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DYNAMIC POSITIONING CONFERENCE

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WORKBOAT SESSION

Dynamic Positioning For Workboat Applications

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Abstract

Recent cycles in the offshore market have further expanded the workboat market for dynamic positioning (DP) systems. As vessel owners try to get the most out of their vessels, they are turning to more advanced control systems to reduce crew size and increase capabilities. Typical vessel missions and power arrangements will be discussed as they relate to the capabilities of simple positioning systems. In addition, the system architecture and interfacing details for the positioning system will be discussed to familiarize the reader with the technical requirements for working with 'workboat' DP systems. With the information provided, potential users will have a better understanding of the capabilities available and the design concerns involved, when considering a DP system for a workboat application.

Introduction

The offshore market has a variety of specialized vessels to provide critical support operations. Workboats are one of the most influential of the support vessels providing multiple mission capabilities now totaling over 4,000 vessels around the world. As costs have increased and the industry has looked more towards deeper water, the workboats have had to adapt to new expectations. More often the owners attempt to reduce their costs by reducing the number of required crew while increasing the number of tasks a particular vessel can carry out. One of the most popular methods to reduce crew size while increasing capabilities is the addition of a coordinated control or dynamic positioning (DP) system. Over the last several years either coordinated control joystick systems or simplex DP systems have almost become standard equipment on newbuilds and a standard option during refits. Not only do coordinated control systems allow more complicated operations to be performed but also they improve the safety of the vessel. Unfortunately, with the immense variety of workboats already in the field and currently being constructed, the interfacing between the DP system and the vessel becomes a major concern. In addition, this area of the market has expanded rapidly without a similar flood of information becoming available. Workboats present many unique challenges when compared to the larger dedicated DP drilling vessels or DP dive operations vessels, typically trying to perform a variety of operations instead of a dedicated mission. After a review of the typical vessel layouts and their attributes and some of the thruster types encountered, the requirements for the interfacing to these systems will be discussed. Next a review of the most common vessel missions and their relation to DP will be discussed. DP systems are only beginning to be used for some of the many applications possible. Finally, the hardware architecture of a typical simplex DP system will be discussed with regards to the interfacing required between the various systems of the ship. In addition the available classifications and their requirements will be noted. This will provide a better understanding for the potential user and enable more informed decisions for not only the purchase of simplex DP systems but also the design of vessels for use with these systems.

Typical Workboat Propulsion Layouts

Workboats come equipped in many different ways taking advantage of virtually all of the available thruster options. Typically there are three distinct layouts with variations from there (Figure 1). The classic workboat is equipped with two clutch operated fixed pitch main propellers, two standard ganged rudders and a simple fixed pitch bow thruster. This standard configuration represents the largest area for workboats since older boats were equipped this way. This type of controls offers a large market since many vessels are available and also provides a solid mechanical interface between the controls and the propulsion systems. Unfortunately, the clutching controls, which alter the direction on such fixed pitch propulsors, provide the least

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precise control when a DP system is installed. The mechanical lag time introduced by the clutching mechanism degrades the overall system accuracy by 10-15%. The clutched propulsion systems also offer a non-zero minimum that reduces the resolution of the controls and further impacts the performance of a DP system. In addition, many of the systems in older boats were designed for periodic use during docking maneuvers only. They often suffer significant breakdowns when subjected to continuous use typical of DP systems. Generally, these systems require the ability to specify a bias on the engines forcing one to operate ahead while the other operates astern to prevent excessive wear on the clutching system. The bow thrusters installed

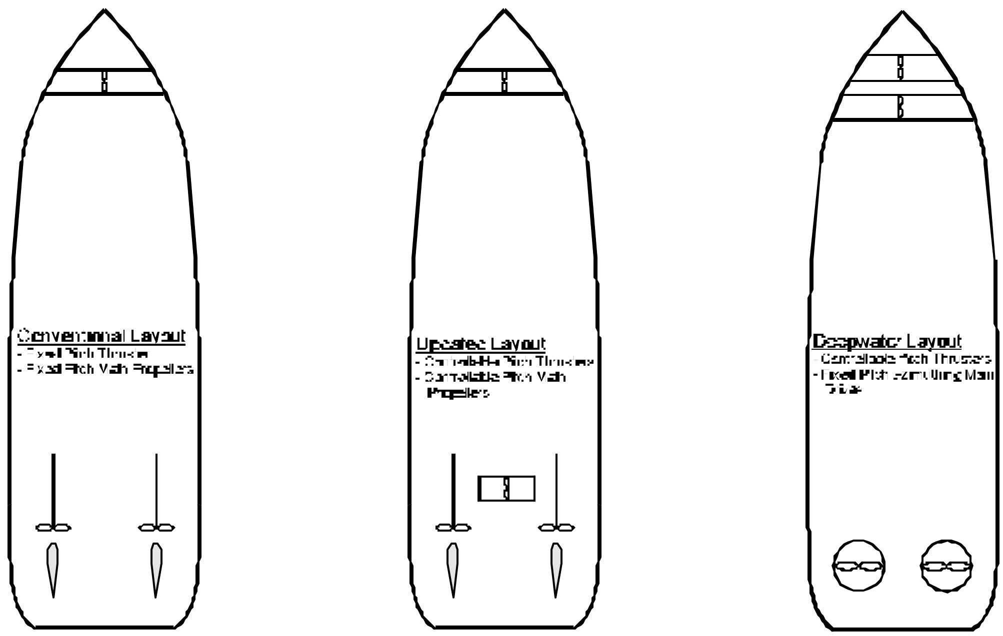

Figure 1 - Typical Workboat Propulsion Layouts

are often too small to offer much help during DP operations as they were simply designed for low power operations in protected waters. Many older vessels have upgraded to controllable pitch bow thrusters with significantly more power to enhance DP performance. Several variations have been introduced to help improve the control on older boats with this type of equipment. Splitting the rudder controls for independent operation, along with high lift rudders can have a dramatic effect on the performance. Generally, the first upgrade for older vessels is the addition of a controllable pitch bow thruster that is higher power and designed for continuous usage under DP operation. Such improvements often bring the performance of boats equipped with these controls closer to that of newer more modern designs.

As controls systems improve, more and more vessels are equipped with complete inventories of controllable pitch propellers including the main propellers, a bow thruster and a smaller stern thruster to supplement the sway forces provided by the rudders. These systems provide smooth control with the ability to react quickly and provide precise calibration for repeatable operation. Controllable pitch systems operate more effectively than the older fixed pitch systems because they are designed for heavier use under DP control. In addition, they provide a larger range of adjustment enabling DP systems to command smaller increments of thrust for finer control. Unfortunately, since the controllable pitch mechanisms are more complicated they can require additional maintenance. In addition, the engines powering them typically run at a constant rate which, while operating closer to optimum efficiency, generates a substantial amount of noise, which can cause crew fatigue and generate vibration problems for other on-board systems. With these systems the most likely upgrade is simply adding larger, more powerful thrusters. Typically, these systems already have split rudder controls and more efficient rudder shapes than the previous propulsion layout.

The latest style of powering which is gaining popularity consists of two high power Z-drives as the main propulsion accompanied by two large controllable pitch tunnel thrusters in the bow. These systems can provide thrust more precisely by being able rotate through a full 360 degrees, which allows the DP system to more effectively direct the thrust for optimum station-keeping. In addition these systems are designed specifically to handle the rigorous operation generated by DP controls. Many of these systems are much higher power, which not only improves the capability of the vessel but also maintains manageable maintenance costs by running at a lower level for general positioning operations. One of the most important benefits of these systems is the redundancy they provide with multiple propulsion devices. While these systems typically do not require redundant thrusters, it can further reduce costs as operations can continue while repairs and maintenance are carried out on one of the thrusters. These systems are designed to continue holding position in reduced conditions even with one bow thruster and one Z-drive off-line. These systems suffer from the same mechanical complexity of the controllable pitch systems. Unfortunately, such complexity often requires more maintenance and suffers longer delays during service. As these layouts are generally installed on newbuild vessels, few alterations have been completed at this time. Some concern has again been raised regarding the constant rate on the engines powering the bow thrusters from a noise standpoint but no recent alterations have been made.

Many different thruster types are added to the three typical layouts noted to produce different variations depending on the intended area of operation or the prevailing weather conditions. These additional types include pump jets, “drop-down” azimuthing thrusters and portable “strap-on” thrusters. Pump jets allow operation in areas where draft is a major concern. They provide easily directed thrust without increasing the draft of the vessel. Unfortunately, they provide less thrust per installed horsepower than typical screw propeller type thrusters. Often they are used alone in systems operating in relatively calm conditions, allowing the main engines to be completely secured reducing operating costs. Pump-jet thrusters also allow the addition of azimuthing thrusters without increasing the vessel’s draft. Retractable or ‘drop-down’ azimuthing thrusters are a relatively recent addition to workboats that are gaining popularity very quickly. These thrusters can be secured in the hull during transit to reduce vessel drag and save fuel. Once on site they are extended and provide full azimuthing thruster performance. Some models can even operate as tunnel thrusters while retracted in the hull. In addition, they can be used as the sole means of propulsion while performing standby duties offering further fuel savings. Often DP capability is required on a simple vessel-of-opportunity. Instead of installing a completely new propulsion suite retractable thrusters can be installed directly to the sides of the hull such that they can be quickly removed at the completion of the job.

Each of the propulsion devices must be interfaced to the DP system for optimum performance, each with their own form of interfacing. Typically, the interfacing between the propulsion devices and the DP system is completed using analog signals. These can include simple voltage ranges such as 0-10 volts DC, current loops ranging from 4-10 Ma and ‘Digital’ constant voltage signals that generally operate at 24 volts DC. The standard voltage and current signals are used for the direct command and feedbacks of the propulsion units, while the ‘digital signals are used for the ‘Select’ and ‘Ready’ signals. Select signals are activated by the DP system when it wants to take command of a propulsion unit. Ready signals are activated when a thruster is ready for the DP system to send commands. Both signals are required for DP control of a given propulsion unit. Newer controls are utilizing serial data connections allowing a single cable connection for all propulsion control interfacing.

Missions

Workboats fulfill the highest number of different missions of any of the offshore support vessels. Everyday supply duties are carried out by virtually all of the workboats in the fleet and the addition of a coordinated control system simply makes them easier. Typically, a vessel whose sole purpose is supply duties will only add a basic joystick system that provides coordinated control along with automatic modes for wind compensation and heading control. The latest trend is to add basic positioning control as well due to the relative ease of adding a DGPS to the vessel also. This allows faster and safer visits, as the vessel is no longer required to actually tie off to the rig it is supporting. In addition, this reduces the likelihood of damage to the rig itself. All of these systems require a minimum selection of sensors including a gyrocompass for heading control, a wind sensor for wind compensation and a DGPS for positioning. Many systems will add additional types of sensors for improved accuracy and redundancy. With any system using automatic positioning, the accuracy of the DGPS is of major importance. In any positioning use, some type of differential correction is mandatory to maintain acceptable position accuracy. These signals can be further adjusted for pitch and roll of the vessel using a vertical reference unit (VRU) for enhanced accuracy. As the accuracy of positioning required increases the type of differential correction used will change. Some missions require little more than the easily available US Coast Guard correction signal while others require survey-quality corrections. Workboats performing anchor handling or core drilling duties require the more accurate survey-quality differential corrections combined with pitch and roll compensation to provide precise station-keeping. These highly accurate corrections are also required for vessels engaged in cable laying or cable burial operations in conjunction with additional control modes from the DP system.

DP systems can provide additional track follow modes that allow a more automated approach to cable related operations with the vessel automatically following a prescribed route. The input of the tracking can be a very simplified approach similar to an autopilot, which relies only on a bearing and a distance off the track, or it can be a more complex method deriving true position information at each instant. Some of the more advanced workboat systems also directly monitor the tension in the cable being installed to prevent damage.

ROV support is another growing area of workboat operation. When outfitted with an appropriate hydro-acoustic tracking system, DP systems can provide modes to automatically follow the ROV along its route. Combined with automatic positioning, this allows the ROV support crew to safely remain in position before, during and after ROV operations which reduces the risk of damage to the ROV while it moves independently from the vessel. ROV's being much smaller and lighter, are much more agile than the vessel, allowing them to quickly maneuver into positions which could endanger the umbilical cord connecting them to the ship. ROV follow mode allows the ship to stay very close to the ROV itself to prevent such problems. While the ROV is being deployed the risk of damage is also very high. Using the automatic heading and position modes, the vessel can select the safest heading to deploy the ROV, further protecting it. An added benefit for vessels equipped with hydroacoustics is the ability to use a fixed beacon on the seafloor as an additional position reference for automatic positioning effectively adding a redundant sensor.

Many simplex DP systems are specially adapted for use on government missions including search and rescue and buoy operations. Using a variation of track follow these vessels are able to follow pre-described search patterns automatically. This provides not only more efficient operation as the search area is covered completely without retracing, but also allows longer hours of operation since it requires less crew intervention to actually control the vessel. In

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addition, with the precise control offered by DP, vessels are able to perform complex buoy operations to maintain waterway markings. DP systems allow the vessels to work in close proximity to navigation marks without risk of tangling their own moorings with those anchoring the mark. Joystick and simple DP systems can allow virtually any vessel to carry out a selection of these missions in a safe and efficient manner.

Typical System Architecture

Simple DP systems consist of several different parts which allow interaction with the vessel (Figure 2). The control console includes the actual control actuators, typically a heading

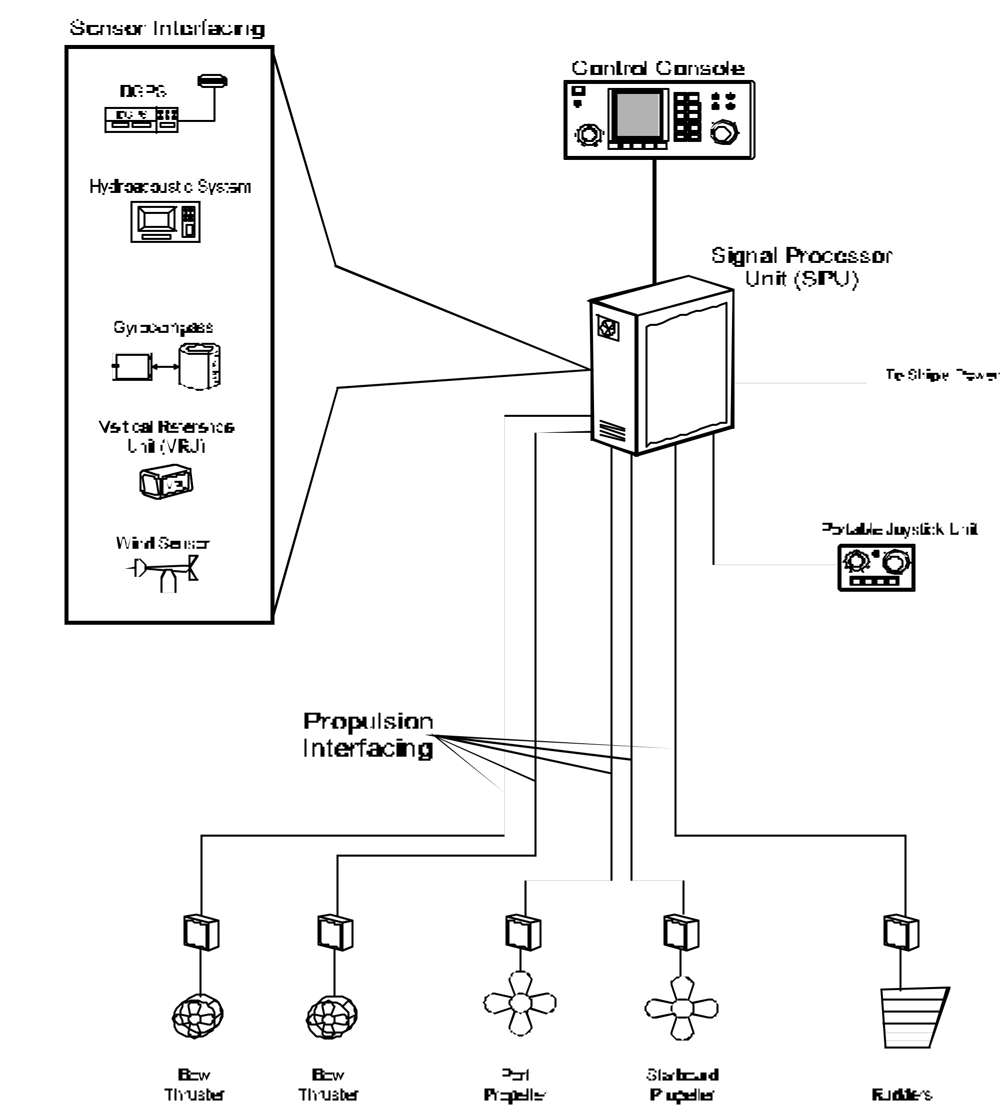

Figure 2 - Simple DP System Architecture

control potentiometer for control in the yaw axis and a position control joystick for control in the surge and sway axes. A small keyboard that allows the user to manipulate the system typically accompanies these controls. Most simplex DP systems offer some direct mode keys for the major modes of operation. On a typical joystick system this would include wind compensation and automatic heading control along with any positioning modes which could include automatic positioning, ROV Follow and tracking modes. Other modes can be included as well such as switching the system to a remote center of rotation. Direct key access allows the operator to quickly enter and exit these modes should it become necessary. Along with the controls, the system typically provides a display to provide the operator with feedback about the system. Displays range from simple LCD screens to full function monitors similar to those found on full-scale dual and triple redundant systems. These displays not only show the vessel's position but also provide feedback from both the propulsion units and the sensors. Generally, the displays remain fairly simple to prevent confusion during operation. Since most workboat operators are not certified Dynamic Positioning Operators (DPO), these systems display only a limited amount of information vital to positioning operations. Alarms and system status indicators are also displayed on the control console either through individual lamps or text displays. The control console connects directly to the central processing unit (CPU) for the system, which is located within the signal-processing unit (SPU). The operating software is typically stored either on a fixed disk drive within the system or actually loaded onto one of the processor chips in the CPU. Either method offers ease of changing the operating parameters on-board the vessel and good protection from accidental alterations.

Typically, all of the interfacing for the DP system occurs in the SPU. This unit provides the analog to digital conversion for the analog sensors such as vertical reference sensors, wind sensors and the propulsion controls. Signal isolation is also performed in the SPU to prevent any interference with DP operation due to power problems located at the thruster or sensor locations or along the interconnect cables. While most propulsion controls are currently interfaced with simple analog voltage or current signals more advanced controls are emerging in the industry allowing direct serial connection to engine governors and thruster controllers. Signal processor units are generally small bulkhead mounted units that require only a power connection and the interfacing cables. They are usually located on the bridge not far from the control console. Generally, an uninterruptible power supply (UPS) is used to power both the control console and the SPU to provide safe operation with protection from power surges that are common on workboats.

With the many functions available on DP systems operators typically want multiple access to operate the system. Remote operating stations and portable units offer this flexibility by extending the DP system capabilities to other locations around the vessel. Typically remote operating stations offer all of the controls and modes provided by the main control console. These stations are usually located on the aft bridge, ROV support area or other locations where complete function is required. Portable joysticks provide a limited number of functions for less critical locations. Typically, these units are located on the bridge wings or on deck where the operator can rely on visual feedback instead of sensor feedback.

Not only does the DP system interface with a variety of propulsion options, it also interfaces with reference sensors to provide a baseline for performance. A basic coordinated control system or Joystick system typically provides two main automated functions including wind compensation and automatic heading control. In addition, manual control of the vessel is achieved using a potentiometer for control in the yaw axis and a joystick for control in the surge and sway axes. For each mode to work properly a reference sensor is required. Wind sensors and gyrocompasses are the most basic sensors interfaced to a joystick system. Wind sensors must be accurate to within ±1knot to allow the system to calculate accurate forces acting on the vessel. Most marine industrial grade units provide this level of accuracy. Wind sensors can be interfaced using either analog signals for speed and direction or a serial data string that provides the same information. Gyrocompasses also need to meet a certain level of accuracy typically within 1

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degree depending on the latitude where the gyrocompass is operating. Interfacing with gyrocompasses can be done either through a standard serial data link or through analog signals using the stepper method. Gyrocompasses that use stepper output do not reference s specific heading, but are designed to note relative changes through a given number of steps for a given amount of rotation. Often adapters are installed on these gyrocompasses to convert the stepper signals into a serial data string. Position Reference sensors come in many different forms. The most common position sensors used on workboats are DGPS, hydro-acoustics and laser radars. DGPS receivers are readily available and provide high accuracy for positioning applications. Their accuracy can be dramatically improved by using a survey-quality differential correction signal in place of the publicly available Coast Guard differential signal. Accuracy for DGPS systems typically range from 1 to 3 meters depending on the environmental conditions and the number of operating satellites being tracked. The accuracy of the DGPS is extremely important to the performance of the system. If the DP system does not have a reliable sensor to use for positioning the performance will not be satisfactory. Recently, many vessels are requesting laser radar units for positioning. These units track a reflective target up to 2000m away with accuracy nearing .2m. Unfortunately, these systems are very susceptible to weather conditions. The realistic range for DP operations is much shorter than the maximum, nearing only 10-15%. Many workboats use hydroacoustic systems tracking beacons fixed on the seabed for positioning as well. There are a number of systems available including Long Baseline (LBL), Short Baseline (SBL) and Ultra-short Baseline (USBL). These systems depend on different beacon and hydrophone configurations for operation in different conditions, which will not be covered. Typically, workboats are equipped with USBL systems that use a single hydrophone head to track fixed or moving beacons. These systems also provide the vessel with the capability to track ROV's, further expanding their capability. Another position reference sensor widely used in offshore fields is ARTEMIS microwave positioning. Range and bearing are derived using linked low power microwave antennas with accuracy for these systems close to 1.0m for position and within 0.1 degrees for heading depending on conditions. ARTEMIS systems are more susceptible to weather interference than DGPS which has led to a decline in their popularity. Many other positioning systems are available around the world including LORAN and SYLEDIS microwave systems however, DGPS is typically the least expensive and most available.

As workboats install more and more DP systems, classification from regulatory bodies Such as American Bureau of Shipping (ABS) becomes a consideration. Several regulatory bodies offer classification for simple coordinated control or joystick-only systems (Figure 3). Class-0 systems require minimal sensors including wind sensor input, gyrocompass input and a single position reference. No redundant sensors are required for Class-0 systems. Class-0 systems are required as back-up units provided for Class-1 systems. Only minimal sensors are required for

	IMO	Class Designations			
Description	DP Class	ABS	BV	LRS	DNV
Manual position control and automatic heading control under specified maximum environmental conditions	*Class 0*	DPS-0	MSA	DP(CM)	DNV-T
Automatic and manual position and heading control under specified maximum environmental conditions	Class 1	DPS-1	MA	DP(AM)	DNV (AUT)

Figure 3 – Regulatory Body DP Classifications for Typical Workboats

Class-0 systems including a single gyrocompass, wind sensor and position reference. Class-1 systems require each of those sensors in duplicate, in addition to requiring a separate stand alone Class-0 system for back-up.

Installation and Commissioning

Workboats run extremely busy schedules which rarely include enough downtime to install and commission new systems. Installing a DP system can take as few as two days if planned correctly. If other vendors are involved or problems are encountered, it can take as long as a week. The types of interfaces required can play a large role in the amount of on-board time necessary for installation. Typically, sensors interfaced using serial data lines require less on-board time and more development time for the software to process the intended message correctly while analog signals require less development time and more on-board time to perform the correct calibration for software operation. For installation and commissioning to be carried out in a timely fashion some additional things must be addressed. The appropriate interface cables for both the thrusters and the reference sensors should be identified and pulled if necessary. This allows the installation to go smoothly and quickly. Once the DP system is installed, all of the peripheral systems should be checked out and operational before the trials are scheduled. If the either the sensors or the thrusters are not operating correctly the DP system cannot be properly tested. Once all of the external systems are operating correctly, the DP system can be calibrated. This involves setting the specific ranges for the commands and feedbacks for the best resolution of control. Once the system is correctly calibrated and the DP system is properly commanding the vessel the system can be trialed. Sea trials include verification of all sensor inputs and thruster interfaces along with individual tests for each mode of operation. In addition, the system gains will be tested to assure their range is appropriate for the vessel. Finally, system is subjected to several failures to assure that the system alarms are operating correctly. When the system successfully completes these tests it is ready for operation. Generally these tests can be completed in 1-2 days provided there are no mechanical failures with the other systems. The DP system relies so closely on the other systems that even minor changes, such as engine tune-ups and routine thruster maintenance, can affect holding performance. As the top-level system, DP system performance is directly linked to the thrusters and the sensors. If problems are experienced with any sub-systems the DP system performance suffers and trials will be extended.

Summary

As the workboat market becomes more competitive, owners are looking to technology to reduce their costs and meet the requirements of their customers. The addition of coordinated control systems or simple DP systems allows workboats to more easily and more safely complete their missions. In addition, it allows a single vessel to complete more different missions, making it more attractive in the marketplace. Typically, a DP system can control the vessel as accurately as a good captain and can maintain such an effort consistently almost for long time duration again making the vessel more attractive to potential customers.

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