific DP functionalities are described and analyzed as to existing methods of implementation with recommendations of how they can be verified.

To support this testing guidance, many examples of existing FAT, Dock Side and Sea Trial test procedures have been collected from the various DP System manufacturers, Position Reference Systems providers, drilling contractors and other DP application users such as workboat and diving support contractors. These tests have been sorted by component and/or functionality and used to produce examples of general purpose test procedures that should be preformed on a particular piece of equipment or procedures that can be used to test specific functions that a DP system is capable of performing. This appendix is not intended to be a recipe book for a “cut and paste” trials document, but rather as a reference of proven examples of tests that can be used to rationalize the test in the proposed test documents.

A particular advantage of this methodology is that the document can be updated easily to include test items based on information from actual DP Incidents and Lessons Learned.

DP Control System - Component and Functional Description

1. **Controller –** The controller is the heart of the control system that takes all the inputs from the various sensors and the operator and calculates and outputs the required thrust to keep the vessel at the desired location. In general, the various components and functions of the controller are discussed as follows:

A. **Control Console**

1) Computer Systems **–** Typical modern control systems use either off-theshelf or manufacturer developed “PC” based computer systems generally coupled with industry standard PLC’s for low level computation and I/O. It should be verified that all the hardware and operating systems for the various controllers are at the correct revision level. Additionally, many modern control system components use dedicated imbedded controllers to perform various tasks. These controllers are typically firmware controlled and the “Make, Model and Revision Level” of these devices should be verified.

2) DP System Redundancy **–** To satisfy regulatory requirements DP Systems consist of multiple controller stations located at both a main and back up control location with automatic as well as manual switching capability between stations to ensure positive control in the event of station failures and fire and flooding emergencies. It is important to verify the switching functions of the system are tested when provided:

a. Verify that the operator can switch system control to any of the operating system stations and that control cannot be switched to a non-operational system station.
b. Verify that system control automatically switches in the designated order to the next operational system stations upon defined failure of the controlling system station.
c. Verify consistency of controller set up including operator inputs, control modes and parameters before and after switching system control between controllers.
d. Verify that critical data entry functions that directly affect the performance of the system can only be entered at the on line system. Additionally, verify that certain display or data entry functions that could disable or disrupt the functions of the on line controller are only enabled on back up systems.
e. If installed, verify that the backup control station can be isolated from the main control station such that failures in the main location do not affect the ability of the back up location to maintain DP control of the vessel.

3) Communications – The Controller must communicate with its peripheral devices for data input and command output. In systems that contain multiple controllers, these must communicate with each other. Communications may be by a network or individual serial data links. Where serial data communications are employed, verify that the system level communications functions operate correctly. Where network communications are employed, verify that single point "hard" failures of any of the network components do not fail the network and that "soft" data corruptions failures can be detected and do not cause system failure or erratic behavior. Verify that sufficient capacity exists on both serial and network communication links for all expected loading levels. Past failure modes have included "jabber" where the network or serial port receives a high volume of messages, enough to prevent other massages or to stall the DP controller through constant interrupts.

4) Operator Feedback (Out Put) – In order to communicate to an operator, DP systems use a variety of output devices such as CRT Screens, Lighted Switch Feedbacks, Alarm and Warning Lights, and Displayed and Printed Messages and Alarms. Attention should be given to the following where applicable:

a. CRT Screens should be large enough and place for easy viewing. CRT controls such as gain, brightness, contrast and focus should be available to the operator. Where "Night mode" is included it should be verified.
b. Where used, Feedback Lighted Switches should be verified for correct operation and indication.
c. All Alarm and Warning Lights should be verified for correct operation and indication.
d. All Displayed and Printed Messages and Alarms should be exercised and verified.
e. All printed logs should be reviewed for data accuracy.
f. All Screen Print functions should be exercised.

5) Operator Interface (In Put) – For control, the operator must be able to input data and commands to the DP System. This is accomplished through the use of Dedicated Switches, Pointing Devices and Key Board entries. Attention should be given the following where applicable:

a. All Switch inputs should be verified for proper operation and indication.
b. Operation, polarity and scaling of all Hand Set potentiometers should be checked.
c. Operation of a Pointing Device should be verified.
d. Correct Key Board entries should be verified.
e. Proper acknowledgement should be verified for the input of any critical data.

6) Operator Communications – For reliable control, sufficient and redundant communications should be available between the Main and Back Up DP Control stations, the Drill Floor and the Engine Room Control stations. These should have hands free capability.

B. **Program Functions** 1) Program Revision Level – It is extremely important to control the inventory of backup disks and the revision level of the DP Program to ensure that only the latest fully tested version is used in all on board systems. 2) Program Data Base – The DP Program relays on input feedback information as well as vessel parameters to calculate the required output commands to keep the vessel on location. Accordingly all vessel parameters used in the program database such as mass values, wind and thrust coefficients and equipment locations should be verified for accuracy and consistency of units with data from model tests or design calculations. Also, all input data, and output commands should be verified for accuracy as well as consistency of units.

3) Position Reference Processing – Raw position reference data is processed by the controller for validity and accuracy to qualify its use by the control algorithms. The following aspects of this operations should be checked:

a. All input "telegrams" are of the proper format.
b. Raw position data can be inspected by the operator.
c. Verify operation of position data tests such as frozen position reference, jump or high rate, slow drift, median, and triple voting checks and that all qualifying tests limits agree with operator or system set values.

4) Computation of Vessel Position and Heading – All modern DP Control systems utilize a form of Kalman Filtering usually referred to as "Model Based Control" to calculate the vessels position and other parameters used by the control algorithm. The following aspects of this operations should be checked:

a. All vessel information used for control should be displayed to the operator rather than raw data values.
b. Adjustment of the Kalman Gain, either by the operator or as system data, directly affects the “filtering” characteristic ranging from heavy weight on the raw data to heavy weight on the model data.
c. Demonstrate the “dead reckoning” characteristic of this type of processing.

5) Computation of Required Thrust including Feed Forward Requirements – The data from the Kalman filter (Model) is utilized by the control algorithm to determine the required thrust. This data includes the “position error”, vessel velocity, and “position error integral”. In addition, all DP Control systems use “Wind Feed Forward” data if enabled to counter the affects of wind loading both long term static and short term dynamic due to wind gusts. Other forms of environmental loading feed forward data that can be used may include, wave and current feed forward, pipeline tension in pipe lay operations and measured riser loading due to current. The following aspects of this operations should be checked:
a. Position error data should be used for display and alarm conditions such as “Position Error” alarms.
b. Demonstrate the affect of changing various parameters within the control algorithm including operator set values for axis gain.
c. Verify the correct operation and values for Wind Feed Forward and other feed forward values if used.
d. Demonstrate the affect of changing the Position and Heading set

points. 6) Allocation of Thrust including Biasing and Power Limiting Requirements

- Thrust Allocation Logic (TAL), converts the calculated thrust requirements as described above into individual thruster commands for all thrusters enabled. If thruster biasing is available and enabled, the TAL must incorporate these additional requirements. In addition, once the calculated thruster outputs are determined, TAL should check that sufficient capacity is on line so that the output commands will not cause a power overload. The following aspects of this operations should be checked:
- Verify accuracy of all required input data and system and operator entered parameters.
- Verify thrust commands satisfy the calculated surge, sway and heading moment requirements.
- Thrust commands should only be allocated to enabled thrusters.
- Demonstrate proper allocation of the designated bias scheme in accordance with operator and/or system parameters.
- Verify, the thrust re allocation scheme when any thruster would receive a thrust command above its capability.
- Verify thrust cut back when the required thrust commands would result in a power overload condition. This should include Yaw Axis priority.
- Verify proper DP response to loss of a thruster.

C. **Operating Modes**

1) Automatic Position Keeping and Heading Control Modes – Typical automatic position and heading control modes include maintain position and maintain heading. Verify the following modes:

a. Automatic Heading control only.
b. Automatic Position control only.
c. Automatic Heading and Position control.
d. If system allows for separate control of Surge and Sway position, verify Automatic Sway control only and Automatic Surge control only.

2) Special Purpose Control Modes – Verify selection, parameter entry and operation of the following modes if available:

a. Hold Heading for Minimum Moment, Sway Thrust or Power.
b. Hold Position to Maintain Desired Riser Angle.
c. Coordinated Position Moves for pipe lay operations.
d. Single thruster operation Maintaining Position only.
e. ROV follow.
f. Follow a specified track set up by operator.
g. Auto Pilot or Auto Sail modes.

3) Manual Modes – Verify Joy Stick and Manual Moment operations as follows:

a. Maneuver vessel position using Joy Stick with or without automatic heading control.
b. Maneuver vessel heading using Manual Moment control.
c. Verify Power Limiting using Joy Stick and Manual Moment control.

D. **Operator Control**

1) System Configuration – Verify operator can set up the following system operating conditions:

a. Select On Line System.
b. Assign Position Reference Systems.
c. Assign Environmental Sensors.
d. Assign On Line Thrusters.
e. Select Position and Heading Control Modes.

2) Control Set Points – Verify operator can enter the following control set points:

a. All possible modes of entering Position and Heading Set Points.
b. Set Up and Control Set Points for special modes of operation. 3) Alarm Set Points – Enter and verify all “alarm” set points. 4) Axis Gain Settings – Verify operator can change all control axes Gain settings. 5) Kalman Filter Control – Verify operator can vary Kalman Filter Gain settings.

E. **System Performance**

1) Station Keeping Performance – Using all possible combinations of Position Reference Sensors, System Gains and Kalman Filter Gain, verify using logged data the station keeping performance by calculating Average and RMS watch circle radius and maximum excursion for various environmental conditions during at least 1 hour of operation.
2) Maneuvering Control – Using logged data, plot position and heading response as well as power consumed for various Position and Heading set point maneuvers. Observe system overshoot, dampening and time to reach steady state.
3) Special Control Mode Operation – Using logged data verify and evaluate performance of vessel under all available special control modes.
4) Environmental Fast Learn – Demonstrate that the operation of the "Fast Learn" modes decrease the time required for the system to determine the steady state environmental loading with out adversely affecting system stability.
5) Drift Off Test – Under prevailing environmental conditions, determine the drift off characteristics when all thrusters are de assigned. Verify proper operation of Yellow Warning and Red Disconnect Alarms at the operator set values to the Drill Floor.
6) Control Stability Checks – Perform a Gain Stability Test for the Surge, Sway and Heading control axes.

2. **Position and Heading Sensors –** Position and Heading Reference Systems provide the feedback information necessary for the DP System to accomplish its assigned task. Although numerous types of Position Reference Systems exist, Heading Reference Systems are always Gyro Compasses. Ensure that the minimum number of independent Position and Heading Reference Systems are installed to meet type classification requirements. These systems are discussed as follows:

A. **DGPS Systems**

1) GPS Operation (Single/Dual Frequency) – Demonstrate the operation of the GPS receivers to operate on either single or dual frequencies. Dual frequency systems have superior immunity to atmospheric degradation and are the preferred type of receivers.
2) GLONAS Operation – Demonstrate the operation of dual constellation receivers to utilize the Russian GLONAS satellites for position fixes.
3) Differential Correction Operation – Verify the reception of Differential Correction data using more than one method for redundancy. Sources include Inmarsat, Spot Beam and radio link. Verify performance with each set of correction data by itself and as a normal set of available data.
4) Blockage of Antenna – Verify those headings on which some of the required GPS and Differential antennae are blocked by vessel structures or exhibit degraded data due to multipath reception off close by structures. Ensure that no headings exist at which all signals are lost. Note that the GPS antenna results are dependent on the GPS constellation during the test, and that the results for differential correction antennas may be earth location specific because of the relative position of those satellites to the vessel. Crane booms can also produce variable results in near to antenna.

5) Non Corrected GPS Operation – Determine if uncorrected GPS data can be used for position data.

6) Communications – Verify correct telegram format and rate.

7) Lightning Protection – Verify proper lightning protection has been provided for all antennas.

8) If the GPS/DGPS system has a independent watch circle alarm verify it.

9) Verify expiration date of the differential subscription at the receiver, if applicable

B. **Acoustic Position Systems**

1) Type of Operation – Verify acoustic system accuracy for the type of base line used to manufacturer and/or customer specifications as follows:

a. Ultra Short Base Line (USBL) – typical (0.5 %WD).
b. Short Base Line (SBL) – typical (0.25 %WD).
c. Long Base Line (LBL) – typical (1-2 meters).

2) Installation Alignment – Verify the location with respect to the vessel installation reference point and vertical alignment of all hydrophones. Verify the mechanical operation and alignment repeatability of all hydrophone deployment systems.

3) Available Channels – Determine the total number of frequencies available. This should include not only frequencies used by position transponders/beacons but also transponders used for Riser Angle data and ROV position data, and frequencies used by acoustic back up BOP control systems. Acoustic Doppler Current Profilers (ADCP) or acoustic modems may also use frequencies that need to be considered.

4) Set Up and Calibration – Verify Set Up and Calibration procedures exist and are proven.

5) Redundant System Operation – If redundant systems are installed, verify the independent operation each system. This is especially true for systems that use transponders as apposed to system using free running beacons. Additionally, verify that both systems can operate simultaneously without interfering with each other. If Master/slave design then verify transfer.

6) Multiple Target Operation – Verify operation of system to simultaneously track fixed and mobile targets.

7) Water Depth Rating – Verify water depth rating of transponders/beacons.

8) Noise Survey – Perform an operational and background noise survey of vessel under various thruster configurations and power levels. This can be used to determine the worst case water depth capability of the acoustic position reference system as installed on a specific vessel.

9) Communications – Verify correct telegram format and rate. 10) If the acoustic system has a independent watch circle alarm verify it.

C. **Taut Wire Systems**

1) Water Depth Rating – Verify water depth rating of wire and clump weights.

2) Peripheral Equipment and Support Systems – Verify proper operation of wire wench and tensioning systems and that they are suitable for the water depth rating of the system.

3) Location and Ease of Operation – Verify ease of operation to launch and recover taut wire and adjust system tension.

4) Installation Alignment – Verify the location with respect to the vessel installation reference point.

5) Tilt Measurement Calibration – Verify the proper polarity and scaling of the output tilt measurements.

6) Communications – Verify correct telegram format and rate.

D. **Radio/Radar Positioning Systems** 1) Set Up and Calibration - Verify Set Up and Calibration procedures exist and are proven.

2) Antenna Blockage – Verify heading limitations due to antenna blockage.

3) Communications – Verify correct telegram format and rate.

4) Lightning Protection – Verify proper lightning protection has been provided for all antennas.

E. **Laser Position Systems (relative position)** 1) Set Up and Calibration - Verify Set Up and Calibration procedures exist and are proven. 2) Sensor/Target Blockage – Verify heading limitations due to line-of-sight blockage between sensor/s and target/s. 3) Environmental Limitations – Verify system operation under manufacturer's stated limiting environmental conditions. 4) Communications – Verify correct telegram format and rate.

F. **Riser Angle Systems**

1) Electric Operation, Hard Wired or Multiplexed – Verify operation of both upper and lower electric riser angle sensors and data transmission especially if multiplexed through BOP control system. This should include orientation, polarity and latency of the received data by the DP system.

2) Acoustic Operation – Verify operation of Acoustic Riser Angle Sensors including orientation, polarity and latency of the received data by the DP system.

3) Communications – Verify correct telegram format.

G. **Gyro Compass** 1) Shock and Vibration Sensitivity – Ensure proper mounting of compasses to meet shock and vibration specifications.

2) Communications – Verify correct telegram format and rate.

3) Data – Verify heading reference data to all DP and peripheral equipment is received correctly.

3. **Environmental Sensors** – Environmental sensors are used to determine feed forward requirements for thrust and vessel attitude for correction of position reference data. These sensors are discussed as follows:

A. **Wind Sensors**

1) Type of operation (propeller, cups, vortex shedding, etc) – Verify that the operating principle of the device is consistent with the expected operating environment. For example, vortex shedding sensors should not be use in rainy or foggy environments.
2) Locations – Ensure that sensors are located such that structural blockage is minimized. This especially true when a minimum number of sensors are use to obtain full 360 degree coverage with little or no over lap in coverage zones.
3) Accuracy – Verify accuracy of measured speed and azimuth data.
4) Data Reference – Verify that all wind velocity data is adjusted to a common plane, usually 10 meters above sea surface, regardless of the vertical position of the sensors.
5) Communications – Verify correct telegram format and rate. 6) Lightning Protection – Verify proper lightning protection has been provided for all external sensors

B. **Vertical Reference Units** 1) Measured Degrees of Freedom – Verify measurement of Roll, Pitch, Heave, Roll Rate and Pitch Rate as applicable.
2) Location (cross axis coupling compensation) – Ensure that sensors are located a close to the Roll/Pitch center of the vessel to minimize lateral acceleration effects.
3) Parameters – Verify that correct location parameters are entered in the sensor for correct compensation. 4) Communications – Verify correct telegram format and rate. 5) Alignment - Verify the alignment of individual sensors with each other as well as to the vessel.

4. **Actuators** – All DP Systems use thrusters, including the main propulsion on ship shape vessels, to develop the required force to keep the vessel on location. In some vessels with limited thrust capability, the rudder or rudders are also used. The most common types of thrusters are discussed as follows:

Thrust Development Methods – Thrust is developed either from a fixed pitch propeller by varying its speed or from a constant speed propeller by varying its pitch. Variable speed thrusters usually can go to almost zero power consumed at zero thrust output. However, variable pitch thrusters have a minimum power loading at low pitch values when the blade is actually working in two directions. This minimum power loading can be quite high, in some cases as much as 25 % of full power. Variable pitch thrusters are more prone to failure than variable speed thrusters because he pitch control mechanism is much more complicated than speed control devices. Also, accessibility favors speed control since the speed control device is generally located with in the hull where as the actuator of a pitch control mechanism is located in the underwater part of the thruster.

Thrust Direction Control – Typical hull-mounted thrusters in ships as well as the main propellers are examples of Fixed Axis thrusters. Thrust allocation and control of these types of thrusters is extremely simple in that only the thrust level must be determined. Alternatively, azimuthing thrusters are more efficient because they can be aimed in the exact direction to deliver the countering thrust. However, azimuth drives increase the probability of thruster failure due to loss of azimuth control.

The various aspects of the installed thrusters should be checked as follows.

A. **Controller Functions –** Various aspects of the installed controllers should be tested as follows: 1) Azimuth Controller – Verify proper operation of the azimuth control including rate and direction of the azimuth drive.

2) Pitch Controller – Verify proper operation of the pitch control device including rate of change of pitch and maximum pitch. Verify that the thruster delivers 100% thrust at the 100% pitch command. Test pitch limiting to avoid thruster overload if included.

3) Speed Controller – Verify proper operation of the shaft speed control device. Verify that the thruster delivers 100% thrust at the 100% speed command. For fixed axis thrusters verify smooth and stable operation of direction change of rotation to reverse thrust output. Test speed limiting to avoid thruster overload if included.

4) Power Controller – Some systems use either Pitch or Speed control as appropriate in a closed loop control system that actually controls the input power level of the thruster. This type of control is superior to simple Pitch or Speed control in that it keeps the power consumed from spiking and adjusts in part for current inflow degradation. Verify the operation of the power control device. Verify that the thruster delivers 100% thrust at the 100% power command and that the controller protects against thruster overload.

B. **Commands** 1) Thruster Assignment – Verify proper operation of thruster assignment functions.

2) Automatic Operation – Verify Automatic DP and/or Joy Stick/Manual Moment calculated azimuth and/or thrust commands are correctly received by the assigned thrusters.

3) Individual Manual Operation – Verify manual azimuth and/or thrust commands are received by the assigned thrusters.

C. **Feedback** 1) Azimuth Angle Feedback – Verify calibration of azimuth angle feedback. 2) Pitch Angle Feedback – Verify calibration of pitch angle feedback. 3) Speed Feedback – Verify calibration of speed feedback. 4) Power Feedback – Verify calibration of power feedback.

D. **Thruster Drive System Operation** 1) Verify thruster Start protection and operation. 2) Verify thruster Stop protection and operation. 3) Verify thruster Emergency Stop protection and operation. 4) Verify thruster drive system protection settings.

5) Verify time needed for thruster restart

E. **Characteristic Parameters** 1) Bollard Pull – Verify Bollard Pull thrust is used by system to determine required thrust control. 2) Current Inflow Degradation – Verify degradation data is correct if included.

3) Location – Verify installed location of all thrusters with respect to the vessel installation reference point.

5. **Power Systems –** In order to take advantage of the on line thrust capacity, sufficient electrical power must be available on a continuous basis. Typical power plants consist of a number of diesel electric skids. For redundancy, a minimum of two skids should be on line at all times and skids are added to or taken off line as the average total power requirement fluctuates. In order to maintain continuous power, some level of automatic power plant control is desirable. It is also desirable to keep the DP System operational during a black out to facilitate as quick a recover as possible and to keep key personnel informed as to the vessels position during the drift off. Accordingly UPS systems are provided as part of the DP System to keep continuous power available to run the DP System and all critical peripheral equipment.

A. **Main Power**

1) Buss Structure – Verify proper indication and data from both closed and split buss operation. Also that power limit recognized and responds correctly to split buss operation

2) Engine/Generator – Verify that proper engine and generator data is transmitted to the DP System.

3) Thruster Supplies – Verify that all thruster power data is transmitted to the DP System. Verify that Start permissive logic is properly implemented and operational.

4) Thruster Auxiliaries – Verify that data from all thruster auxiliaries is transmitted to the DP System.

B. **UPS Power** 1) Redundancy – Verify distribution of equipment between various UPS systems to minimize DP System degradation on loss of any one UPS. 2) Battery Life – Verify stated performance on battery operation. Typically 30 minutes.

3) Inverter – Verify that the output of the Inverter is not phase locked with the in put line frequency. This will cause UPS problems when there is a low frequency condition with out a black out.

4) Input Power Selection – Verify that the UPS has multiple input power sources. 5) Bypass Modes – Verify that the UPS can be bypassed such that the output is fed directly from the input. This is an emergency mode of operation. 6) Verify key UPS alarms to DP

C. **Operational Checks**

1) Closed/Split Buss Operation – Test the operation of the power plant in all Closed and Split Bus combinations with all combinations of thrusters to ensure safe and stable operation.
2) Black Out Recovery – Under normal DP operations, cause a Black Out of the main plant and determine the time to recover to full operational DP holding station. Note the time required to get each engine and thruster back on line and operating.

6. **Documentation –** No system is complete with out a comprehensive set of documentation as well as as-built drawings for all the equipment provided. In addition, there should be a comprehensive system in place to control the inventory and revision level of the official documents. This documentation should at a minimum include the following:

A. **Manuals**

1) Operation and Maintenance manuals for all control systems, position reference systems, environmental sensor systems, actuator systems and power systems regardless of which manufacturer is responsible for delivery.
2) Functional Design Specification defining all the Hardware employed and Functional capabilities of the installed DP System again including all major components.
3) Operators Manual that gives vessel specific detailed guidance and instructions for the operation of the DP System under all foreseeable operating conditions.
4) Failure Mode and Effect Analysis including FMEA acceptance test results.

B. **Drawings** 1) As-installed Power distribution drawings of all equipment supplied.
2) As-installed Signal flow drawings of all equipment supplied.

2. General

- Documentation of the trial should include software and firmware version numbers
- • The DP logger should be tested first, then used to document the system testing
  - o Verify recorder channel assignments are correct
  - o Verify logged data agrees with data shown at origin of data.
  - o Verify units are correct. Generally best to be same as seen on system HMI
  - o Verify system used to make plots from the logger data channels
  - o Verify the ability to copy files to media
  - o Verify the logger corrects its time in response to system used to synchronize time on all loggers on the vessel.

3. Commissioning

- o Locations of reference sensors should be determined by a surveyor
- o Sensors should be clearly and permanently marked, especially where there are multiple sensors

Periodic and Continuous Evaluation Trials

Periodical Survey (Class Society) Refer to Class Rules for their specific requirements.

Client's On Hire Acceptance Trials Such trails should always have a script that is agreed before the test, because of a history of "scope creep." Where recommendations are made they should be closed out properly. Copy of the test plan and any recommendations with close out should be retained in vessel files.

Drills Drills are primarily training exercises but also provide a measure of equipment verification. Performing Drills for various DP operations can help prepare vessel personnel to respond correctly to real DP crises events. The planning for the drills, role playing, involvement of other vessel personnel with the DPOs, and "demonstration", all provide a foundation of awareness of possible problems and possible responses to DP problems. Participation in DP Drills is an important part of DPO training and should be tracked in training records and be a criteria for promotion.

Some of the drills described below require wide participation of vessel crew, such as the blackout recovery drill. Others may require less involvement but still coordination, such as joystick practice. Others may involve DP only and may be done on DP simulators. Most involve careful selection of safe opportunity and some vessel time.

Blackout Recovery

The vessel would be intentionally blacked out and the vessel personnel then take action to recover power. Power plant watch-standers, mechanics, electricians, DPOs, etc, participate directly so they gain good knowledge of the requirements of their own role in black out recovery, and it is a hands on exercise. It can be varied with different root causes of blackout to add depth to the training. Planning the drills and thinking them through has also had benefits.

Joystick Practice

To give the DPO a "feel for" the joystick operation, transfer of operation, recovery to auto and includes thinking through when and why they might choose to use joystick. This drill could raise the credibility of the joystick as a useful short term mitigation for certain types of DP faults.

Fast heading changes The DPOs might not have experience changing vessel heading rapidly to match incoming weather direction, say for a approaching squall line. This drill could provide practice and understanding of allowable high rates of turn and how the vessel and its power plant responds. This might avoid a case where a vessel loses station from a change in weather from beam. This drill would mainly apply to ship-shape vessels.

Runaway thruster

Thrusters can fail in various ways and develop high uncommanded levels of thrust or wrong thrust direction. Since other thrusters try to counter-balance the failed thruster it is sometimes difficult to quickly determine which thruster has failed so it can be stopped before vessel position is affected. This drill could improve ability of DPO to react correctly to runaway thruster failures

Manual thruster restart

Some vessels have a high level of automation in thruster restart. Practice of restating thrusters manually would improve knowledge of thrusters/thruster auxiliaries.

Dead Reckoning

Most rigs rarely operate in dead reckoning and DPOs have little experience with it. This drill could demonstrate dead reckoning , including what things can and can not be done while in this mode, and it will show how well the DP system can hold position in this mode. This drill could improve DPO knowledge of the capabilities and limitations of dead reckoning.

Reboot DP Computers

Most rigs rarely have a case where one or more DP computers or DP operator interface computers lock up. But if this rare event were to happen it would be useful experience for DPO to have seen a recovery, to know how and when to reboot, what to expect from the rest of the DP computers during this event, and how long it takes to reboot and restore the system.

Acoustic Position Reference

Operation on acoustic position reference only (no DGPS). For vessels with LUSBL systems the drill would include operation on USBL, as might happen if transponders failed and system dropped to default USBL operation.

Drive Off

Though drive off is rare and there are several mitigations, a drill could demonstrate them and when and how to best use each.

Annual or Continuous Evaluation Trials IMO 645 included the concept of an annual trial with a focus on verification the vessel is in “good working order”, and on FMEA testing. International Marine Contractors Association (IMCA) recommends an annual DP trial. The annual DP trial has been used successfully with vessels that do seasonal work or that do a large volume of short projects. For vessels with continuous work programs, such as DP MODU, IMCA will soon release a Continuous Evaluation DP trial.

Coming on location trials These are vessel specific trials used primarily to verify “good working order” of the DP system. For example

1. Restart all operator stations pertaining to the DP and the thruster control systems
2. Simultaneously reset and restart all three DP control computers and let them re-load from an operator station. Restart independent backup controller.
3. Restarted both DGPS systems and let them settle. Checked setup and verified all relevant reference stations enabled and active
4. Restarted both acoustic transceivers inside bilge keels and verified transducer shafts fully extended.
5. Enabled sensors and made sure there were small differences between all three compasses and between the three Vertical Reference sensors.
6. All thrusters 'running' and 'ready'. DP systems in 'lever' mode; tested responses of each thruster individually using levers. Two engines running and on the switchboard, four on standby. All bus-ties closed.
7. Set DP in 'Joystick' mode and tested all thrusters responding correctly to small joystick deflections in all three axes (surge, sway and yaw)
8. Set DP in auto mode using two DGPS inputs and let settle for 30 minutes.
9. Performed 'box' test, i.e., moving vessel 30 meters to starboard, then 30m ahead, then 30m to port and finally 30m astern. All moves at low speed. Done at low, medium and high gain separately. Observed position plot correct and little or no overshoot at each new position. Sent position plot to hard-copy color printer for filing purposes.
10. Informed engine room of power management test. Made a 50m transversal move at a high speed setting (~3.5 knots) to observe levels and timing of the autostart of each standby generator in turn. Ultimately, all generators on the switchboard. Alternate use the joystick at its high gain setting.
11. Checked that independent backup system was reading parameters correctly, i.e., following the main system's inputs and outputs.
12. Tested emergency transfer to the independent backup system. Observed 'bump-less' transfer.
13. Transferred control back to main system
14. Reset two of the three main DP controllers and observed no change in position, heading

or thruster usage on one controller. Observed proper restart of controllers. This also verified auto-switch to 'live' controller.

15. Tested emergency stop of each thruster in turn by using panel mounted buttons. Restarted thruster after each one.
16. Moved into well-head position under DP control and verified with independent surveyor. Heading set at predetermined desired stack heading based on oceanographic and meteorological statistical data from nautical 'pilot' charts.
17. Deployed ROV carrying four transponders. Deployed transponders, each in turn, in a predetermined array based on depth and bathymetric data (if available)
18. Activated acoustic systems and calibrated the transponder array. Then enabled in the DP system. Checked both systems operational and satisfactory. Checked DP system and positioning stability for a while using only acoustics as position reference.
19. Restored DP system to normal operational status and set warning and alarm limits for excursions according to safety calculations done for the site.
20. Logged all activity and declared vessel operational and ready

Root Cause Exposure Testing

This type of trial is intended to prove that a DP vessel is immune to a certain type of fault. Information from a DP Incident on another DP vessel is used to design a test to show how your vessel performs when it undergoes a specific fault. Though it is primarily FMEA testing it does have a “drill” dimension to it.

Trials to Test Upgrades

Upgrades are usually thought of as planned changes to software that adds or improves features or functionality. But equally, changes to software that are required to fix a recognized problem should be thought of as upgrades. We also have upgrades due to hardware obsolescence/replacement issues. Often Upgrades experience narrow or no testing because of assumption that the software has been previously tested by the vendor, or that it is so discrete or compartmentalized that there is no risk that is not covered by simple functionality testing.

For any upgrade consider testing that could be done. For some changes it would be appropriate to update the FMEA.

Life Cycle Assessment

Much of the input of position of equipment in its life cycle comes from the original equipment vendor. The information often comes through warnings from the vendors to customers of the anticipated end of support for equipment, or though their inability to supply repair parts when the users place parts orders. Sometimes the computer hardware is simply is no longer adequate for code that has grown in size and complexity.

Documentation

For initial trials and for trials of upgrades it is recommended that the logger files from the trial period be attached to the test record. This could be CD ROM or other file media of the logs from the systems and sub systems that were tested, for example DP loggers and power management/vessel management loggers. Moreover individual tests may have results that can be prepared in plot form from logger data

An arrangement drawing should exist of the DP system and associated equipment to show the as-built nomenclature or label on each device. There is a history of confusion over which devices are which that has resulted in DP events of near miss DP events when technicians have mistakenly shut down healthy equipment by mistake when attempting to address problems in redundant equipment.

Vendor manuals and drawings should be vessel specific rather than generic. All features and equipment in your specific vessel set should be covered in the documentation, but no features or equipment that is not included should be covered in the documentation.

It is important to have software version tracking for every piece of DP equipment, to have available on the vessel back up copies of software and to have procedures for restoring the system to operation.

Committee Function and Contacts

The work of the committee will have a initial phase with construction and approval of the plan, and a ongoing phase where maintenance and enhancement will be the main activity. The work of the committee will be to

- Determine the desired characteristics of the plan
- Acquire existing test plans from experienced personnel in the vessel owners organizations, from third parties and from the Class Societies.
- Acquire information about DP vessel operating experience that can be developed into test issues.
- Direct the editing of the comprehensive test plan.
- Approve the plan and each revision
- for continuous improvement and to maintain the quality of the plan
- Review new material submitted for update to the test plan
- Monitor field results of use of the plan
- Monitor industry DP experience for evidence of new test issues.

The sub committee seeks information to improve the Guidelines. Any test material or vessel experience information may be sent to the sub committee chairperson, Pete Fougere