DYNAMIC POSITIONING CONFERENCE
September 17-18, 2002

Workboats

A Packaged System Approach to DP Vessel Conversion

Joe R. Bekker and Shaw X. Dou
Thrustmaster of Texas, Inc.

Abstract

As older offshore production areas become more and more congested and new exploration moves to deeper and deeper waters, the demand for dynamically positioned vessels continues to be strong. Rather than scrapping older vessels and replacing them with DP-capable newbuilts, many existing vessels can be upgraded for DP at a fraction of the cost of replacement.

A good DP system uses multiple azimuthing thrusters with either variable speed, fixed-pitch propellers or fixed-speed, controllable pitch propellers. The whole system is complex and comprises many components and subsystems. Proper integration of all parts of the system requires a good understanding of the interdependence of all critical system components. Acquiring and installing the sub-systems in an existing hull is always challenging and often requires major vessel modifications requiring extensive design work and lengthy dry-docking.

This paper discusses a different approach to these challenges. The packaged system approach introduced here uses standard, pre-engineered modules provided by a single source as an integrated, factory-tested system. This system is designed to allow installation on any vessel without the need for modifications or dry-docking.

Real-world experiences with the implementation of this approach on a number of different vessels are discussed. A detailed description of the system is provided including DP system, deck-mounted thrusters and deck-mounted diesel-hydraulic power units. Thruster-to-vessel interface is discussed, including the effects from propeller ventilation, vessel motions, wave action and slamming impacts.

An overview is presented on how such a system satisfies Classification Society Rules for DPS-1 and DPS-2 including Failure Modes and Effect Analysis (FMEA) and Power Management System (PMS).

Introduction

Adding dynamic positioning capability to an existing vessel generally involves adding thrusters and machinery to power and control the thrusters. Ideally, the thrusters will allow true thrust vectoring whereby the thrust force can be steered to any horizontal direction and the amount of thrust force can be set at any magnitude between zero and maximum thrust (Ref. 1). This can be accomplished by using azimuthing thrusters with controllable-pitch propellers running at constant speed or by using azimuthing thrusters with fixed-pitch propellers running at speeds that can be freely controlled from zero to maximum RPM. A number of papers presented at DP Conferences in past years have addressed the relative merits of the two concepts and concluded that fixed-pitch at variable speed is preferable over controllable-pitch at fixed speed (Refs 2, 3, 4). The authors of this paper concur with that conclusion.

Most of the DP conversions in recent years have involved installation of retractable thru-hull azimuthing thrusters with diesel-electric drive. Those conversions required the creation of additional machinery space, acquisition and installation of diesel-generator sets, SCRs or variable frequency controls, and electric motor-driven retractable thrusters. The projects required substantial planning, engineering and coordination. It required that the vessel be taken out of service and put in dry dock for an extended period of time. All of this made those conversions rather expensive. This paper introduces an alternate, less expensive approach to DP conversions. Let's first take a look at how these conversions are currently done.

The Conventional Method of DP Vessel Conversion

A typical vessel conversion to DP capability starts out with several studies. These include:

- Definition of Vessel Capability Requirements
- Determination of equipment and machinery to be added to meet capability requirements
- Determination of where to install the new machinery (new thrusters, generators, control cabinets) and how to create space for it.
- Stability analysis based on removal/addition of weight and changes in centers of gravity and vessel rotation.
- Preparation of project proposal with budget and time line.

The next step is procurement of long lead items and contracting with a shipyard to modify the vessel and install the new machinery and equipment.

These conversions are costly. In addition to equipment purchases and installation costs, the support systems are a major cost component. They involve lots of shipyard work, including installation of ventilation blowers and ducting for the new machinery spaces, ladders and platforms, fire walls and fire protection equipment, bilge water pumps and piping, thruster wells, electric starters for hydraulic steering pumps, diesel engine starting systems, fuel storage and treatment and transfer systems, exhaust piping and mufflers and stacks, thermal and noise insulation, cooling water pumps and piping, seachests, alarm systems, machinery controls, power management system, and lots of plumbing, cabling and wiring. And then there is the cost of engineering and project management.

Here are a few examples of such conversions.

The *Global Explorer* is a 279 ft. cargo vessel recently converted to a multi-purpose offshore construction support vessel (Fig. 1). The conversion included addition of a DPS-2 System. This involved acquisition and installation of an Alstom DP System, three 715 kW and one 1440 kW Caterpillar generator sets, SCR systems, and DC electric motor-driven thrusters provided by Thrustmaster. The two stern thrusters are 1100 HP azimuthing L-drives, one of the bow thrusters is a 66-inch, 1000 HP tunnel thruster, and the other bow unit is a 1000 HP retractable combination thruster which is freely azimuthing in the lowered position, while functioning as a tunnel thruster in the retracted position (Fig. 2). Each thruster is driven by a GE 752 variable-speed DC traction motor.

Installing the DP computers was easy. Finding a place for the generators, SCRs and thrusters and then installing that equipment with all its interconnecting buses, cables, controls and ancillary equipment was a complicated, time-consuming and expensive project. Some of the work was done dockside, but installation of the thrusters could only be done in dry dock.

Another recent conversion was the *Elkhorn River*, a 218 ft. PSV that started out as a 178 ft. twin-screw OSV (Fig. 3). Besides a 40 ft. mid-body extension, the conversion included adding a Kongsberg-Simrad DP System and two Thrustmaster 500 HP retractable combination thrusters, one in the bow and one in the stern skeg between the two shaft lines (Fig.4). Each thruster uses a Cummins KTA 19M diesel engine

driving a hydrostatic transmission that powers the podded hydraulic propeller drive.

The vessel has a shallow hull depth of only 15 ft. and is frequently used on projects in very shallow water. On those projects, the thrusters are retracted and work in tunnel mode on DP in combination with the CP main screws and rudders. When working in deeper water, the thrusters are dropped down, and the 50" props in nozzles are freely azimuthing.

For this vessel, the diesel-hydraulic thruster drive was selected because it was less expensive, and the diesel hydraulic power packs are a lot smaller in size and easier to install than diesel generators with SCRs or VFDs (Fig. 5). This is generally true for projects where total thruster power is less than 4000 HP and individual thruster sizes are 1000 HP or less, unless the vessel already has a large electrical plant.

The mid-body extension required lengthy dry-docking, and thrusters were installed during the same period. The total cost for conversion and upgrade approached 70% of the cost for a new-built vessel.

While expensive, these conversions were economically feasible. Changing market conditions had rendered the original vessels obsolete, and they were laid up. The DP conversions turned those non-performing assets into very marketable vessels with excellent utilization at high day rates.

So why don't we see more of these conversions?

1. Many vessels are dismissed as viable candidates for conversion due to lack of space for new machinery or insufficient hull depth for installation of adequate drop-down thrusters (Fig.6).

2. The projects are complicated. A lot of study has to be done before you can even start working on a rough cost estimate. You must spend a lot of money before you even know if the project is technically and financially feasible.

3. The projects are risky. There are many opportunities for surprises: Design modifications may be based on old drawings that turn out to be inaccurate; one of the equipment suppliers may be late causing delays and extra dry-docking time; during dry-docking for conversion, vessel structure or hull plating may be found to require replacement; equipment may not fit or be incompatible with other equipment; major obstructions may be found when routing new exhaust, ventilation ducts, fuel lines, cooling water, electrical cables, etc.; the conversion may affect gross tonnage, changing USCG requirements for manning the vessel; etc.

In summary, vessel DP conversions are expensive and have great potential for cost overruns and schedule delays. Is there a better way?

The Packaged System Approach

As far back as the 1960's, Murray and Tregurtha built a number of packaged, deck-mounted propulsion units for dynamic positioning applications (Refs 5, 6). An example is the *Cuss I*, a 260-ft. drilling ship for core sampling in up to 12,000 ft. of water (Project Mohole) (Fig 7). The vessel was fitted with four diesel engine-driven right angle drives over the side, one on each quarter.

Following the same basic concept, Thrustmaster developed a packaged system for DP conversion using deck-mounted over-the-side thrusters with deck-mounted self-contained power units, DP system, sensor

suite and all interconnecting cables and interface for ready installation on any vessel or barge from 100 to 600 ft. long (Fig 8).

The first such system was installed in the late 1980's on the *Arctic Discoverer*, a 300 ft. trawler converted to a dynamically positioned treasure hunter that found the wreck of the *Central America* in deep waters off the Carolinas (Fig. 9, 10). With an ROV, the vessel recovered some $300 million in gold over a period of about 5 years. The system was comprised of two 500 HP cradle-mounted azimuthing thrusters stuck to the side shell, two Caterpillar powered hydraulic power units sitting on the aft deck, and a Robertson DP system with DGPS.

To effectively produce omni-directional thrust, the thruster propellers had to extend below the bottom of the vessel. This required a stem length of over 26 feet (Fig. 11). In a dynamic environment with continuous vessel motions, varying thrust forces and wave action, a long stem containing right-angle gears, drive shafts and bearings has limited prospects of longevity. This is due to continuous flexing or deflection of the stem as well as lateral and torsional vibrations of the lengthy drive shafts at varying RPM and torque. It's a mechanic's nightmare.

To avoid this, we used podded hydraulic propeller drives on these thrusters. The benefits of podded propulsion have recently been rediscovered and described in several papers (Refs 7,8,9). While podded electric drives are still relatively new and unproven (Refs 10,11), Thrustmaster has been building podded hydraulic drives for many years. A lot of these units, like the 600 HP retractable azimuthing thrusters on the DP pipe lay barge *Chickasaw*, have been operating for more than ten years without a single failure.

With the podded hydraulic drives, the long stems contain hydraulic hoses only. There are no moving parts in the stem other than the hydraulic fluid flowing through these hoses. Flexing of the lengthy stems has no effect on the drivelines whatsoever.

The DP conversion of the *Arctic Discoverer* took only a couple of weeks and was done dockside.

During the 1990's, the packaged system approach was used on a number of temporary DP conversion projects whereby a vessel of opportunity was temporarily equipped with thrusters and a DP system for the performance of a specific contract. Here you see a deck barge being outfitted in Singapore for a cable-lay project in Thailand, using 500 HP deck-mounted thrusters and diesel-hydraulic power units (Fig. 12). Each thruster uses its own dedicated hydraulic power unit. Hydraulic hoses run between thruster and power unit using quick disconnects at the ends. The diesel-hydraulic power packs are very compact, suitable for outdoor installation and completely self-contained. A fuel day tank is incorporated in the unit. It also includes a local control panel for start-up and emergency operation. Controls use battery power from the engine start system and the engine has an alternator for battery charging. No vessel utilities are required: no cooling water, no electrical power, no air, and no control power. All it needs is daily diesel fuel refills.

Another temporary DP conversion was the *Seabeach*, a 270-ft. vessel chartered for cable lay in the Bay of Campeche (Fig. 13). Four 500 HP thrusters and HPUs and a Nautronix DP system were leased as a "Portable Dynamic Positioning System."

The U.S. Navy leased a pair of 500 HP deck-mounted thrusters and HPUs with a Simrad SDP-01 for temporary conversion of the *NAWC 38* (Fig. 14). This vessel acquired acoustical profiles of NATO submarines in the Caribbean.

Western Geophysical used a pair of 500 HP units mounted on platforms cantilevered off the side shell of one of their ocean bottom seismic data processing vessels, the *Western Orient*.

A cable repair vessel owned by Delba Maritima in Brazil was equipped the same way, using two platform-mounted thrusters and two deck-mounted diesel-hydraulic power units connected to a Kongsberg-Simrad DP System.

Some Lessons Learned with the Packaged System Approach

One of the lessons we learned quickly is that a motion reference unit (MRU) can be a real lifesaver. An MRU is required equipment to correct taut wire angles and hydro-acoustic signals for vessel motion. Quite often you can get by without an MRU on a barge with a simple DP using DGPS if you place the position reference sensors near the point of rotation, but a ship-shape vessel can have substantial roll and pitch in rough weather, swinging the DGPS antenna from port to starboard (Fig. 15). This makes the DP system think that the vessel is alternately pushed off station in port and starboard direction and will try to correct for this. As a result, the thrusters constantly go from full power starboard to full power port to full power starboard, etc. This can set up a harmonic pattern whereby the thrusters actually increase the roll angle amplitude. Adding an MRU to the system will solve this. An MRU will correct the DGPS signal for vessel motions and dampen the roll.

Another interesting lesson we learned pertained to propeller ventilation. In recent years, many oilfield supply vessels serving the deep water exploration and production platforms experienced problems with their bow thrusters. They typically use a geared tunnel thruster directly driven by a diesel engine. The deepwater offshore platforms do not allow them to dock to their structure and the boats use their bow thruster to stay on location while offloading supplies. When the weather gets rough, the heave, pitch and roll of the vessel combined with wave action frequently lift the thruster tunnel ends out of the water. Whenever this happens, large slugs of air are sucked into the tunnel and the propeller is instantly unloaded. This is called propeller ventilation. As the tunnel is submerged again, water hits the propeller and the load is instantly reapplied. This heavy shock loading punishes the drive train causing premature failure of gears and couplings.

When deploying thrusters over the side of a vessel, the propeller typically extends below the baseline, putting it deep in the water. Nevertheless, propeller ventilation may occur if the vessel has significant roll. This is because the thruster is quite a distance outboard from vessel centerline and thus has a large radius of rotation from roll. The thruster travels a substantial amount in vertical direction and the propeller and nozzle may break the water surface frequently during bad weather, exposing the drive to heavy shock loading. Fortunately, a podded hydraulic propeller drive can cope with this without any harmful effects. The rotating inertia is quite small and the hydraulic drive dampens the shocks from these load variations while pressure compensators and reliefs provide the perfect torque limiter.

Dynamic Loads on Thrusters and Platforms

In addition to instant and frequent thrust load variations, the thruster is exposed to the following dynamic loads (Fig. 16):

1. Acceleration loads (g-forces) from vessel motion.

2. Drag loads from the submerged portion of the thruster thrashing through the water due to vessel

motion.

3. Wave slam impact loads.

All of these loads are transferred through the stem to the support platform or the main deck. On some of our early installations, the combined magnitude of all these dynamic loads was not fully understood and recognized. In one case, it resulted in fatigue failure of the stem, which fractured at the upper end. Fortunately, the hydraulic hoses inside the stem kept the lower part of the thruster dangling and prevented it from dropping down to the ocean floor. Repair was relatively easy.

The failure prompted thorough study and testing and resulted in redesign of the thrusters whereby the stem and top structure are now capable of easily dealing with all dynamic loads on a continuous basis.

Classification

The Classification Societies have established rules for DP class. Even though there are differences between the rules of each Society, the basic concept is pretty much the same. First, to get DP class, the vessel has to be classed. Then there are various levels of system redundancy.

In the Packaged System Approach, we can take care of class upgrade to DP. The system lends itself very well for DPS-2 or DPS-3 (Ref 12). DPS-2 requires that the vessel can hold station upon any single point of failure. This requires a second DP system and redundant thruster capacity. In the Packaged System Approach, each thruster has its own dedicated power unit. There is no sharing of power. There are no common cooling water systems or fuel supplies. Control power of each thruster is from the battery of its own HPU. There are no common points of failure on thrusters or HPUs. This makes the Failure Modes and Effect Analysis (FMEA) very straightforward. It also eliminates the need for a Power Management System (PMS). For DPS-3, the loss of a vessel compartment must be considered a single point failure. As thrusters and HPUs are deck-mounted and not installed in a compartment, the only requirement for upgrade to DPS-3 involves adding another DP system and a firewall between DP systems on the bridge.

Installation Examples

Here you see a packaged system on a cable-lay barge operated by Pirelli-Jacobson in Seattle, WA (Fig. 17, 18). It is comprised of four 500 HP platform mounted thrusters with deck-mounted HPUs and a redundant Kongsberg-Simrad DP system. It started out as a leased system but was soon purchased.

Another interesting DP conversion was the *Ulises*, an oceanographic research vessel (Fig. 19, 20). Two 500 HP thrusters were installed, one on a platform off the bow and the other on centerline at the stern on the launching ramp. The vessel reportedly found an ancient city on the ocean floor off Cuba. Some people speculate that they have found the lost city of Atlantis.

On this reel pipe-lay barge from Nippon Salvage, we used a Kongsberg-Simrad DP system with electronic chart display and special pipe-lay software (Fig.21). It was provided with four 500 HP deck-mounted thrusters and HPUs.

The *Titan 2* is a 440 x 177 x 43 ft. twin hull offshore construction vessel (Fig. 22, 23). It is under long-term charter with Global Industries, who put a DNV AUTR DP system on it with all the bells and whistles.

They added eight Thrustmaster 1000 HP thrusters, installed on platforms off the hulls. Thrustmaster also provided the eight 1000 HP diesel-hydraulic power units. The conversion was completed ahead of schedule and within one percent of budget. The ship is operating in the Bay of Campeche and is holding station within half a meter.

All of these DP conversions have a few things in common: they were done dockside with only minor vessel modifications, completed within a few weeks, and the owner knew exactly how much it was going to cost.

Conclusion

Quick and relatively inexpensive conversions of existing vessels and barges to DP capability are quite feasible using the Packaged System Approach. In many cases, the total cost is only half of what a conventional conversion would cost. Almost any vessel or platform can be converted regardless of hull depth or machinery congestion. Since there is just one single equipment supplier involved, project budget and schedule are easily established with a high degree of accuracy. While deck-mounted power units and outboard thrusters may not be very elegant, it allows leaving the vessel in its present state, avoiding major surgery. And while outboard thrusters are somewhat exposed to collision damage, repair can be done quickly, without dry-docking. For DP conversions requiring up to 10,000 HP of thruster capacity, the Packaged System Approach is the better way.

References:

1. Deter, Dietmar, 1997: Principle Aspects of Thruster Selection, DP Conference, Houston, TX.

2. Adnanes, Alf Kare, 1996: Variable Speed FP vs. Fixed Speed CP, ABB Industri AS.

3. Adnanes, Alf Kare, et al, 1997: Essential Characteristics of electrical Propulsion and Thruster Drives in DP Vessels, DP Conference, Houston, TX.

4. Kallah, Amrik, 1997: A Comparison of Thruster Propellers and Variable Speed Drives for DP Vessels, DP Conference, Houston, TX.

5. Dewhurst, Peter K., 1969: Steerable Right Angle Drive Units for the Main Propulsion of Ships, SNAME Great Lakes and River Section.

6. Dewhurst, Peter K., 1969: Experience in the Control of Ships by Right Angle Drive Thrusters, Second Ship Control Systems Symposium Annapolis, MD.

7. Raynor, S.J., 1998: The Benefits of Podded Propulsion in the Offshore Market, DP Conference, Houston, TX.

8. Strand, Jann Peter, et al, 2001: Compact Azipod Propulsion on DP Supply Vessels, DP Conference, Houston, TX.

9. Adnanes, Alf Kare, et al, 2001: New Thruster Concept for Station Keeping and Electric Propulsion, DP Conference, Houston, TX.

10. Woodyard, Doug, 2001: Popular Pods still striving for Perfection, Marine Propulsion International.

11. Woodyard, Doug, 2002: Electric Propulsion exerts strong Attractions, Offshore Support Journal.

12. ABS, Rules for Building and Classing Steel Vessels 2001, Part 4.

Figure 1: *Global Explorer*

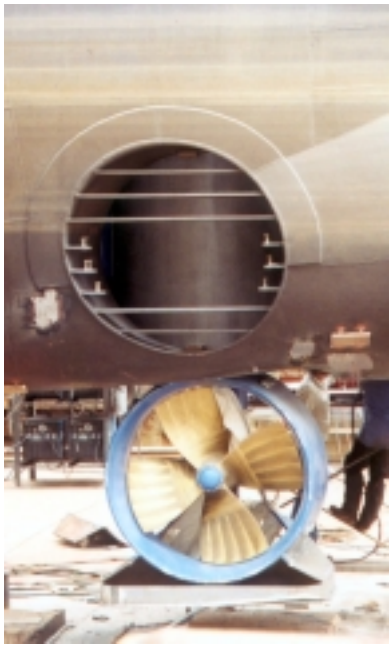

Figure 2: Retractable combination thruster

Figure 3: *Elkhorn River*

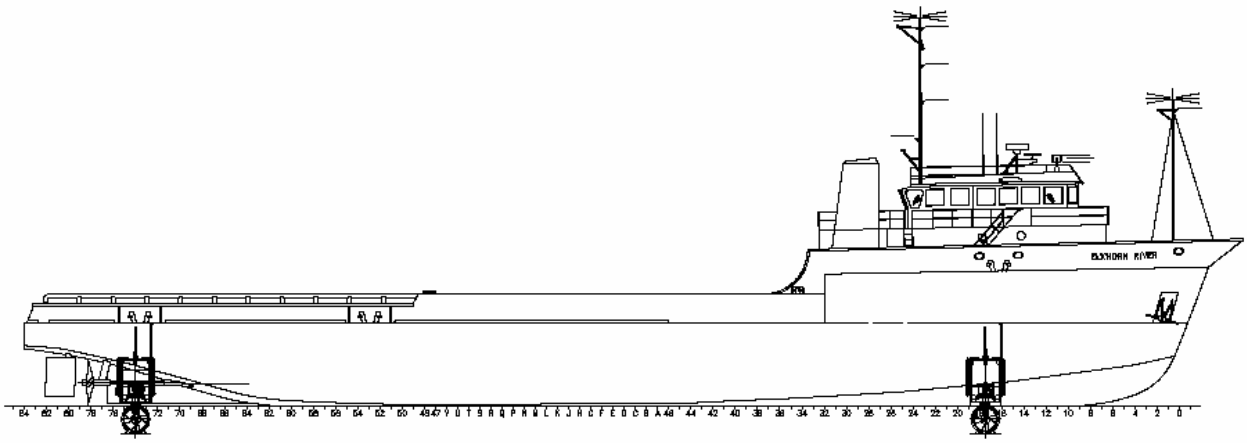

Figure 4: *Elkhorn River* thrusters

Figure 6: Retractable Azimuthing Thruster with Hydraulic Drive

Figure 5: Retractable Azimuthing Thruster with Electric Drive

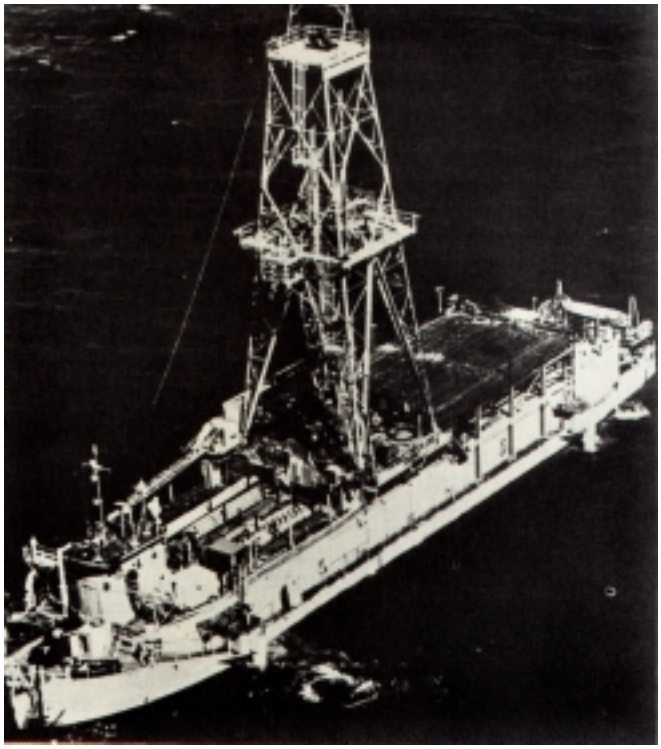

Figure 7: *Cuss I*

Figure 8: Packaged DP System

Figure 9: *Arctic Discoverer*

Figure 10: *Arctic Discoverer*

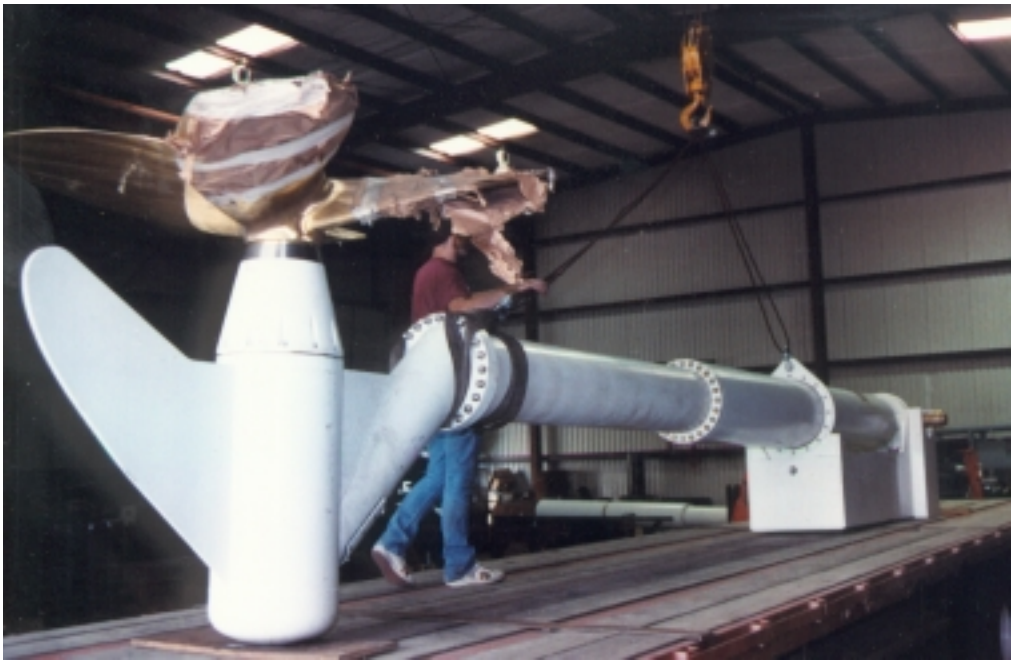

Figure 11: *Arctic Discoverer* thruster

Example 12: Thai cable-lay barge

Example 13: *Seabeach*

Figure 14: *NAWC 38*

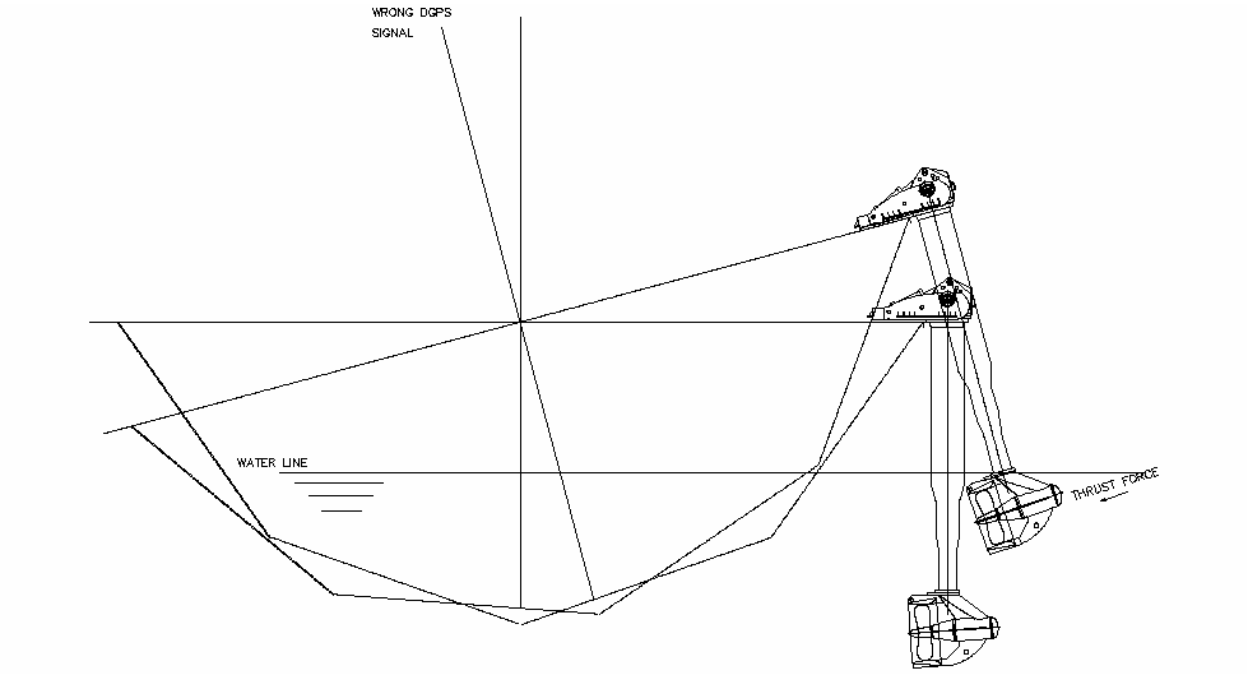

Figure 15: Propeller ventilation

Figure 16: Propeller Ventilation - DP Stem

Figure 17: *Pirelli Jacobsen*

Figure 18: *Pirelli Jacobsen*

Figure 19: *Ulises*

Figure 20: *Ulises*

Figure 21: *Nippon Salvage*

Figure 22: *Titan 2*

Figure 23: *Titan 2*