Guide to Dynamic Positioning of Vessels

Power Conversion
Marine & Offshore

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Dynamic Positioning of Vessels (DP) - Principles

INTRODUCTION

The basic purpose of dynamic positioning of a vessel is the automatic control of the vessel position and heading. A more sophisticated definition is to maintain variations in vessel position and heading within acceptable limits, while achieving minimum thruster activity.

This chapter considers the factors:

- Vessel motion
  This is the dynamics of a free floating vessel in an offshore marine environment.

- Control system
  This is a review of the control loop of force and moments: sensing: counteraction to force. The forces and moments are environmental plus task related i.e. pipe tension.

- Operational modes
  Each vessel is supplied with several different modes of operation.

  The difference between the modes is the level of control available and how the position, heading speed and set points are generated. The combination of modes provided for a vessel depends upon its role. Thus, a cable laying vessel will need Auto Track mode, which will not be required for a drilling platform.

A DP system is usually a combination of a position control system and a heading control system.

A position control system uses the vessel's position measurement equipment (PMEs) and operator commands as inputs. The control system then provides commands to the thrusters to maintain the position of the vessel at the desired location. This is a feedback control system.

A heading control system uses the vessel's compass as the input to maintain the heading of the vessel in response to the environmental elements (forces) and operator commands.

VESSEL MOTION

A free floating body will translate (move fore and aft and port and starboard) and rotate due to forces acting upon it. In turn, if there is to be control of the vessel position and heading, the vessel needs counterforces and moments to control its motion.

The vessel can move in three planes. For the purposes of DP systems we are interested in controlling the vessel in the horizontal plane. However, it is necessary to sense vessel motion in other planes, and to monitor the wind, to be able to make corrections to PME and sensor readings.

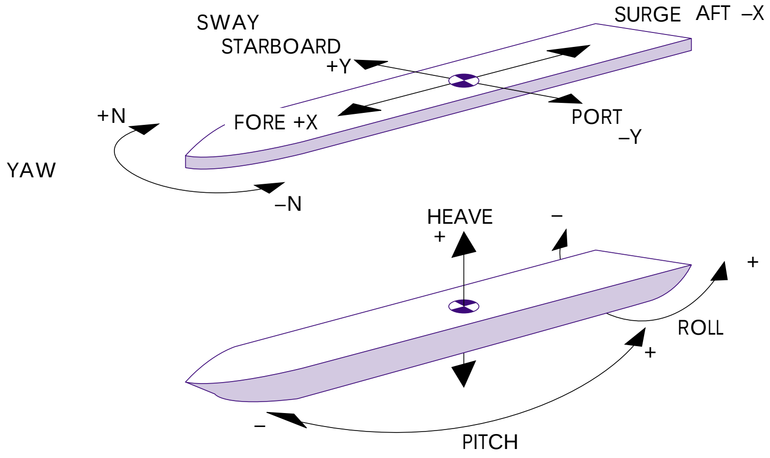

Figure 1.1 Vessel Movements

Axis of movement	Positive Direction	Coordinate System	Use in DP
Surge	Forward	±X	Position Control
Sway	Starboard	±Y	
Yaw	Clockwise (seen from above)	±Z	Heading Control
Heave	Upwards	±Z	
Pitch	Bow Down		Compensation for acoustic beacon and radio aerial & same taut wire
Roll	Stbd Down		

Table 1.1 Vessel Movement Terms

The axis of movement are the traditional names for a vessel's motion. The direction is the navigation term which identifies the direction of the motion. The coordinate system is the way that the navigation term is described to the computer. The DP control system uses these co-ordinates.

Forces

The forces acting on the vessel are the environmental forces, including wind, current and waves, and task dependent forces such as cable, pipe, anchors, tow ropes, fire monitor reaction. It is important to realise that environment forces are very variable.

Environmental forces:

- Wind
  Wind speed and direction are constantly changing. The wind forces can be defined by three components, surge, sway and yaw. To be meaningful, the point of application of the forces must be defined. The wind speed varies as a function of height above sea level, but above 3-5 metres to the height of the vessel, the change is small. The forces acting on the vessel are very dependent on the superstructure shape (the part of the vessel above the water line), and the wind direction relative to the vessel. Wind is normally defined in knots or metres/sec, and in direction with respect to north or the vessel. In normal usage, a north wind moves the vessel from north to south.

- Sea Current
  The sea current can be caused by the slope of the seabed, tidal or storm surges along coastline, outflows from rivers. It can also be wind driven. It can be caused by the effect of heating and cooling and salinity (thermohaline). The effect is only a few knots, and usually slow variation over hours and days. The effect of current on the vessel is a characteristic of vessel shape. In normal usage, a northerly current moves the vessel from south to north.

- Waves
  Waves are also described as sea state. A fully developed sea is the maximum wave size generated by a given wind. It takes many hours to build up and die down. The significant wave height is the mean of the 1/3 highest waves. The spectral density of the waves increases and moves to lower frequencies as wave height increases. The spectrum of wave energy is defined by Jonswap for the North Sea, and Pierson-Moskowitz for the North Atlantic. The direction of propagation of the waves also matters, but predicting wave drift forces is complex.

Counterforces

Moving from one to point to another, or remaining stationary, requires lots of counterforce devices to produce a controlled combination of forces. Traditional devices included oars, sails, anchors, paddle wheels, propellers and rudders.

- Static Positioning Systems
  These gain their counterforces from anchors alone. They are also called multipoint mooring systems, and can be used for station keeping or moving very slowly. By changing the anchor line lengths, and hence the forces, limited control of the vessel is possible. The alternative of moving the anchors is not very practical. The anchors form an elastic pattern and the vessel will take up a position in the middle of the pattern, where the forces balance. The use of anchors is depth dependent, with the cost increasing in proportion to the depth.

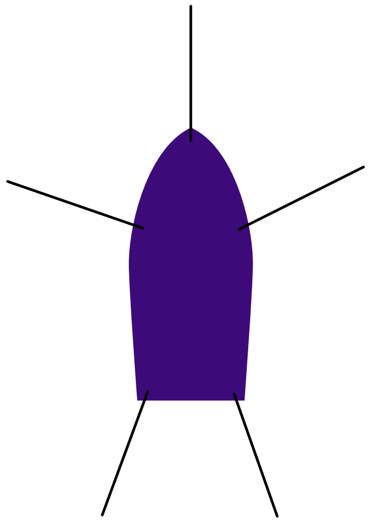

Figure 1.2 Static Positioning with Anchors Alone

- Dynamic Positioning Systems
  These use combinations of thrusters, propellers and rudders. In this guide, the term "thrusters" is used to include propellers and rudders.

- Thrusters
  There are four types of thrusters:

  - Propellers
    Provide thrust in the fore/aft direction.

  - Tunnel thrusters
    Provide thrust in the port/starboard direction

  - Azimuthing thrusters
    Provide thrust in a 360° arc

  - Propellers and rudders
    Provide thrust forward, some side thrust and thrust straight astern

Thrusters can be used for roles such as station keeping through to complex track following. They are not depth dependent. The thruster array must provide independent control of surge, sway and yaw.

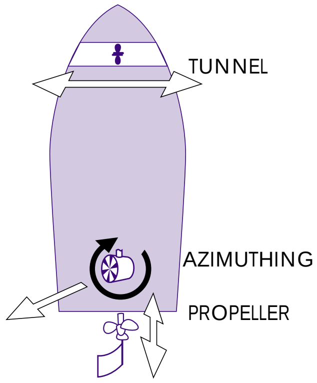

Figure 1.3 Thrusters

- Anchors and Thrusters
  There are two configurations of anchors and thrusters that differ in how the anchors are connected to the vessel. In the simple configuration, the anchors are connected directly to the extremities of the vessel. The thruster is then used in combination with the anchors to increase their capability.

  The second configuration is turret moored. Here the anchors are attached to a turret about which the vessel can rotate. The thrusters are now used mainly to control the vessel heading, with a secondary task of reducing anchor loadings.

In steady to strong winds, the vessel will align itself to the direction of the wind, usually called weathervaning. However, in light winds, the vessel will wander and oscillate about the turret, which can be problem if the vessel is connected to a shuttle tanker for instance. The thrusters can be used to damp out any oscillation in the heading, and provide a steady heading. For combined applications, either a tunnel thruster or an azimuthing thruster is used. For maximum effectiveness, the thrusters should be as far as possible away from the turret.

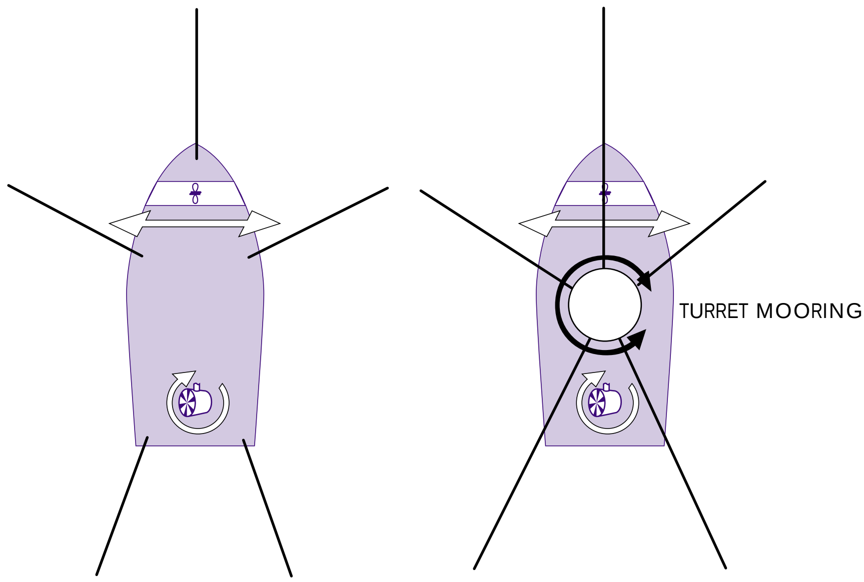

Figure 1.4 Anchors and Thrusters

Thruster Configurations

DP and heading control of a vessel requires control in X, Y and N axes. There are three basic thruster configurations which will control the vessel in X, Y and N. Most vessels have thruster configurations beyond the minimum, as these allow redundancy and other control options such as minimum power consumption, fine position control and barred zones for azimuthing thrusters to protect equipment.

Minimum Thrusters

The three minimum configurations are:

- Two tunnel thrusters and a propeller
- A tunnel thruster and an azimuthing thruster
- Two azimuthing thrusters

The objective is to independently control X_D, Y_D and N_D (the demands from the control system to the thrusters), to control the vessel in the required manner.

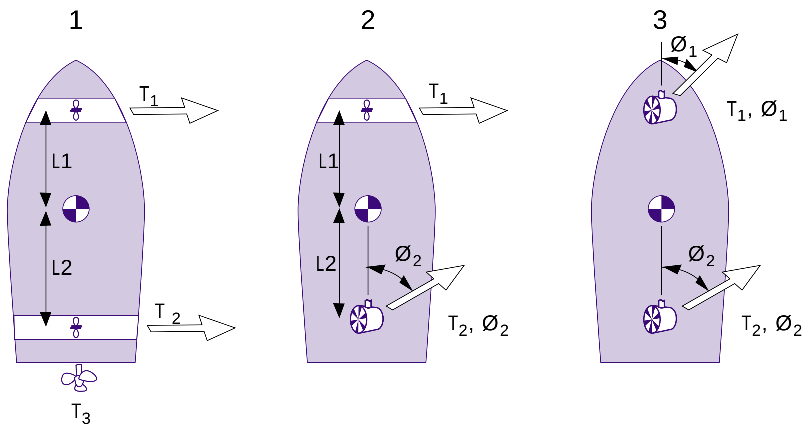

Figure 1.5 Minimum Thruster Configurations

For configuration 1

$X_D = T_3$

$Y_D = T_1 + T_2$

$N_D = T_1L_1 - T_2L_2$

Solving the equations provides values for T_1, T_2 and T_3. The same procedure is used for configuration 2.

$X_D = T_2 \cos Ø_2$

$Y_D = T_1 + T_2 \sin Ø_2$

$N_D = T_1L_1 - T_2L_2 \sin Ø_2$

Again values can be calculated for T_1, T_2 and $Ø_2$.

With configuration 3, there are three equations, but four unknowns. This gives the opportunity to set conditions to one of the unknowns, which can create an advantageous vessel option. For example, the thrusters can be arranged to use minimum power, while maintaining the required DP conditions.

Other Thruster Configurations

Multiple thrusters provide redundancy and extra operational conditions. For example, the thrusters can be biased against each other to provided controlled slow movement. The two propellers can be placed in push-pull to provide controlled movement.

The third example shown is a semi submersible with four azimuthing thrusters. These can provide control of the semi-submersible in several different ways. In the example, the thrusters have barred zones over which they cannot operate, so as not to effect each other's wash.

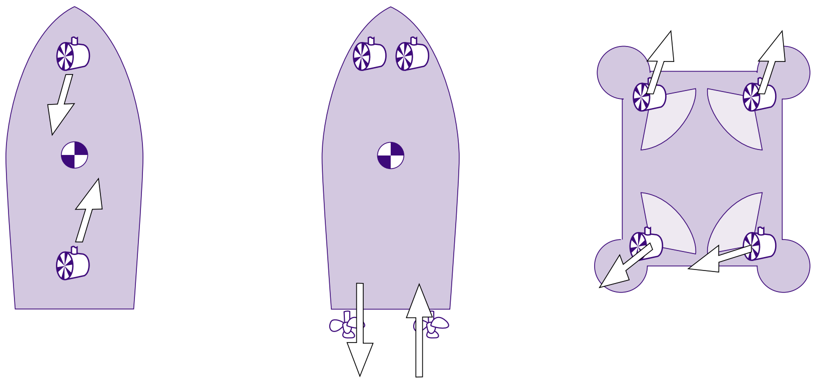

Figure 1.6 Other Configurations

Thrusters are usually placed so as to provide a maximum moment, minimum interference with other thrusters and sensors, and in the case of tunnel thrusters, as far below the water line as possible.

CONTROL SYSTEM

DP is a multiloop feedback control system. The primary function of the control system is designed to keep the vessel at a specified position, or on a specified track, and with a set heading, each within tolerable limits. The system must be able to handle transient conditions such as changes in external forces, failure of a signal from sensors and position measurement equipment, and system hardware failures.

Secondary functions are to control the vessel so as to minimise fuel consumption and to keep the thruster wear to a minimum.

It is possible to divide DP control into two separate functions:

- Measure the deviation of the vessel from its target position and estimate/calculate the forces needed to restore the vessel to the required position
- Measure the environmental forces acting on the vessel and estimate/calculate the forces needed to counteract their effect

The control system usually relies on the first function, but makes use of the second, particularly when dealing with wind gusts.

The basic control action can be summarised as:

- Measure the vessel's deviation from its target position and set heading
- Calculate the deviation in X, Y and N axes
- Calculate the required counteracting forces in the X, Y and N axes
- Transform the counteracting forces into commands to the individual thrusters

To do this we need:

- Sensors to give position reference with respect to a given location
- Sensor for measuring vessel heading
- Something to calculate the commands to the counterforce devices and to implement the commands.

For simple loop feedback control systems, a change of a sensed condition causes an action to counteract the change. The effect of the change is again sensed and so on. The main feature is to have some damping in the loop to reduce oscillations in the control.

The feedback control of a vessel is complex because of the nature of the displacing forces, the sensing systems and the vessel characteristics. The control system therefore incorporates a model of the vessel.

Figure 1.7 illustrates the components of the control system.

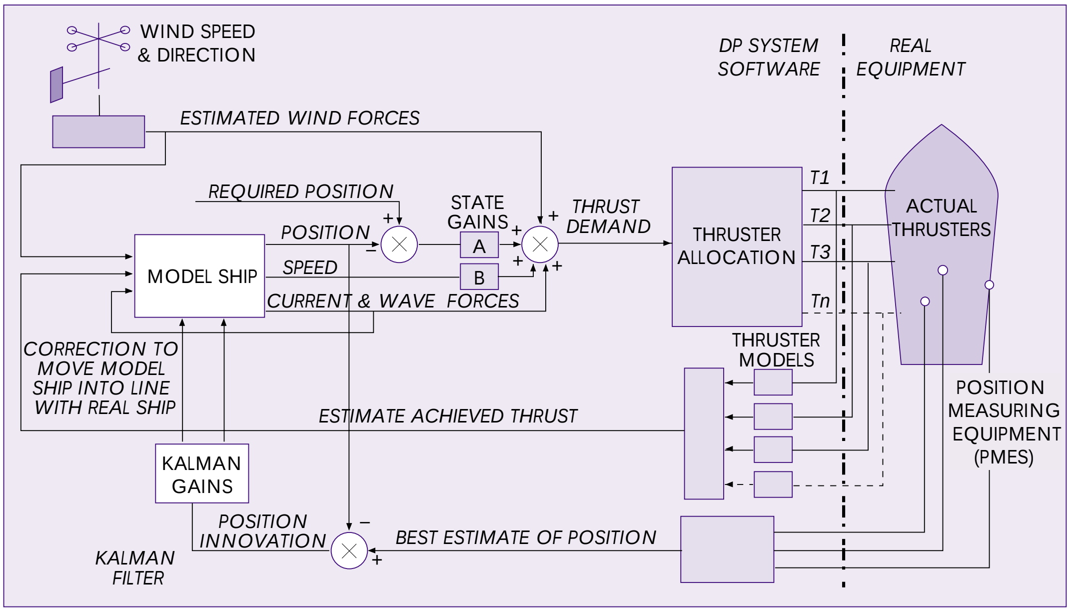

Figure 1.7 Vessel Control System Schematic

The control system consists of the following components:

- Model Ship
  This is as accurate a description as possible of the vessel's response to any external forces. The model should be subjected to the same forces that effect the real vessel: thrusters, wind, and waves, currents, anchors, other external forces such as cable/pipe tensions.

- State Gains
  These are the factors that determine the tonnes thrust from the speed and position errors.

- Thruster Allocation
  This is a set of equations which take the total thrust demand, expressed in X, Y, N coordinates, to be applied by the vessel's thrusters and converts it into individual thrusts matched to the available thrusters and their characteristics.

- Actual Thrusters
  These are the available working thrusters.

- Thruster Model
  This model takes the individual thruster demands and calculates the total thrust exerted on the vessel.

- Pool
  This combines the various estimates of the vessel position, and creates a best estimate of position.

- Kalman Gains
  The factors, which can vary between 0 and 1, determine if the model or estimated position is to be given preference. A value of 0.5 would provide equal weight.

- Wind Speed and Direction
  The wind speed and direction are converted into the estimated wind forces on the vessel.

The mathematical model of the vessel is as accurate as possible, but will never be 100% correct. To make it as accurate as possible, at a given time, continuous minor corrections are fed back into it. The ship model creates estimates of the vessel position, speed and current and wave forces. This data is compared with the required position of the vessel, input by the operator, the speed and any other forces and a thruster demand created. The result of the thrust is then fed back to update the model vessel.

The use of a model vessel and Kalman Gains provides many advantages:

- Signals from the sensors can be filtered to reduce noise and thruster activity

- Rogue data can be compared with model data and rejected

- The data from the different position reference systems can be combined while matching the characteristics of the individual reference system

- In the absence or loss of position or heading inputs, the vessel can remain under automatic control using predicted data based on the conditions of the previous few minutes. This is called Model Control or Dead Reckoning (DR)

- Positioning can be maintained over a greater range of weather conditions, enabling the vessel to extend its operational window

OPERATIONAL MODES

DP Systems use Operational Modes to control the vessel. Each vessel, depending upon its roles, will support several operational, or control, modes, but the vessel can only be under the control of one operational mode at any one time.

The difference between the modes is the way in which the position and speed are controlled. The operational modes are selected by the operator using either the display or dedicated keys on the console keyboard. More details on the console operation are provided in a later chapter.

The following is a typical list of Operational Modes currently available.

Joystick Manual Heading (JSMH)	The vessel is controlled by the joystick in fore/aft and port/starboard movement, and rotated by the turning control knob about its centre of rotation. This mode is used for totally manual vessel manoeuvring.
Joystick Auto Heading (JSAH)	The vessel heading is automatically controlled. The joystick controls fore/aft and port/starboard movement. This mode can be used for close manoeuvring.
DP	The vessel heading and position are both automatically maintained. This mode is used to maintain a fixed position in relation to a stationary target with a fixed heading.
Min Power/ Weathervaning	Maintains the heading of the vessel into the prevailing weather, while maintaining DP control.
ROV Follow	The vessel's position is maintained either relative to a moving target, such as a Remotely Operated Vehicle (ROV), or maintaining position until the ROV moves outside a defined area.
Auto Track	The vessel position is automatically moved along a track, at a set low speed, between two or more predetermined points (waypoints) with automatic heading control.
Auto Pilot	Normally uses main propulsion and rudder to move along a fixed course. Used as a transit mode. Azimuth thrusters can be used instead of main propeller and rudders.
Auto Sail	Providing forward movement along a track with automatic heading control to keep the vessel on track, normally uses main propulsion and rudder only. Used as a transit mode. Azimuth thrusters can be used instead of main propeller and rudders.
Auto Speed	Maintains zero or constant low fore/aft and port/starboard speeds using Doppler Log signals with automatic heading control.

Table 1.2 Operation Modes

Pick-up/Fixed Loading	Vessel heading determined by prevailing weather whilst position maintained at fixed point. Used for Shuttle Tankers.
Approach/Loading	Vessel heading determined by prevailing weather whilst position maintained at fixed distance (radius) from a reference (base) point. Used for Shuttle Tankers.
Riser Follow	Controls the position of the vessel so that the riser angle tends towards zero. Used for drilling vessels
Simulation	An offline mode providing simulated input/output data for training and testing in all modes.
Model Control	Maintains vessel in current operational mode in the case of position or heading sensor failure.

Table 1.2 Operation Modes

Before an operational mode can be selected, the system will check that the minimum set of equipment needed to operate the mode is available and has been selected. For example, before entering the DP mode, the following are checked:

- Sufficient thrusters are selected or "available to select" to support the mode
- A gyrocompass is selected or "available to select"
- A PME is selected or "available to select"

Joystick Manual Heading (JSMH)

JSMH mode allows single lever control of all selected thrusters. In this mode, the inputs to the system are provided by the operator alone.

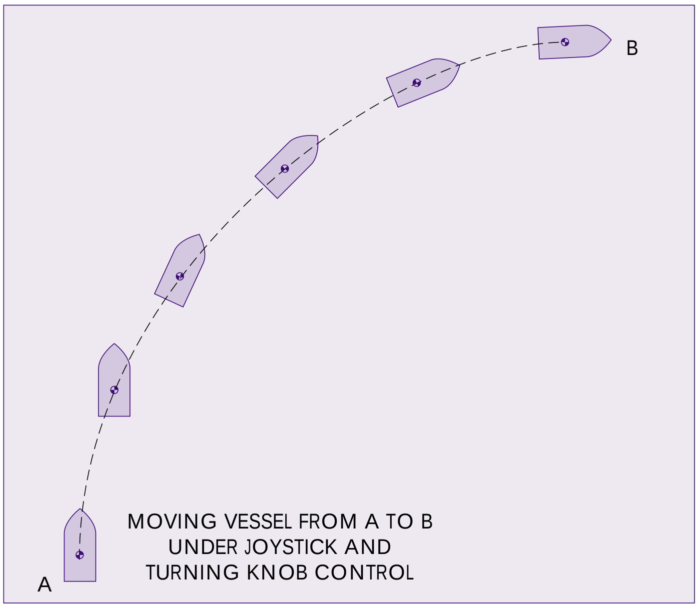

Figure 1.8 Joystick Manual Heading

Thrust can be applied to the vessel in fore/aft and port/starboard directions. The joystick controls the thrust on the vessel in the direction in which the joystick is pointing. The magnitude of the thrust is controlled by the amount the joystick is pushed forwards or backwards.

The thrust can either move the vessel, or hold it stationary against the environmental forces. Heading is controlled by the turn control knob, which rotates the vessel about its centre of rotation, using the selected thrusters.

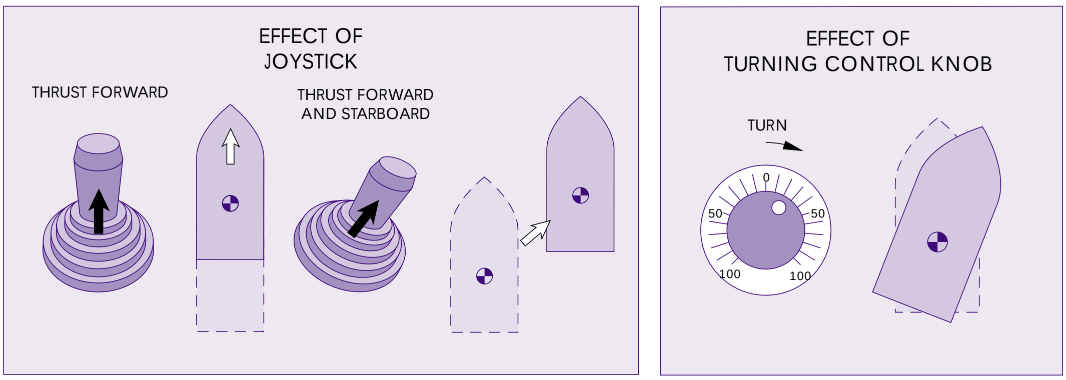

Figure 1.9 Joystick Manual Heading Controls
Joystick Auto Heading (JSAH)

Joystick Auto Heading (JSAH)

JSAH mode allows single lever control of all selected thrusters. In this mode, the level and direction of thrust is provided by the operator, and the heading is controlled by the gyrocompass. Thrust can be applied to the vessel in fore/aft and port/starboard directions, while maintaining the operator set heading.

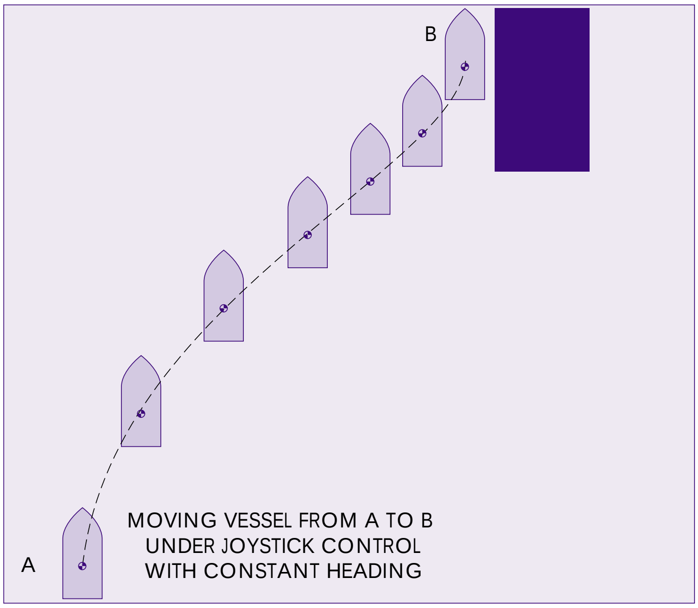

Figure 1.10 Joystick Auto Heading

The joystick controls the thrust on the vessel in the direction in which the joystick is pointing. The magnitude of the thrust is controlled by the amount the joystick is pushed forwards or backwards.

The thrust can either move the vessel, or hold it stationary against the environmental forces. The heading of the vessel is maintained at a set heading using the signal from a gyrocompass. The turning control knob is disabled.

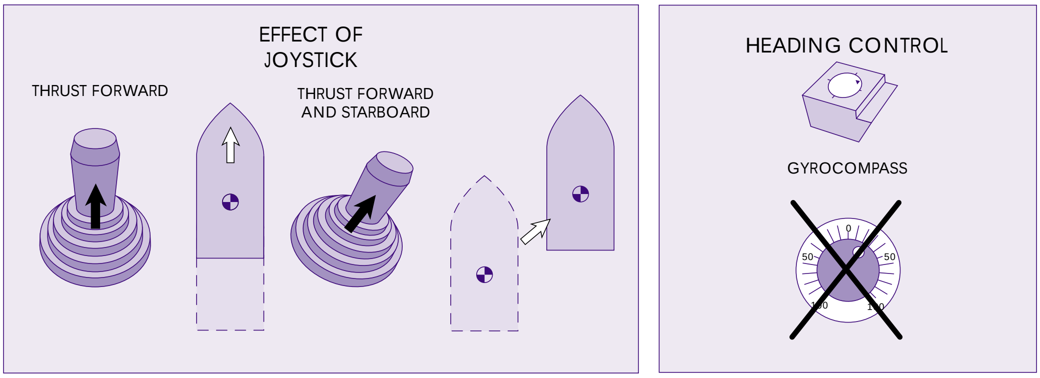

Figure 1.11 Joystick Auto Heading Control and Input

Dynamic Positioning (DP)

DP mode maintains the vessel in a fixed position relative to a fixed reference point, while maintaining a fixed heading. In this mode, the vessel position is controlled by a PME and the heading controlled by a gyrocompass.

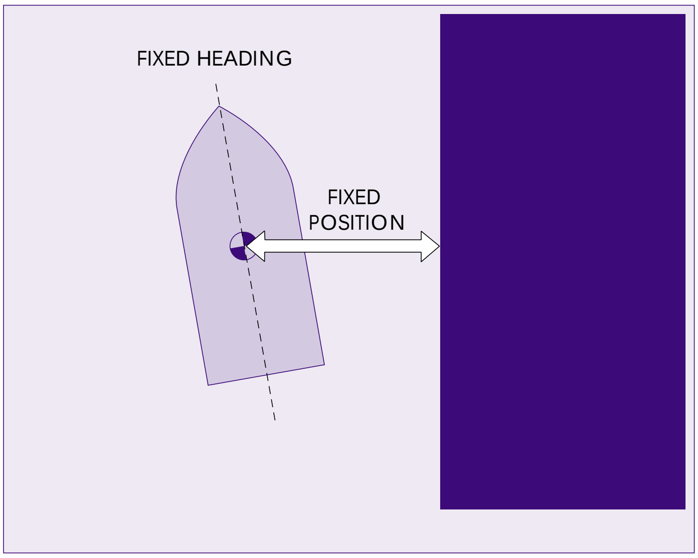

Figure 1.12 Dynamic Positioning

The system receives the vessel's heading from the gyrocompass, and the vessel's position from a PME. When DP mode is selected, the current position and heading of the vessel are taken as the reference position and heading. The vessel's thrusters control the vessel to maintain the position and heading. The operator may change the position and heading of the vessel using the console display facilities (Change position and change heading).

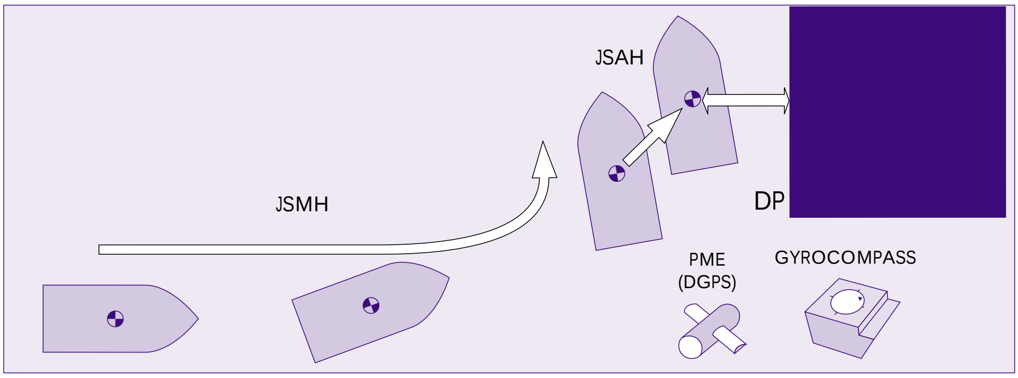

Figure 1.13 Dynamic Positioning Inputs

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Dynamic Positioning, Minimum Power

DP Minimum Power mode maintains the vessel's position relative to a fixed reference point, whilst minimising the vessel's port/starboard thruster demands resulting from the net weather forces on the vessel. This mode is also sometimes called Weathervaning. In this mode, the position of the vessel is controlled by a PME.

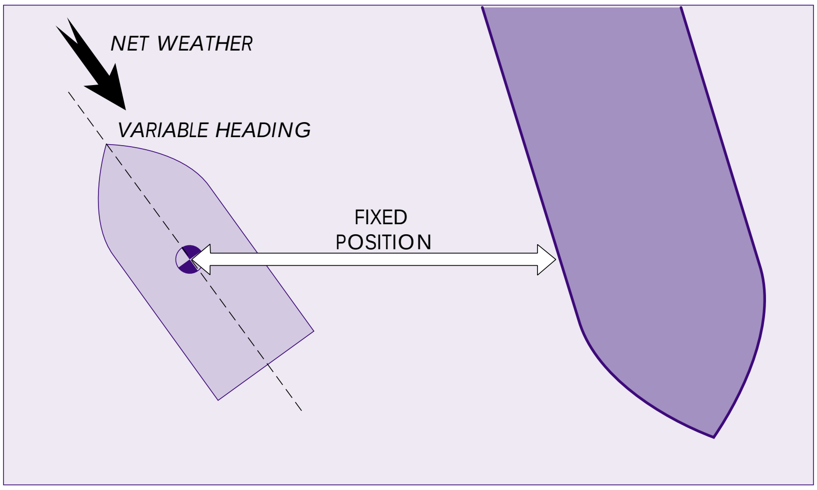

Figure 1.14 Dynamic Positioning Minimum Power

The vessel's position is measured using a PME, and the thrusters are controlled to maintain the vessel at this position, as for DP mode. The vessel heading is then controlled so as to minimise the power used by the thrusters.

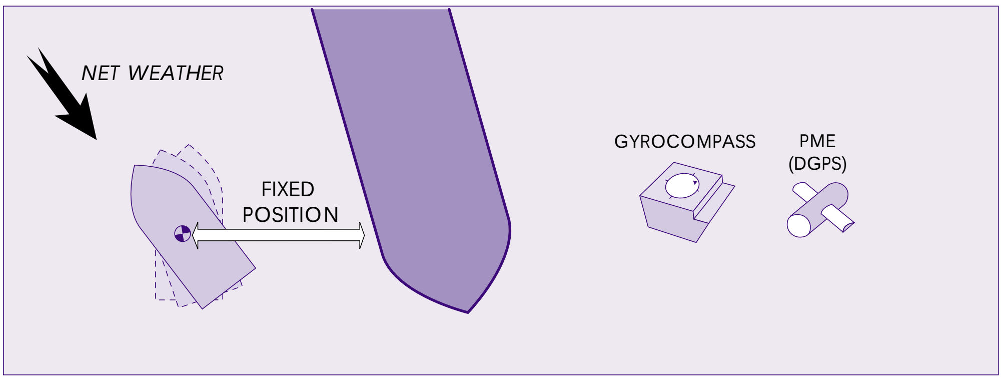

Figure 1.15 Dynamic Positioning Minimum Power Inputs

Chapter 1 Dynamic Positioning of Vessels (DP) - Principles

Remotely Operated Vehicle Follow (ROV Follow)

The purpose of ROV Follow is to maintain the vessel position relative to an underwater vehicle which is usually connected to the vessel by an umbilical providing it with services and a data link. There are two possible forms of this mode:

- Fixed Position Reference
  The vessel is maintained in a fixed position and the ROV is allowed to move within a predefined area. If the ROV wanders outside the area, the vessel is moved to position the area so that the ROV is at its centre again. This form of the mode involves minimum vessel movement and is used when the ROV is moving over a limited area. The mode uses a PME and gyrocompass to control vessel position and heading, and an acoustic system to position the ROV relative to the vessel.

- Fixed Distance
  The vessel and the ROV move together maintaining a fixed horizontal (fixed seabed) distance apart between the vessel Centre of Rotation (COR), and the beacon on the ROV. In this mode, the vessel heading is controlled by a gyrocompass and the relative separation controlled by an acoustic PME. This form of the mode is used when the ROV is following a pipe or cable.

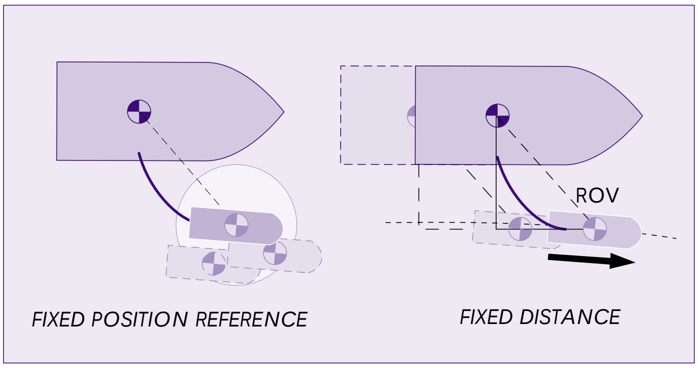

Figure 1.16 ROV Follow Mode Types

The relative separation of the vessel and ROV is measured with an acoustic transducer and transponder.

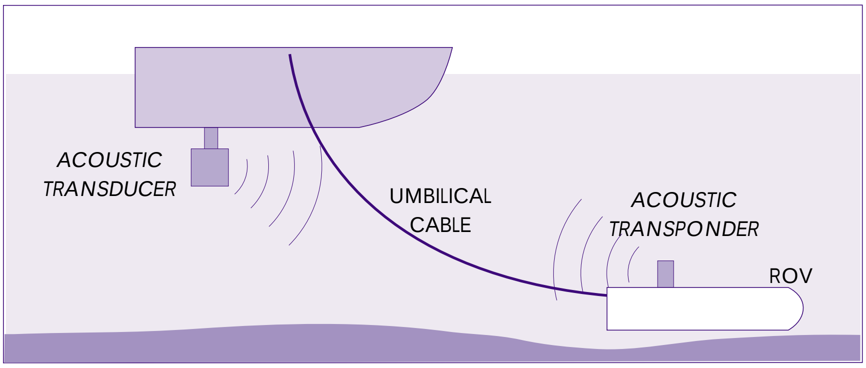

Figure 1.17 ROV Follow Inputs

With Fixed Position Reference, the vessel is maintained stationary using a PME such as Artemis or DGPS. The ROV is allowed to move around in a circular area with a radius equal to the reaction radius. The reaction radius is positioned at a constant heading on the offset radius. While the beacon or transponder on the ROV remains within the reaction radius, the vessel remains stationary. As soon as the transponder moves outside the area defined by the reaction radius, the vessel is moved so that the centre of the area is placed over the transponder.

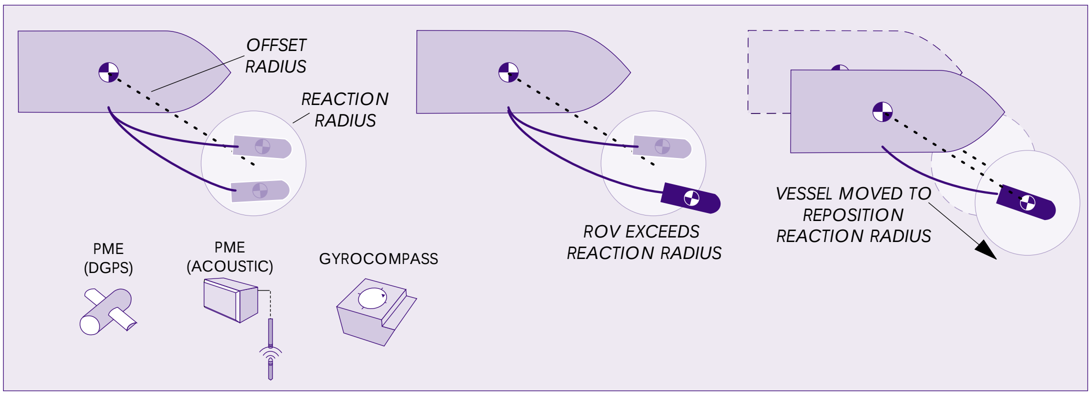

Figure 1.18 Operation of Fixed Position Reference

Auto Track

The purpose of Auto Track (or Track Follow) is to move the vessel along a track defined by two of more waypoints.

The vessel speed is usually slow in Auto Track. The mode uses a PME for position and a gyrocompass for heading.

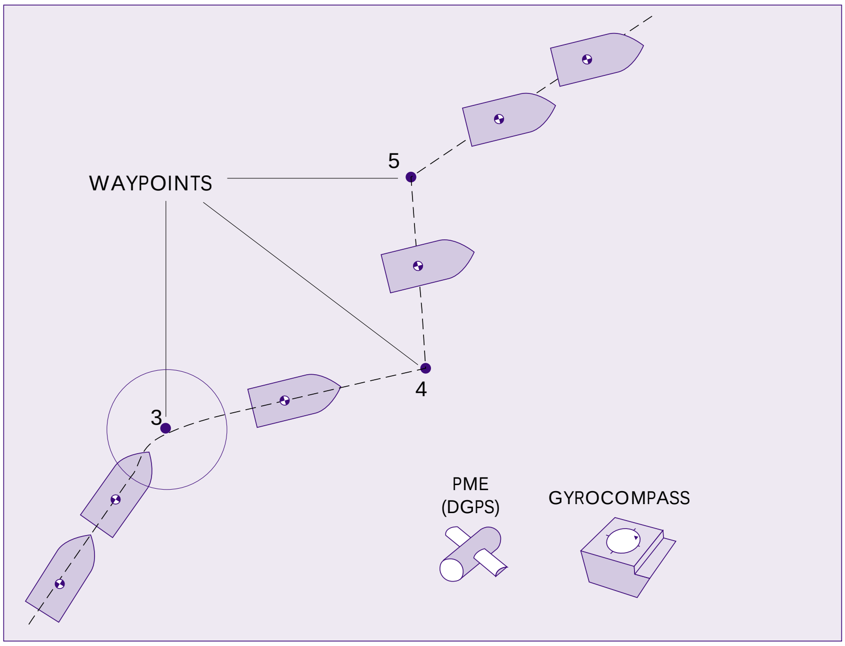

Figure 1.19 Auto Track

In Auto Track, the track may follow a pipe or cable, a plan for paying out a pipe or cable, or a survey path. The first stage in Auto Track is to set up a series of waypoints in the system. These can be either input manually by the operator, loaded from diskette or downloaded from a survey system. In the second stage, the vessel automatically follows a target which moves along the track.

In practice, there are several additional functions which make Auto Track mode more effective. The first refinement is that the vessel speed and heading between waypoints can be independently set. The next refinement is the control of the change of vessel direction when it reaches a waypoint.

To provide a controlled change of direction, a radius is defined around the waypoint. When the vessel reaches this distance from the waypoint, its direction is gradually changed so that it enters the next leg of the track in the same direction as the track.

Another refinement is to offset the vessel's actual track by a set amount, say 10 metres, from the track defined by the waypoints. This vessel offset is sometimes required in cable or pipelaying. Additional sophistication in the vessel track is also necessary when moving between legs of the track so as to lay the pipe or cable at the required point on the seabed.

Auto Pilot

The Auto Pilot mode is a fast sailing transit mode to move the vessel on a constant set heading. Heading control is provided by the gyrocompass, with speed (thrust) input by the operator using the joystick.

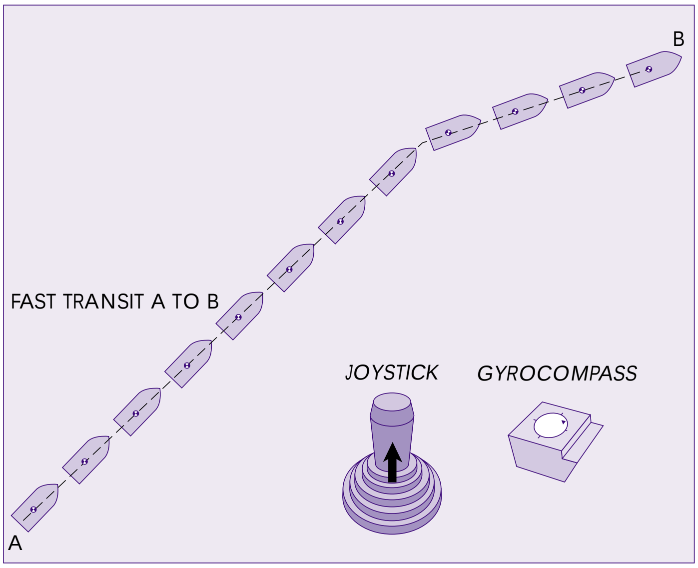

Figure 1.20 Auto Pilot

The gyrocompass is used to control the vessel heading. The joystick is used for the operator to control the thrust on the vessel (not the vessel speed).

The direction signal from the joystick and the heading control knob are deactivated.

Auto Sail

Auto Sail mode controls the vessel along a track between two or more waypoints, and can be used at speeds of 2 knots (1 metre /sec) and above. In this mode, the vessel position is controlled by the PME and the thrust by the joystick.

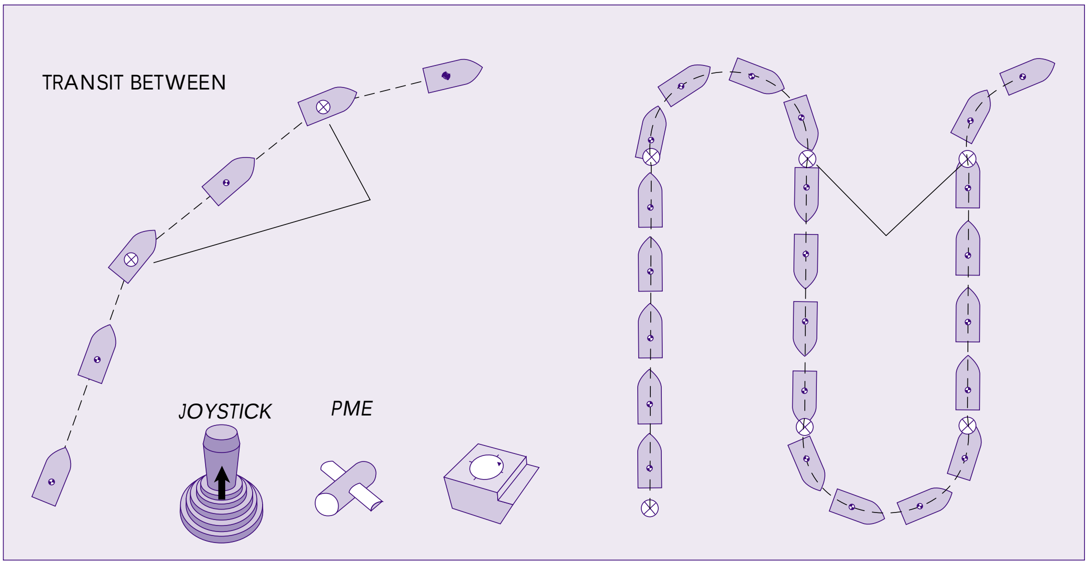

Figure 1.21 Auto Sail

The vessel track is set up in the same way as for Auto Track. The control system controls the vessel by monitoring the vessel's variation from the set track and brings the vessel back on track by adjusting the set heading.

Auto Speed

Auto Speed mode maintains the vessel at a constant X, Y (fore / aft, port / starboard) speed. Control of the speed of the vessel comes from the operator input using the joystick and measurement of the vessel speed using a Doppler log or possibly DGPS PME. Vessel direction is also set by the operator using the joystick together with the heading from the gyrocompass.

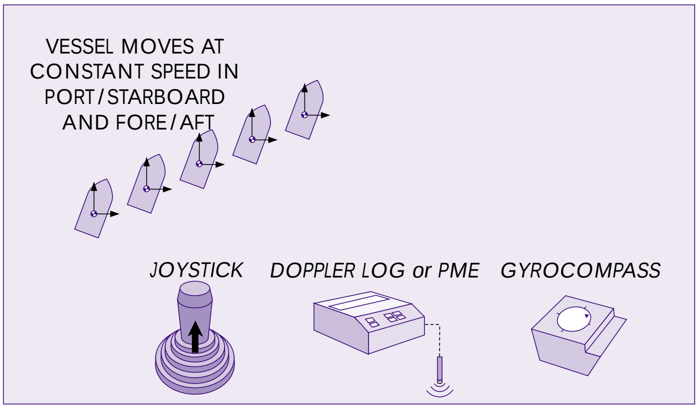

Figure 1.22 Auto Speed

Shuttle Tanker Pickup

This is used for shuttle tankers for picking up buoys.

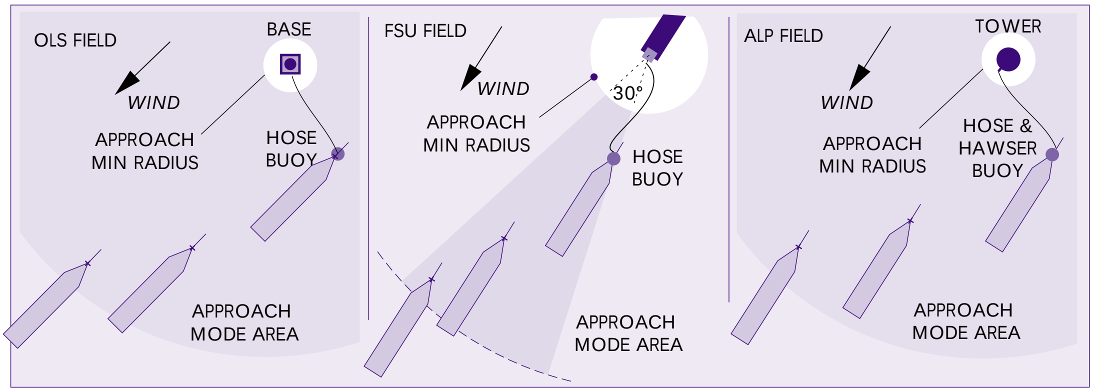

Figure 1.23 Pickup with Various Field Types

Pickup mode positions the vessel bow at a specific point e.g. the offloading hose buoy, to enable the offloading hose (and hawser in an ALP field) to be easily lifted aboard the vessel. The mode enables the vessel to be positioned at a fixed point, without the heading pointing at the loading point, which is the case with the approach and loading modes.

As an option, fixed heading can be selected in calm weather, or whenever preferred.

Shuttle Tanker Approach

Approach mode takes the vessel from the outer perimeter of the controlled area surrounding the offloading point, to a position to either select Pickup or Loading mode, while maintaining a heading into the prevailing weather.

In OLS and ALP, the vessel heads towards the loading base and the position setpoint moves around an unlimited arc centred on the loading point.

In FSU, the arc is limited to the stern of the FSU.

There is also an option to select a fixed heading in calm weather or whenever preferred.

After loading, Approach mode can be used to move down weather and leave the hose for the next tanker.

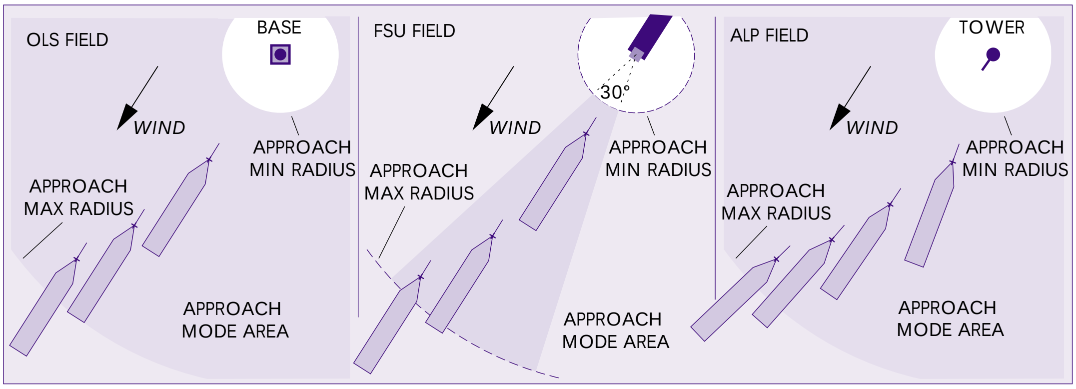

Figure 1.24 Approach with Various Field Types

For an ALP field, the vessel heading points to the end of the boom and the vessel always approaches with the boom to port side.

Shuttle Tanker Loading

Loading mode positions and holds the vessel at a suitable position for offloading.

The vessel moves on an arc, maintaining a heading towards the loading point and into the prevailing weather.

With an FSU, the arc is limited by the loading boundaries.

There is also an option to select a fixed heading in calm weather, or whenever preferred.

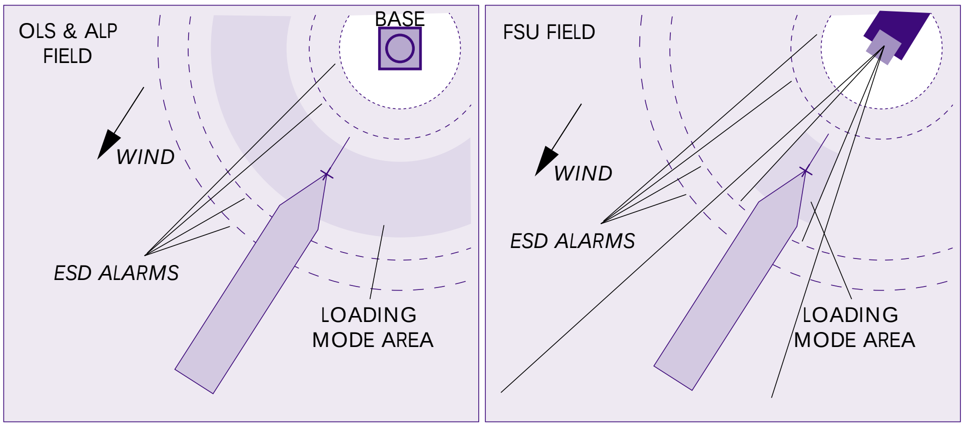

Figure 1.25 Loading Mode with Various Field Types

Shuttle Tanker Fixed Loading

Fixed Loading mode allows the vessel position to be offset from that determined by the heading. The mode is used in ALP and OLS fields to position the vessel so as not to drift into another structure.

There is also an option to select a fixed heading in calm weather, or whenever preferred.

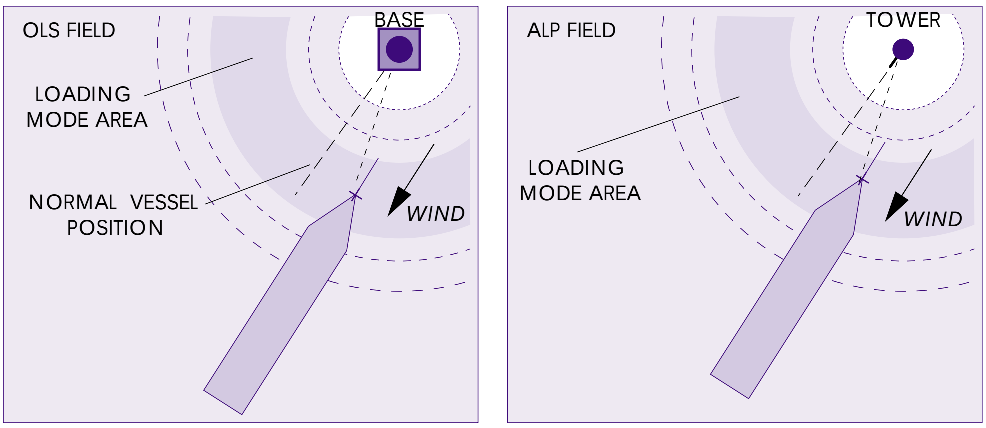

Figure 1.26 Fixed Loading Mode with Various Field Types

Riser Follow

Riser Follow mode, which is used in drilling vessels, controls the position of the vessel so as to maintain the Riser Angle close to zero.

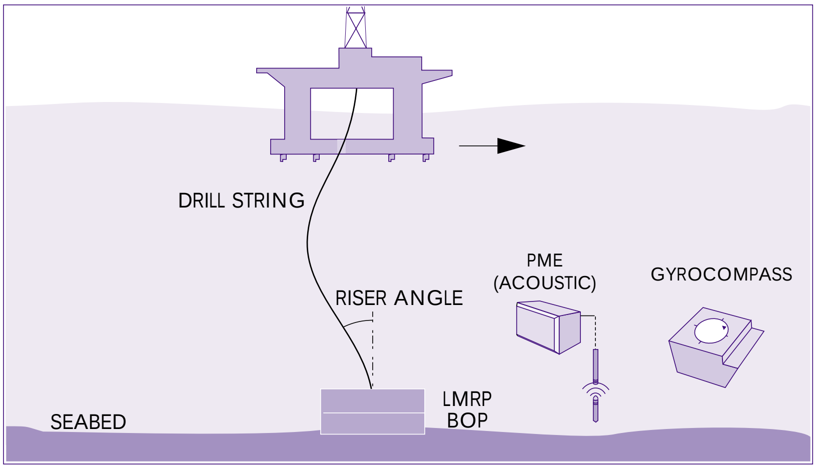

Figure 1.27 Riser Follow

In Riser Follow mode, the system receives inclinometer and position signals from the drilling module. The system calculates the vessel position at which the riser angle will be zero, the zero angle position or ZAP. To avoid constant repositioning of the vessel, the riser angle is allowed to vary from the ZAP within a small Reaction Angle, similar to one of the ROV Follow modes. When the riser angle exceeds the Reaction Angle, the vessel is repositioned to again reduce the riser angle to zero. The reaction angle is actually translated by the system into a Reaction circle around the vessel control point.

When the ZAP moves outside the reaction circle, the vessel's target position is moved towards the ZAP, and the new reaction circle drawn around it. The vessel moves towards the new target position to again reduce the riser angle.

Heading Control for Anchor Moored Vessels

To increase the life of the anchors on an anchor moored vessel, such as an FPSO, the vessel thrusters can be used to control the vessel heading and reduce the anchor tensions.

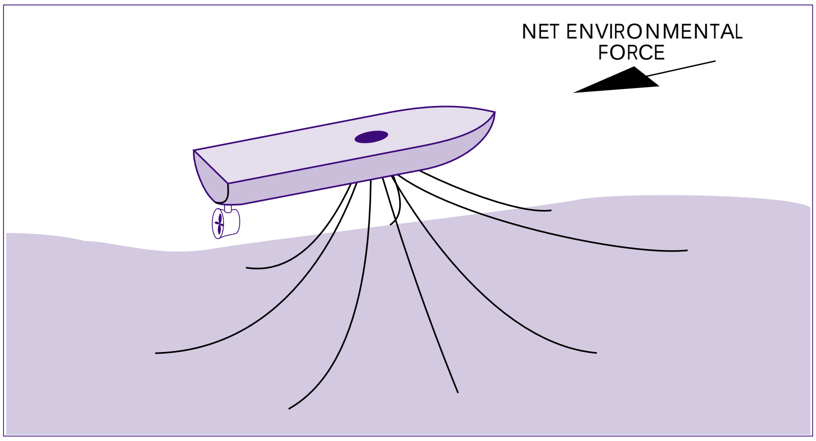

Figure 1.28 Heading Control and Anchor Mooring

The simplest anchor mode provides monitoring of the anchor tensions and vessel parameters.

Three other modes provide various methods of reducing the anchor tensions.

- Manual Assist
  The operator controls the vessel in fore/aft movement using the joystick, and rotates the vessel using the turning control knob. This mode is used for rough manoeuvring.

- Auto Assist
  In this mode, the system controls the thrusters to compensate for the effect of the net environmental force on the anchors.

- Damped Assist
  This mode also provides auto assist but in addition the vessel fore/aft vessel movement is damped.

SIMULATION

This is a facility rather than a mode, in that it can simulate the operation of any mode. Its purpose is to provide operators with the opportunity to be trained on the system and to familiarise themselves with the system operation while using only the operator's console.

Simulation can only be selected if the vessel's thrusters are not under automatic control. When the system is in simulation mode, it allows the operator to set the external environment such as wind, vessel heading, provide PME readings etc. With all the inputs selected, the vessel behaves as if it is controlled at sea.

MODEL CONTROL

Model Control is a mode that is automatically entered if there is a failure of all the vessel's reference systems. Model Control allows the vessel to be controlled for a period of time using the conditions prevailing at the time of failure. Model Control will allow the vessel to be bought under manual control in a safe and orderly manner. Model Control can be useful for periods of 1 to 10 minutes or longer, depending on the stability of the environmental conditions and other external factors.

Equipment Selection

INTRODUCTION

This chapter reviews the choice of equipment available to implement DP control of a vessel. The sections cover:

- Thrusters
- Sensors
- Position Measurement Equipment
- Power Supplies

The actual control system is covered in a later chapter.

THRUSTERS

Reliable and efficient thrusters are essential to effective DP vessel control. The selection of appropriate thrusters for a vessel will be based on:

- The size of the vessel
- The role of the vessel
- The operating conditions in which it will be required to work

Computer programs are available that can be used to propose or confirm the sizing of thrusters, and to prove that a particular vessel can operate in a given working situation. Using the general arrangement of the vessel, in terms of its side and front elevations, the expected environmental forces, the thruster locations and sizes, plots of vessel performance can be produced. These plots are known as Capability Plots.

General Thruster Configuration Advice

As was mentioned in the previous chapter, the control system takes the surge, sway and turning moment demands and transforms them into actual thrust demands allocated amongst the thrusters currently available and selected.

The thrusters should be sited to achieve fore/aft, athwartships and rotational thrust. Redundancy may be required so that the loss of any one thruster will leave sufficient thrust in each direction to ensure that the vessel can hold its position and heading when operating within its operational capability.

In the event of a pitch, azimuth or speed control malfunction, or if a control error becomes unacceptable, the function controlled should remain either:

- The same as it was at the time of failure
- Pitch or speed automatically set to zero
- Thruster automatically stopped or deselected

Under **no** circumstances should it be possible for the thruster to assume maximum thrust condition.

The thruster should be located and operate to minimise potential interference of its wash with other thrusters, sensors systems, position measurement systems, diving systems etc.

It should be possible to stop any thruster from the DP control centre, without using the DP computer to generate the command. The method of stopping the thruster should not allow inadvertent operation.

If the thruster demand cannot be fulfilled in all axes, the priority given to the axes is usually:

- 1st priority
  Heading

- 2nd priority
  Sway

To summarise, the thruster set required for DP control of a vessel must satisfy the following conditions:

- The thrusters must provide independent control of X, Y and N axes
- The thrusters must be sufficiently large to counteract the wind, waves and current
- The thrusters must respond promptly and accurately to the DP system commands
- The predicted output thrust under the stated conditions must be actually achieved
- The thrusters must withstand the frequent changes of setting required by the DP system

Thruster Size

The size of the thrusters depends on the size of the vessel above and below the waterline, and the weather conditions in which it will operate. The weather definition is expressed in terms of

- Wind speed and direction
- Wave height , period and direction
- Current speed and direction

In practice, several assumptions can be made in order to simplify the calculation. The wave direction is considered to coincide with the wind direction. The waves are a fixed proportion of the "fully risen set" for each wind speed, and conform to the Jonswop spectrum. Current speed is fixed at say 1.0 knots, and its direction is fixed on the vessel's beam.

This allows a capability plot be drawn for the vessel. The plot shows the maximum wind speed, with corresponding waves, that the vessel can withstand, plotted as the wind direction moves around the vessel.

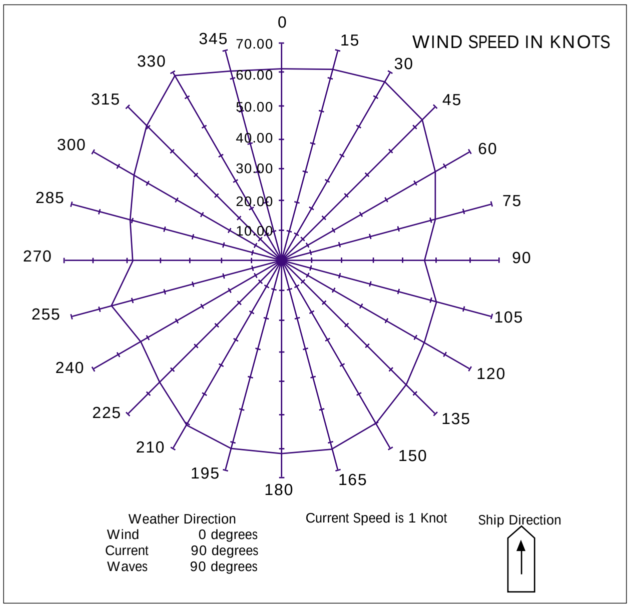

Figure 2.1 Typical Vessel Plot

CONTENTS

Thruster Response and Accuracy

A DP controlled vessel can only function if the thrusters respond promptly and accurately.

Either slow response or inaccurate setting can cause the vessel to oscillate. The following table indicates usual acceptable performance levels.

Speed or Pitch Response	Zero to full thrust within 8 seconds (small thrusters) Zero to full thrust within 15 seconds (large main propeller)
Azimuth Rate	180 degrees of rotation within 15 seconds (2 rpm)
Speed or Pitch	±2% of maximum
Azimuth Accuracy	±1.5 degrees

Table 2.1 Thruster Response and Accuracy

Prediction of Output Thrust

DP system designers must have available accurate thrust predictions for each type of thruster used on a vessel. Thruster manufacturers provide "Open Water Bollard Characteristics". These graphs show the thrust produced against pitch (speed) when the thruster is operated in still water remote from an obstruction. Unfortunately, this information does not take into account thruster-hull interactions and thruster-thruster interactions. These factors can give rise to errors in thrust magnitude of up to 40% and thrust direction alterations of up to 25°.

Azimuthing thrusters are particularly vulnerable to interactions, particular when used on the stern of monohulls. One way to avoid interaction problems with azimuthing thrusters is to specify barred zones where the thrust wake is not allowed. This technique is useful but not a total answer as, from time to time, thrusters will have to cross barred zones, causing temporary disturbances.

Other factors effecting thrust are the presence of tidal currents etc.

Thruster Modes

It is possible to control thrusters so that they work together in fixed positions or over restricted ranges. By selecting a thruster mode, fine control of vessel positioning is possible or thruster wear can be reduced.
Modes usually apply to azimuth thrusters and propellers. Tunnel thrusters are only included if controlled port/starboard movement is required. Barred zones can be considered a special case of thruster modes.

There are three types of thruster mode or pattern:

- Bias
- Fixed
- Push/Pull

When a thruster can operate over its full range i.e. 360° for an azimuth thruster, port or starboard for a tunnel thruster, is usually referred to as FREE.

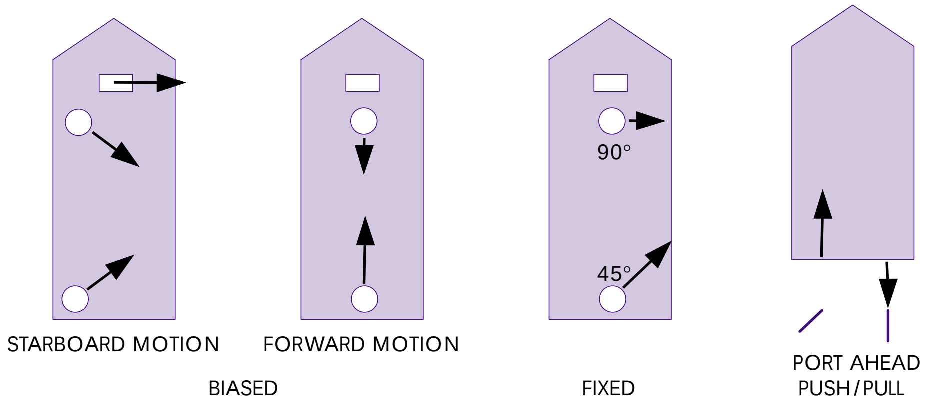

Figure 2.2 Thruster Modes

The types of modes available on a vessel are determined by the types of thrusters available.

Bias Mode

In Bias mode, thrusters or groups of thrusters are placed in opposition to each other. The mode usually applies to azimuth thrusters.

However, for forward/aft motions, propellers could be included, and for port/starboard motion, tunnel thrusters could be included.

Fixed Mode

Fixed mode applies only to azimuth thrusters. The thruster can be set at any fixed angle.

Push/Pull Modes

Push/pull modes apply only to propellers and rudders. They provide sideways thrust using the propellers and rudders. The push/pull modes are also called Port Ahead and Stbd Ahead. In push/pull modes, one propeller only runs ahead, and the other is allowed to run astern. The rudder behind the ahead propeller is used to create side forces. The rudder is allowed to operate at full rudder angles, although being primarily a light weather, low force mode, demanded rudder angles are normally small.

Types of Thrusters

Four main types of thruster are commonly employed in DP controlled vessels. The thrusters that will be considered are:

- Propellers
- Rudders
- Tunnel thrusters
- Azimuthing thrusters

and less common

- White Gill thrusters
- Epicyclic thrusters

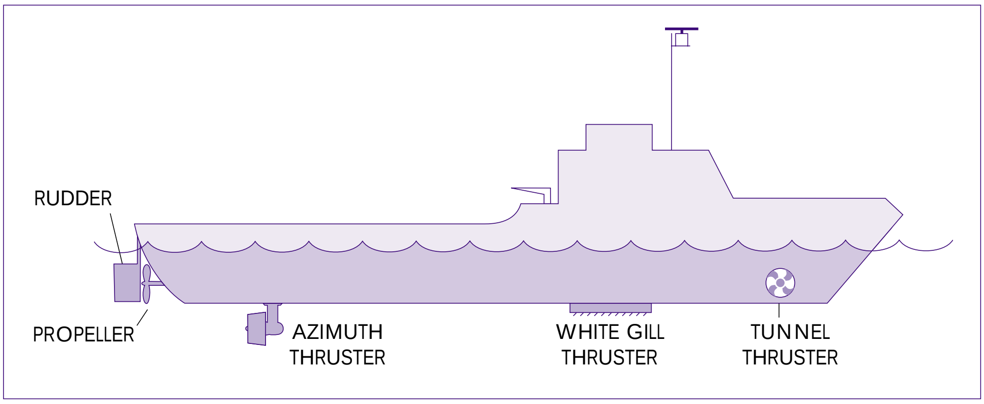

Figure 2.3 Types of Thrusters

Propellers

Propellers are the traditional main vessel propulsion method. They may be either single or twin configurations. Control of the thrust is provided in two ways:

- Fixed Pitch Propeller (FPP)
  The thrust is controlled by varying the rotational speed of the propeller

- Controllable Pitch Propeller (CPP)
  The thrust is controlled by varying the pitch of the propeller, and keeping the speed constant. A variation of CPP varies both pitch and speed using a variable speed drive to gain better efficiency.

Controllable pitch propellers have a variety of methods to vary the pitch of the blades. These can be fairly complex and are therefore liable to fail at some time. Care must therefore be taken to ascertain the failure mode of the propeller.

Propellers provide thrust in both directions, but due shape of the blades and to the effect of the hull the amount of thrust in the reverse direction is only 40-60% of that available in the forward direction.

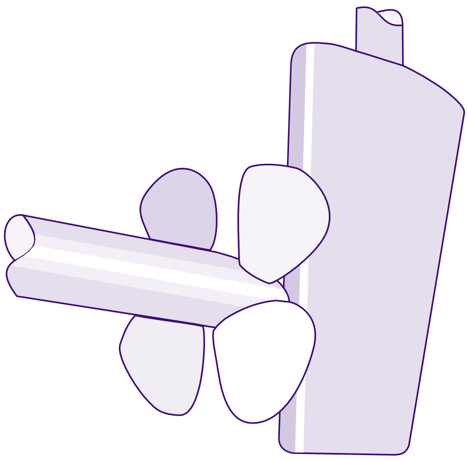

Figure 2.4 Propeller and Rudder

Rudders

Rudders provide sway force to the vessel in conjunction with the propeller. In order to be effective at low speeds through the water, the rudder must be positioned in the propeller's wake. A central rudder on a twin propeller vessel is of little use for DP. Rudders are inefficient side thrusters.

Tunnel Thrusters

Tunnel thrusters are mounted in the bow and/or stern of the vessel, and enable the vessel to be displaced sideways, and to provide a turning moment. Tunnel thrusters use FPP and CCP propellers.

Tunnel thrusters are only effective at very low speeds, say up to 2 knots. The longer the tunnel the less efficient the thruster will be.

Tunnel thrusters can be positioned at the bow and/or stern of the vessel, either singly or in groups. For maximum effectiveness they should be as far below the waterline as possible. They should be placed $1^1/_2$ times their diameter below the water line.

A tunnel placed just forward of a main propeller is ineffective when the vessel goes astern.

The failure modes must be checked.

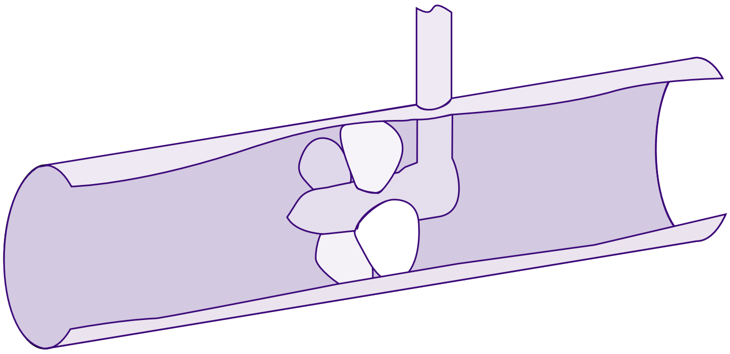

Figure 2.5 Tunnel Thruster

Azimuth Thrusters

Azimuth thrusters are able to rotate and control both the magnitude and direction of thrust. There are two types, fixed and retractable. The thruster can be controlled in pitch or speed. To reduce wear on the rotating gear, the propeller can be reversed, but with the consequent reduction in thrust.

Azimuth thrusters are positioned so as to interfere as little as possible with each other, and to not be damaged by touching the sea bed.

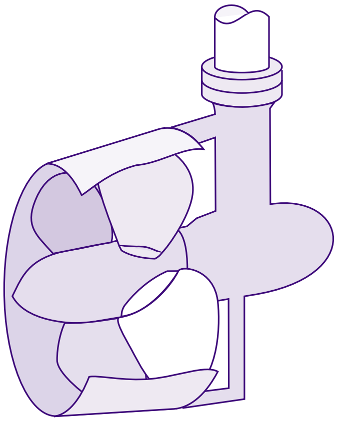

Figure 2.6 Azimuth Thruster

Other Thruster Systems

Cycloidal Propellers consist of four, or more horizontal rotating aerofoil sections which can be controlled about their centre of rotation so as to provide a directional thrust. They are fitted to the bottom of the hull and therefore subject to damage in shallow water.

The Gill Jet Thruster is a combination of a jet and a rotating deflecting nozzle. The deflector placed under the centre of the vessel, with water being drawn in at the sides of the vessel. The thrust is controlled by the water pump speed.

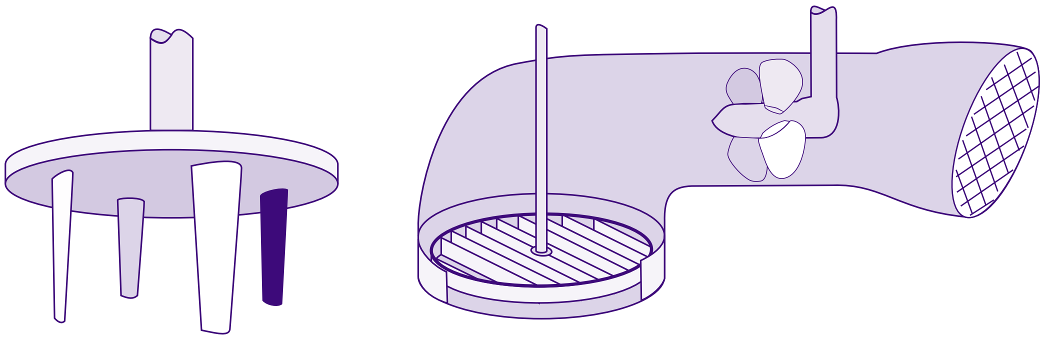

Figure 2.7 Cycloidal Thruster and Gill Jet

Sensors

The vessel sensors are:

- Gyrocompass for heading
- Vertical Reference Unit (VRU) for vessel attitude, roll and pitch
- Anemometer for wind speed and direction
- Doppler Log for vessel speed

Gyrocompass

The gyrocompass is used for heading control and is needed to perform coordinate transforms. The gyrocompass is a pendulous suspended gyroscope which is gravity controlled and damped, with a rotor running at 11,500 rpm. The earth's rotation causes it to assume a position pointing north.

There are several sources of possible error in a gyrocompass reading:

Latitude error is the vertical component of the earth's rotational rate at the set latitude. A 10° error results in 0.3° on the compass. Gyrocompasses work over the range of 80N to 80S.

- North speed, east speed, north acceleration, east accelerating gimbal all have automatic compensation with speed input

The normal startup cycle of a gyrocompass is 6 hrs. However, slew controls can override the automatic starting cycle after 5 mins. The vessel speed compensation is set to the vessel's average speed for the duration of the voyage.

Gyrocompasses have been developed which use vibrating crystals, fibre optics and other sensors to eliminate the vulnerable high speed gyro wheel.

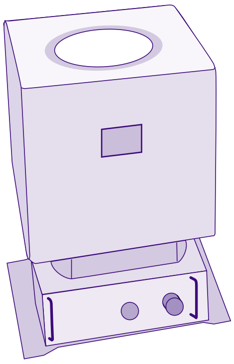

Figure 2.8 Gyrocompass

Vertical Reference Unit (VRU)

Although a DP system does not control a vessel in the pitch, roll and heave axes, pitch and roll must be measured to provide accurate compensation for some position measurement equipment.

The VRU on the vessel determines the difference between the "local" vertical and reference plane of vessel. VRU signals are used for position holding rather than transit.

The compensation values of pitch and roll are used for:

- SBL and USBL acoustics
- Inclinometer for slope of taut wire
- Inclinometer for slope of riser
- Compensation for aerials

VRUs measure pitch, roll and acceleration. Heave is calculated by the double integration of the vertical acceleration of the unit. Heave is not needed for DP operation, but it is often useful for other purposes, e.g. advice to helicopters.

Several methods are used in VRUs. The following list is in order of age of introduction

- Simple pendulum or liquid level, which is seriously affected by lateral acceleration
- Complex pendulum, simple mechanics, reliable, large
- Gyro stabilised platforms are common in aircraft, but are seldom used on ships, as they require frequent servicing
- Solid state VRUs use strap-down accelerometers and crystal rate gyros to measure the mean inclination and the angular rate.

A typical VRU provides heave readings in the range ±10m with an accuracy of 5cm or 5%, and pitch and roll readings to ±30° down to accuracy 0.1°.

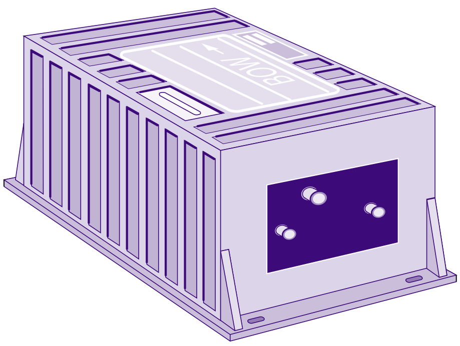

Figure 2.9 Vertical Reference Unit

Anemometer

An anemometer is a device for measuring both the speed and direction of the wind. Wind is a major disturbing element on the vessel.

The wind speed and direction are used to improve position control by modifying thruster demands. They have two main purposes: to assist in weathervaning for large stationary vessels such as shuttle tankers or production platforms, and to make allowance for gusty wind conditions.

Separate sensors are provided for wind direction and wind speed.

- Wind speed sensor. Instantaneous wind speed sensing is captured by a helicoid propeller, or cup anemometer. This can operate at wind speeds up to 60 metres/sec., and gusts up to 100 metres/sec. The lower threshold is around 1 metres/sec. The accuracy is ±0.3 metres/sec.

- Wind direction. The windvane uses a synchro with rotor and stator, which needs a power supply. The accuracy ±3°.

Care must be taken in installing the anemometers to avoid wind shadow from the vessel superstructure and spars. An anemometer should be at least 10 diameters from any spar or mast.

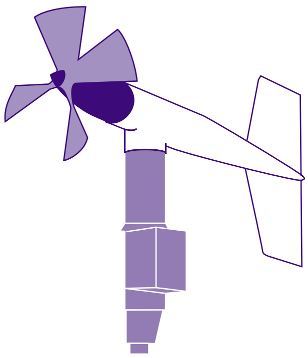

Figure 2.10 Anemometer

Doppler Log

The Doppler log measures the vessel speed over the seabed. It uses sound and the Doppler effect of a moving sound source having an altered reflected frequency which varies in proportion to the speed of the sound source.

A Doppler log can typically operate in water depths from 1m to 600m. It is not affected by water temperature or salinity.

The system measures both longitudinal and transverse speed and is insensitive to pitch and roll using a broad beam echo sounder. Longitudinal speed is measured from -5kts to +30kts, and transverse speed to ±5kts. Measurement accuracy is better than 0.01kt or 2%.

It is also possible to use the Doppler log to measure the speed of the water mass, at say half the depth to the seabed, by selecting weak reflection in a shorter time window than the reflections from the seabed. Similarly, in deep water, the weak reflections can be used to measure the relative speed of the vessel and the water mass at a known depth.

POSITION MEASUREMENT EQUIPMENT (PME)

Introduction

DP systems depend upon being able to position the vessel in a manner appropriate to its role. So, a drilling platform will need PMEs to maintain it in a stationary position, whereas a shuttle tanker will need PMEs to be able to position it relative to a structure or vessel. The accuracy of PMEs depends on their role and the other PMEs with which they are used. The reliability of PMEs is usually handled by presuming that PMEs will fail and therefore providing redundancy both in similar and alternative PMEs.

There are many different PME systems used for position reference with DP systems. The selection of PMEs for a vessel is based on the role of the vessel and the characteristics of the PME. It is possible to have a DP system supported by just one PME but for reliability, two or more PMEs are usually used.

PMEs can be grouped based on the technology used.

- Taut Wire
- Radio
- GPS
- Hydro Acoustic
- Laser

PME TYPE	RANGE	MAX DEPTH	ACCURACY	GEOGRAPHICAL RANGE
Taut Wire	25% of water depth	500m	2% of water depth	Worldwide
Radio	30Km	N/A	±1m	Limited to beacon availability
GPS	Unlimited	N/A	±3m	Worldwide
Hydro Acoustic	5x water depth	4000m	1-2% of water depth	Worldwide
Laser	250m (Useful range for DP)	N/A	<0.5m	Needs fixed target

Table 2.3 Typical PME Characteristics

Where several PME position references are available, their values can be pooled in several ways. The simplest form of pooling is to use the average value. A more sophisticated method is to discard any readings which fall outside a window placed around the average position. A further sophistication is to place weightings on each PME for creating the mean value. The pooling of PMEs complements the individual PME checks for signal reliability, which may cause the PME to be deselected.

When several PMEs are available, a voting system can be used to pool the position values, weighting the values as appropriate.

In certain weather conditions, the reference position from the PMEs may vary rapidly or erratically. To avoid unnecessary thruster demands, the operator can alter the vessel response to PME inputs by adjusting the Kalman filter in the control system.

Taut Wire

A Taut Wire system measures the variation in the position of a fixed point on the vessel relative to a fixed point on the seabed. The two points are joined by a constantly tensioned wire, and it is the variation in the angle of the wire which is measured.

The system determines the horizontal displacement of the vessel relative to the fixed point on the seabed using the length of the wire deployed and the angles of the inclinometers attached to the wire.

The mechanical system consists of a sinker weight, which is lowered to the seabed and a winch on the vessel which maintains tension in the wire.

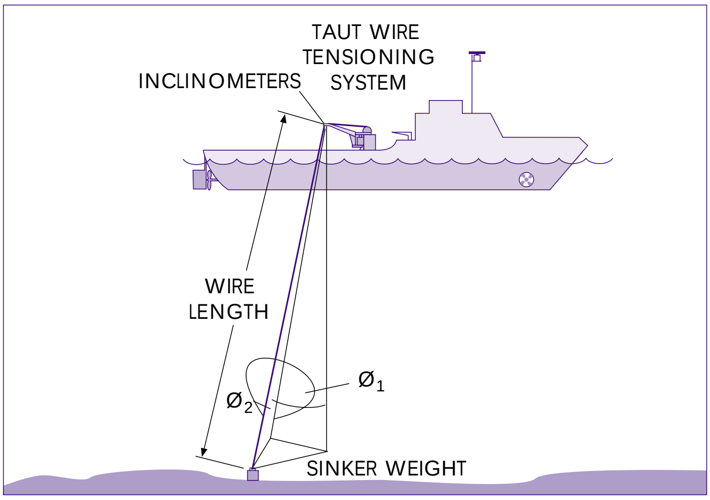

Figure 2.11 Taut Wire

Two inclinometers measure the angle of the taut wire to the vertical in two planes which are at right angles.

The Taut Wire davit can be installed at any convenient point at the side, stern or bow of the vessel. The closer it is to the centre of rotation of the vessel, the less will be the effect of pitch and roll. This will reduce the wear on the tension control mechanism. A major consideration is choosing a position which enables the maximum inboard angle before the wire touches the vessel. The Taut Wire is installed on the vessel either parallel or at right angles to the axis of the vessel. The control station must be positioned so as to provide the operator with clear view of the sinker weight when it is being lowered and lifted past the vessel.

Typical accuracy of a Taut Wire is ±2% of the water depth, up to 500 metres.

Taut Wire systems are reliable and rugged. They are excellent for maintaining position for long periods of operation. Set up and operation are rapid and simple, in moderate weather conditions.

As the depth and/or angle becomes greater, the catenary effect increases, causing the accuracy to decrease due to the effect of currents and tides. Typically, the maximum angle allowable is ±30° in either plane. A service working range is ±15°. Deployment and retrieval of the sinker weight can be a problem in heavy sea conditions, as can dragging of the weight.

Radio Systems

The two main radio systems are:

- Artemis
  A microwave system operating between a fixed and mobile station, which provides range and bearing data relative to the fixed station

- Differential Global Positioning System (DGPS)

  This USA based system is a development of the GPS satellite system which uses signals from several satellites, a signal from a fixed reference station and a receiver on the vessel to provide the vessel position.

Glonass (Russia) is an alternative satellite system to DGPS.

Other radio systems include Syledis, Argo, Trisponder, Microfix.

Artemis

The Artemis range and bearing system was developed by Christian Huygenslaboritorium BV in Holland. The current model, the Mk IV, was introduced in 1989.

The system consists of two directional tracking antennae, which align themselves and then stay locked, whilst data is passed between them on a microwave link. The alignment of the antennae and the link are then maintained while the mobile station moves with respect to the fix station.

The data passed between the two stations provides separate data on range and bearing between the fix and mobile stations. This data enables the vessel position to be calculated.

- Range
  The range between the fix and mobile stations is determined by measuring the time lapse between a signal leaving the mobile station, transiting the fixed station and returning to the mobile station.

- Bearing
  The fix station transmits the bearing from true north (or a set reference) that the fix station antenna has turned in order to point at the centre of the mobile antennae. The measurement is made by a precision shaft encoder coupled to the fix antennae shaft that measures the angle the antennae has to move to lock with the mobile station.

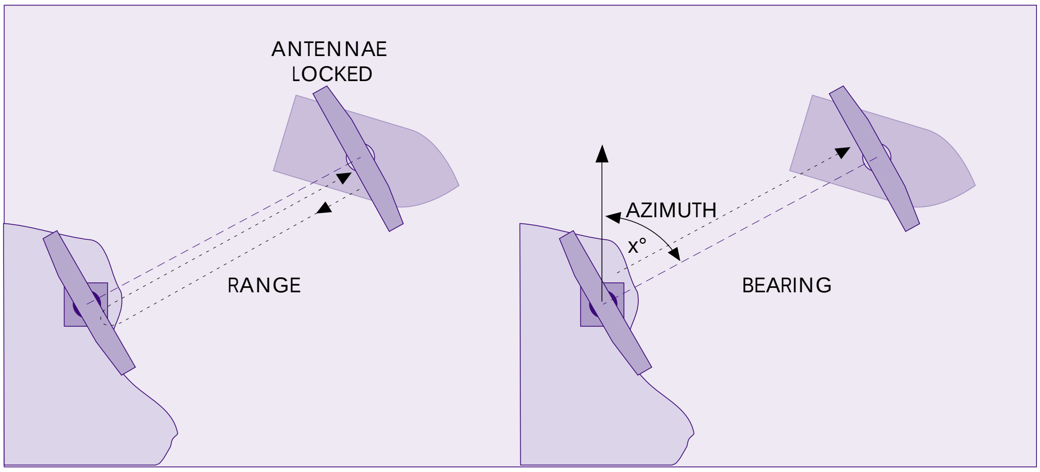

Figure 2.12 Artemis

Artemis has a range of 10 metres to 30 Kms and full 360° coverage around the fix station. The range value is an average of between 512 and 4069 values in a .25 second interval. This gives an accuracy, depending upon the range, of between 5cms at >3Km, and 0.15 metres at >30Km. The azimuth resolution is 0.0025 degrees, so at 15Km, the error is 0.65 metres.

At short ranges, the fixed antennae can be replaced by a beacon. It is then necessary to measure the bearing at the mobile station which introduces compass errors and limits the useful range to about 200m.

Artemis operates at 9.2 GHz and is therefore unaffected by rain, fog or haze. It does, however, require an unobstructed line of sight. Its use is limited to areas where fix stations or beacons have been installed.

Artemis is used for positioning applications such as support vessels, in and offshore positioning and surveying. Beacon operation is used between Offshore Loading Terminals (OLT) and shuttle tankers.

Global Positioning System (GPS)

GPS is a satellite based passive ranging navigation system which provides latitude, longitude and altitude data anywhere in the world.

It is based upon the US Department of Defence Navstar Global Positioning System (GPS). GPS consists of 21 operational satellites, with three spare satellites, in six orbits of 20,200 Kms. Each satellite takes 12 hours to orbit the world. This pattern of satellites means that 4 satellites are always in view from any point on the earth's surface.

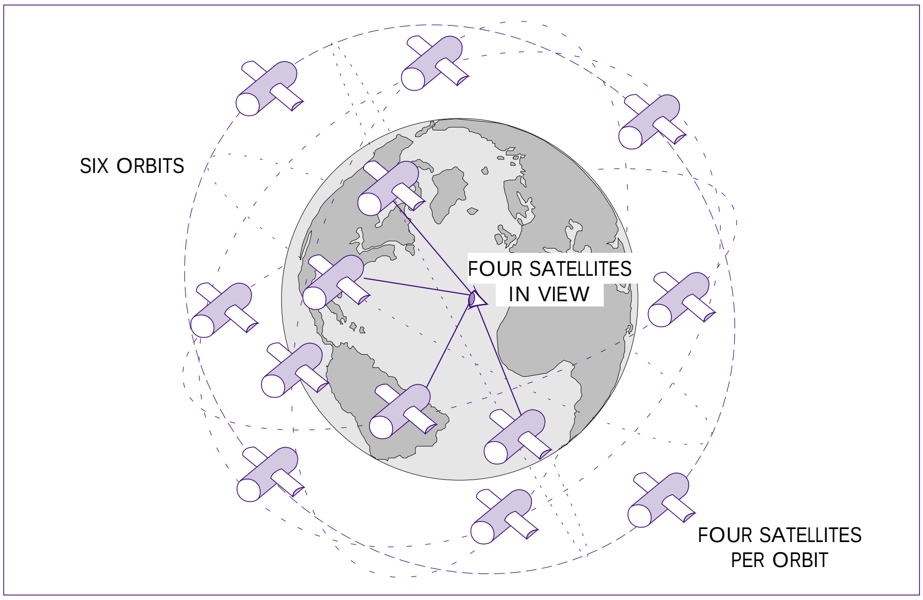

Figure 2.13 GPS Satellite Orbits

For security reasons, the GPS system provides two levels of accuracy:

- Precise Positioning Service (PPS)
  This is accurate to better than 20 metres and only available to certain military users.
- Standard Positioning Service (SPS)
  This is accurate to 100 metres and available to non military users.

The Differential GPS improves the accuracy of the SPS to 1-5 metres.

The GPS satellites all transmit two frequencies, L1 and L2. The L1 frequency is modulated with Precise code (P code) and coarse acquisition code (C/A code). The L2 frequency is only modulated with P code. The critical feature is timing the satellite transmissions. To do this, each satellite has a caesium frequency standard onboard.

The positioning receivers on the vessel have 8 or more receive channels to track and decode the C/A code from the L1 frequency of 8 or more satellites. The GPS receiver uses two observations to enable it to position itself, a pseudo range and the carrier frequency.

The Pseudo Range is the signal travel time between the satellite and the vessel receiver, converted into metres. The travel time is obtained by decoding the C/A code received from each satellite and calculating a time offset. The range is called a pseudo range because it is contaminated by errors in the cheaper less accurate receiver clock. But as the error in the clock is the same for each satellite and as long as four satellites are in view, the error can be derived from quadratic equations. Four ranges are required as there are four variables to be found: x, y, z, and the clock error.

The position of the satellite is provided in the navigation message part of the C/A code (a sophisticated set of Ground Monitoring Stations track the satellites and return position data to the satellites using the WGS84 geodetic system).

DIFFERENTIAL GPS (DGPS)

The accuracy of SPS GPS can be significantly improved using a technique known as DGPS. DGPS operates using fixed GPS reference stations at convenient locations around the world. Each reference station receives the satellite position data and calculates its position using this data. Knowing its true position, it calculates a correction value for each satellite, which it transmits over a data link to the vessel.

The vessel's receiver then applies the correction to its own satellite fixes. This system is possible because two receivers (reference and vessel) which are up to 500Km apart will be subjected to almost the same satellite signal timing distortion.

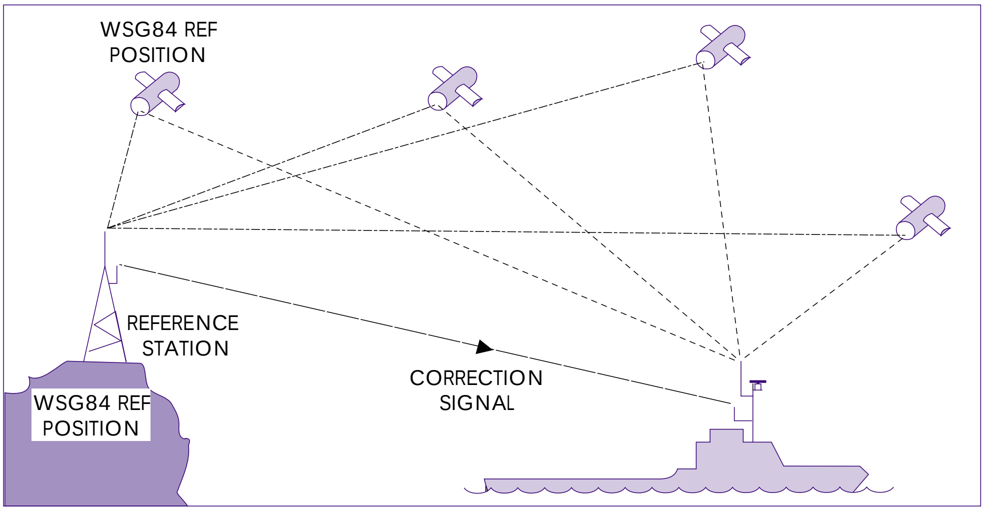

Figure 2.14 Differential GPS

The reference station and differential links are run by a variety of commercial organisations such as Racal Skyfix and Pulselink, Difftech, DiffStar, Starfix, Subsea survey Veripos. The system type selected will depend upon vessel operation area and function. The data links have varying characteristics.

The differential links transmit in the RTCM 104 format. This defines a range of messages covering Differential GPS corrections and rate of change, reference station parameters etc.

RADIO BAND	RANGE
Satellite	Worldwide
Spotbeam	Worldwide
UHF	40 Km
HF	600Km
LF	700Km

Table 2.4 Differential Links

Relative GPS

DGPS provides accurate position for a fixed position. Some vessel operation require accurate positioning between moving vessels. Such a situation is a shuttle tanker and an FPSO which weathervanes. Typically the stern of the FPSO describes a figure of eight which the bow of the shuttle tanker must follow.

The DiffStar Absolute and Relative Positioning System (DARPS) produced by Seatex solves this positioning problem.

The FPSO uses a standard DGPS to monitor its position. The shuttle tanker receives GPS data on its own receiver and receives GPS data from the FPSO over a UHF link. The shuttle tanker then compares the two positions and derives a range and bearing which is fed to the DP system. The UHF link also provides various telegrams from the FPSO. The UHF aerial is provided with offset compensation by the VRU. The DARPS UHF link has a range of 2-3 Kms, and will therefore be in use during the approach and loading modes.

The FPSO can receive its differential signal from DiffStar, Starlink or IALA beacons.

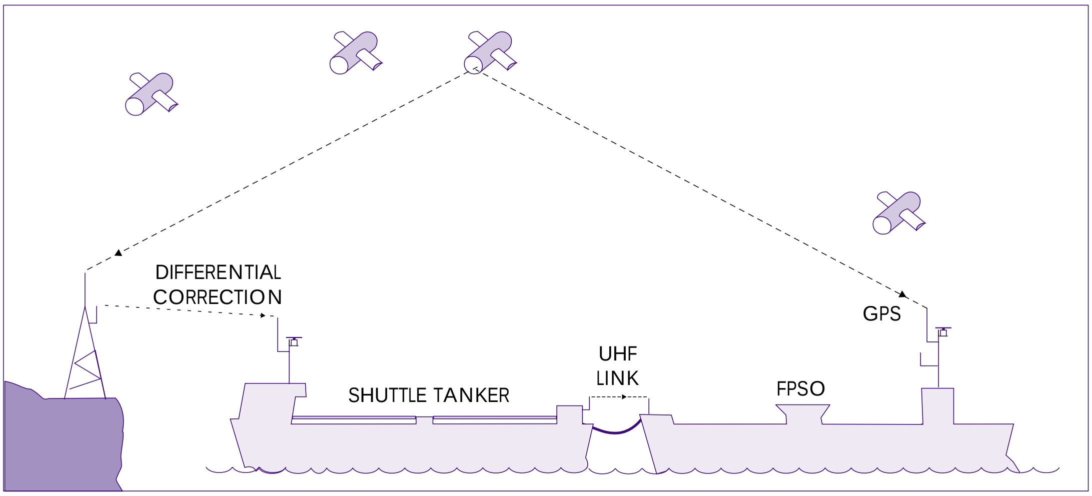

Figure 2.15 Relative GPS

Other Satellite Systems

In 1996 the Russian equivalent of GPS, GLONASS became available in the West. GLONASS also uses a pseudo range system, but is different in its use of frequency (FDMA as opposed to CDMA) and it its choice of geodetic system PZ90 as opposed to WGS84). Translation between the systems is computationally possible, and combined receivers are available.

Real Time Kinematic GPS (RTK GPS) is a differential system which uses the pseudo range and carrier phases to improved accuracy to within 5cms. The system is processor intensive, but with improvements in computer speed, acceptable update delays are becoming possible.

Other Radio Position Systems

Syledis

Syledis is a proprietary UHF radio positioning system developed by Sercel of France. It relies on a network of shore based transponders or beacons to provide positioning over defined areas. Many areas exist all over the world which have Syledis cover. It is a propagation time measurement system

Typical positioning is up to 100Kms with an accuracy of 1 metre within line of sight. The accuracy depends upon the beacon height, atmospheric conditions and the network geometry relative to the vessel.

There are two types of Syledis, Range-Range Mode and Hyperbolic Mode.

- Range-Range Mode
  An array of between 5 and 60 fixed radio transponders are placed to provide cover for an area. A transponder responds to radio pulses issued by the vessel by sending a response. The time taken to send and receive the response from each transponder is a measure of its distance. With three ranges, the vessel position can be completely defined. The output is provided in UTM coordinates. A five beacon array can support 10 vessels.

- Hyperbolic or Passive Mode
  With hyperbolic mode, the vessel receives a pair of signals from fixed stations. The signals are placed in synchronisation by a master beacon. The pair of signals define a hyperbola upon which the vessel lies. With three hyperbola defined, the vessel can be positioned. There is obviously no limit to the number of vessels that can use this mode.

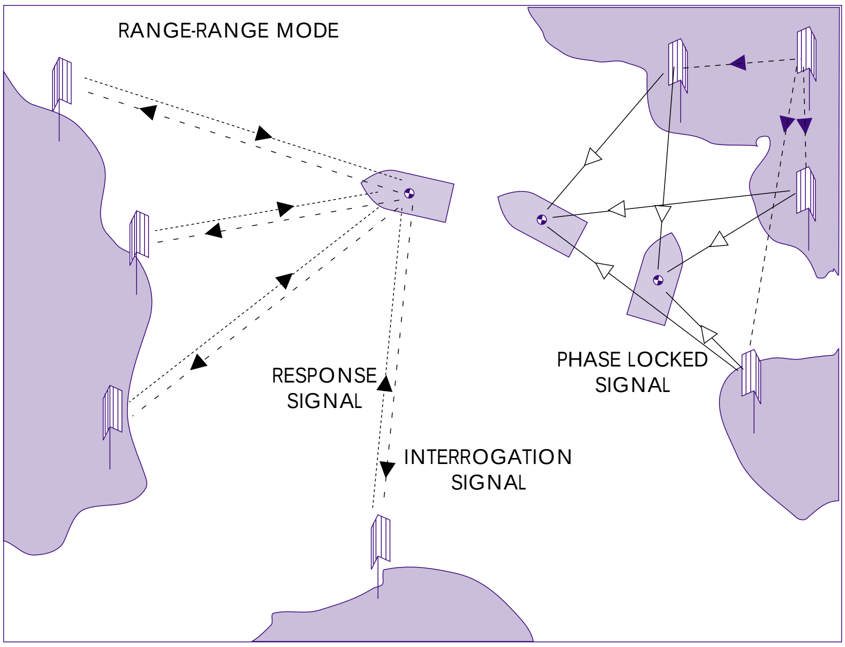

Figure 2.16 Syledis

Microfix

Microfix is a short range, 50Km, microwave positioning and survey system. Arrays of transponders are placed in fixed locations or on platforms. The system uses range-range mode interrogation. It has a multiuser capability of up to 16 users in an array. Accuracy is about 1 metre. As with all microwave systems, they are limited to line of sight and atmospheric conditions.

Trisponder

Trisponder is similar to Microfix, but offers both microwave and UHF capability. The microwave version offers a single beacon interrogation providing range and bearing. For line of sight microwave, the accuracy is 1 metre.

Argo

Argo is an HF multiuser positioning system which provides cover with an array of fixed and mobile beacons. The array is controlled by a fixed master station which provides the synchronisation pulse. As expected with HF radio, the range varies between day and night, varying between 300 and 700Kms. Accuracy is about 5 metres.

HYDRO ACOUSTICS

More commonly called just acoustics.

Acoustic systems provide positioning with devices below the water using the propagation of sound through water in the same way as radio waves above the water in the previous section.

There are three basic system types and a fourth which is a combination of two of the basic types. The four types are:

- Long Base Line (LBL). Accurate, but requires an array of seabed beacons.
- Short Base Line (SBL) Now superseded
- Ultra Short Base Line (USBL) Less accurate than LBL, uses one beacon
- Long and Ultra Short Baseline (LUSBL). Combines best of both.

Although the names of the systems suggest a continuum, each uses a different technique for the sound sources and detection system.

Basic Features

Acoustic systems use transducers which transmit and receive the acoustic signal and transponders which receive the acoustic signal and retransmit it.

Acoustic systems are effected by the depth of the water, salinity, temperature and frequency of the sound source.

Currently, transponders are available which produce an acoustic signal at a depth of several thousand metres, which can be reliably detected at the surface. When considering system accuracy, the constant components can be eliminated, whereas the random components (acoustic noise and acoustic attenuation) only reduced. Air is major source of attenuation and thrusters a main noise source.

Coordinate calculation must take account of alignment of transponder array with the vessel coordinates and the pitch and roll compensation provided by the VRU.

In comparison to light or radio, acoustic signals travel very slowly. The typical speed of sound in water is 1485 metres/second. Therefore at depths of 4000 metres, the signal will take approximately five seconds to return, which is well beyond the normal PME position update rate of under one second.

In selecting an acoustic system, the following factors should be considered:

- Water depth
- Accuracy
- Area of coverage
- Data rate
- Operating convenience
- Reliability
- Cost of ownership

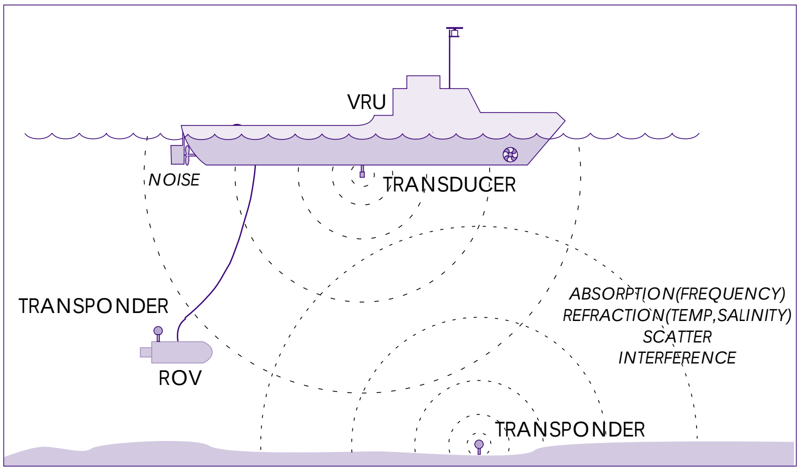

Figure 2.17 Acoustic Basics

Long Baseline

LBL acoustic systems consist of a single transducer on the vessel, and an array of at least three transponders, which are separated by more than 500 metres. It is a range-range measuring system, with no angular measurement. The transponders are placed on the seabed and their positions accurately determined.

The distance for the vessel transducer to each transponder is measured by timing a signal from the transducer to the transponder and back again. A single transducer signal is sent and each transponder then replies with a different frequency signal.

An acoustic signal around 10KHz is used with LBL. Three ranges can provide the vessel position; however, more ranges are usually provided for redundancy.

The baseline for the transponders can be over 100% of water depth. The layout of the transponder array and position of vessel above the array affects when interrogations can be made. Obviously, the effect of multiple acoustic pulses being received affects the data rate. Interrogation is complete when all return pulses are received. At 4000m, the effective data rate can be over 10secs.

Multiple interrogations are easier if the vessel is near the centre of the array.

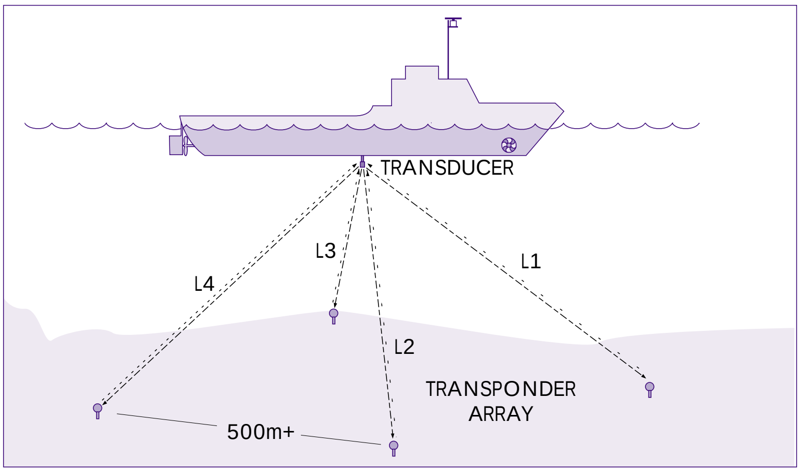

Figure 2.18 Long Base Line Acoustics

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The accuracy of acoustic systems is very dependent upon the depth of water and so generalised figures are of little use. However, LBL is more accurate than either SBL or USBL. It also has the advantage that the technique used with LBL does not require a VRU for angle compensation for vessel motion.

The main disadvantages of LBL are that deploying and calibrating the array is expensive.

Short Baseline

SBL uses a single transponder and array of transducers mounted under the vessel hull. The term acoustic beacon is usually used because it sends out a series of pulses, rather than responding to an input.

Similarly, the transducers are sometimes called hydrophones as all they need to do is listen. The baseline for this technique is the separation of the transducers along the vessel bottom. Again, it is a range system but now it needs compensation for vessel motion, which is provided by the VRU.

The beacon on the seabed emits short bursts of acoustic energy with a known periodicity and frequency. The time of arrival of a single pulse at three or more transducers is measured. Detecting the required sound from the background noise requires hydrophones which reduce noise effects. The minimum distance between hydrophones is 15m.

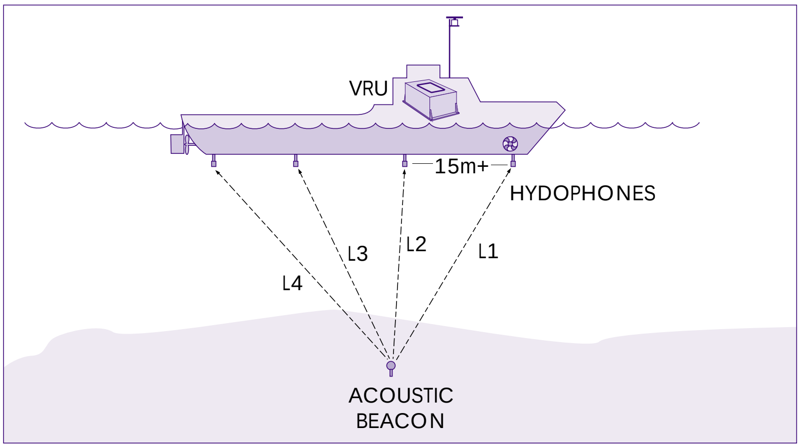

Figure 2.19 Short Baseline Acoustics

SBL can be used up to about 1000m. The positioning of the hydrophones on the bottom of the vessel should try to keep them away from sources of aeration (thruster).

An alternative design uses phase comparison on the beacon signal. This is a similar time of arrival system, but hydrophones need to be only 10 cms apart. Therefore, only one hydrophone assembly is needed, and the VRU can be put in hydrophone assembly.

Ultra Short Baseline

USBL (or Super Short Base line SSBL) was introduced in 1993. The technique used is phase comparison with many receiving units positioned around the transducer assembly. Position is calculated from the measurement of range and angles.

The time delay of the round trip is used to calculate the range. Small differences in time of arrival translate into direction, measured in time-phase differences which are measured in two axes to calculate the slant angle. As the technique requires angle measurements, vessel motion correction is required from a VRU. An accuracy of better than 0.2% of slant range is possible with VRU correction.

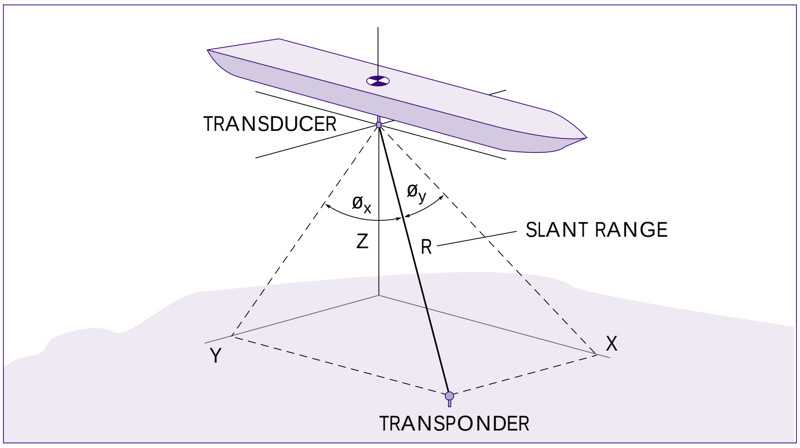

Figure 2.20 USBL Slant Range and Angles

USBL is the most used PME acoustic system. It can be used for both fixed position and tracking applications. A transducer array can handle up to ten stationary or mobile transponders by using different interrogation and reply frequencies. Frequencies used range between 19KHz and 36KHz. The vessel coordinates with respect to the transponder are calculated from R, Øx and Øy.

Care is required in the adjustment and calibration of the transducer.

Long and Ultra Short Baseline

LUSBL provides improved accuracy for repeatability in deep water and survey operations. With LUSBL, transponders are calibrated using USBL. The overall accuracy depends on the accuracy of the velocity profile, calibration of LBL array and survey geometry. With baselines of 30-50% of water depth, accuracy of less than a metre is achievable, independent of water depth. The additional ranges to the USBL provide a high degree of redundancy. The system is useful for poor acoustic conditions.

Specific Applications for Acoustics

Drilling

For drilling in deep water, a combination of USBL on the vessel and the LBL transducer on the BOP is used. In addition, the drill string has inclinometers which have both wired and acoustic coupling.

Placing the transducer on the BOP and wiring it to the vessel has several advantages:

- The transceiver is removed from vessel noise
- Update rates are reduced to 2.5 sec at 2500m
- Lower power transponders can be used, giving additional life
- EHF transponders with an accuracy of ±10mm can be deployed

ROVs

For ROVs, towing, drill string or other mobile target, USBL is used to track in terms of range and bearing relative to vessel.

LASER SYSTEMS

CyScan

CyScan is a short range laser based high precision positioning and tracking system. It consists of a stabilised rotating laser and three or more reflective targets positioned on the fixed vessel or structure. The reflective targets are fixed at defined spacing along a baseline. Vessels can be uniquely identified by altering the spacing between the targets.

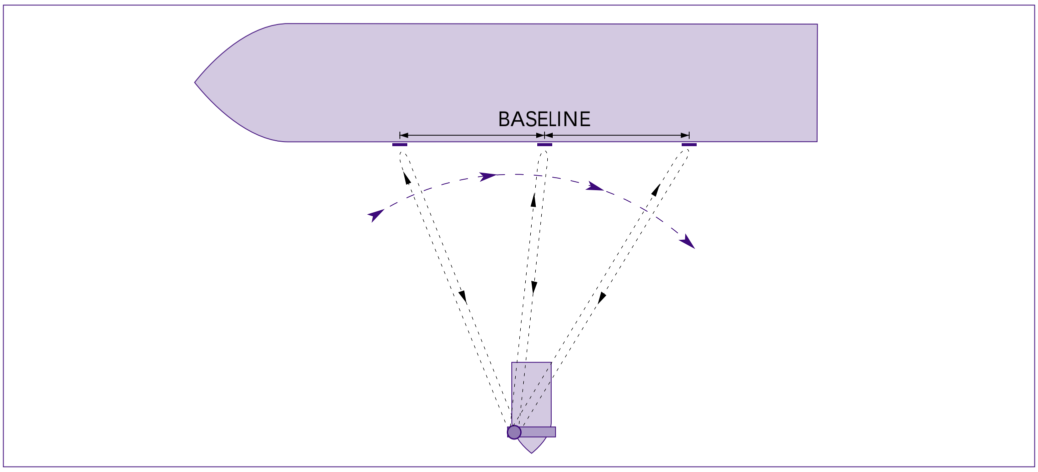

Figure 2.21 CyScan Positioning System

The CyScan has a range of 250m+ with an accuracy of 20 cms, and a bearing accuracy of 0.01°. A pulse of light is fired at a reflective target and the round trip timed to provide the range measurement. At the instant the pulse is returned, an optical encoder on the shaft is triggered to provide the angle.

The laser unit can be mounted anywhere on the vessel, but is normally placed above the bridge. It can easily be lifted and repositioned.

The rotating laser head is placed on a 2 axes stabilised platform which provides compensation for pitch and roll.

The system is set up for a particular vessel with the number of reflectors and their separation. The system receives range fixes and pattern of pulses. The use of three or more reflectors provides a high degree of redundancy and enables erroneous reflections to be discarded. The system is therefore not affected by objects getting in the way or direct sun.

Fanbeam™

The Fanbeam™ system is an alternative short range laser based positioning and tracking system. The system consists of a vessel borne laser unit and a reflector, providing range and bearing.

The reflector can be fixed onshore or on a fixed structure. Although range-range and range and bearing modes are available, currently only the range and bearing model is used for DP.

The range can be up to 2Km with an accuracy of 20 cms, and a bearing accuracy of 0.02°. The practical useful range for DP is around 200-250 metres. The laser unit must be aligned to the vessel axis, to which all bearings are referred. A VRU is needed for compensation for pitch and roll.

The system consists of an array of lasers, which emit a vertical fan of light, mounted in a unit which can rotate up to 360°. Many returns are processed and average values provided. A reflector using reflective tape can be used up to 100m. Above this range, a retro prism reflector is used. At longer ranges, multiple retro prism arrays are needed.

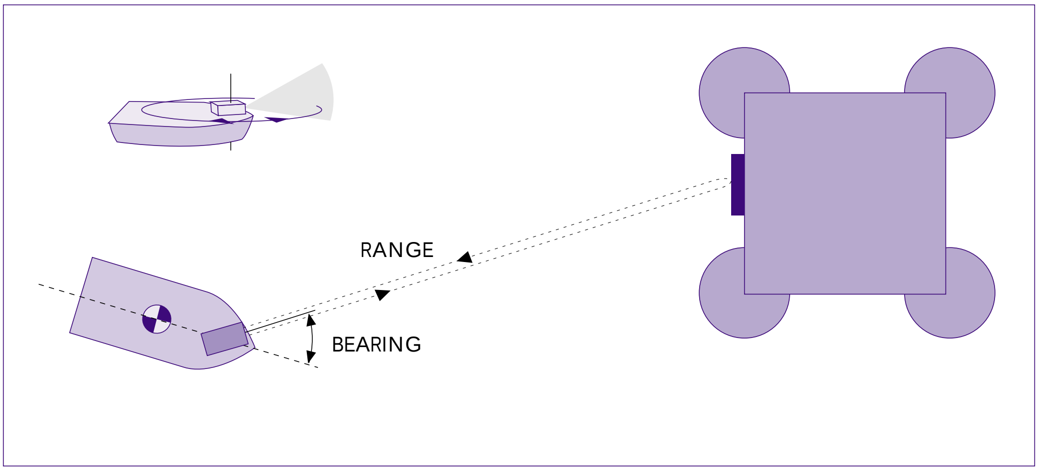

Figure 2.22 Fan Beam

Fanbeam requires care in positioning to provide a clear line of sight, and to avoid disturbances to the laser beam. The device can be affected by direct sun, atmospheric conditions affecting the lens and atmospheric conditions occluding the reflector.

Navigational Systems

There are three parts to the process of positioning a vessel:

- Locate the vessel relative to a known position in X, Y coordinates (a Cartesian system presuming a flat surface).
- Define the global position of the known position in an accepted coordinate system (a geodetic system which makes allowance for the shape of the world).
- Relate the coordinate system to the coordinate system used to define the required vessel position (all maps which define positions are based on specified geodetic systems).

If a vessel position need only be relative to another object, say a vessel/ROV relationship then X, Y coordinates are sufficient. If the positioning system provides a global reference, such as DGPS, then the conversion of the X,Y values is not necessary.

The Geodetic System will be based on one of two main coordinate systems to define the vessel position:

- Latitude and Longitude
  This positions a vessel in degrees north/south and east/west. It is defined in relationship to a reference datum. The reference datum describes the shape of the earth either globally or in an area of the world. Most used datums are WGS84 (used for DGPS), WGS72, European 1980, Bermuda etc. Selection of the wrong datum can cause errors of 100s of metres.
- UTM Grid
  The Universal Transverse Mercator grid is based on northings and eastings in metres from a set point. It divides the world into 60 strips each 6° of longitude wide. It presumes the strips to be part of a horizontal cylinder, which makes the grid rectilinear. With 60 zones, the distortion in each zone is minimal. Zone 1 covers 180° to 174° West, based on a central point of 177°. The North Sea is covered by Zone 31. There are separate sets of north and south zones. By a clever use of offsets, the easting and northings in the southern hemisphere increase as the vessel moves north. Another adjustment is required to translate the Grid North of the central meridian of the UTM zone with True North.

NMEA Messages

Sensors and PMEs communicate with the control system by sending messages. These messages may be standards such as NMEA 0183, or proprietary such as HPR400 used for acoustics. The advantage of using standards, where available, is interchangeability and independent supply.

The NMEA 0183 Standard For Interfacing Marine Electronic Devices is available for gyrocompasses, anemometers and DGPS, and other devices. The data rate is 4800 bps. The messages are ASCII character strings from 11 to 79 characters, the string being preceded by a $ sign. For example, $__HDT is for gyrocompasses and $__GGA for DGPS.

Vessel DP Solutions

INTRODUCTION

Most vessels which use DP systems are designed for a single task, or two associated tasks. The demands of the tasks determine the safety requirements placed on the DP system, and the manner in which the vessel moves and orientates itself to accomplish its task. The system sophistication and redundancy depends on risks associated with loss of position while working.

The vessels are expected to perform tasks safely to set environmental limits of maximum mean wind speed, wave height and current speed.

For the purpose of this guide, the DP system covers position control and the reference systems for position, environmental forces and vessel attitude. However, when considering the implementation of a DP system in a vessel, several other factors which affect safety and performance must be taken into account. These are usually combined into the Integrated Control System (ICS) and include:

- Power generation
- Power distribution
- Power management
- Thruster control

These may or may not be supplied by the DP system supplier but they must be designed to support the DP system, especially in their reliability. The following vessel descriptions presume that the ICS matches the needs of the DP system.

COMMON DP NEEDS

All DP systems provide a combination of manual and automatic control. A minimum configuration is a single automatic system and a joystick based manual control. Depending on the vessel task, the automatic system may be required to be duplex or triplex.

The operator will be provided with a comprehensive data display and alarms. The system information will cover changes in status of the DP system due to weather, equipment malfunction or operator action. The operator must understand the outcome of an operation, and be restrained from carrying out any inadvertent act which may cause a fault.

The system will provide automatic position and heading change and system changeover. The system will be internally self checking.

A variety of means of position measurement will be used, some of which may be duplicated. The sensors may also be duplicated or triplicated. In general, if the system needs to be triplicated, the sensors will be too.

All vessels will have the basic control modes of Joystick Manual Heading (JSMH), Joystick Auto Heading (JSAH) and DP. For transit purposes, Auto Pilot and Auto Sail may also be provided. Other standard modes are Minimum Power, Simulation and Model Control.

COMMON ICS NEEDS

Thrusters
The thruster must be assessed for response, efficiency and interference to other services. A possibility of failure to full power, or a failure which destabilises the DP must be minimised.

The thrusters should be as independent as possible. They should have independent emergency stops and independent monitoring and alarms.

Power Generation
The need is a secure power supply with backup. This concerns the number, locations and utility support systems of the diesel generators.

Power Management
This needs to be fast and reliable and should include load shedding facilities.

Power Distribution
The key purpose of power distribution is to maintain power to thrusters. This entails the provision of main and emergency switchboards.

THE DP REQUIREMENTS OF STANDARD VESSEL TYPES

The follow descriptions describe in terms of DP, the vessel purpose, the main DP task and how it is met, and other useful facilities.

Cable Laying

The basic requirement of a Cable Layer is to provide a steady tension on the cable. The secondary role is to lay the cable on a precise path. Damage to a cable can be expensive and so a duplex DP system is often considered to be desirable.

The main mode used is Track Follow, supported by Auto Slowdown. Track Follow mode precisely controls the track of the vessel. The vessel track may not be the same as the cable position in deepwater, where allowance can be automatically made for changes in direction and depth.

Tension control is provided by the Auto Slowdown facility. When the vessel is towing a plough, the plough tow wire tension is measured. If the plough tow wire tension exceeds the set alarm value, the vessel can be automatically slowed down to zero if necessary, thus protecting the tow and cable.

Closely associated with cable laying is cable repair. Cable repair vessels are stationed around the world waiting for a problem to arise. Their initial need is to reach the fault as fast as possible. For this, Auto Pilot or Auto Sail modes can be used. When on site, ROV Follow mode can be used to locate the cable ready for retrieval and repair. Obviously, DP mode is essential during the repair phase.

Cable layers are conventional monohulls, even if they do have unconventional superstructures. The thruster systems for cable laying concentrate on main propulsion and port/starboard control using tunnel or azimuthing thrusters.

Diving Support

The key requirement for Diving Support Vessels is safe deployment and recovery of divers. No failure mode should prevent the safe recovery of the divers. It is also essential that safe working limits, based on location and water depth, are laid down.

Diving support, where human life is at stake, demands the highest levels of reliability. Most systems are therefore duplicated or triplicated. Three or more position reference systems are necessary, selected according to the situation, shallow water, deep water, close to another installation.

No special modes are provided for diving support, although ROV Support may be used in conjunction with the diving.

Diving support vessels may be monohull or semi-submersible.

Dredger

The main requirement is to protect the draghead from damage. The second role is to control the track and speed of the draghead. High levels of redundancy are not usually required.

The main mode used is Track Follow, supported by Auto Slowdown. Track Follow mode precisely controls the track of the vessel. Auto Slowdown monitors the forces on the draghead.

Dredgers are mono hulls and use main propulsion and limited port/starboard control from tunnel or azimuth thrusters.

Drilling

The key requirement for drilling operations is to prevent the uncontrolled release of hydrocarbons, which can cause fire or pollution. The secondary role is to provide reliable position keeping for a period of days. Reconnection for drilling can be expensive. Drilling a well can take 150 days. Safe limits are set for the time to secure the drill floor, with different limits for drilling, running casing or testing. Duplex, triple voting or Class III system redundancy is required.

Drilling vessels can be either monohulls or semi-submersibles. In both cases, the task is to maintain the drillstring with minimum bend and torsion. For monohulls, Weathervaning will provide minimum thruster activity. However, rotation of the vessel will be constrained by the twist allowed on the drill string.

To drill, the drill string riser angle must be kept within tight limits. The special drilling Riser Angle mode is used to achieve this. ROV Support may be used in conjunction with the drilling.

Fire Fighting

These are a special form of utility vessel used for well blowouts etc. They must be able to perform in heavy weather.

They use the main DP modes, together with an optional facility which makes allowance for force of water from the fire monitors, similar to a Wind Feed Forward function.

Floating Production Storage and Offloading Units (FPSO)

The main requirement of an FPSO is to prevent the uncontrolled release of hydrocarbons causing fire or pollution. This involves the time to secure the riser and change heading.

FPSOs are usually turret moored with anchors. The DP system has a Weathervaning mode centred on the turret and a special anchor mode designed to increase anchor effectiveness.

FPSOs are usually monohulls with sufficient thrust to meet 100 year environmental conditions.

Lifting Vessels

The main requirement of a lifting, or crane, vessel is to operate in close proximity to other structures without making contact . Damage can be expensive and so duplicated DP systems are necessary. Some use of anchors or tugs may be an alternative.

They use the standard DP modes, but will include special position measurement to accurately measure the distance between lifting vessel and structure. This can be DARPS, laser types or Artemis.

Passenger Vessels

Cruise liners are a category of passenger ship which is using DP for "mooring" and manoeuvring in restricted locations. Larger and larger cruise liners are going to smaller and less well equipped harbour facilities. DP provides more reliable manoeuvrability.

Pipelay

The basic function of a pipe layer is to provide a steady tension on the pipeline. The secondary role is to lay the pipe on a precise path. Damage to a pipe, especially backing into the pipe, can be expensive and so a duplex or triplex system is necessary.

The main mode used is Track Follow. Track Follow mode precisely controls the track of the vessel. The vessel track may not be the same as the pipe position in deepwater where allowance can be automatically made for changes in direction and depth.

Shuttle Tankers

The key task of the DP system is to avoid the need for an emergency disconnect between the tanker and offloading field. Duplex systems are necessary, together with special relative position measuring equipment, such as DARPS.

Each system has a common need:

- To approach the loading point in a safe manner. This phase uses the Approach and Loading modes.
- To maintain the vessel in a stable and power conserving position during the loading phase which can last many hours.

Shuttle Tankers can use a Weathervaning mode for all close proximity movement, together with three special modes, Approach, Pickup, Loading and Fixed Loading. The exact form of each mode depends on the field type, loading buoy, loading tower, FPSO etc.

All shuttle tankers are monohull.

Surveying

In the main, survey vessels present few constraints to DP. However, survey vessels may be required to operate close to structures or mooring lines. Effective positioning equipment must take this into account.

The main modes used are Auto Track and Auto Sail.

Utility - tugs, supply

Supply vessels come close to other structures and therefore, must be sufficiently responsive to maintain a safe distance. They use no special modes.

A Series

A SERIES PRODUCT RANGE

The A Series is the latest product range from ALSTOM.

Since the early 1970s, ALSTOM has supplied high quality DP control systems for a wide variety of applications. The A Series offers new power, flexibility and reliability in a family of products:

AJS 01	Stand alone joystick
AJS 02	Integrated joystick
ADP 01	Stand alone simple DP
ADP 02	Integrated simple DP
ADP 11	Stand alone simplex DP
ADP 12	Integrated simplex DP
ADP 21	Stand alone duplex DP
ADP 22	Integrated duplex DP
ADP 31	Stand alone triple voting DP
ADP 32	Integrated triple voting DP

Where a product designation refers to an "integrated" version, this relates to the DP system being supplied as part of a complete package of equipment. This package will include other ALSTOM products, such as the AVC (ALSTOM Vessel Control), which includes functions such as Power Management, Alarms/Monitoring, Remote Control etc.

ALSTOM can also supply Diesel Electric Power systems, from prime movers to propellers.

Other products in the A Series include:

APM	Position mooring
AOT	Remote/portable joystick
ATW	Taut wire
ATC	Manual thruster control
AVC	Vessel control system (Integrated control)

The above range of products are collectively known as the A Series. The A Series is based on well proven hardware and software platforms which are chosen for flexibility, reliability and affordability.

The use of common platforms across the range ensure full integration and seamless functionality. This, in turn, ensures that the purchaser is rewarded with first class products, minimised spares holding and technician training requirements.

TYPICAL ADP SYSTEM SUPPLY

ALSTOM can supply a DP Control System consisting of:

- ADP Console(s) with computers and DP software
- Sensors - Gyrocompasses, VRUs and Anemometers
- PME Console
- PMEs - Taut Wire System, Hydro Acoustics, DGPS, Laser Reference System etc.
- AOT Remote/portable operator terminal
- Outstations
- Peripherals - Uninterruptible Power Supply (UPS), PCs and printers

The peripherals, sensors and PMEs are selected from leading suppliers.

ADP CONSOLE

The ADP Console consists of a display unit, control panel and control processor. Maintenance access is via the front of the console and system cable access through the base. Console suites can be constructed from the basic unit into straight or wraparound configurations.

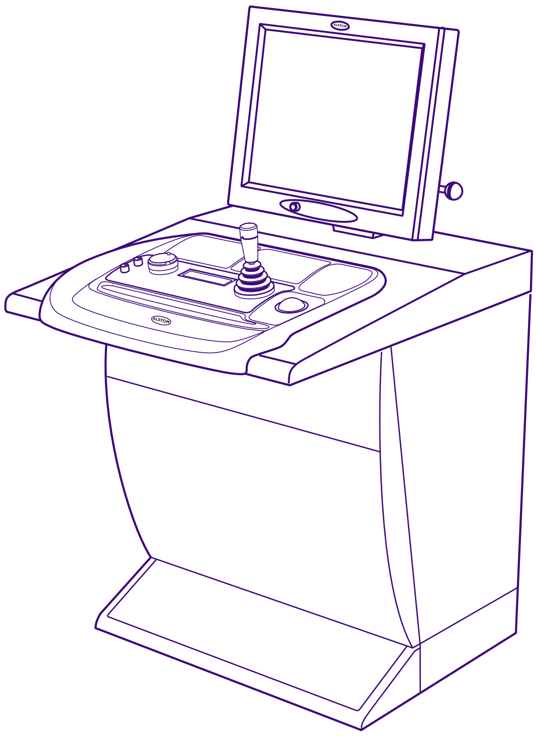

Figure 4.1 ADP Console

CONTENTS

Display Unit

The display unit is an 18" high resolution flat screen display (SXGA or 1280 x 1024 pixel resolution).

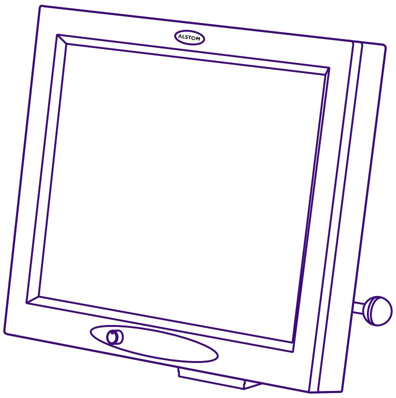

Figure 4.2 Display

Control Panel

The control panel can contain up to five sub-panels:

- Joystick panel

  - XY Joystick
  - Position control pushbuttons
  - Turning moment control knob
  - Heading control pushbuttons
  - Mode selection buttons
  - Operator control pushbuttons - 5 console control pushbuttons
  - 2 line LCD
  - Lamp/LED dimmer

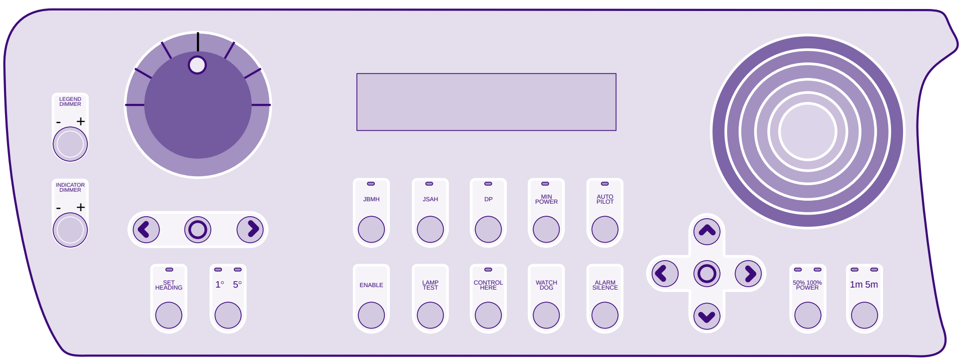

Figure 4.3 Joystick Panel

Chapter 4

A Series

CONTENTS

- Trackerball panel

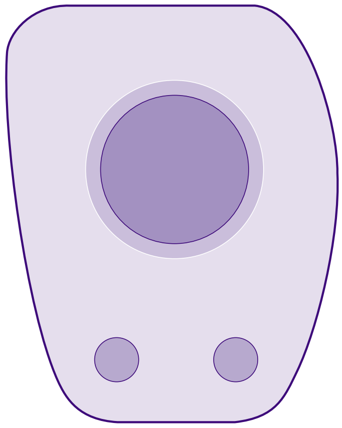

Figure 4.4 Trackerball Panel

- Numeric keypad panel (optional)

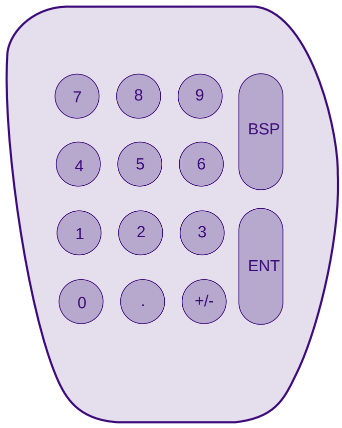

Figure 4.5 Numeric Keypad

- Expansion pushbutton panel (optionally two), comprising 15 configurable pushbuttons and indicators (per panel)

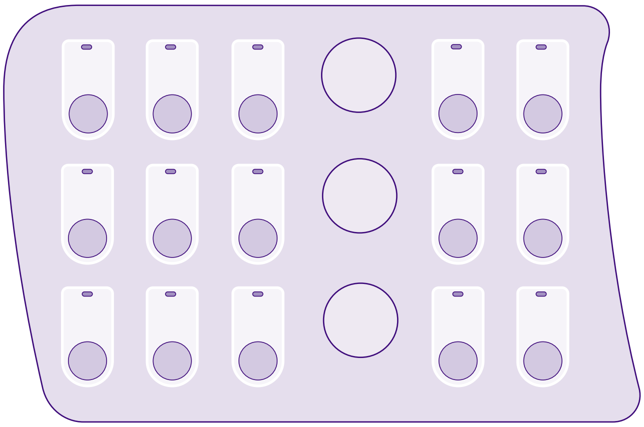

Figure 4.6 Extra Pushbuttons

CONTENTS

These individual panels are combined to provide the complete operator interface panel on the ADP console.

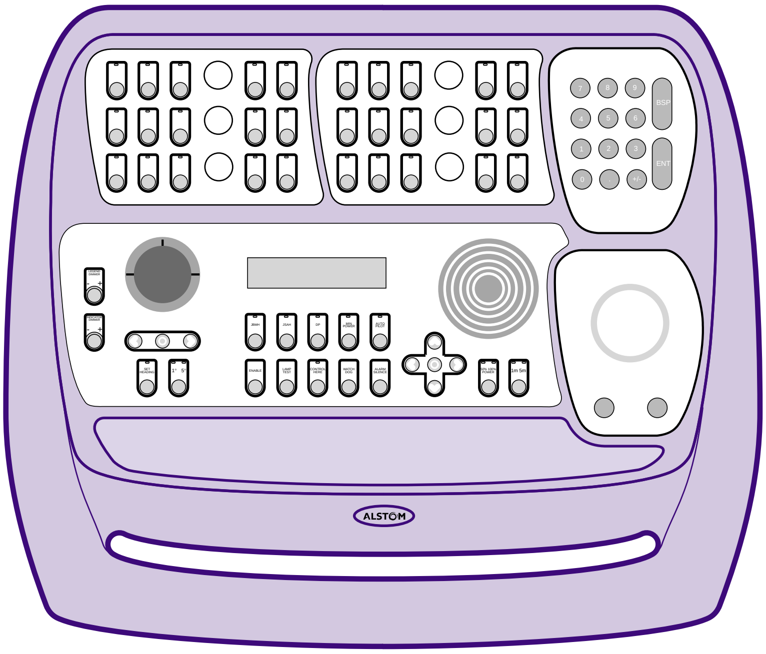

Figure 4.7 Operator Controls

Control Processor

This is situated in the lower half of the console and provides control for:

- All DP logic
- Input and output system interfaces
- Display facilities

The processor, expansion boards, VME backplane, PSU and I-Drive is housed in a 19" rack. The display facilities, serial communications, FIP network and extra Ethernet ports are on PMC cards.

The I-Drive is fitted with 64Mb flash on a PCMCIA card. There is no hard disk, so therefore no rotating parts. Software upgrades can be carried out by replacing the PCMCIA flash cards.

PME Console

The console is in the same style as the ADP console and is configured to integrate the PMEs, such as the hydro-acoustic controls and processor and taut wire control panel into the DP system.

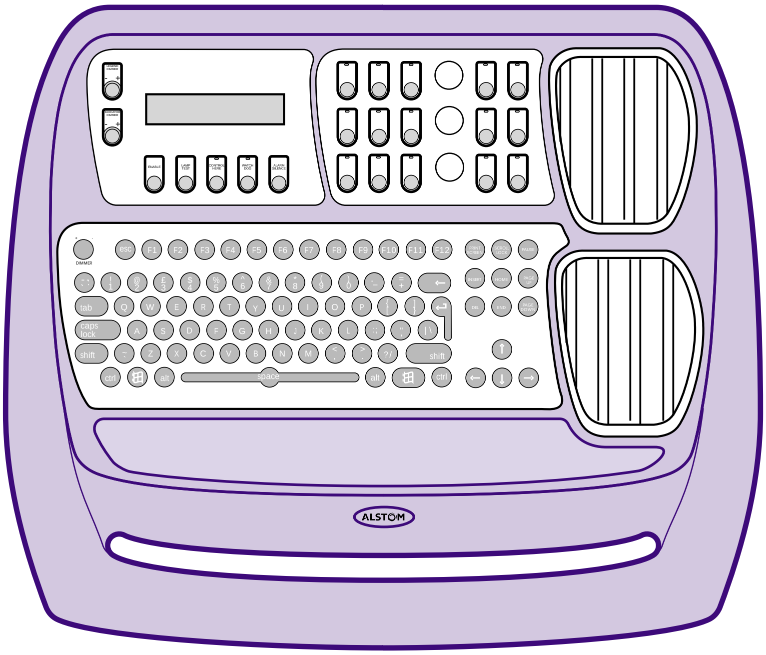

Figure 4.8 PME Console

The console consists typically of a display and control panel, often with an acoustic system processor.

The display is the same as the ADP console. The sub panels inserted in the control panel depend on the PMEs. The sub panels available are:

- Qwerty Keypad
- Taut Wire Bridge Controls

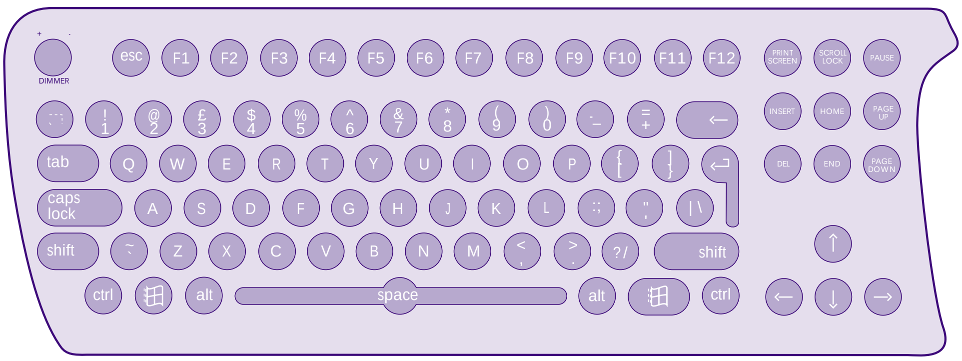

Figure 4.9 Qwerty Keypad

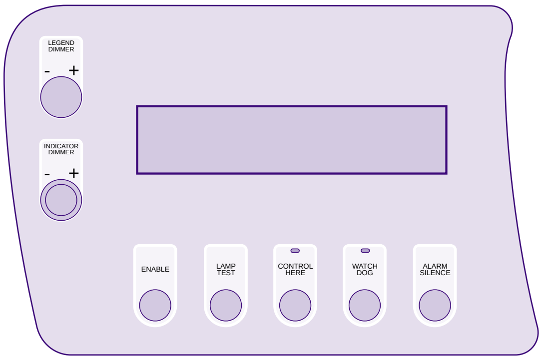

Figure 4.10 Taut Wire Bridge Controls & Extra Pushbuttons

AOT (OPERATOR TERMINAL) PORTABLE JOYSTICK

Remote or portable operator terminals compliment the facilities provided by the ADP console. They provide control of a subset of the modes available on the ADP console.

The portable AOT can be plugged in at pre-arranged positions around the vessel (e.g. bridge wings) and is suitable for use on open deck.

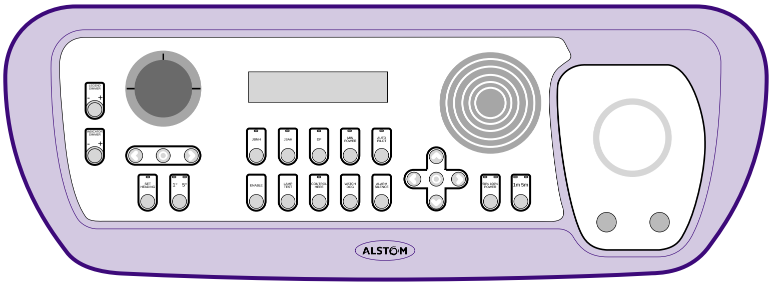

Figure 4.11 AOT

Sensors

Serial sensors interface to the system through voltage isolation panels using standard RS422 or RS232 signal.

SENSOR	MEASURED VARIABLE	PREFERRED MESSAGE PROTOCOL
Gyrocompass	Heading (relative to True North)	NMEA $HDT
Anemometer	Wind Speed/Direction	NMEA $MWV
VRU	Roll/Pitch	TSS1

Table 4.1 Sensor Messages

If existing analogue sensors need to be used, they are interfaced through the Sensor Junction Box.

This unit serialises data from one of each type of sensor using ALSTOM's own protocol. Other interface formats can also be considered.

PMEs

PMEs interface to the system through voltage isolation panels using standard RS422 or RS232 signal.

PME	MEASURED VARIABLE	PREFERRED MESSAGE PROTOCOL
DGPS	Absolute vessel position in UTM coordinates	NMEA $GCA or $GLL
Hydro-acoustics	Fore/Aft and Port/Stbd transponder positions	HPR400
Taut Wire	Fore/Aft and Port/Stbd angles of tensioned rope	ALSTOM $TW
Artemis	Range and bearing to a beacon	Artemis Mk. 1V
CyScan	Range and bearing to each target	ALSTOM $RLS

Table 4.2 PME Messages

Other measurement systems and other interface formats can also be considered.

OUTSTATIONS

Thrusters and other plant associated with DP operation (e.g. switchboard signals, tow tension signals) interface to the DP system via FIP networked PLCs which provide standard I/O interfaces.

These outstations are sited at the most convenient locations. These include switchboard rooms, machinery space, bridge etc.

By gathering I/O signals close to the plant, cable savings are achieved by running just network cables through the vessel to the ADP console on the bridge.

Outstations can be supplied and located on an individual one per thruster basis or several thrusters may be interfaced to a single outstation. This decision is usually dependent upon budget and the desired level of redundancy.

In a similar way, it is possible to group several outstations into a single cabinet.

HARDWARE CONFIGURATIONS

The requirements of the client, the Classification society and National and International legislation must all be considered when establishing the hardware/software configuration and when choosing the appropriate level of redundancy.

Some examples of configurations follow.

Simplex non-redundant control (ADP11 or ADP12)

This is IMO Class 1. Loss of position may occur in the event of a single fault.

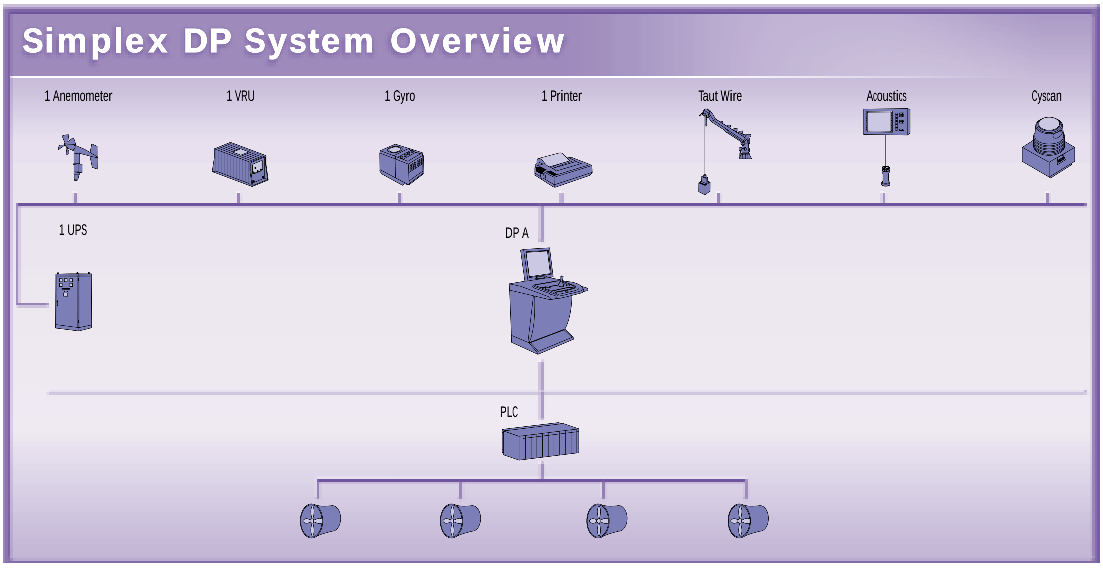

Figure 4.12 ADP11 or ADP12

Duplex redundant control (ADP21 or ADP22)

IMO Class 2. Loss of position should not occur from a single fault in an active component or system.

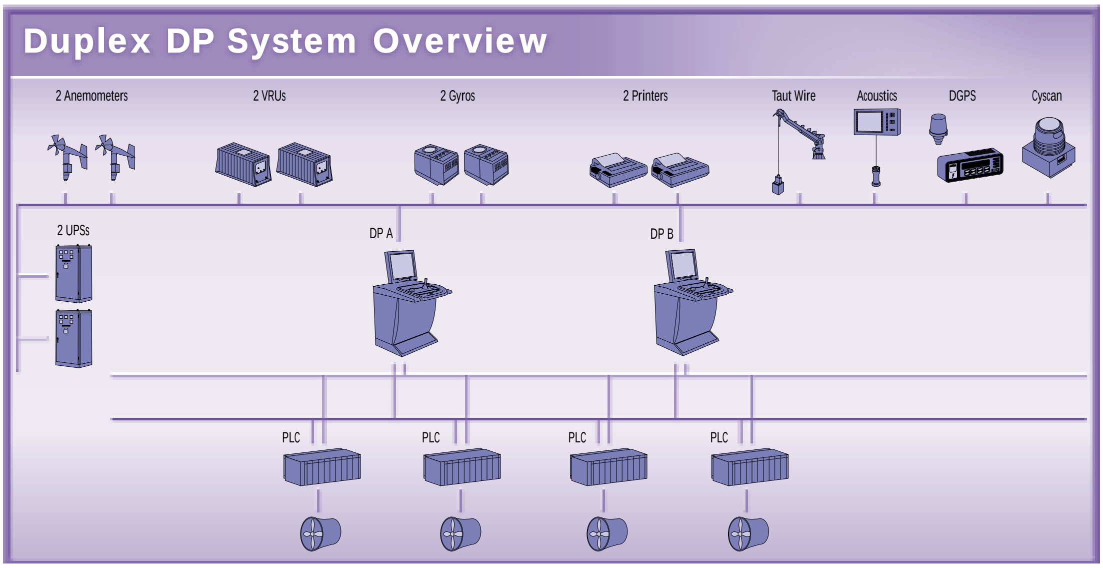

Figure 4.13 ADP21 or ADP22

Triple voting (ADP31 or ADP32)

IMO Class2, Loss of position should not occur from any single failure.

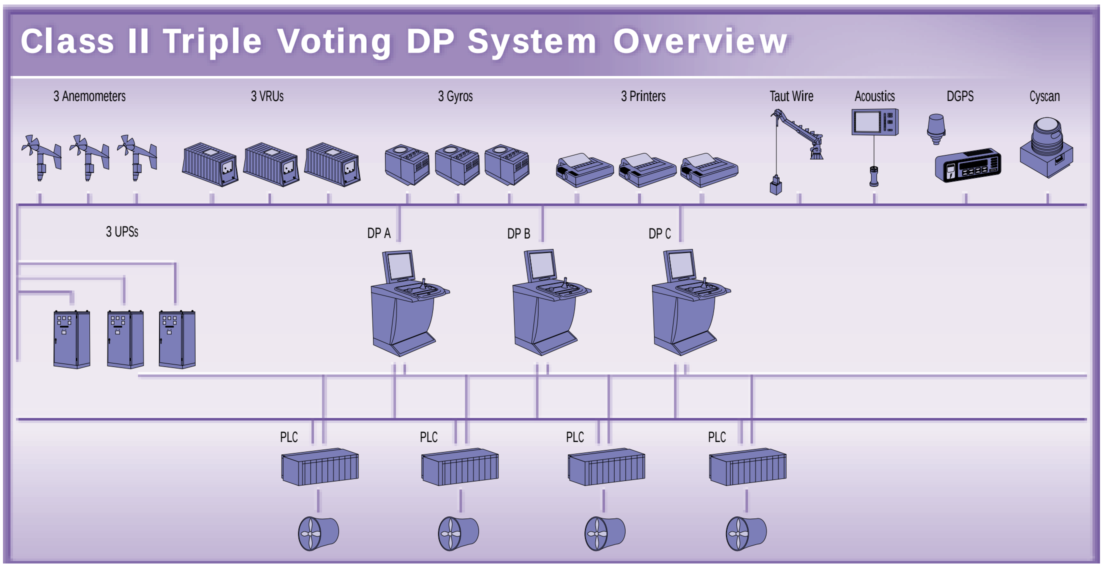

Figure 4.14 ADP31 or ADP32

IMO Class 3 (ADP21 or ADP22 plus ADP11 or ADP12)

DP C acts as a stand alone simplex system. The exact requirements for Class III depend upon the classification society.

ALSTOM offers an option to provide a slave from DPC which gives triple voting facilities at the main control position at negligible additional cost.

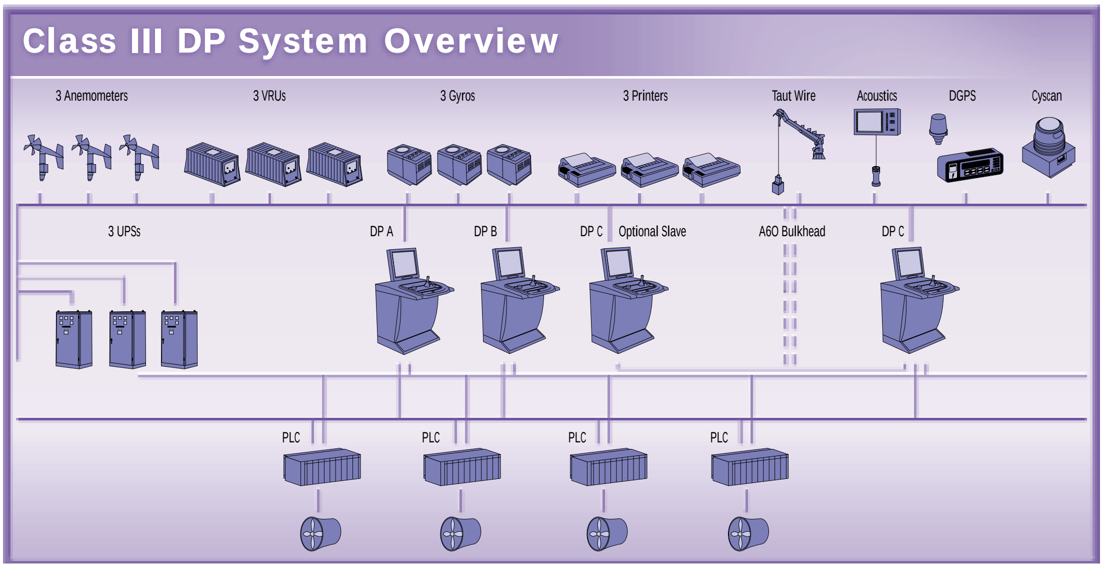

Figure 4.15 ADP31 or ADP32

ALSTOM DP systems have been approved by:

LLoyds Register

DNV

Bureau Veritas

American Bureau of Shipping

ADP OPERATIONAL FACILITIES

Operator Interface

To reduce operator error to a minimum, the controls and indicators provided for the operator are clear and unambiguous, consistent throughout many displays and intuitive.

Control

The controls for the A SERIES are clearly visible and identifiable. Where necessary, they are protected against unintentional operation, either by the inhibition or confirmation of an action.

The effect of initiating a control is clearly displayed in the appropriate places. The controls are logically associated either on the control panel, the display banners or control pages and windows.

Indicators

The indicators are clear in their purpose and importance. Status and warning indicators may be illuminated buttons or fields on the display. A colour code is used to show the status of devices such as thrusters, sensors or PMEs.

COLOUR	MEANING
Grey	Not selected
Blue	Working and available for operator selection
Yellow	Selected by operator as active input to system
Yellow - Flashing	Selected by operator, but not available possibly due to malfunction
Red	Alarms

Table 4.3 Colour Conventions

Data Input

Most operator instructions to the system are by clicking on a button using the trackerball and cursor buttons. All the display buttons which offer control, as opposed to just indications, have a shadow.

If the operator has to input data, for example, setting up a frequency or entering an alarm limit, a numeric keypad is automatically displayed, or the numeric keypad panel can be used (if fitted).

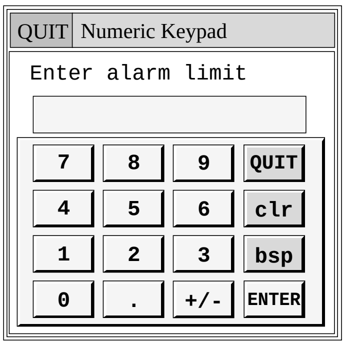

Fig 4.16 Numeric Keypad

Any amendments to data which will affect/alter the operational control must be positively confirmed as correct by the operator before they will be accepted by the system.

Display Structure

The current status of the vessel displayed on the monitor is divided into three areas, two of which are fixed, while the third displays the pages and windows most relevant to the operator's current activity.

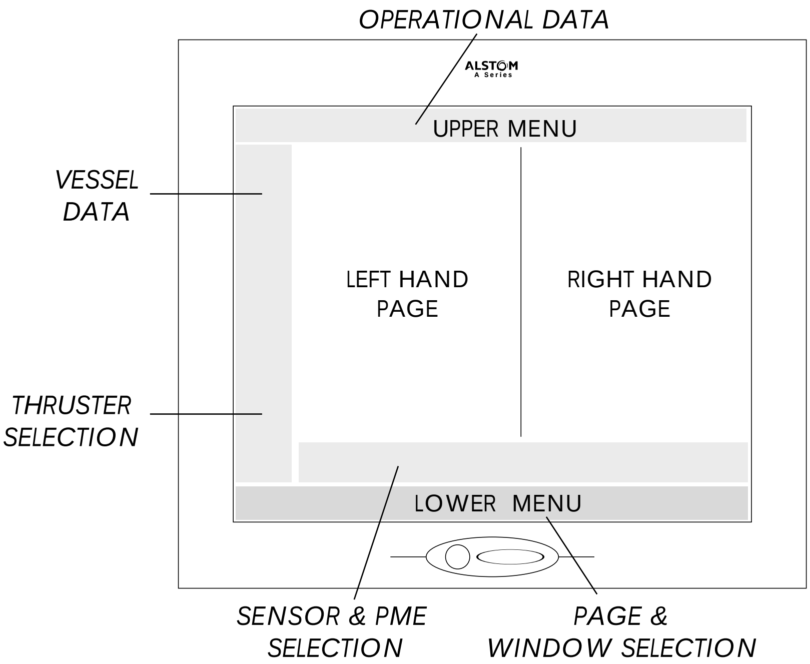

Figure 4.17 Display Structure

The upper menu provides basic operational data and the latest alarm.

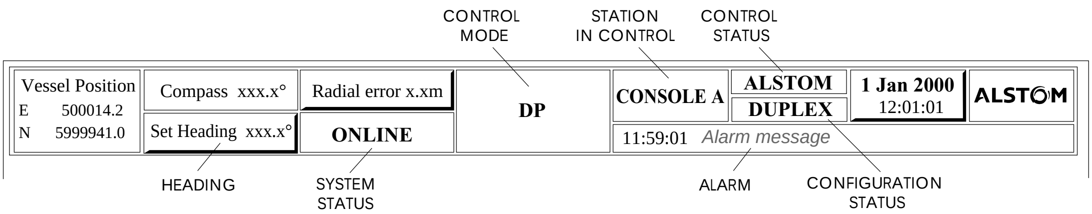

Figure 4.18 Upper Menu

The lower menu provides 'one click access' from any display to the most commonly required pages and windows.

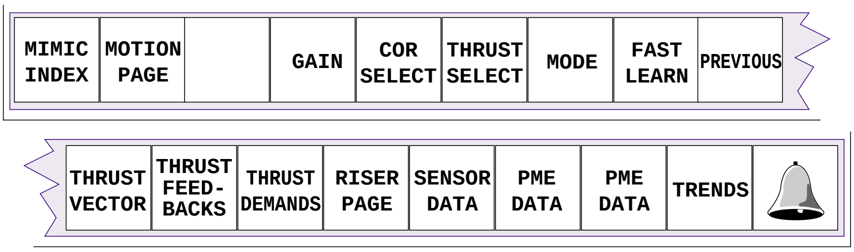

Figure 4.19 Lower Menu

The operator can immediately see the status of the thrusters, PME or sensors – “non available”, “available” or “selected”. Available devices can then be selected by clicking on the appropriate symbol. These facilities are also available on other specialised pages such as Sensors, Thruster Select etc.

The current readings from the sensors are shown below their icons. The position fix data for selected PMEs is shown below their icons.

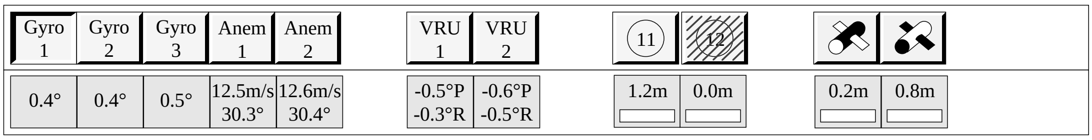

Figure 4.20 Sensor and PME Selection

Thruster status and selection is displayed on the left hand side of the display. The thruster feedbacks are displayed below the thruster selection buttons.

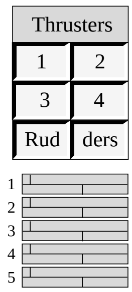

Figure 4.21 Thruster Status and Selection

Additional Vessel Data is displayed above the thrusters. Certain control modes require additional operator control and monitoring facilities, for example, in cable laying, where the cable tension is monitored and alarmed. In Shuttle Tanker modes, essential information, relevant to the particular field type, is displayed.

Motion Display

A comprehensive view of the vessel status is provided by the Motion Display. The Motion Display shows the position and motion of the vessel and its environment. It can occupy half or the whole display.

The displays cover:

- Vessel and Weather displays
- Vessel Position and Heading Setting
- Display Options

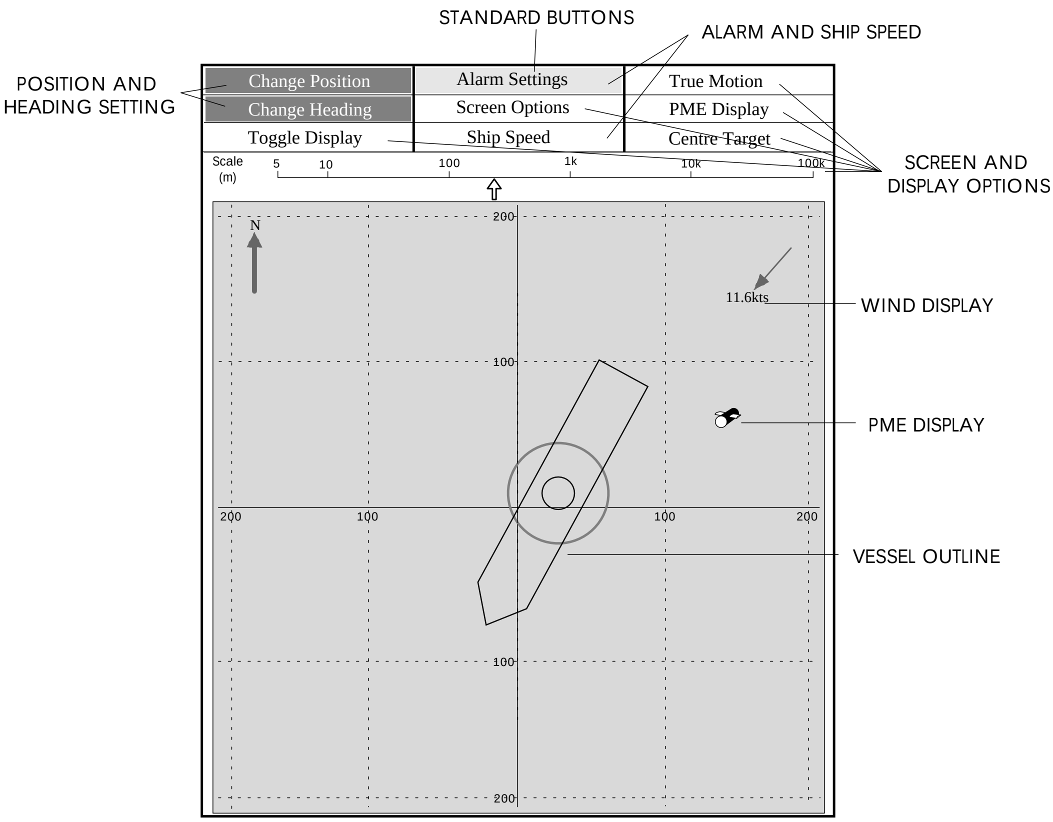

Figure 4.22 Motion Display

Vessel, PME and Weather Displays

This display provides the operator with constant visual monitoring of the vessel heading, the direction and force of the wind, the control point of the vessel and alarm radii and position of PMEs.

If the vessel is following a track, the track followed can be displayed. The operator can adjust the area displayed to suit the operational mode. If the vessel is in a DP mode, the display can be in metres. If the operational mode is a transiting mode, such as Track Follow, the display can show several kilometres.

Mimic Indices

The mimic displays which, together with supporting windows, provide the set up and control for the variety of system controls are selected using the Standard Mimics and Mimic Index.

Both indices provide the operator with the flexibility to select the two most appropriate pages which are displayed alongside each other.

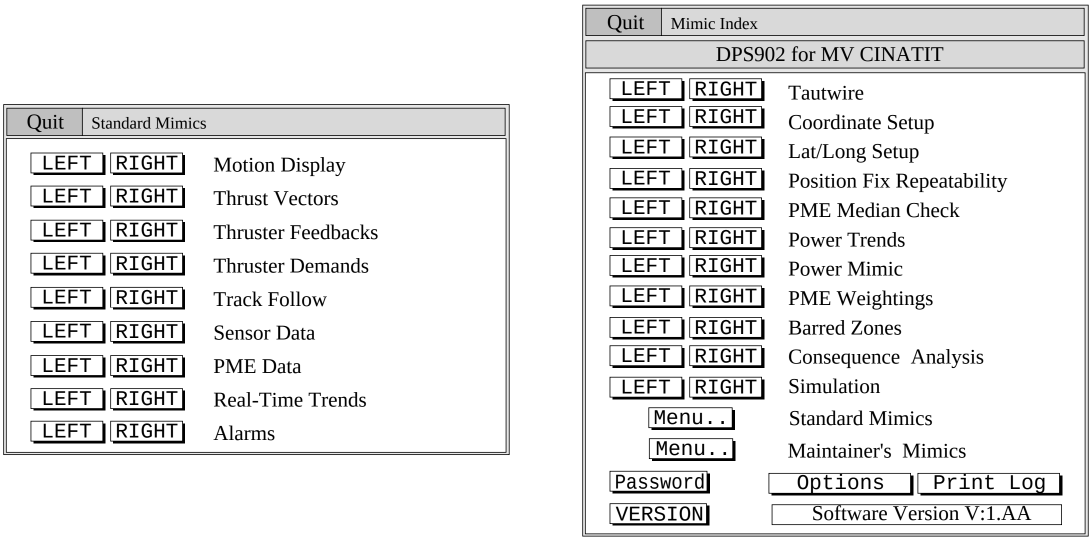

Figure 4.23 Typical Mimic Lists

The units of speed, knots, meters/sec, km/hr can be set up for each owner's requirements using the Options button.

The Mimic Index window also provides secure system access for the maintenance staff.

Control Modes

The Control Mode for the current vessel operation is selected from the Control Modes Window. This shows the operator which mode is currently selected and which modes can be selected with the currently selected thrusters, sensors and PMEs. A subset of the modes can also be selected from the Control Panel buttons.

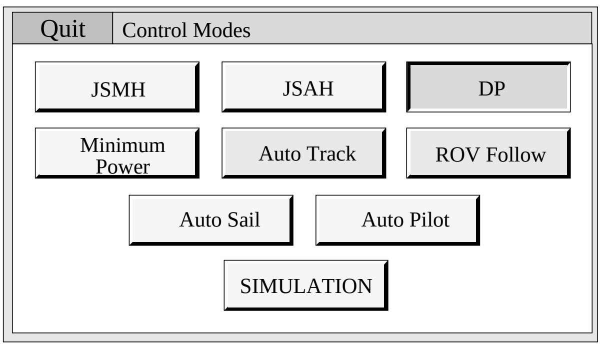

Figure 4.24 Control Mode Selection

Movement Control

The operator has a set of powerful tools to quickly, accurately and reliably alter the vessel position and vessel heading. Position and heading changes can be carried out in three ways:

- Joystick and turning control knob (These are only available in JSMH, and the joystick only in JSAH mode)
- Using the buttons on the control panel
- Using the position control facilities on the Motion Display page

The vessel position and heading are changed independently. The following movement controls can only be operated when the vessel is in a position control mode, such as DP.

On the Control Panel, the vessel can be moved in 1 or 5 metre increments, and the heading changed in 1° or 5° increments. If the vessel is moving, it can be stopped using the Present Position button or Present Heading button.

On the Motion Display page, the vessel position or heading can be changed in two ways:

- Marker Control
  The target is moved and the vessel control point follows it. The target can be moved to the marker position, moved to the vessel's previous position, stopped at the vessel's present position or moved to a position input by the operator. Similarly, the vessel heading can be changed by moving the target to the marked heading or to a heading input by the operator.
- Increment Control
  The vessel can be moved in 1 metre increments or operator configurable steps, and the heading changed in 1° increments or operator configurable steps, in the same way as at the control panel.

Display Options

The operator can set up the display to suit his operational needs. Some options apply to all modes, some just to a specific mode such as Auto Track.

The vessel can be displayed in relative motion, which moves the target to the centre of the display, or true motion. The vessel outline can be deleted or shown as a dotted outline of a fixed size vessel or a solid line vessel outline proportional to the display scale. The PME to be displayed can be selected from those available.

Grid Display can be displayed or not displayed. Furthermore, the grid can be Cartesian or polar. The alarm circles, vessel trail and selected track can be displayed. The marker, target and control point positions can be suppressed.

Finally, the vessel velocity, wind force and sea force can be displayed.

Thruster Control

Several pages are provided to enable the operator to view the thruster and power generation.

Thrust Vectors

The thrust vector page displays tonnes thrust magnitude and direction vector information for each selected thruster. Each thruster vector arrow is coloured to indicate the percentage of maximum thrust being delivered. The total thrust magnitude and turning moment vectors are also displayed.

A thruster vector can have an alarm limit set to either % speed or % pitch on any thruster.

To provide fine control, or to reduce thruster wear the thrusters can be arranged to operate in patterns to oppose each other, provided the thruster types and their configuration allow it.

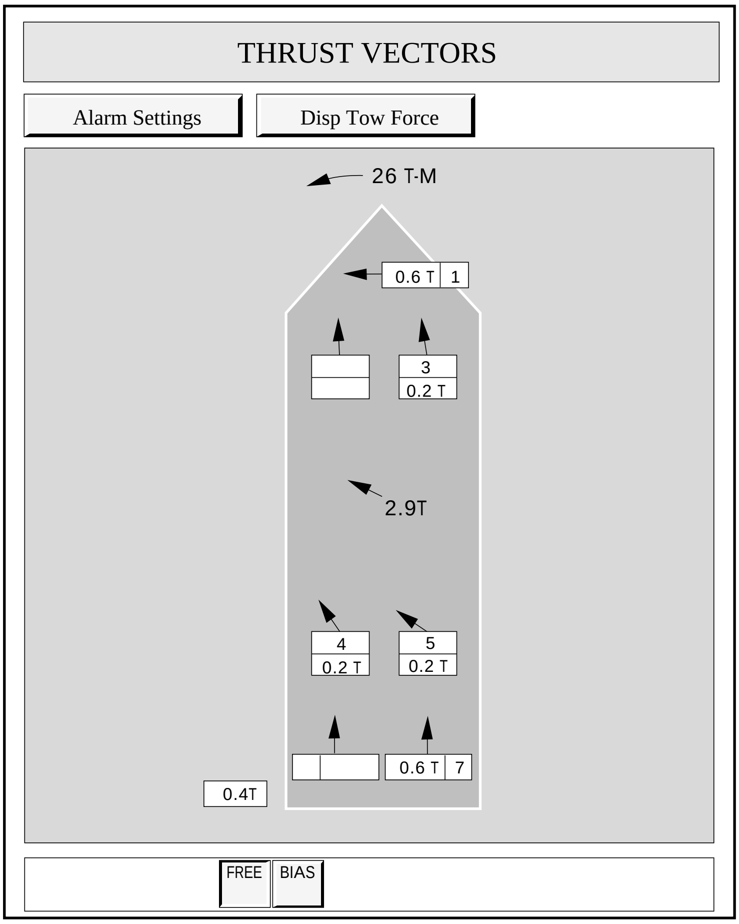

Figure 4.25 Thrust Vectors

In Bias mode, thrusters 2 and 3 oppose thrusters 4 and 5, providing port, starboard motion or no motion.

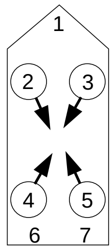

Figure 4.26 Thruster Bias Mode

Thruster Feedback

The Thruster Feedback page provides the operator with details of the performance of each thruster in terms of the actual and required thrusts and direction, and overall thrust available.

The page also displays the barred zones for the azimuthing thrusters. The setup of the barred zones is described shortly.

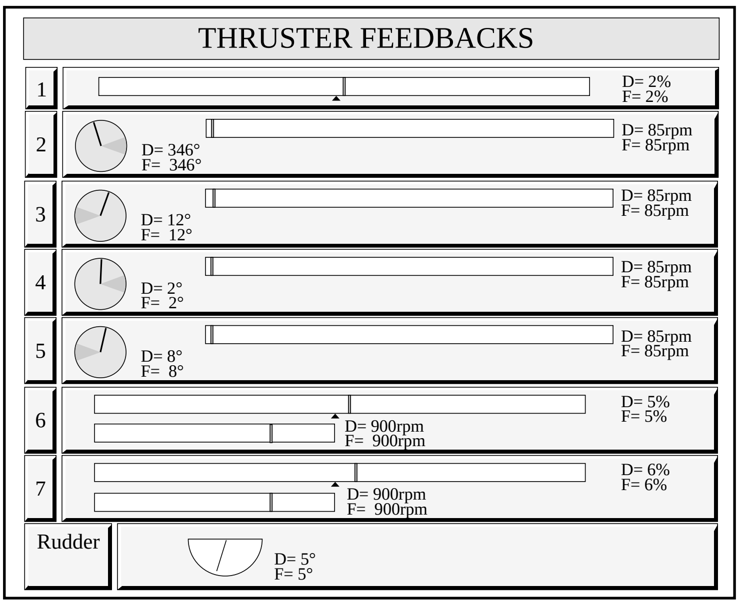

Figure 4.27 Thruster Performance

Thruster Demands

This page provides an overview of the thrust demands made by the DP system. It shows the status of the thrusters and the level of demands in terms of capacity.

THRUSTER DEMANDS			
Thruster	Demands		
	Tonnes	Thrust %	Azimuth°
1	0.2	10	
2	0.7	5	12
3	0.7	5	7
4	0.2	2	9
5	0.3	3	14
6	0.6	1	
7	0.6	1	

Rudder	Tonnes	Angle°
	-0.4	16.7 stbd

Cable Tension	Tonnes	Angle°
	1.4	21.7 stbd

Figure 4.28 Thruster Demands from DP System

Thruster Select

The Thruster Select window provides the operator with another method of selecting thrusters. It also provides selection of thruster patterns.

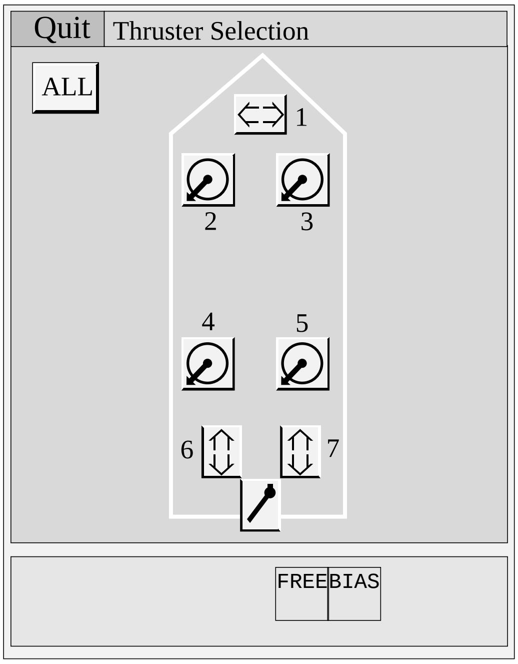

Figure 4.29 Thruster Select

Barred Zones

The wash from azimuthing thrusters can effect the performance of other thrusters and affect some PMEs. To avoid such problems, the aximuth thrusters can be inhibited from working over set sectors.

The Barred Zones page enables the operator set up barred operational sectors which improves both safety and position control performance.

BARRED ZONES				
Thruster	Zones			
	Configured	Configured	Configured	Operator
2	255-285			
3	75-105			
4	255 -285			
5	75- 105			

Figure 4.30 Barred Zone Setup

Gain Control

Gain Control adjusts the speed of the vessel's response to environmental changes. High gain gives a faster response than low gains. The selection of gains is dependent upon the control mode selected.

With PMEs that sometimes produce unreliable signals, such as acoustics, it is also helpful to provide a relaxation of the DP control system to reduce unnecessary vessel movement.

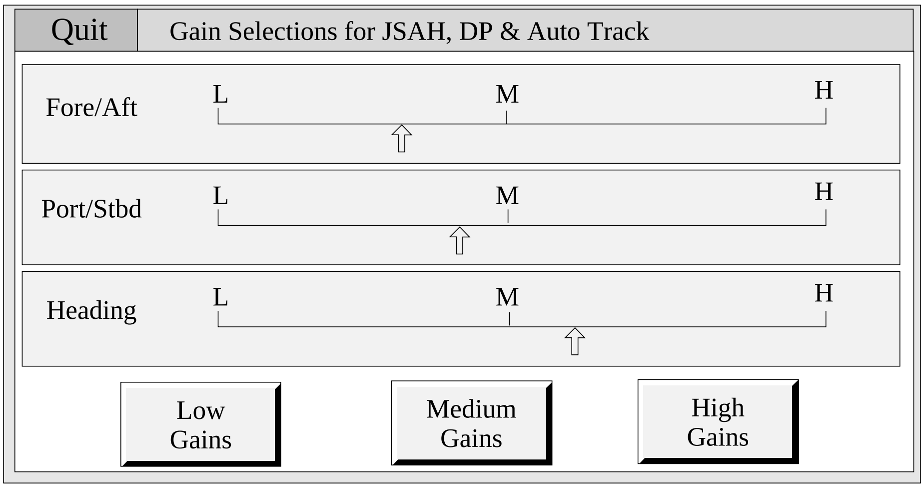

Figure 4.31 Gain Control for DP Mode

Fast Learn

This operator command speeds up the rate of learning for the environmental forces in the Kalman Filter in the control system to improve heading change response time.

Fast Learning can be initiated either:

- Manually by the operator

or

- Automatically via a heading change or by a plant signal from the PLC

Fast Learn operates for a fixed time and in two phases, constant and ramp. During the constant phase, the chosen multiplier value is applied to the Kalman Filter. During the ramp phase, the multiplier is reduced from the chosen value down to 1.

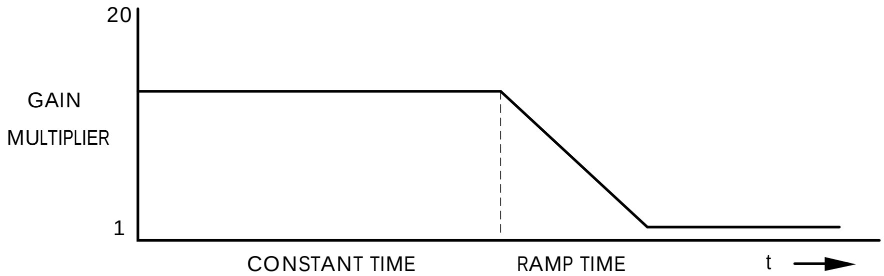

Figure 4.32 Time Phases of Fast Learn

Env Force Fast Learn window displays the current status of Fast Learn.

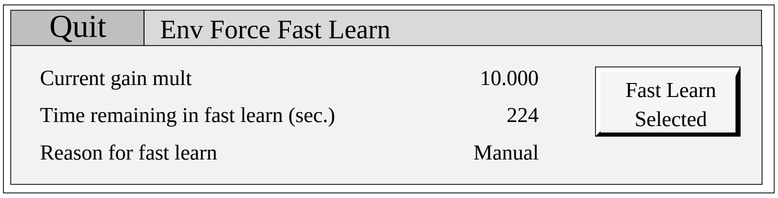

Figure 4.33 Fast Learn Window

This window indicates :

- That Fast Learn is selected.
- The current Gain Multiplier
- Time remaining until the multiplier reaches 1
- Method by which Fast Learn was selected

The Environmental Fast Learn page enables the parameters to be set up by clicking on the button and entering the required value. For small heading changes small durations are used, and large durations for large heading changes.

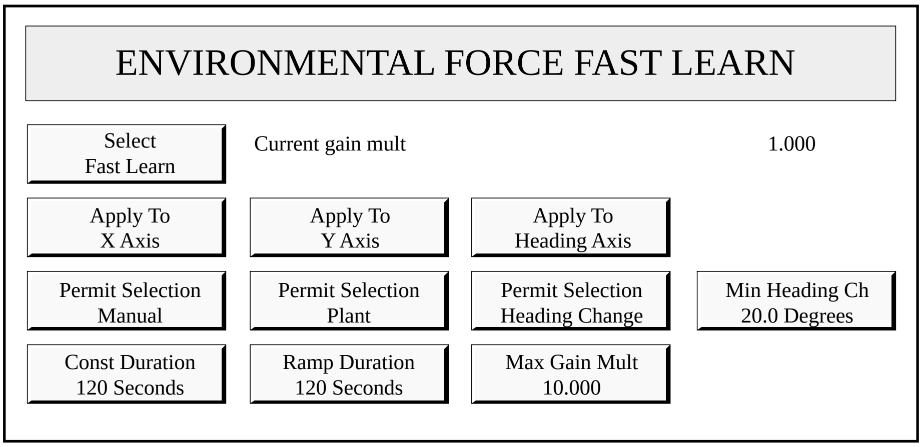

Figure 4.34 Environmental Force Fast Learn

Power Management

It is important that the operator is aware of the status of the power plant and that protection is provided to avoid overload. Monitoring of power generation and distribution is provided by the Power Mimic. Power control is provided by a power chop facility which senses high load situations and reduced the power demands, allowing more power to be brought on line.

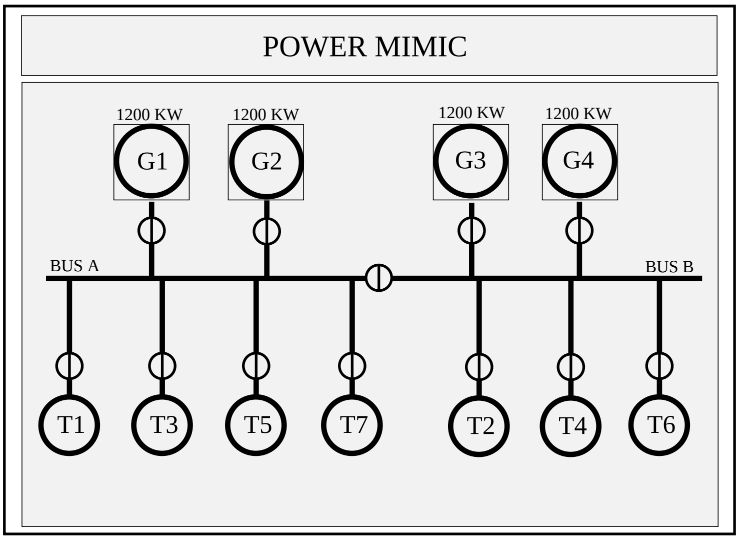

Figure 4.35 Power Monitoring

Sensors

The sensor readings are displayed on the Sensor Data page, together with the value used by the system, where more than one sensor is selected.

SENSOR DATA

COMPASS	Heading
1	27.4°
2	28.1°
3	27.6°
Value Used	27.7°

ANEMOMETER	Speed	Direction
1	7.2 m/s	347.6°
2	7.8 m/s	341.2°
3	7.5 m/s	340.7°
Value Used	7.5 m/s	343.4°

VRU	Pitch	Roll
1	6.3°	8.6°
2	6.1°	8.2°
3	6.2°	8.4°
Value Used	6.2°	8.3°

DRAFT	7.6m

Figure 4.36 Sensor Data

CONTENTS

PME Handling

The operator is provided with two types of PME pages, those providing a range of setup facilities and those for monitoring the operational performance of selected PMEs. In some cases, such as Taut Wire and PME Data, the monitoring and setup are carried out from the same page.

Lat/Long Setup

Some PMEs, such as DGPS and Syledis, provide position fixes in latitude and longitude. Such fixes are calculated with reference to a particular geodetic system. The ADP System is set up for the standard geodetic system, WGS84. The system can however be set using a local geodetic.

In addition, as the ADP System requires position fixes to be presented in a grid reference system (X, Y), the fixes referenced to the local geodetic must have the local projection method applied to them to produce the grid coordinates.

The Lat/Long pages allow the operator to:

- Specify the geodetic system used by each Lat/Long PME
- Specify the local geodetic
- Specify the projection method that is applied to the Lat/Long position fixes to produce grid coordinates for use by the DP system

PME Data

The PME Data page provides the operator monitoring data for each PME, which is described in the next paragraph. It also enables the operator to set up acoustic transponder frequencies and aerial offsets for the radio PMEs.

COR Select

It is sometimes more convenient to set the centre of rotation of the vessel at a point which is not the geometric centre. Obvious examples are drilling vessels where the moonpool may not be at the centre of the vessel and cable laying vessels where it may be more appropriate to rotate the vessel about its bow or stern.

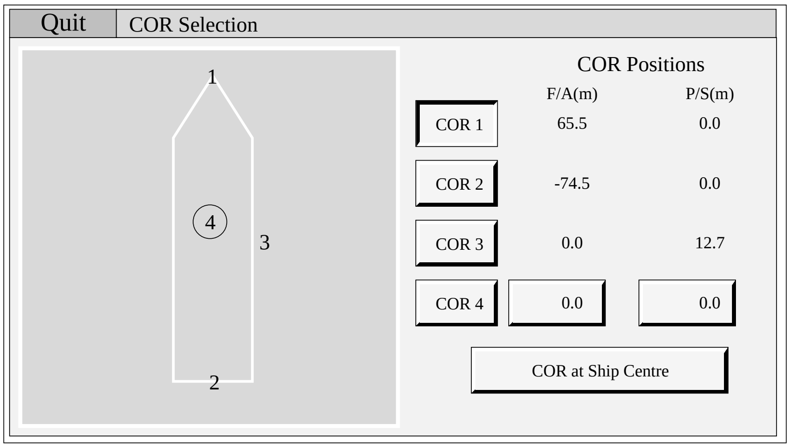

Figure 4.37 Setting the Centre of Rotation

PME Weightings

The PME Weightings page is used to set a bias towards preferred (usually more reliable) position measurement device fixes, and to adjust the repeatability of the individual PMEs by setting the rejection window. When mobile PMEs are selected, they are given separate percentage weightings from the vessel fix PMEs.

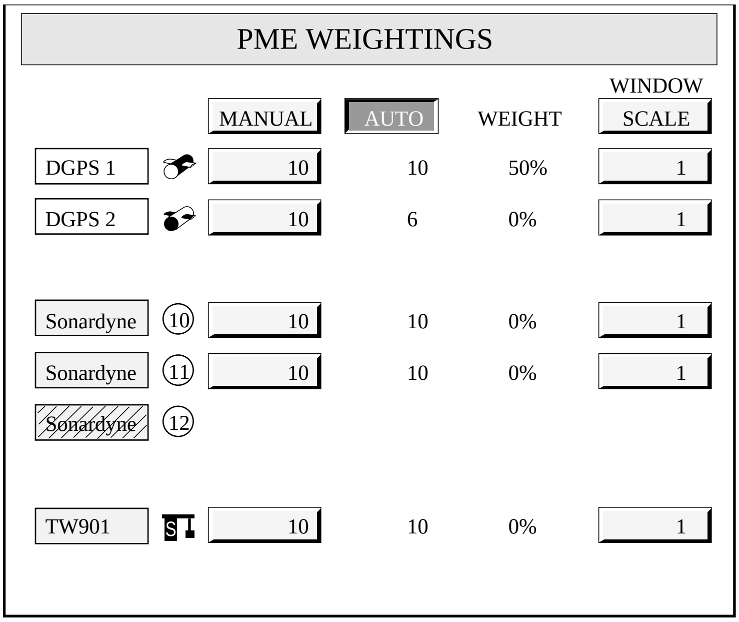

Figure 4.38 PME Weightings

Coordinate Setup

Sometimes it is important that the position of the vessel is accurately maintained in absolute coordinates. The Coordinate Setup page is used to set up reference PME(s) which are used to calculate the absolute position of the vessel. Typically, the DGPS is used as a reference to correct other PMEs such as Syledis. This is the position displayed on the Motion Display pages.

When more than one PME is used as a reference PME, an average value is computed.

Setting up a non-DGPS PME as a reference can be useful if one of the main references is lost; however, only fixed PMEs can be selected as reference PMEs.

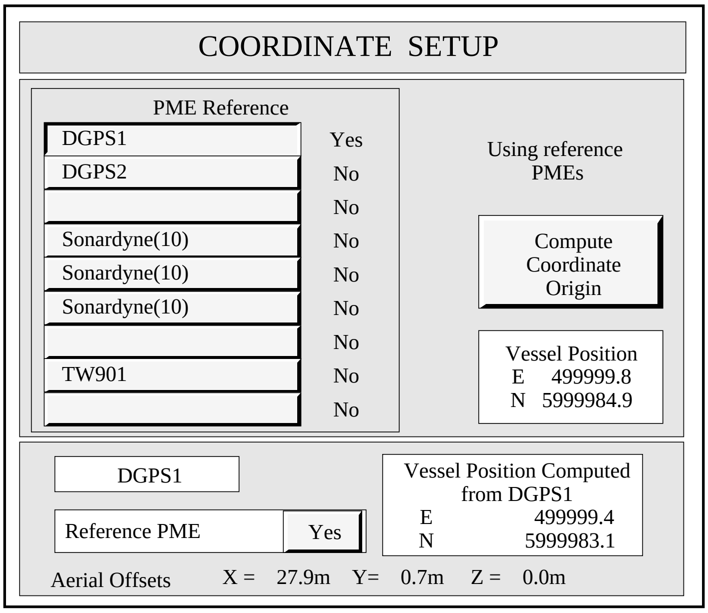

Figure 4.39 Coordinate Setup Page

Taut Wire

The Taut Wire page provides setup and monitoring facilities. The setup facilities are the alarm limits and the water depth.

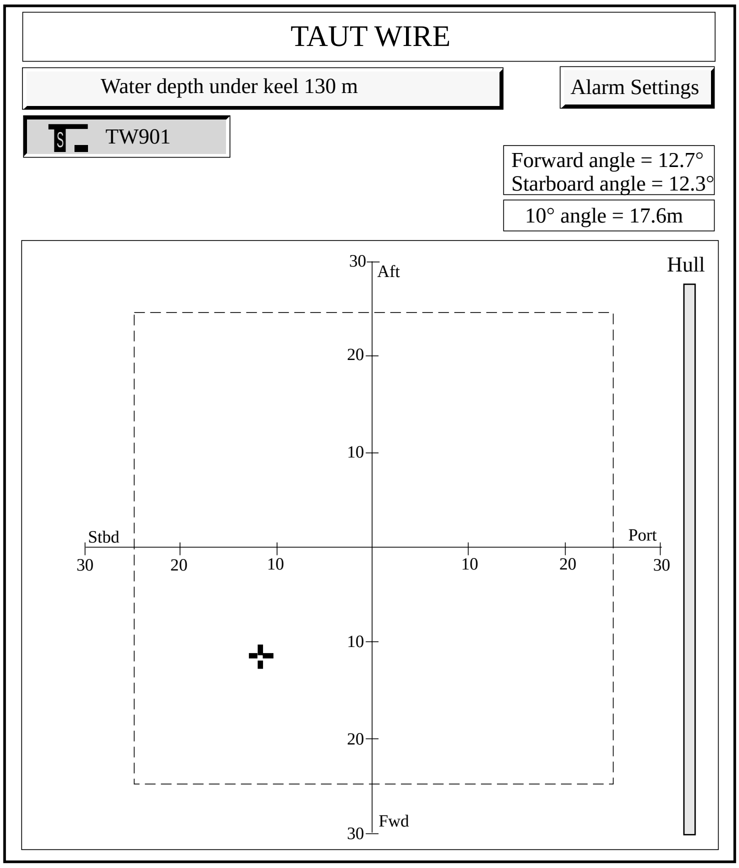

Figure 4.40 Taut Wire

PME Data

This page shows the position fixes and errors for all the selected PME devices. Position Fix is defined as:

- The absolute UTM coordinates of the vessel's Control Point, as measured by DGPS
- The seabed distance of the acoustic transponders from the vessel's centre measured in fore / aft coordinates (metres north and east) as relative or absolute figures, depending upon the coordinate setup of the PME.

Position error is defined as the distance between the Target position and the Control Point as determined by a PME's measurements.

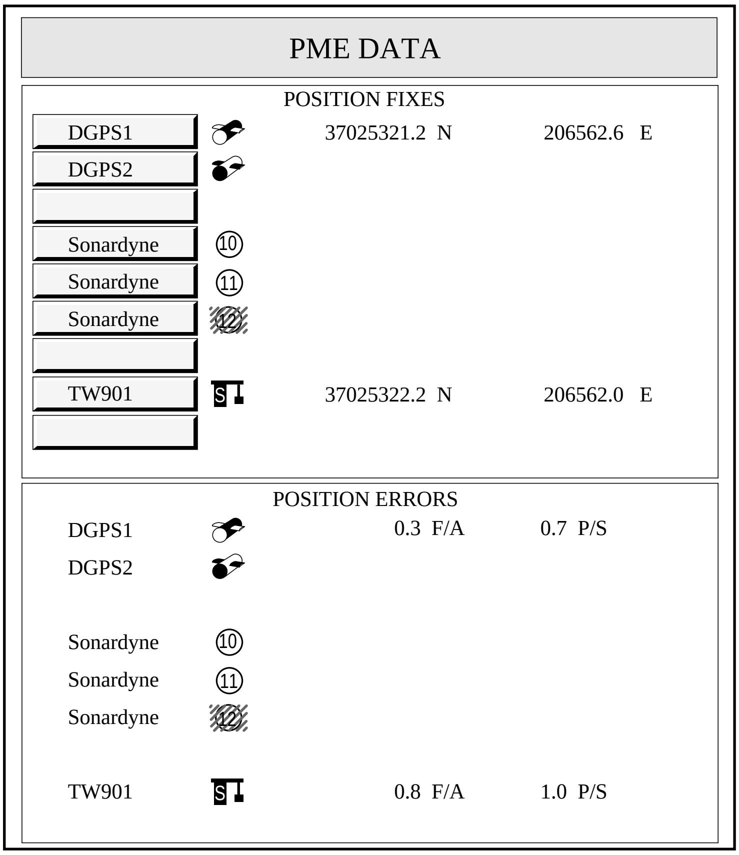

Figure 4.41 Position Measurement Data

Position Fix Repeatability

The display gives the operator an indication of how good or bad the position data is for a particular PME. This page can be used as a quick guide to:

- PME performance prior to selecting for use with the DP system (in the case of good performance)
- PME performance prior to deselecting (in the case of poor performance)

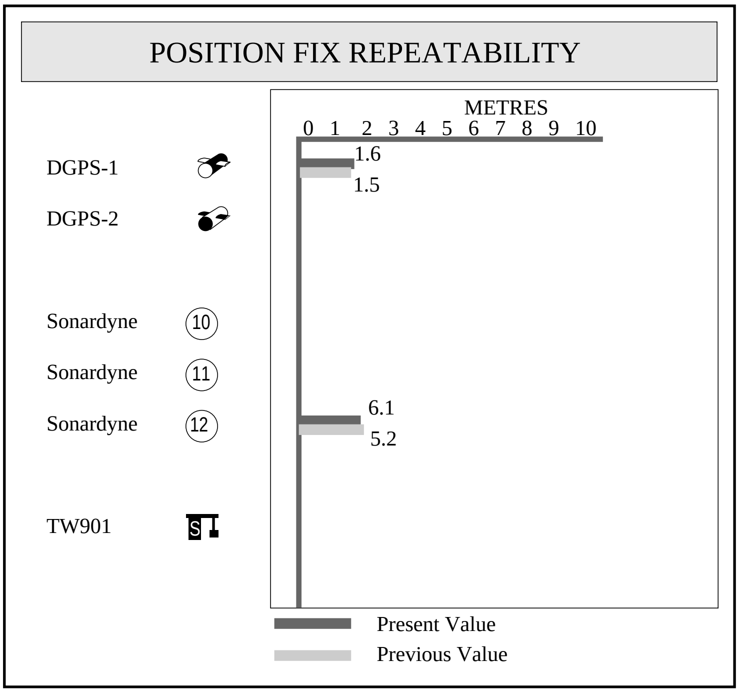

Figure 4.42 Position Fix Repeatability

PME Median Check

If three or more PMEs are selected, it is possible for the system to use only those PME fixes which are within a predetermined range.

The Median Value calculation finds the median value of three or more PMEs in the X and Y planes.

Any PMEs which fall outside a set distance from the median point are discarded and are not used in the calculation of the average position value.

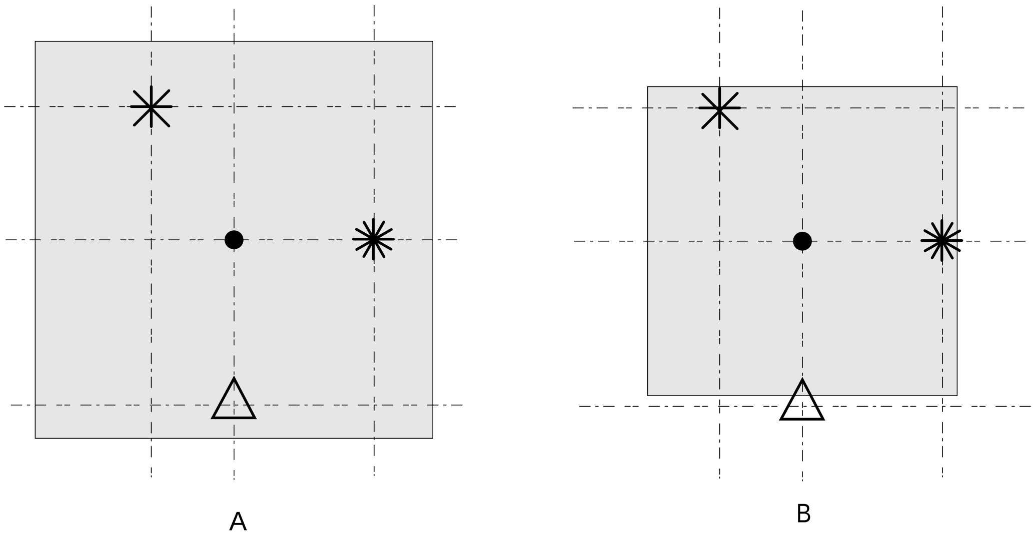

Figure 4.43 PME Rejection Limit

In A, all the PMEs are used to calculate the average. In B, with the reduced median window, only the cross and star are used in the averaging calculation.

Alarms, Logging and Trending

It is important that the operator and engineering staff receive pertinent and accurate information on the hour-by-hour performance of the system and are made immediately aware about any fault situations.

Alarms

The most recent DP system alarm is always on view to the operator, displayed on the top menu. All unaccepted alarms are shown on the Alarms page. Alarms are categorised according to their importance, so that the operator can attend to alarms in the most effective manner.

- Flashing red alarm - active, unaccepted alarm
- Steady red alarm - active, accepted alarm
- Flashing white alarm - temporary, unaccepted alarm

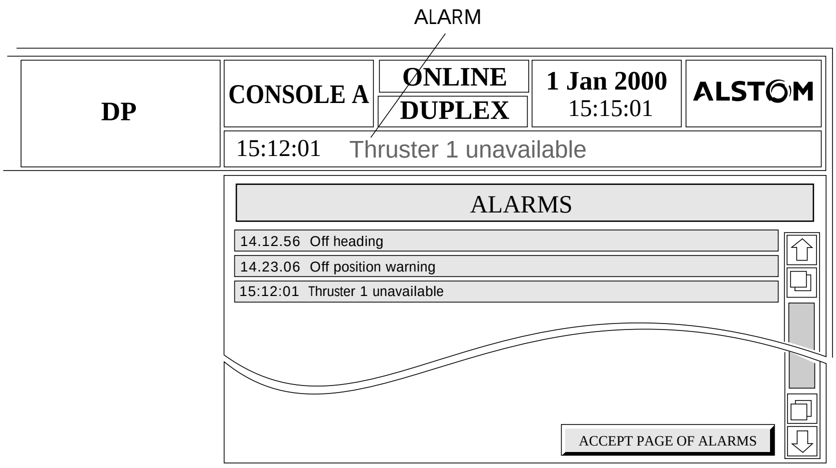

Figure 4.44 Latest Alarm and Alarm Page

As well as all the system alarms, the operator can set alarm levels for thrusters, heading, position, taut wire angles, power levels and the results of consequence analysis checks.

Real Time Trends

The operator can scroll through a chart showing the performance, over the previous 8 hours, of a wide range of DP variables. The actual screen display can show an 8 minute or 64 minute timescale. The data can also be stored on diskette for future analysis.

The variables can include:

- Position Error X/Y
- Heading
- Heading Error
- Windforce X/Y
- Wind Speed
- Thruster Demand X/Y
- DGPS Error
- Acoustic Error
- Pitch
- Roll
- Power Available
- Power Used

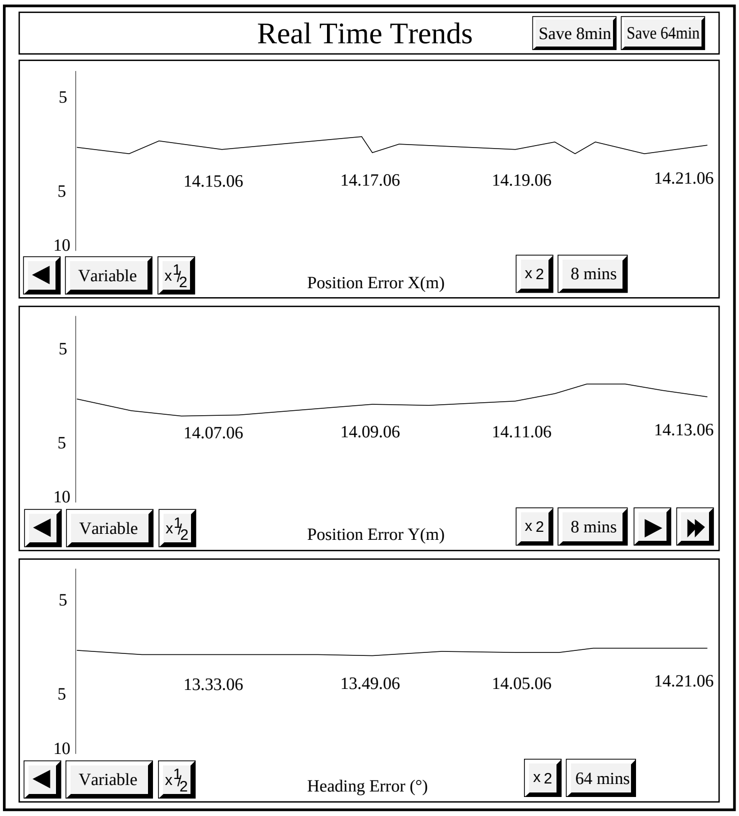

Figure 4.45 DP Variables Trend Display

Power Trends

Power Trends are similar to the Real Time trends, except that the operator can set alarm levels for the trends.

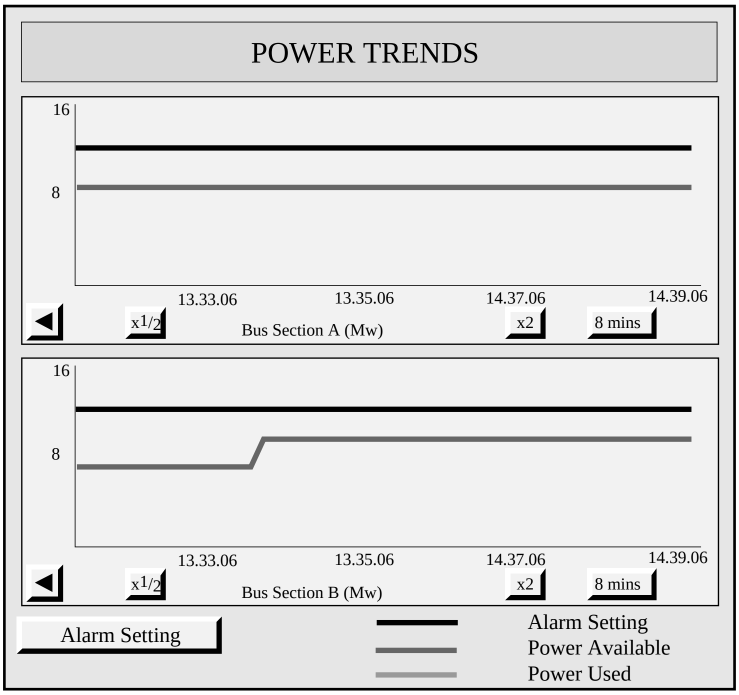

Figure 4.46 Power Trends

Consequence Analysis

Consequence Analysis provides the operator with prior warning that a single failure would potentially result in insufficient thrusters being available to satisfy the current thrust demands. The operator then has time to select more thrusters or generators, or select a less demanding control mode.

Two types of failure are considered:

- Failure of one of the thrusters
- Failure of a bus section

Each 14 second scan of the consequence analysis takes place in three phases to answer the following questions:

- Do the remaining thrusters satisfy the minimum configuration for the mode?
- Are the remaining thrusters capable of satisfying the required thrust demand?
- Is there enough power from the generators currently connected to the bus to satisfy the required thrust demand?

A scan stops immediately when the answer to any question is No, and the failure is displayed on the page.

CONSEQUENCE ANALYSIS

Analysis by Thruster	Alarms Active
1	Not Essential
2	Not Essential
3	Essential (Min Thrusters)
4	Not Essential
5	Not Essential
6	Not Essential*

Analysis by Bus Section	Alarms Active
1,3,6	Not Essential
2,4,5	Not Essential

Figure 4.47 Consequence Analysis

Training

To provide operators with real system experience without actually controlling the vessel, the system can be taken offline and fed with simulated signals in response to operator actions.

Simulation provides inputs and outputs to the system for use in training, providing no thruster is in ALSTOM control. The Simulation page enables the system to be set up in an “almost real life” situation.

PMEs can be deployed or recovered. A high noise/low noise option adds a “real life” element to the PME position data.

The simulated wind can be varied in 5° steps in speed and direction. The Screen Options are a subset of the Motion Display screen options and apply only to the simulated Motion Display. Ship's position consists of arbitrary figures originally set up when the system is configured, which are moveable within the limits of the simulation. Ship speed shows the resolved components of the vessel speed.

In case of loss of control, clicking on the Zero Velocity button has the effect of immediately setting vessel movements to zero, while the Centre Ship button restores an errant vessel to the centre of the display.

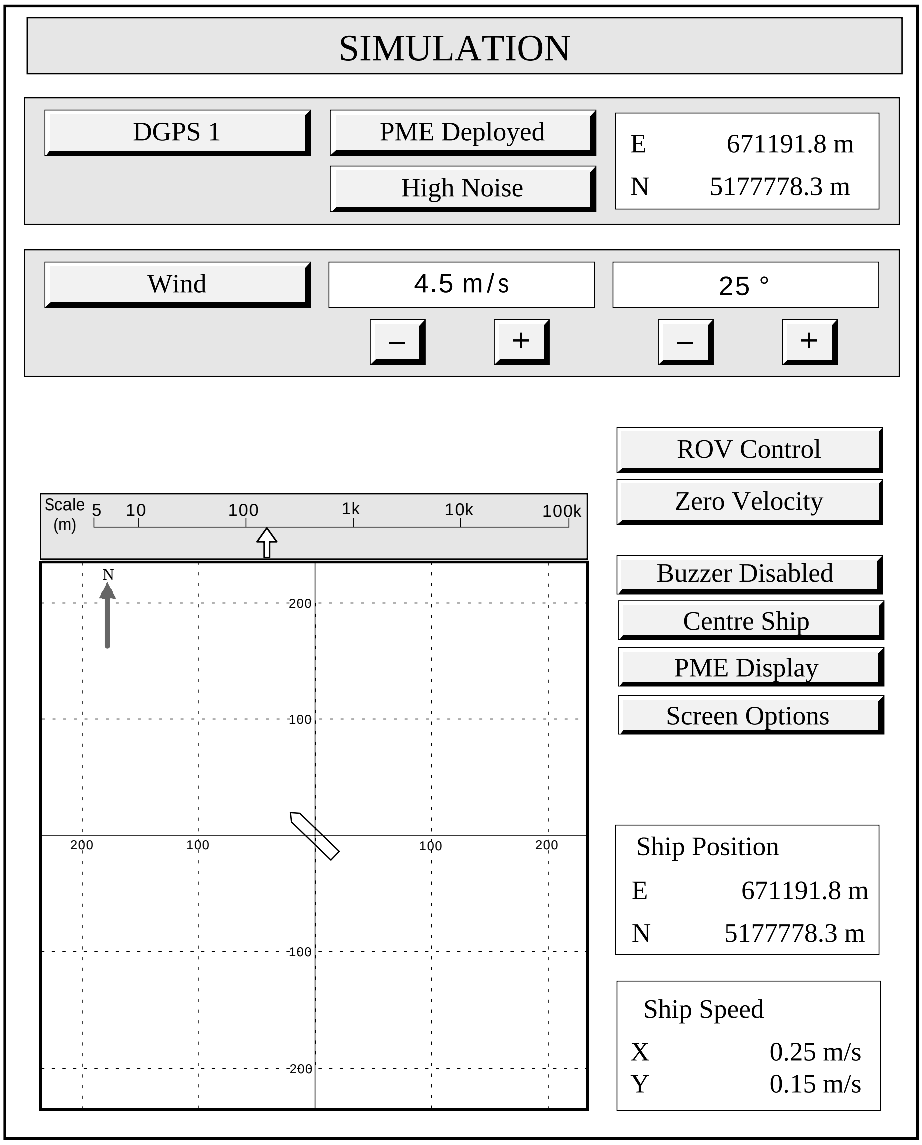

Figure 4.48 Vessel Simulation

Trialling Facilities

It is often useful to check the vessel's response offline to a range of environmental conditions and equipment failures. This can be done using the Capability Plot and trial facilities of Consequence Analysis.

Capability Plot

The Capability Plot enables the operator to check the ability of the vessel to maintain position and heading under different environmental conditions, with different combinations of thrusters, generators, etc.

The Capability Plot is carried out in two stages:

- Set Parameters and Perform Calculation
- Examine and Display Results

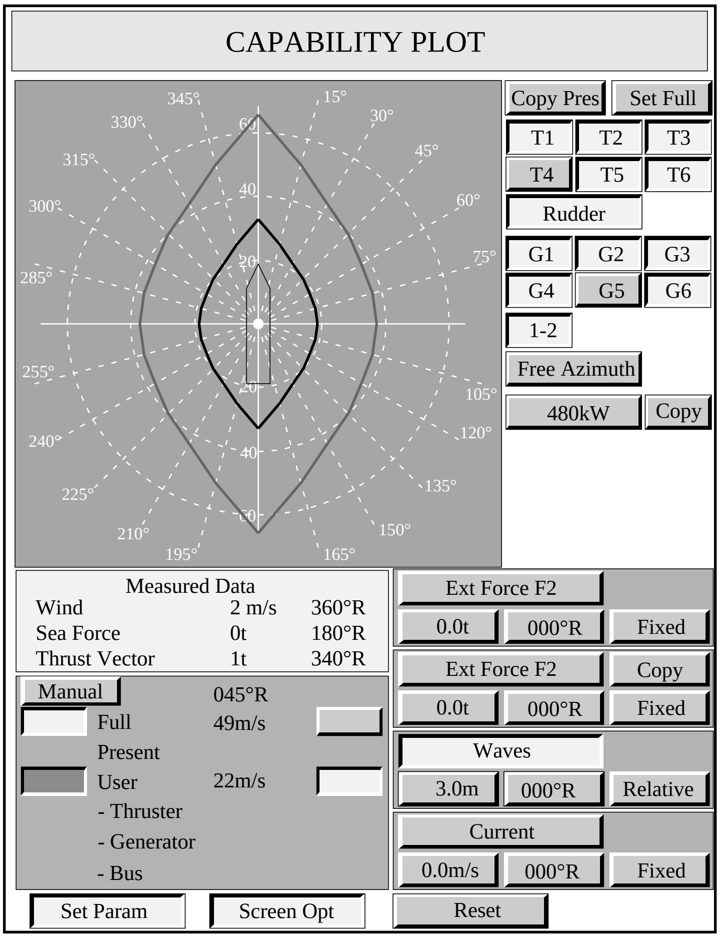

Fig 4.49 Capability Plot Result

For the set conditions, the system calculates the critical windspeed at 15° angles with one device failed at a time. The worst case is then selected. The minus plots may contain different failed devices at different angles.

The results are available as a graphical plot and as the critical wind speed at selected angles.

Trial of Conditions for Consequence Analysis

Consequence Analysis can be carried out using trial thrust demands to test different situations. The thrust demands alter the fore / aft, port / starboard and rotation axes' thrust by a percentage.

FACILITIES FOR SPECIAL VESSEL TYPES

Drilling Platforms

The Riser Data page provides data for two separate actions:

- Positioning of the Lower Marine Riser Package (LMRP) over the Blow Out Preventer (BOP) to enable reconnection or re-entry
- Manual and automatic positioning of the vessel to keep the Riser Angle close to zero after the LMRP and BOP are connected.

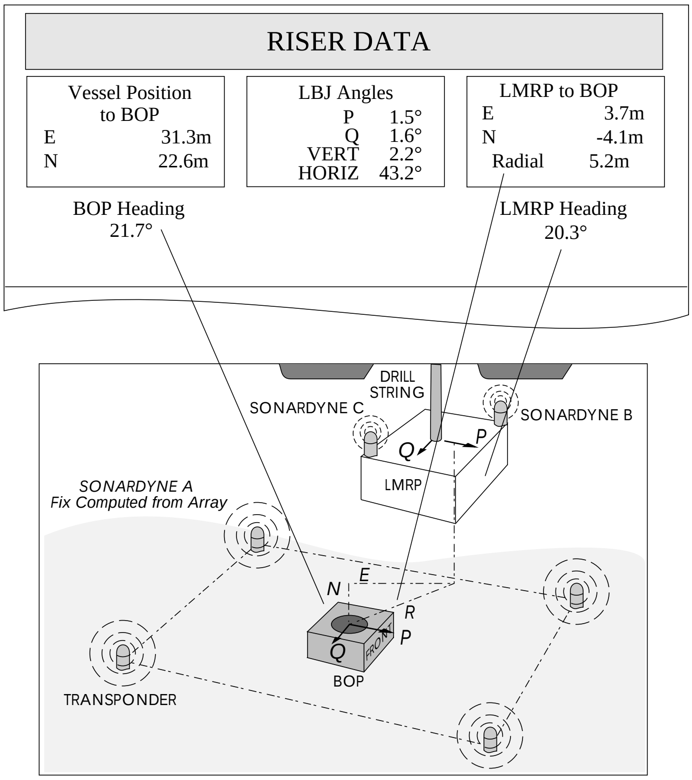

Figure 4.50 Riser Data

In reconnection, the DP system displays position and heading information for an ROV operator to manoeuvre the LMRP exactly above the BOP. The DP system provides no control. Four fields on the Riser Data page are used.

When the LMRP and BOP are connected, the DP system provides three forms of support:

- Zero Angle Position (ZAP). The ZAP is the position of the vessel which makes the riser angle zero. The DP system provides two levels of assistance with the riser angle:

a) Calculation and display of the ZAP
b) Riser Follow where the DP system controls the vessel position to maintain it close to the ZAP.

- Riser Twist. An alarm is raised if the BOP and vessel headings diverge more than 45° in either direction

- Electric Riser Angle (ERA) as a PME. When connected, the ERA and the water depth are used to calculate the vessel position relative to the BOP. This is available as a PME when the water depth is less than 250m.

When the LMRP and BOP are connected, the Riser Data page displays data changes. The Offsets to Zero LBJ Angles is used by the operator to alter the vessel position to zero the LBJ angle. The BOP Heading displays the Riser Twist.

Cable and Pipelaying Vessels

So far, most of the vessel position keeping has concerned keeping the vessel stationary in DP mode. However, dynamic positioning is equally effective in moving a vessel along a defined track, which is necessary in cable and pipe laying, surveying, etc.

The track that the vessel is to follow is defined as a series of waypoints which are specified in absolute or relative coordinates. Tracking is then performed by moving the vessel from waypoint to waypoint. Tracking is the basis of Auto Track and Auto Sail modes.

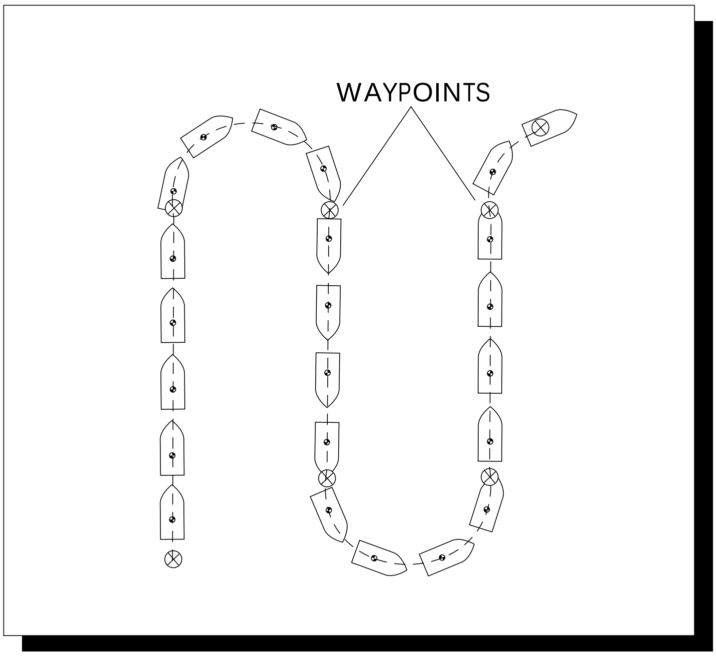

Figure 4.51 Following a Track through Waypoints

A vessel does not have to follow the track exactly. The vessel can start changing heading towards the next waypoint before the current waypoint is reached, providing a smooth transition.

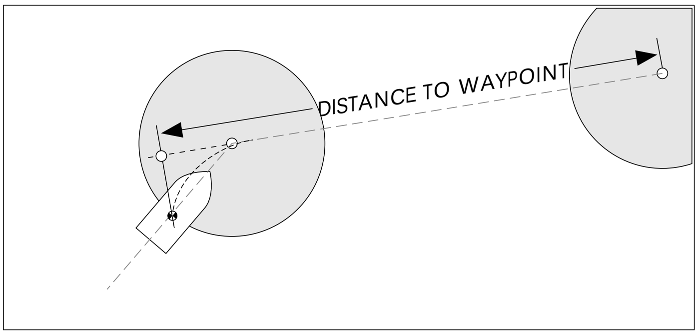

Figure 4.52 Changing Track

In certain circumstances, it may be operationally advantageous not to exactly follow a track but to be offset a few metres from the track, as in cable retrieval. This is called track shift, where the vessel follows a track offset from the waypoint track

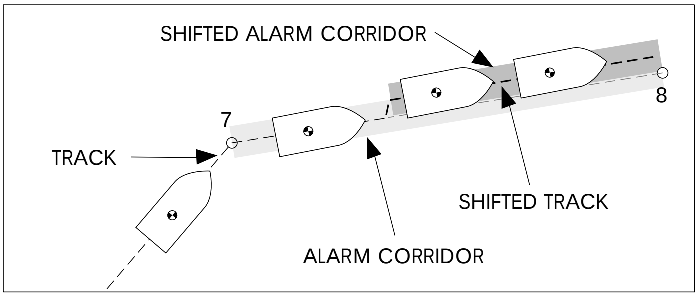

Figure 4.53 Track Shift

Track Follow using waypoints is very flexible. It enables the vessel to:

- Move continuously between waypoints
- Move from waypoint to waypoint, stopping at each one
- Change the order of progression through the waypoints
- Go backwards or forwards through the waypoints

Setting up and operating Track Follow is performed using the Track Follow page.

The Track Follow page performs two functions:

- Loading the track details (waypoints) and the method of moving between the waypoints selected from the tracking options. Track details can be entered by the operator, loaded from diskette or by serial link from a survey package.

- Operating the tracking mode

Track Follow also provides the operator with information on tracking progress. If the cable, pipe or plough hawser tension is monitored, the value is displayed in the Additional Data on the Motion Display and on the Thrust Vector page.

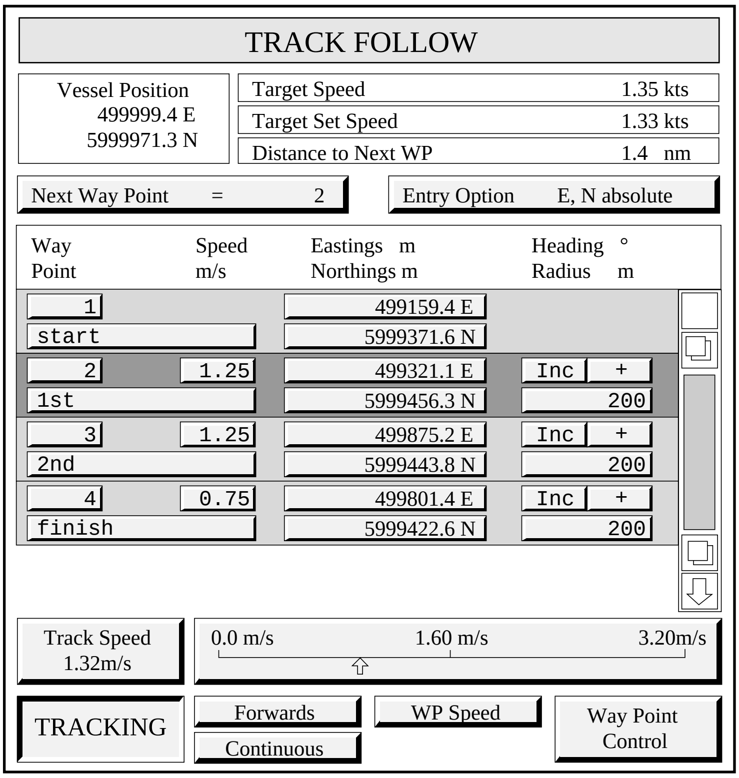

Table 4.54 Track Follow Setup

Auto Slowdown

When a vessel is track following and towing a plough, the plough tow wire tension is measured and a 'plough tow' wire tension alarm can be raised.

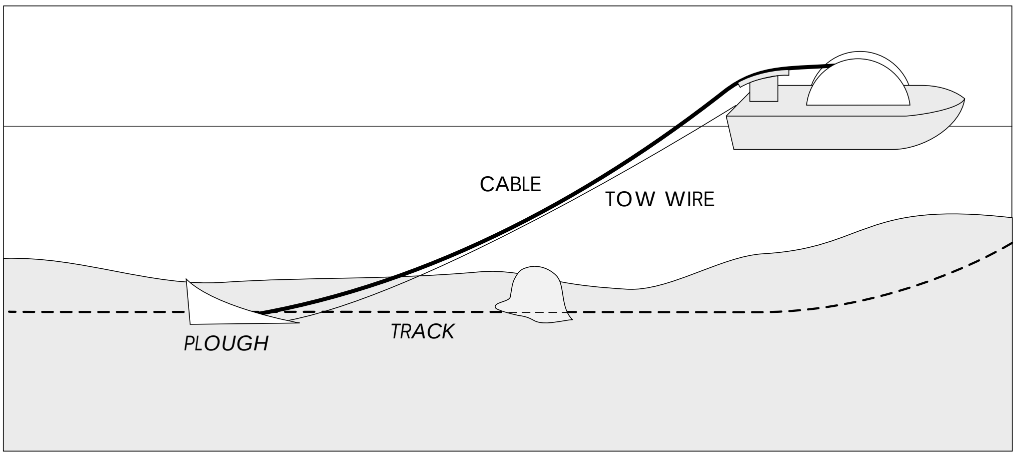

Figure 4.55 Tow Wire Tension

When the plough tow wire tension exceeds the set alarm value, in addition to the alarm being raised, the vessel can be automatically slowed down to zero if necessary.

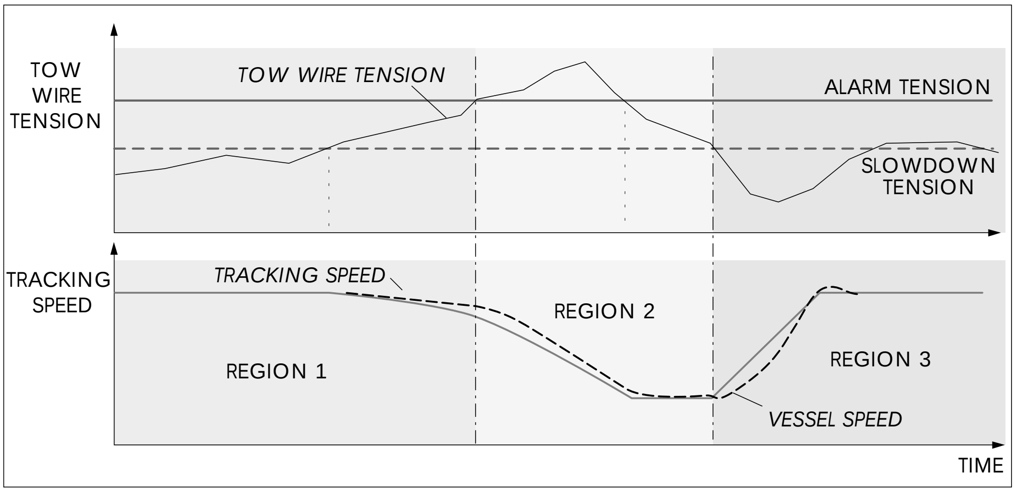

Figure 4.56 Auto Slowdown and Tow Wire Tension

When the tow wire tension exceeds the Slowdown Tension, the tracking speed is gradually decreased. As soon as the tow cable tension rises above the Alarm Tension, the DP system reduces the tracking speed at a faster rate, further slowing the vessel's forward motion.

If the plough is stuck, the tow wire tension will remain above the Alarm Tension and the tracking speed is reduced to zero. The vessel will slowdown to a standstill and remain at a standstill while the operator decides what action to take.

Emergency Steer

When a vessel is track following in Auto Sail mode, the operator can deviate from the track to avoid obstacles using Emergency Steer. The rudder is then controlled by the Turning Control knob. The thruster references are forced to zero while emergency steer is in control. Once released, the vessel will return to its original track

Shuttle Tankers

In Chapter 2 the three Shuttle Tanker modes were described: Pickup, Approach and Loading. Three main types of oilfield pick up points were also mentioned: Offshore Loading System (OLS), Floating Storage Unit (FSU), Articulated Loading Platform (ALP).

Before a shuttle tanker can use the three loading modes, the details of the field being used must be selected. This is done on the Field Data page. Each field has a base position, the approach and loading radii and the radii at which the emergency shutdown alarms are activated.

FIELD DATA

FIELD NAME "TYPICAL"

FIELD TYPE:	FSU		
BASE POSITION:	Latitude	Longitude	
	060°20'37.06"N	004°00'51.94"W	
	Altitude		
ANTENNA:	41.0m		
	fore/aft	port/stbd	
OLP POSITION:	-120.0m	-8.6m	
PME POSITION:	fore/aft	port/stbd	
ARTEMIS	-120.0m	-7.6m	
Fanbeam	-120.0m	-7.6m	
REL GPS	-120.0m	-7.6m	
BOUNDARIES:	Approach	Loading	
	30°	15°	
	Max. Radius	Min. Radius	Max. Speed
APPROACH:	1000m	55m	1.9 kts
LOADING:	150m	24m	0.5 kts
ESD ALARMS I	85m	55m	
ESD ALARMS II	105m	45m	

Figure 4.57 FSU Field Setup

In addition, FSU fields have details of the PMEs used to monitor the vessel and supply unit separation.

FIELD DATA			
FIELD NAME	SOUTH		
FIELD TYPE:	OLS		
BASE POSITION:	N	E	
	5178901.2m	671266.5m	
BASE POSITION:	Latitude	Longitude	
	61°15.767	1°53.151	
ANTENNA:	Altitude		
	40.0m		
APPROACH:	Max. Radius	Min. Radius	Max. Speed
	1000m	80m	2.0 kts
LOADING:	Max. Radius	Min. Radius	Max. Speed
	125m	20m	1.0 kts
ESD ALARMS:	Max. Radius	Min. Radius	
I	92m	30m	
II	114m	20m	

Figure 4.58 OLS Field

FIELD DATA			
FIELD NAME	North		
FIELD TYPE:	ALP		
BASE POSITION:	N	E	
	0.0m	0.0m	
BASE POSITION:	Latitude	Longitude	
	000°00'00.00"N	000°00'00.00"W	
ANTENNA:	Altitude		
	0.0m		
BOOM:	Radius		
	0.0m		
	Max. Radius	Min. Radius	Max. Speed
APPROACH:	1000m	50m	1.9 kts
LOADING:	70m	24m	1.0 kts
ESD ALARMS I	0m	0m	
ESD ALARMS II	0m	0m	

Figure 4.59 ALP Field Setup

Further details about the status of the mooring are provided in the Additional Vessel Data on the Motion display.

The range to the set point circle is provided for all fields. The Offloading Position is the range and bearing to the offloading point (the boom end for ALP).

The field type confirms the field and, for FSU fields, provides the storage unit heading.

In FSU and ALP fields, the hawser tension is displayed to indicate when hawser compensation is selected.

The selection of PMEs is preconfigured to each particular oil field. As soon as a field is selected, the appropriate PMEs are displayed. For FSU fields, the mobile PME icons are split in two, the upper half selects position and the lower half the FSU heading input where relevant

Anchor Moored Vessels

Heading control of anchor moored vessels is used to reduce the anchor tensions, and so increase their life. The operator has several pages available to setup, monitor and control anchor tensions. Facilities are also provided to carry out predictions, similar to the Capability Plot, except checking anchor tensions under a range of environmental conditions.

Anchor Setup

ANCHOR SETUP

Vessel Position	E 573642.7m	N 646355.3m
Pattern Centre	E 573642.7m	N 646355.3m
Water Depth under Keel 105m	Vessel Draft 14.0m	

Anchor: 4

Range (m)	Bearing (°) True	Bearing (°) Relative	
1267.0	209.0	45.8	E 573030 / N 6462484

Section	Type	Length (m)	Diameter (mm)	Weight (kg/m)	Elasticity (10^4kN/m^2)
Upper	S/Link	40	137	357	1260
Middle	O/Link	250	142	374	1189
Lower	Cable	1000	134	82	1826

Buoy	Buoyancy (T)	Strop Length (m)	Distance from Anchor (m)
1	14	24	210
2	12	24	426
3	11	24	784
4	0.0	0.0	0.0
5	0.0	0.0	0.0

Figure 4.60 Anchor Setup

Each anchor is set up in the initial system configuration. The anchor setup defines the form of the anchor and its positions. The position of the vessel control point and the position of the centre of the anchor pattern are defined. The water depth and vessel draft are entered by the operator from external measurements.

Force Vectors

The key page for monitoring the vessel is the Force Vector page. It displays the force vector acting on the vessel in vessel axes. The force vector is supplemented by a bar graph and table, which can be toggled. The table displays the components of the force vector, while the graph displays the components of the turning moment on the vessel.

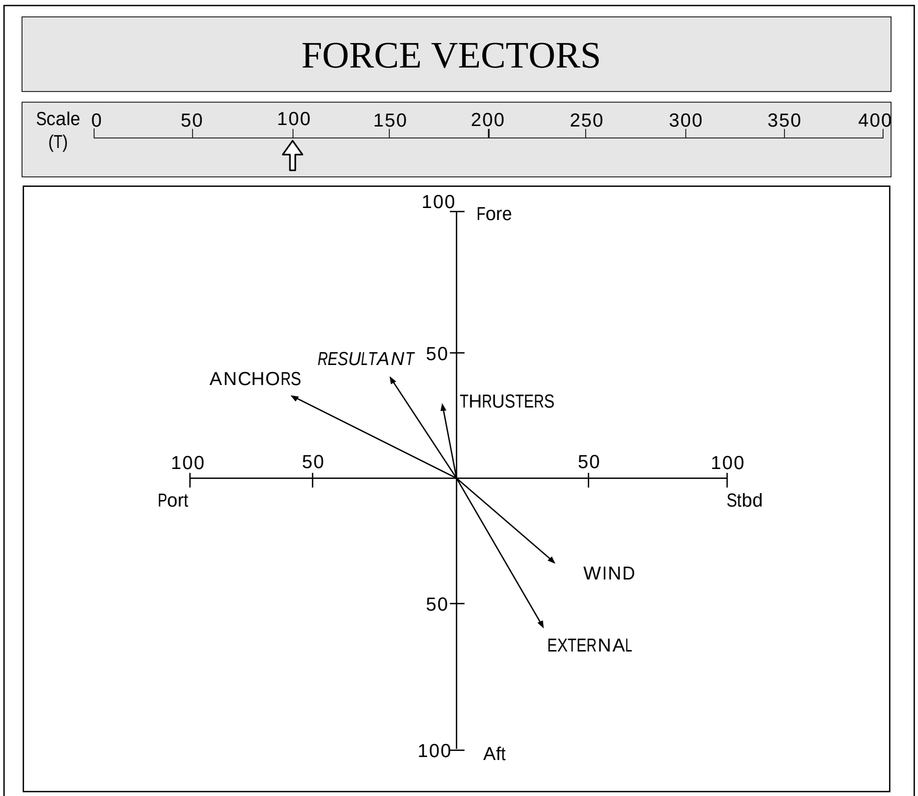

Table	F/A(T)	P/S(T)	T(Nm)	Anchor Pattern Stiffness	
External	-70	30	800	Fore/Aft (T/m)	1.0
Manual	0	0	0		
Wind	-35	25	700	Port/Stbd (T/m)	6.7
Anchors	25	-5	-860		
Thrusters	60	30	-720	Heading (Tm/°)	234
Offset	0.0	0.0			

Figure 4.61 Force Vectors

Anchor Measurements

The Anchor Measurements page details the conditions on each anchor in terms of tension, and effective length. These values are the inputs to the control system.

ANCHOR MEASUREMENTS

Anchor	Tension (T)		Alarm Levels (T) Low	Alarm Levels (T) High	Upper Section Length (m)		Touchdown Distance (m)	Total Length (m)
1	62	M	20.0	150.0	40	E	267.0	1265
2	65	M	20.0	150.0	40	E	274.0	1265
3	65	M	20.0	150.0	40	E	278.0	1265
4	67	M	20.0	150.0	40	E	265.0	1265
5	72	M	20.0	150.0	40	E	255.0	1265
6	70	M	20.0	150.0	40	E	267.0	1265
7	69	M	20.0	150.0	40	E	268.0	1265
8	67	M	20.0	150.0	40	E	271.0	1265

Estimated Data | Measured Data | Accepted Data

Anchor Compensation: 100%

Figure 4.62 Anchor Measurements

Anchor Tensions

This page is a graphic display of the tension on each anchor, which can be viewed against the alarm setting. The Measured Anchor Tensions button toggles with Anchor Tensions at Line Break. If an anchor line breaks, the anchor tensions at line break is displayed for future analysis.

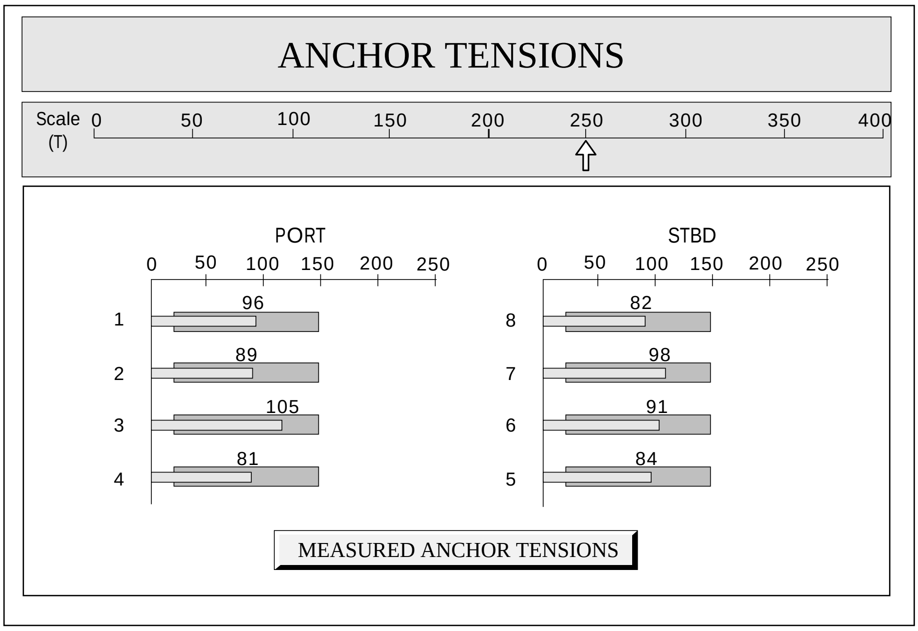

Figure 4.63 Anchor Tensions

Glossary of Terms to be used with Dynamic Positioning Systems

This glossary lists, and briefly defines, many of the words and phrases used by ALSTOM to describe their Dynamic Positioning systems. Many, but not all, of the entries will be used by other DP suppliers and users. Sometimes the same words will be used to describe different things, the vocabulary is not rigorously defined and is continuously evolving.

This glossary has no statutory or contractual authority, and the authors can accept no responsibility for any inaccuracies it may contain. We will accept your corrections and additions with gratitude.

A

ABS. American Bureau of Shipping. Classification Society based in USA.

Acoustics. PME based on sound to determine the vessel's position.

Anchor Moored Vessel. A vessel maintained in position by a pattern of anchors. The anchors may be supplemented by a DP system.

Anchors. Devices fixed to the seabed and connected to the vessel by an anchor chain or cable.

Anemometer. A wind measuring sensor.

AOT. ALSTOM Operator Terminal

Approval Organisations. Organisations charged with ensuring that equipment and systems meet the required standards, which includes Classification Societies and government agencies such as the Health and Safety Executive (HSE).

Argo. A radio PME. It is an HF multi-user positioning system which uses an array of fixed and mobile radio beacons.

Artemis. A radio PME. It is a microwave radio system which measures the range and bearing between a fixed and a mobile station.

Anchor Pattern. An array of a least 3 anchors laid out so that the vessel's position and heading is controlled. Usually there are between 6 and 16 anchors.

Auto Pilot. A DP operating mode. Auto Pilot mode enables the vessel to move forwards, while maintaining a constant heading. It is useful when on transit and moving at speeds above 2 or 3 knots. Often uses only main propulsion and rudders.

Auto Sail. A DP operating mode. Auto Sail mode is an enhancement of Autopilot, the heading is adjusted to keep the vessel on a track between defined waypoints. Often uses only main propulsion and rudders, useful at speeds above 2 or 3 knots.

Auto Slowdown. A facility in pipe or cable laying or ploughing where the vessel speed is decreased if the tension in the pipe or cable exceeds a certain figure.

Auto Speed. A DP operating mode. Auto Speed mode maintains the vessel at a constant X, Y (fore/aft, port/starboard) speed. Vessel direction and speed is set by the operator using the joystick. The heading is maintained at a value set by the operator.

Auto Track. A DP operating mode. Auto Track mode moves the vessel along a track between two waypoints. The heading is held at a value set by the operator. This mode requires a full array of thrusters. Useful at speeds below 1 or 2 knots.

AUT. The DNV notation for a DP system which is very similar to IMO's Class 1. Usually called a simplex system by ALSTOM.

AUTR. The DNV notation for a DP system which is very similar to IMO's Class 2. Usually called a duplex system by ALSTOM.

AUTRO. The DNV notation for a DP system which is very similar to IMO's Class 3.

Azimuth Thruster. Thruster capable of providing thrust through 360° in the horizontal plane.

B

Barred Zones. Angles at which the DP system is prohibited from using an azimuth thruster. Often used to protect divers and acoustic transducers from the thrusters' wash.

Beam. The beam of a ship is the width across the ship. Another ship or object is said to be on the starboard beam if it is to the starboard side of the observer's vessel.

Bias Mode. Placing two or more thrusters in opposition to obtain fine movement control. Used to eliminate large change of azimuth angle when azimuth thrusters are used in light weather. It can reduce wear and tear.

BOP. Blow Out Preventer. Device on the well-head which is used in an emergency to prevent the well discharging into the environment.

Bow. The front or pointed end of a ship. Both "Bow" and "Bows" are used to describe the one end of a ship.

Busbar or Bus. A section of a distribution switchboard which can be isolated from other sections when a fault occurs on the busbar.

C

Capability Plot. A method of calculating and displaying the ability of the vessel to remain on station despite a range of environmental conditions and equipment failures.

Classification Society. A non-governmental organisation which publishes and enforces rules for the construction of ships and other marine structures. Includes Lloyds Register (LR) in the UK, DNV in Norway, Bureau Veritas (BV) in France, American Bureau of Shipping (ABS) in the USA, and RINA in Italy. All the societies operate worldwide.

Compass North. The direction indicated by the compass. If a magnetic compass is being used, then compass north and magnetic north differ due to the magnetic effects of the vessel's hull and machinery.

Consequence Analysis. A procedure which continuously checks the effect of an equipment failure, and raises an alarm if a single failure will cause loss of control.

Control Modes. A selection of procedures built into the DP system, which provide control of the thrusters in order to control the vessel's position and heading. DP, Auto Track and Auto Pilot are examples.

Control Point. The fixed point on a vessel which is held stationary by the DP system. On a drillship, the control point will normally be the under the centre of the derrick; on a diving vessel, the control point will be at the centre of the moonpool. The control point is the same as the Centre of Rotation. See COR.

Control System. The multi-loop feedback control system designed to keep the vessel at a specified position, or on a specified track, and with a set heading, each within tolerable limits.

CPP. Controllable Pitch Propeller. A primary thruster whose pitch is altered to vary its thrust.

COR. Centre of Rotation. The point on the vessel which will be maintained stationary over the seabed when the heading is changed while under DP control. The COR is the same as the Control Point.

Counterforces. Forces exerted by the vessel thrusters, or anchors, to overcome the environmental forces acting on the vessel.

Cycloconverter. A variable speed ac drive system.

Cycloidal Propeller. A type of azimuth thruster which uses vertical blades rotating around a vertical axis rather than a conventional screw propeller.

CyScan. A laser PME which measures a vessel's position and heading relative to several reflective targets.

D

DARPS. Diffstar and Relative Positioning System. A combination of DGPS and Relative GPS, that is used with shuttle tankers and FPSOs. DGPS is used by the shuttle tanker to approach the FPSO. Once the two tankers are close, a communications link is established which provides the shuttle tanker with the FPSO heading and its GPS data. By combining the FPSO data with its own GPS data, the shuttle tanker can calculate its position and heading relative to the FPSO.

Dead Reckoning. A technique used to estimate a vessel's position from knowledge of its previous position and velocity. Sometimes the terms Model Control and Dead Reckoning are used to mean the same thing. See also Model Control.

DGPS. Differential Global Positioning System. A combination of one or more fixed GPS systems with a GPS on a vessel which enables many of the errors inherent in a single GPS system to be eliminated. Frequently used for DP work since a single commercial GPS system is unable to provide the required accuracy.

DNV. Des Norsk Veritas. A Norwegian Classification Society.

Doppler Log. Device for measuring vessel speed. Two Axis Doppler Logs measure the vessel's speed along the port/starboard axis as well as the fore/aft axis. The system transmits underwater acoustic signals and listens for the echo off the seabed. The Doppler frequency shift between the transmitted signal and the echo indicates the vessel's speed relative to the seabed. A Doppler log can also measure the relative speed between the vessel and the water mass, at various chosen depths.

DP. Dynamic Positioning.
A technique used to control the position and heading of a vessel without the use of anchor lines. The vessel's position and heading are measured, and an array of thrusters is used to control its position and heading. A computer based control system is used to calculate the required thrusts. See also Control System, Kalman Filter.

Drilling Platform. A floating or fixed structure which carries the derrick and drilling equipment needed to drill offshore oil and gas wells.

Duplex Configuration. A DP system in which every essential component is duplicated. An automatic monitoring and changeover system ensures that, if a component fails, the vessel's position and heading is kept under control. Also known as a fully redundant system. See also Triplex Voting and Simplex.

E

Eastings. Distance east of a reference point or origin. An object which has negative easting is west of the origin In the UTM system, a False Origin is defined so that Northings (N) and Eastings (E) are always positive. N and E are normally measured in metres along the plane of projection, not over the surface of the geosphere. See also UTM.

ECR. Engine Control Room

Ellipsoid. The solid shape made by rotating an ellipse about its minor axis. The world's ocean surface approximates closely to a true ellipsoid. Also called an spheroid.

ESD. Emergency Shutdown and Disconnect. A Control system which will automatically shut down all hazardous machinery, whenever an emergency is detected.

F

Fanbeam. A laser PME which measures a vessel's position relative to a single reflector.

FiFi. A notation used to define the facilities carried by a fire fighting vessel.

FPP. Fixed Pitch Propeller. A screw propeller whose pitch is fixed, and whose rotational speed is varied to change the thrust developed. The most efficient and reliable form of propeller thrust.

FPSO. Floating Production Storage and Off-loading Unit. A floating vessel which is connected to a subsea well-head, and both stores and refines the gas and oil taken from the well.

G

Gain Control. A facility which enables the operator to adjust the DP system's response to changes of environment and position.

Geodetic System. The dimensions and position of the spheroid used to measure latitude and longitude. The world is not a regular spheroid and different spheroids are used by surveyors in different parts of the world. See also Spheroid.

Gill Jet Thrusters. A type of azimuth thruster consisting of a pump which draws water into the hull and then generates thrust by expelling it at high velocity. The thrust magnitude is adjusted by varying the pump speed, and thrust direction adjusted by rotating a circular deflector plate which covers the jet outlet. Originally manufactured by Samuel White on the Isle of Wight, and sometimes known as a White Gill thruster.

Glonass. A Russian satellite navigation system similar to GPS.

GPS. Global Positioning System. A galaxy of satellites, maintained by the US Dept. of Defence, which enables a user to obtain a three dimensional position fix almost anywhere in the world. Military users can obtain fixes to about 3 metre accuracy, commercial users are limited to about 100 metre accuracy. See also DGPS.

Grid North. The direction Parallel to the Central Meridian of the chart projection in use.

Gyrocompass. A sensor which measures the vessel's heading relative to True North. A gyrocompass incorporates a gyroscope which enables the earth's rotation to be detected, the gyroscope is then aligned with the earth's axis of rotation. Errors occur if the vessel is moving north or south.

H

Heading. The direction in which the vessel is pointing. Heading is measured in degrees from north to a line drawn from the ship's centre through its bows. A ship moving forwards with a heading of 090 degrees is moving to the east. Headings should be given with three figures before the decimal point and followed by a capitol letter to indicate their nature. e.g. 090T - 90 degrees clockwise from true north; 270M - 270 degrees clockwise from magnetic north. A bearing of 170R is 170 degrees clockwise from the vessel's bow, a relative bearing.

Heave. Vertical motion of a vessel, positive is upwards, measured in metres.

HF. High frequency. Radio frequencies in the band 3 MHz to 30 MHz.

Hydrophone. An acoustic device fitted to the underside of a vessel which transmits and receives acoustic signals. More commonly called a Transducer.

I

IACS. International Association of Classification Societies. An association which endeavours to harmonise the different Classification Societies' rules, and prevents malpractice by vessel owners.

IMCA. International Maritime Contractors Association. An association of Offshore vessel owners which produces guidance notes and recommendations for its members; it also organises conferences and commissions studies and investigations of interest to its members. It has produced many reports of value to DP system owners, users and suppliers.

IMO. International Maritime Organisation. The organisation drafts regulations for worldwide application, which are subsequently adopted and enforced by the member state governments.

IMO Class 1. Vessel classification. This class requires a Simplex DP system, and is for vessels which are used in situations where loss of DP control causes little danger.

IMO Class 2. This class requires a Duplex DP system and is for vessels which are used in situations where loss of DP control causes danger to life or property.

IMO Class 3. This class requires that the vessel has a Duplex DP system backed up by a Simplex in a separate emergency control centre. Duplicated isolated engine rooms are required and each thruster must be in its own watertight compartment. Class 3 is for vessels which are used in situations where loss of DP will cause major accidents, such as vessels which operate close to offshore oil installations.

Inclinometer. An instrument which measures the inclination of an object to the vertical gravitational field. Inclinometers move away from the true vertical when subjected to horizontal acceleration; 0.1G creates an error of 6 degrees. See also VRU, Taut Wire.

Independent Joystick. A control system which provides joystick control with automatic heading control, and is totally independent of the vessel's DP system.

Integrated Control System. A control system which uses data highways to interconnect the engine room alarm systems, the thruster and propeller control systems and the DP system into one coordinated system, which uses common hardware and software.

J

JSAH. Joystick Auto Heading. A control mode of a DP system where the vessel direction and speed is controlled by the joystick and the heading is controlled by the gyrocompass.

JSMH. Joystick Manual Heading. A control mode of a DP system where the vessel direction and speed is controlled by the joystick and the heading is controlled by a heading control knob.

K

Kalman Filter. A part of the DP control system. A Kalman Filter enables a single best estimate of position and heading to be calculated from two distinct sources. An estimate of position and heading is obtained from the PMEs and compasses. An additional estimate is obtained by using a "model" of the vessel together with knowledge of the environment and thruster settings. The Kalman Filter combines these two estimates and provides a best estimate of position, heading, velocity and yaw rate. A well designed Kalman Filter provides good control while minimising thruster activity.

L

Latitude and Longitude. A system for specifying a vessel position in terms of degrees north and south and east and west. Latitude is measured from the equator and longitude from the Greenwich Meridian, except in some rare circumstances. It is important to note that the latitude of any position cannot be established until the geodetic system has been specified; if the spheroid is changed then the latitude of any position will also change.

Lifting Vessel. A vessel equipped with cranes or shear legs for lifting heavy loads. Lifting vessels are used to lift machinery and structures off transport barges and place them onto offshore platforms.

LBL. Long Base Line. Acoustic PME consisting of a transducer on a vessel, and an array of widely separated transponders on the seabed. LBL systems are expensive to deploy, but give the best results especially in deep water, over 1000 metres.

List. A ship that is loaded so as to have a permanent inclination to port or starboard is said to be listing or to have a list. See also Roll.

LMRP. Lower Marine Riser Package. Equipment fixed to the bottom of the riser which connects to the BOP to enable reconnection of the riser.

LUSBL. Long and Ultra-short Baseline System. A combination of LBL and USBL acoustic PME systems.

M

Magnetic North. The direction which leads to the magnetic north pole, which is currently in northern Canada and moves slowly.

Manual Assist. A mode for Anchor Moored Vessels fitted with thrusters, where the operator controls the thrusters using a joystick.

Mermaid Thruster. see Pod thruster

Microfix. A microwave radio PME system. Two or more radio transponders are set up in known positions. Equipment on the vessel measures the range to each transponder and calculates the position of the vessel.

Minimum Power. A DP mode which maintains the vessel's position relative to a fixed reference point. At the same time, the vessel's heading is adjusted slowly to minimise the power consumed by the thrusters. It can be used with ships, but is of little use to semi-submersibles.

Model Control. In the absence of position or heading data, the vessel remains under automatic control using predicted data based on the previous few minutes' conditions. Model control uses knowledge of the forces acting on the vessel, as well as previous position and velocity to estimate current position and heading. Model control provides a temporary alternative to reverting to manual control. Model control can keep the vessel on station within a few metres for periods of 5 or 10 minutes, provided it is preceded by a period of settled DP control, and provided that the PME failure is detected before corrupt fixes have been used. see also Dead Reckoning

Moonpool. A hole through the structure of a vessel arranged so that objects such as drill strings and diving bells can be lowered from the vessel's working deck into the water and down to the seabed.

Multi-point Mooring System. An array of a least 3 anchors laid out so that the vessel's position and heading is controlled. Usually there are between 6 and 16 anchors.

N

N. The symbol used by ALSTOM to represent yaw or turning moment, positive is clockwise viewed from above, measured in degrees and Newton-metres.

North. A vessel's heading is always measured clockwise from North in degrees. see also Compass North, Grid North, Headings, Magnetic North, True North

Northings. Distance north of a reference point or origin. An object which has negative northing is south of the origin. In the UTM system, a False Origin is defined so that Northings (N) and Eastings (E) are always positive. N and E are normally measured in metres along the plane of projection, not over the surface of the geosphere.

O

Offshore Loading. Loading a tanker with oil or gas at an offshore terminal rather than in a harbour.

OLT. Offshore Loading Terminal

Open Water Bollard Characteristics. The characteristics of a propeller if it were operated in open stationary water, i.e. a long way removed from any ship's hull, dock wall or seabed. The characteristics are usually graphs of Power (kW) and Thrust (kNewtons) plotted to a base of RPM for FPP propellers and to a base of Pitch for CPP propellers.

Operator Interface. The displays and controls provided for the operator.

Outstations. Hubs which collect signals from thrusters and sensors, and convert them to standard transmission protocols.

P

Passenger Vessels. Vessels which earn revenue by carrying passengers.

Pitch. 1. The pitch of a screw propeller is the distance that the propeller would advance during one rotation if there were no slip between the propeller and the medium in was immersed in. The pitch is a linear distance. Analogous to the pitch of a screw thread on a bolt. The pitch of a propeller is usually expressed as a "Pitch Ratio", this is the pitch divided by the propeller's overall diameter and is dimensionless. Note that the pitch on most propellers varies; it decreases from the root to the tip. This can improve a CPP propeller's performance in the forward direction but spoils it in the reverse direction. In the case of a FPP propeller, pitch variation is helpful in both directions.

Pitch. 2. A vessel's rotation about a horizontal port-starboard axis, which causes changes to the vessel's trim. Pitch is positive if the bow is down, and is measured in degrees. see also Surge, Sway, Heave, Yaw, and Roll

PME. Position Measuring Equipment. PMEs provide the essential position feedback signal for the closed loop position control system,ie, the core of any DP system.

Pod Thruster. A type of thruster which has an electrically driven screw propeller. Typically, an FPP propeller, with a variable frequency motor is mounted in line with the propeller, and is underwater. Pod thrusters are mostly azimuth thrusters. Pod thrusters built by ALSTOM/Kamewa are known as Mermaids.

Port. The side of a ship which is on your left when you are facing forwards. The colour red represents port and the port navigation lamp is red.

Portable Joystick. A control panel with joystick, turning moment control, and associated displays and buttons which can be set up at one or more locations on the vessel. Portable joysticks are more "desk-top" than "palm-top" portable devices. They need to be temporarily fixed so that the joystick is correctly oriented in the vessel, moving the joystick ahead should cause the vessel to move ahead.

Power Management. A Power Management system is a control system which monitors and controls the vessel's generating sets, and determines whether any action is needed to start additional sets, adjust the existing sets, stop sets, allow or inhibit additional loads to be connected, raise alarms, and provide displays.

Projection Method. In order to represent the curved surface of the world on a flat sheet of paper or chart, it is necessary to distort the curved surface. Over the centuries, several different projections have been invented to do this. The commonest projection is Mercator. This makes all lines of latitude straight horizontal lines and all meridians into straight vertical lines. The projection also increases the scaling as you move away from the equator. It has the considerable merit that a vessel's course while on constant heading is represented by a straight line on the plane of projection and on the chart. However, it does not give constant distance or velocity scaling. Note that a straight line drawn on one plane of projection or chart is unlikely to be a straight line on any other projection.

Propeller. The screw propeller is the commonest device for converting the rotary output of an engine or motor into a linear thrust for moving a floating vessel. Alternatives are cycloidal propellers, water jets, and paddle wheels. When the terms "the propeller" or "the main propeller" are used, the user is usually referring to the propellers at the stern of the vessel, which provide propulsion power for moving ahead in transit. Most transverse/tunnel thrusters incorporate propellers, and these are also called thrusters.

Push/Pull Mode. A mode often used by vessels with two main propellers and two rudders. In order to generate transverse thrust without longitudinal thrust, one propeller is run ahead and one astern while the rudder angles are set to give the required side thrust. see also Bias Mode

Q

Quarter. The area to either side of a ship's stern, the port or starboard quarter, a quartering sea is one in which the waves approach the vessel at about 45 degrees to the stern.

R

Radio Systems. A system of radio transmitters and receivers used to determine the vessel position.

Redundant. A component is said to be redundant if its failure will not cause loss of control. A fully redundant system is one in which no single failure will cause malfunction.

Relative GPS. A technique for determining the relative position of two GPS receivers, without the use of differential corrections.

Responder. An device similar to a Transponder, except that it receives electrical signals via cables and transmits acoustic signals via the seawater. Used instead of a transponder where it is possible to connect a signal cable from the mother ship to the structure whose position is being measured. It can be more reliable, and have a faster update rate than transponders since the acoustic path length is halved and the acoustic transmitter is not powered from batteries. It is used on tethered ROVs and at the bottom of a drill-string. See also Transponder.

Riser Follow Mode. A DP mode for maintaining the position of a drilling vessel above the well-head. The angular deflections measured on the riser at the seabed are used to indicate which way the vessel should move to keep the riser at the required angle.

Roll. A vessel's rotation about a horizontal fore-aft axis, yaw causes changes to list. Roll is positive if the Starboard side is down and is measured in degrees. See also Surge, Sway, Heave, Yaw, and Pitch.

ROV. Remotely Operated Vehicle. An unmanned submersible, often used for subsea inspection and repair work.

ROV Follow. A DP mode maintaining the vessel position relative to a ROV.

Rudder. A flat plate suspended vertically at the stern of a vessel, which can be rotated about a vertical axis to produce transverse thrust, and to steer the vessel. A rudder placed behind a propeller can produce transverse thrust whenever the propeller is driving water past the rudder. A rudder placed between two propellers will create side thrust only when the vessel is moving through the water. The maximum side thrust produced by a rudder is about one third of the ahead thrust.

S

Safety Requirements. Requirements which must be met to ensure the safety of either property or life.

SBL and SBS. Short Baseline System. An acoustic PME which uses a seabed beacon and hydrophones on the vessel. A typical installation has four hydrophones at the corners of a 20 metre square. It has now largely been superseded by SSBL or USBL systems.

Sea Current. The movement of the water with respect to the seabed. Currents are greatest in shallow and constricted waters. They often vary on the twelve hour tidal cycle, and on the 28 day lunar cycle. The peaks of the lunar cycle are known as "Spring tides", the minima as "Neap tides". Tidal currents are sometimes referred to as "Astronomical currents". Sea currents are also created by prevailing winds, atmospheric depressions and other effects. Sea currents seldom change rapidly, most changes take hours rather than minutes.

Sensors. Instruments for measuring a variety of parameters, usually refers to those that are not PMEs, i.e. compasses, anemometers, and VRUs.

Shuttle Tanker. An oil or gas tanker adapted and used to transport oil/gas from an offshore production site to a shore based depot. It is usually used with oil fields where the production does not justify the installation of a pipeline from well-head to shore.

Simplex Configuration. A single control system with no duplication of the DP system computer hardware. Often, two or more different PMEs and two compasses are provided, together with automatic changeover for the PMEs and the compasses. see also Duplex and Triple Voting.

Simulation. All ALSTOM's DP systems have this facility for operator training and system testing. Additional software is provided to simulate the behaviour of the vessel's thrusters, the environment and the vessel itself. The facility enables the actual control system, together with its controls and displays, to be used and tested without running the thrusters, and without dedicating the vessel to the operation.

Spheroid. The solid shape made by rotating an ellipse about its minor axis. The world's ocean surface approximates closely to a true spheroid. Also called an ellipsoid in some texts.

SSBL. Super Short Base Line. An acoustic system which uses one or more transponders on the seabed and a single transducer assembly on the vessel. The transducer contains an array of receivers so that the angular position of the transponder can be determined from the phase relationship between the signals received at the multiple receivers. The range to the transponder is determined from the time interval between the interrogation signal leaving the transducer to reception of the return signal from the transponder. Sometimes called Ultra Short Base Line (USBL) systems.

Starboard. The side of a ship which is on your right when you are facing forwards. The colour green represents starboard and the starboard navigation lamp is green.

Stern. The back or blunt end of a ship, the opposite end to the bows.

Surge. Vessel movement in the fore-aft direction. Represented by X in ALSTOM's systems, positive forward, and is measured in metres.

Sway. Vessel movement in a lateral direction. Represented by Y in ALSTOM's systems, positive to starboard, and is measured in metres.

Syledis. An UHF radio positioning system based on shore beacons. It can provide fixes on several vessels simultaneously with a range of a few hundred miles. It has now been largely superseded by GPS and DGPS.

T

Taut Wire. A PME system which measures the angle of a wire fixed between the vessel and a sinker weight on the seabed. Reliable, not very accurate in sea currents, and usually limited to 300 metres water depth or less.

Thrust Vectors. Operator display showing the force and direction of the thrusts acting on the vessel.

Thruster. Device for providing vessel thrust. Used to include all thrusters, fixed and azimuth, all main propellers and rudders.

Track Follow Set-up. The parameters needed to define a track following sequence, e.g. two or more waypoints, speed over the ground and heading. Can be set by the operator or down loaded, either from a diskette or from another processor.

Transducer. An acoustic device fitted to the underside of a vessel which transmits and receives acoustic signals. Sometimes called a Hydrophone.

Transponder. A device placed on the seabed which receives and re-transmits an acoustic signals, an essential part of all acoustic PMEs. Although the term almost always refers to acoustic transponders, some radio system use radio transponders. See also Responder.

Trim. A ship which is loaded so that its keel is not horizontal is said to be trimmed by the stern if the stern is down or trimmed by the bow if the bow is down. Ships are sometimes trimmed by the stern to increase speed or reduce drag and to immerse the main propeller deeper in the water.

Triple Voting Configuration. A system which uses three or more measurement devices, PMEs or sensors. Three independent control systems then compare the parameter values from the devices, and determine which signal is most likely to be correct. See also Duplex and Simplex.

Trisponder. A microwave radio PME.

True Mercator. The original Mercator projection as opposed to a Transverse Mercator projection. See also Mercator and UTM.

True North. The direction which leads to the North Pole.

Tunnel Thruster. A screw propeller mounted in a tunnel through the hull below the water-line. Usually arranged to provide transverse thrust.

U

UHF. Ultra High Frequency. Radio frequencies in the band 300 MHz to 3 GHz.

USBL. Ultra Short Base Line. An acoustic system which uses one or more transponders on the seabed and a single transducer head on the vessel. The transducer contains an array of receivers so that the angular position of the transponder can be determined from the phase relationship between the signals received at the multiple receivers. The range to the transponder is determined from the time interval between the interrogation signal leaving the transducer to reception of the return signal from the transponder. Sometimes called Super Short Base Line (SSBL) systems.

UPS. Uninterruptible Power Supply. These equipments usually consist of a battery charger, a battery and an inverter so that an ac supply is available for the DP system, despite failure of the ship's supply. Most UPSs are fitted with a "no-break" changeover switch so that if the inverter or battery fails, the ship's supply is used.

UTC. Universal Time Corrected. GMT time measured from midnight. Prior to the 1st January 1925, it was measured from midday.

UTM. Universal Transverse Mercator. A projection system for producing flat charts of the world's curved surface. Similar to True Mercator projection except that the plane of projection is not a vertical cylinder touching the world's surface at the equator but a horizontal cylinder tangent to the earth's surface at a north-south meridian. The northern hemisphere is divided into 60 zones, each zone covers six degrees of longitude.

The North Sea is covered by zone 31, longitude 0 to 6 degrees east of Greenwich. UTM projection is particularly suitable for areas which cover long distances north and south. No scale errors occur moving north, however, scale errors arise moving east or west.

V

VRU. Vertical Reference Unit. A device which measures the roll and pitch of a vessel. A VRU is more sophisticated than an inclinometer. A VRU is constructed so that is largely immune to accelerations which occur on a vessel in waves. Three types of VRU are available, gyrostabilised, mechanical and solid state electronic VRUs. Solid state VRUs use strap-down accelerometers and crystal rate gyros to measure the mean inclination and the angular rate. These two signals are combined to provide an estimate of instantaneous angular position. All VRUs require a settling time of several minutes before their outputs are correct. Solid state VRUs can be susceptible to vibration. See also Inclinometers.

W

Waypoint. A reference point, defined in latitude and longitude or UTM coordinates. A series of waypoints are used to define a track or course to be followed.

WGS 84. World Geodetic Spheroid 1984. A geodetic spheroid which closely approximates to the world's shape. Used by all known GPS systems. The spheroid to use in default of any stated preference.

X

X. The symbol used by ALSTOM to represent surge, positive forward, measured in metres.

Y

Y. The symbol used by ALSTOM to represent sway, positive to starboard, measured in metres.

Yaw. A vessel's rotation about a vertical axis, yaw causes changes to heading. Yaw is positive when rotating clockwise viewed from above, and is measured in degrees. See also Surge, Sway, Heave, Yaw, Pitch and Roll.

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