Instruction Manual

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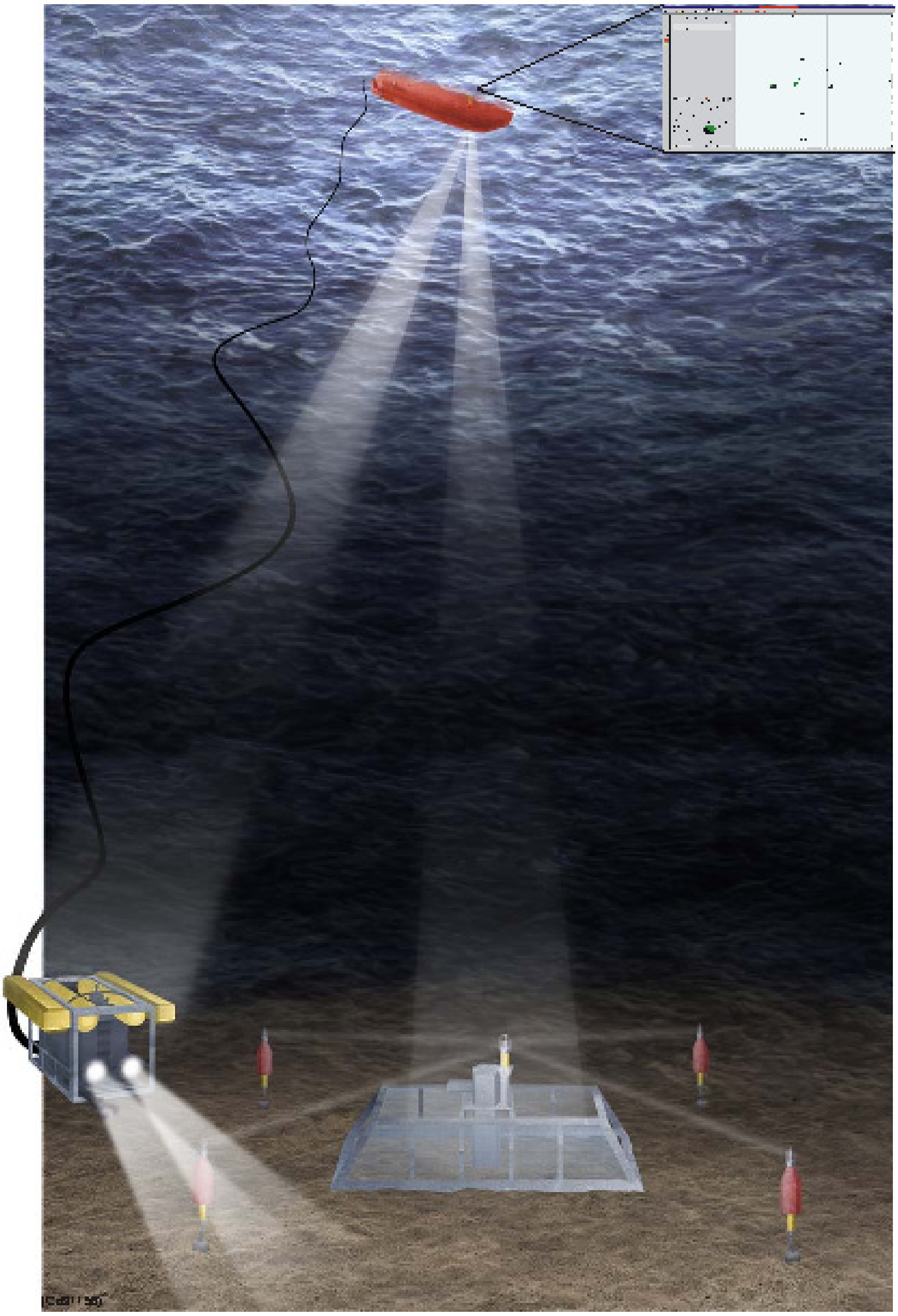
APOS for HiPAP®

High Precision Acoustic Positioning



APOS for HiPAP® Systems

Acoustic Positioning Operator Station

Instruction Manual

About this document

Rev	Date	Written by	Checked by	Approved by
D	13.03.13	AJ	SER	JEF
	Minor updates.			

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The equipment to which this manual applies must only be used for the purpose for which it was designed. Improper use or maintenance may cause damage to the equipment and/or injury to personnel. The user must be familiar with the contents of the appropriate manuals before attempting to operate or work on the equipment. Kongsberg Maritime disclaims any responsibility for damage or injury caused by improper installation, use or maintenance of the equipment.

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Sections

This is the Instruction manual for the Acoustic Positioning Operator Station (APOS) used with a High Precision Acoustic Positioning (HiPAP) system. It contains a general description of the HiPAP system, protocols, and how to get started on the APOS. The manual includes the following sections:

1 APOS Operator manual

This section includes the standard operator manual for APOS and includes an introduction to APOS, abbreviations and terms, how to get started with APOS, LBL and SBBL principle of operation and operator maintenance.

2 HiPAP® Model 501/451/351/101 Product description

This section describes all the HiPAP® systems Model 501/451/351/101. It includes positioning principles, applications, system units, configurations and functions. It also includes technical specifications and drawings.

References

Documents:

Section	Title	Reg. no.	Rev.
0	Instruction manual	319957	D
1*	Acoustic Positioning Operator Station (APOS) Operator manual	160841	x
2*	HiPAP® Model 501/451/351/101 Product Description	317748	x

** The latest versions of the document is included as standard.*

Remarks

Further information about how to operate the Acoustic Positioning Operator Station (APOS) is found in:

- APOS Online help system

Further information about the Acoustic Positioning systems using APOS software are found in the following manuals:

HiPAP® system	**Hull units**
HiPAP® Model 501/451/351/101 Instruction Manual Doc. No. 303490	HiPAP® hull units Model 501/451/351/101 Instruction Manual Doc. No. 311046

The reader

This manual assumes the operator has some knowledge of the general principles of operation, the standard display modes and terminology used in acoustic positioning systems.

APOS

Acoustic Positioning Operator Station

Operator Manual

This document is the Operator manual for the Acoustic Positioning Operator Station (APOS) for use with the High Precision Acoustic Positioning (HiPAP®), Hydro acoustic Position Reference (HPR) 400 series of systems and subsea transceiver cPAP®.

About this document

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G	07.03.13	AJ	AD	JEF
	Removed reference to APC. Added cPAP® information.			

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Remarks

References

Further information about how to operate APOS Operator station may be found in:

- APOS on-line help system

The reader

The manual assumes the operator has some knowledge of the general principles of operation, standard display modes and terminology used in acoustic positioning systems.

Contents

ABOUT THIS DOCUMENT

Content

This Operator manual provides a general introduction to APOS, and how to get started. Operator maintenance, Long Base Line (LBL) and Super-Short Base Line (SSBL) principles of operation are also included.

APOS - SHORT DESCRIPTION

The HiPAP®, cPAP® and HPR 400 Series of systems are controlled and operated by the

APOS software.

The APOS software includes the following main functions:

- Integrates several HiPAP®/cPAP®/HPR 400 transceivers
- User interface
- Interfacing HiPAP®/cPAP®/HPR 400 transceivers
- Ray bending compensation
- LBL calculations
- SSBL calculations are done in the transceiver
- Interfaces DP and survey computer
- On-line help

The APOS software runs on a Windows XP platform. It uses standard Windows graphical user interface.

ABBREVIATIONS, TERMS AND DEFINITIONS

This chapter includes abbreviations used in this manual and general terms used within APOS.

Abbreviations

APOS	Acoustic Positioning Operator Station
OS	Operator Station
DGPS	Differential GPS
DP	Dynamic Positioning
GPS	Global Positioning System
HiPAP®	High Precision Acoustic Positioning
HPR	Hydro acoustic Position Reference
LBL	Long Base Line
ROV	Remotely Operated Vehicle
SSBL	Super-Short Base Line
TD	Transducer
TP	Transponder
UTM	Universal Transverse Mercator

General terms

The general terms are described in alphabetical order.

Bearing - The horizontal direction of one terrestrial point from another, expressed as the angular distance from a reference direction, clockwise through 360°.

Cartesian coordinate system - A coordinate system (local system) where the axes are mutually-perpendicular straight lines.

Clump weight - An anchor line element connected at a fixed position on an anchor line, causing a concentrated vertical force downwards on the anchor line.

Course -	The horizontal direction in which a vessel is steered or is intended to be steered, expressed as angular distance from north, usually from 000° at north, clockwise through 360°. Strictly, this term applies to direction through the water, not the direction intended to be made good over the ground. Differs from **heading**.
Datum -	Mathematical description of the shape of the earth (represented by flattening and semi-major axis).
Geodetic coordinate system -	A mathematical way of dealing with the shape, size and area of the earth or large portions of it. Normally UTM coordinates with reference to a datum.
Heading -	The horizontal direction in which a vessel actually points or heads at any instant, expressed in angular units from a reference direction, usually from 000° at the reference direction clockwise through 360°. Differs from **course**.

GETTING STARTED

This chapter describes the basic operation, how to switch the APOS on and off, and how to lower and raise the transducer(s).

The “getting started” description is based on an already installed APOS software.

Note *For more information refer to the APOS on-line help system.*

Topics

User levels

APOS is - regarding functional possibilities and operation, configured in the following two user levels:

Operator: This level is used for the daily normal operation.

Service: This level requires password, and is for service personnel only.

How to start and stop

Start-up procedure

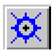
The following procedure describes how to start APOS from **Power Off** position.
Normally the system is kept on 24 hours a day.

1 Switch on the power. (The power On /Off switch is normally located at the front of the cabinet.) APOS is ready for use after approximately one minute.

2 Switch on the monitor. (The power On/Off switch is normally located at the lower front part of the monitor.)

- First the desktop menu appears, and after some time the APOS main window appears.

3 If required, adjust contrast and brightness in order to obtain required display settings. (The buttons are located at the lower front part of the monitor.)

4 Ensure that you are in control of the system by pressing the  button. When in control, the button becomes disabled.

- If the system is already in control, *do not* click the button.

Note *If there is more than one operator station in the system, the button will automatically become enabled again if another operator station takes control.*

Note *Ensure that the configuration of the transponders available in your system is performed. How to configure the transponders, see the APOS on-line help.*

Caution *Remember to lower the transducer(s)!*
Refer to page 7.

You are now ready for operation!

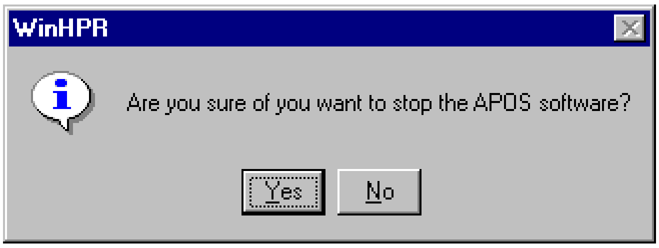
Note *How to operate APOS, see APOS on-line help system.*

Stop procedure

Normally the system is kept on 24 hours a day. If a controlled shutdown is required, it is important to proceed as follows:

1 Select **File -> Stop/Shutdown**

- The following message is displayed.



2 Select **Yes**.

3 The APOS software will shut down, and you will return to the desktop.

How to lower and rise the transducer(s)

Note *The HiPAP®/cPAP®/HPR may be a part of a larger system. Switching on the larger system will then normally power up the HiPAP® /cPAP®/HPR system as well, and only lowering of the transducer will be required.*

Using APOS (Optional)

Some systems have the option to rise and lower the transducer directly from APOS.

See APOS online help for this function.

Using the remote control

1 To lower the transducer, press the **DOWN** button on the Remote Control Unit. Observe that the **IN** and **STOP** lamps extinguish. When the transducer is fully lowered, the yellow **OUT** lamp and **STOP** lamp will be lit.

2 To raise the transducer, press the **UP** button on the Remote Control Unit. Observe that the **IN** and **STOP** lamps extinguish. When the transducer is fully raised, the yellow **IN** lamp and **STOP** lamp will be lit.

Note *The red STOP button on the Remote Control Unit may be used to stop the transducer hoisting and lowering operations at any position. When this button is pressed, the yellow STOP lamp will light. The hoisting or lowering operations are continued from the stop position by pressing the UP or DOWN buttons.*

Using the hoist control

1 To lower the transducer, open the Hoist Control Unit door and set rotary switch **S1** to **LOWER**. Once the Hull Unit has reached the required position, (will stop automatically) set the switch **S1** to **STOP**.

2 To raise the transducer, open the Hoist Control Unit door and set rotary switch **S1** to **HOIST**. Once the Hull Unit has reached the required position, (will stop automatically) set the switch **S1** to **STOP**.

Note

The red STOP button on the remote control unit may be used to stop the transducer hoisting and lowering operations at any position. When this button is pressed, the yellow STOP lamp will light. The hoisting or lowering operations are continued from the stop position by pressing the UP or DOWN buttons.

APOS on-line help system

When operating APOS, the on-line help is available by activating the APOS Help menu button, or the F1 button on the Keyboard.

The on-line help may also be activated from a dialog box, provided that the help button is available in that particular dialog box.

The on-line help menu includes the following selections:

- **Help**
  General help
- **About APOS**
  Includes the APOS version and transceiver version(s)

OPERATOR MAINTENANCE

Topics

Maintenance philosophy

For APOS, corrective maintenance is normally performed by replacing modules and circuit boards. This type of maintenance must be carried out by a qualified maintenance engineer.

Further information about maintenance of the Acoustic Positioning systems are found in the following manuals:

- HiPAP® Instruction manual
- HPR 400 Series Maintenance manual.
- cPAP® Instruction manual

Preventive maintenance however, may be performed by the system operator.

Preventive maintenance

Caution *Do not use strong liquid detergent when cleaning the units. This may damage the surface.*

Cable terminals

All cables should be checked and tightened at least once every three months. This will prevent the screws from loosening resulting in poor contact for the cables.

Operator station

Clean the operator station and display exterior with a damp cloth to remove dirt, dust, grease etc.

The keyboard should be cleaned carefully with a damp cloth.

LBL PRINCIPLES OF OPERATION

This chapter describes the theory of operation of the LBL. The terms used in LBL positioning are defined, and the mathematical principles are described.

Topics

Mathematical terms

Standard deviation tells how much a variable varies around its mean value. It is often written as σ. If the variable is normally distributed, 68% of its values are expected to be between (Mean_value - σ) and (mean_value + σ).

Variance is the square of the standard deviation, i.e. σ^2.

Root Mean Square (RMS) of a set of values is a mean of the values in which the greater values contribute more than the smaller values. It is often used instead of the mean value.

Iteration is a repetitive mathematical process. Some algorithms need starting values for some of the variables before they may be executed. The result of the calculation is a new set of values for those variables that are closer to the answer than the old ones. By repeating the algorithm starting at the new values, the result becomes more accurate each time. Each execution is called iteration, and the algorithm is termed iterative.

Cartesian coordinates are measured in a coordinate system with three mutually perpendicular axes. In this text, the axes are named EAST, NORTH and DEPTH. NORTH is normally the geographical north direction, and EAST the geographical East direction. You are allowed to select other directions, but you must be consistent. The origin of the coordinate system has the coordinates (0,0,0).

Polar coordinates - The polar coordinates of a point are:

Range - The horizontal distance from the origin to the point.

Bearing - The horizontal direction from the origin to the point. 0 is the north direction. The bearing increases clockwise to 360º.

Depth - The vertical distance from the origin to the point.

LBL terms

TP Array. LBL positioning is based on range measurements to the transponders on the seabed. These transponders are called a “transponder array”.

Local calibration. The LBL positioning algorithms must know the coordinates of the transponders in the transponder array relative to a local origin. The process to decide these coordinates is called the local calibration of the transponder array. It is performed by first measuring the ranges between the transponders in the array and then calculating their coordinates based on the ranges.

Geographical calibration. This decides the location of the local origin in latitude and longitude, and the rotation of the local north axis relative to geographical north.

Range residual. HiPAP®/cPAP®/HPR measures ranges to decide the position of a transponder or a transducer. Normally, more ranges than necessary are measured. Then the position is calculated based on a best fit of the measured ranges. The residual of a range is the measured range minus the range calculated by using Pythagoras' theorem on the calculated positions.

Local coordinates. The origin of the local coordinate system is in the area covered by the transponder array. The axes are called EAST, NORTH and DEPTH. The NORTH axis is not necessarily pointing in the geographical north direction. The names of the axes in the coordinate system are written in upper case letters (EAST, NORTH), and the geographical directions are written in lower case letters.

Geographical coordinates. When a geographical calibration is performed, positions may be presented in geographical coordinates; either in latitude and longitude or in UTM coordinates.

Initial positions. The positions of the transponders in the transponder array inserted before the local calibration is performed. The positions are given in local or geographical coordinates. The only requirement to the accuracy of these positions is that they roughly indicate the transponder positions relative to each other.

Calibrated positions. The positions of the transponders in the transponder array calculated in the local calibration. The positions are given in local coordinates.

Error ellipse. There is an uncertainty associated with all positions, both initial and calibrated. This uncertainty is expressed as a 1-sigma error ellipse both in the input to and the output from the HiPAP®/cPAP®/HPR system. The error ellipse has a major and a minor semi-axis, and the direction of the major semi-axis relative to north is specified. Assuming that the uncertainty of the position is normally distributed, the probability that the position really is within the error ellipse is 0.67 x 0.67 = 45%.

HiPAP®/cPAP®/HPR terms

APOS is the HiPAP®/cPAP®/HPR System controller. It consists of a computer with keyboard and trackball. The computer may contain circuit boards for serial lines, Ethernet etc. as options.

HPR 400 is a transceiver. It consists of single Europe circuit boards normally mounted in a 19" rack. The PCBs may be mounted in a cylinder for subsea use. The transceiver measures ranges and SSBL directions and handles telemetry.

HiPAP® is a transceiver with one spherical transducer.

cPAP® is a transceiver with either an integrated or one to three remote transducers.

A Transducer may consist of elements (vibrators) and some electronics. It converts the electrical transmission signals generated by the transceiver into hydroacoustic pulses. It also converts the hydroacoustic pulses received into electrical signals for the transceiver.

The transducer may be of the ordinary LBL type or of the SSBL type. Both are capable of measuring ranges. The SSBL transducer can also measure directions.

The HPR 4xx consists of an Operator unit, transceiver(s) and transducer(s). There may be several transceivers connected to the Operator unit, and there may be two LBL transducers plus two SSBL or LBL transducers connected to each transceiver.

- HPR 410 is an SSBL system
- HPR 408 is an LBL system
- HPR 418 is a combined LBL and SSBL system

A Transponder consists of a LBL type transducer, electronics and batteries. It is placed on the seabed or on an ROV. The transponders may be commanded by telemetry to execute functions.

Most LBL transponders contain a pressure and a temperature sensor. These are used to decide the transponder depth.

NB! The following section does not apply for Cymbal.

When enabled for positioning, the transponder may be interrogated by two pulses on different frequencies and will then reply with a pulse on a third frequency. The HiPAP®/cPAP®/HPR system may command it to switch frequencies.

Each transponder is uniquely identified by a serial number.

LBL measurement principles

LBL positioning is based on range measurements, both for the calibration and for the positioning. The principle is basically the same for positioning and for calibration, but the explanation is split into separate paragraphs in this text.

Positioning

The HiPAP®/cPAP®/HPR system measures ranges from a transducer to the transponders on the seabed. A common interrogation channel is used for all the transponders in the transponder array. The HiPAP®/cPAP®/HPR system knows the transponder positions. Each range measurement indicates that the transducer is on a sphere with its centre at the transponder and with its radius equal to the range. If more than one range measurement is made, the transducer's position must be on the lines where the spheres intersect.

When the measurements are done on a SSBL type of transducer, the directions may be used together with the range in the calculations. In shallow water, and when an accurate HiPAP® transducer is used, the measured directions contribute to a more accurate position.

The depth of the transducer is often known. In these cases, each range measurement indicates that the transducer is on the circle where the sphere around the transponder intersects with the horizontal plane at the transducer. This is illustrated in Figure 1. Here three circles are drawn where the transducer's depth plane crosses the three spheres.

Normally there will be noise on each measurement. That is illustrated on the figure by not letting the three circles intersect exactly in one point. There are three intersections close to each other, and the position can be assumed to be somewhere in the triangle formed by the intersections.

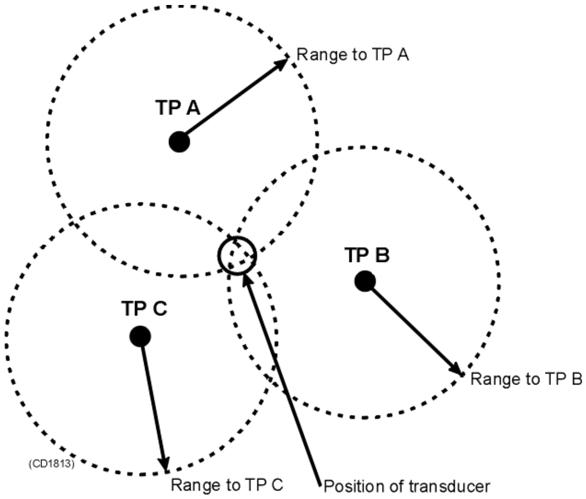


Figure 1 LBL positioning

Normally, more ranges than necessary are measured, and the number of intersections close to each other increases. Still the best guess of the position is somewhere in the space between these intersections. The program uses a weighted least square error algorithm to decide the position. The algorithm is iterative, and the errors are the differences between the measured ranges and the corresponding ranges calculated by using Pythagoras' theorem on the vessel position. These errors are called range residuals.

The iterations start at the vessel's previous known position, and continue until the increment from the previous iteration is less than a preset number of centimetres. The accuracy of the old position does not influence the accuracy of the new position.

Situations may arise when too few ranges are measured. Then there are two possible solutions for the new position. The programs will iterate towards the position closest to the old one.

In standard LBL, the replies from the transponders in the TP array are received on the same transducer as doing the interrogation of the array. In APOS for HPR400 and cPAP® you can request the replies to be received on other transducers too. The extra measurements make the LBL system more accurate and robust.

Calibration

The ”position” used during the calibration consists of the position of each array transponder. Consequently, it contains many coordinate values.

The programs must know something about the transponder positions before the calibration calculations can start. These positions are called “Initial positions”. That information must be inserted by you, or it may be read from an ASCII file. SSBL measurements may be used to identify the initial transponder positions.

You must inform the system of the accuracy of the initial positions. This is achieved by specifying a 1-sigma error ellipse for the horizontal position and a standard deviation for the depth. The transponders are often at approximately the same depth, and the range measurements then contain no information about their relative depths. In this case, the depth standard deviation should be set to 0.00 m for all the transponders.

The next step of the calibration is to measure the subsea ranges between the transponders. The range from one transponder to another is normally measured many times. The mean value and the standard deviation of these ranges are then calculated and used later in the calculations.

The programs use a weighted least square error algorithm to decide the positions of the transponders. The algorithm is iterative, starting at the initial positions of the transponders. There are two types of errors as seen from the algorithm.

The **range errors** are the differences between the measured ranges and the corresponding ranges calculated by using the Pythagoras formula on the transponder positions. These errors are called **range residuals**. In the algorithm the squares of the range residuals are weighted with the inverse of the variance calculated during the range measurements. In this way the ranges measured with a small standard deviation have a greater impact on the resulting transponder positions than the ranges measured with a large standard deviation.

The **position errors** are the differences between the calculated transponder positions and the starting values of those positions. In the algorithm, the squares of these errors are weighted with the inverse of the squares of their uncertainties. The uncertainty of a transponder position starts at the error ellipse for the initial position. The uncertainty reduces in size during the calculation, and the result is the uncertainty of the calibrated transponder position.

Combined use of LBL and SSBL

When a transponder array is active on an SSBL transducer, the HiPAP®/HPR system may perform SSBL measurements when receiving the replies. The direction information is then used together with the range information to make the system more accurate and robust. The transponders in the transponder array are still classified as LBL transponders.

Transponders may be interrogated as SSBL transponders. They are interrogated using their individual channels, and the SSBL measurements are performed as on a pure SSBL system.

The same transponder may not be interrogated as an SSBL transponder and an LBL transponder simultaneously.

When both a transponder array and one or more SSBL transponders are active, the system will alternate between LBL interrogations and SSBL interrogations. The sequence is controlled by the interrogation rate parameters for the LBL and SSBL interrogations.

The transponders used as SSBL transponders may be of the same physical type as the LBL transponders. They are, however, commanded to be interrogated on their individual channels and not on the LBL common interrogation channel.

Geographical calibration

Many LBL applications do not perform geographical calibrations. For those applications, you may ignore this chapter.

The relative positions of seabed transponders in TP arrays are calculated based on range measurements between the transponders. When finished, the transponder positions relative to an origin are calculated. This process is called the local calibration.

Normally the position of the origin and the rotation of the local North axis relative to the geographical north axis, remain unknown after the local calibration. These unknowns are decided in the geographical calibration.

APOS uses positions of the vessel, simultaneously received from a DGPS system and calculated by the LBL system, as basis for the geographical calibration. DGPS and LBL position pairs are logged at many positions in the area before the calculation is performed. The calculation decides the origin latitude and longitude, and the rotation of the local north axis relative to geographical north axis, using a least square error algorithm.

When the latitude, longitude and rotation of the local origin are calculated, the LBL positions logged are converted to geographical coordinates. There is normally a difference between the LBL geographical position and the DGPS position logged in the same place. This is called the distance residual of the position pair. The residual is the statistical sum of the DGPS error and the LBL error. When these systems work correctly, the sound velocity profile used is accurate, and the local calibration was performed accurately, these residuals are normally in the 1 m order of magnitude.

The most accurate results for the origin position calculations are given if the position pairs are logged evenly distributed around the area. If for example the sound velocity profile is inaccurate, the distance residuals of the position pairs logged in the outer parts of the array may be much larger than the error in the origin calculated. If, on the other hand, position pairs are logged in only one part of the array, the situation could be the opposite - with small residuals but an inaccurate calculation of the origin. It must always be remembered that the objective of the calibration is to establish accurate positions, not to obtain small residuals.

The three parameters calculated in the geographical calibration are the latitude, longitude and rotation. When performing LBL positioning in the area later, errors in latitude and longitude will always contribute to errors in the LBL geographical position. The error in the rotation contributes an error proportional to the distance from the centre of the area in which the position pairs were logged.

The origin calculated is valid for the locations in the transponder arrays used in the LBL positioning during the geographical calibration.

Super array and Tp array

A limit of eight transponders can be in use simultaneously when performing LBL positioning or range measurements for local calibration. The limit is due to the use of frequencies within the frequency band available. The transponders in use simultaneously are named a TP array. APOS can handle many TP arrays, but only one can be active at any one time.

In many applications, as for example pipe laying and inspection, there is a need to use more than 8 transponders. The places on the seabed where the transponders are placed are called locations.

When all the locations are grouped together, the resulting array is often called the “superarray”.

Each location is a physical transponder. The same physical transponder may be used in more than one TP array, meaning that the TP arrays can overlap.

Example: Location 8 and 9 are used in both TP array 1 and TP array 2 because the arrays overlap, as shown in below.

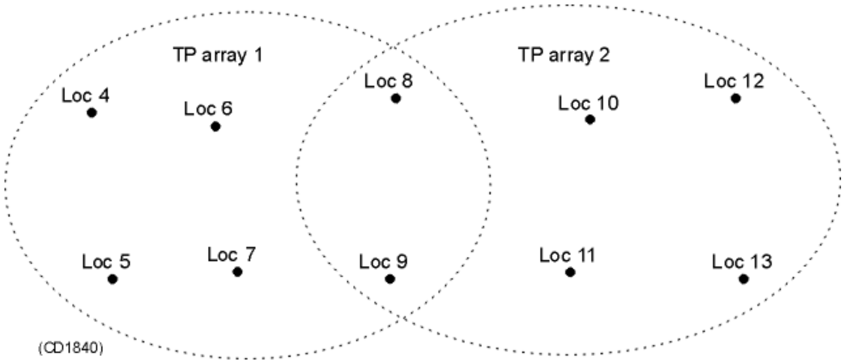


Figure 2 Two TP arrays with overlapping locations

All range measurements for the local calibration are performed within the TP arrays. When finished with the measurements in one TP array, a calculation using only those measurements should be performed to check the measurements. Then, only the locations specified as being part of the actual TP array receive new calibrated positions. The positions of the other locations will remain at their initial values. Normally, some of the locations receiving new calibrated positions will also be used in other TP arrays. The new positions will then also be valid for those arrays, i.e. one location has one and only one position, even when used in more than one TP array.

When the ranges are measured in all the TP arrays with overlapping locations, a local calibration calculation for the super array should be performed. The range measurements performed in all the TP arrays are then used, and all locations receive new calibrated positions.

Geographical coordinates

Many LBL applications do not use geographical coordinates. For those applications, you may ignore this chapter.

APOS may receive geographical positions from a DGPS receiver, and it may present the calculated LBL positions in geographical coordinates.

Geographical coordinates are always referred to a datum defining the ellipsoid model of the earth. APOS may work with three datum simultaneously. These are:

1. **Reference datum**. This datum is used by the HiPAP®/cPAP®/HPR system in the internal calculations. It is by default WGS 84, and you should not change it.
2. **GPS datum**. This datum is the one used by the DGPS receiver. After having received a geographical position from the DGPS receiver, the HiPAP®/cPAP®/HPR system converts the position to the reference datum before starting any calculations. You may select the GPS datum from a list of datum in a menu.
3. **APOS datum**. This datum is used by the HiPAP®/cPAP®/HPR system when presenting LBL positions in geographical coordinates, both on the screen, in printouts and in binary telegrams. You may select the APOS datum from a list of datum in a menu.

The system always performs the LBL calculations in local coordinates. If the LBL positions are to be presented in geographical coordinates, the transformation from local to geographical is performed just before the presentation. APOS must know the geographical coordinates of the local origin and the rotation of the local north axis to perform this conversion.

When the initial coordinates for the locations are entered in UTM coordinates, APOS must convert the position to local coordinates before performing any calculations. To perform this conversion, it must know the geographical coordinates of the local origin to be used. That is inserted by you as a UTM centre. The rotation parameter of this origin is calculated automatically to the angle between the geographical north and the UTM north. You should not change the UTM centre when it is in use for the locations.

The use of the UTM centre as an origin is similar to the use of the origin calculated in a geographical calibration.

The UTM centre or the origin calculated in the geographical calibration may be transferred to the origin(s) of the TP array(s). When transferred to a TP array, the origin is used when:

- Positioning in the TP array. The LBL position calculated may be presented in UTM or in geographical coordinates.
- Printing the calibrated positions of the locations. The calibrated positions are always printed in local coordinates.

Those locations used in a TP array with an origin are also printed in UTM coordinates.

Quality control of data

The quality control of the data is performed on many levels. The HiPAP®/cPAP®/HPR system measures more than strictly necessary, and thereby gains the possibility to check the quality of the results.

Local calibration

The calibration is primarily based on range measurements between the transponders. Each range is measured many times, and the program calculates a standard deviation on each range. You may examine the measurements, and the ranges may be measured anew. You may exclude ranges from the calibration calculations if no acceptable standard deviation is obtained.

The inverse of the standard deviations are used by the algorithms as weights when calculating the optimum transponder array positions.

After having calculated optimum positions for the array transponders, APOS checks how the measured ranges fit with the calculated positions. Ranges that do not fit well have large range residuals, and these ranges may be measured anew or excluded before the calibration calculations are performed again.

APOS calculates the uncertainties of the calibrated positions, and presents them as error ellipses around the positions.

Geographical calibration

APOS uses positions of the vessel, simultaneously received from a DGPS system and calculated by the LBL system, as the basis for the geographical calibration. Only two DGPS/LBL position pairs are necessary to calculate the origin latitude, longitude and rotation, but up to many hundreds position pairs may be logged and used in the weighted least square error calculation. The calculation is over determined, and distance residuals are calculated for each position pair. The RMS value of these residuals indicates how well the position pairs match.

Each position pair has associated statistical information indicating its uncertainty. This information is used in the calculations, and it contributes to the statistical data giving the uncertainty of the origin calculated.

Positioning

During positioning the HiPAP®/cPAP®/HPR system normally measures more ranges and SSBL directions than is necessary. After having calculated the position, it checks how well the measured ranges and directions fit with the position. Measurements obviously wrong may be automatically excluded when the position is calculated again.

APOS calculates residuals of all measurements, and the uncertainty of the LBL position

The uncertainty of the local LBL position calculated depends on several factors:

- The number of ranges and SSBL angles measured, and the geometrical crossings of the vectors from the transponders to the transducer.
- The accuracy with which the ranges and the angles are measured.
- The uncertainty of the sound velocity profile used. You insert this uncertainty in a menu.
- The uncertainty of the calibrated positions of the transponders in the array.

The local LBL positions calculated may be presented in geographical coordinates. In that case, the uncertainty of the origin is statistically added to the uncertainty of the local position before being presented.

Note *The graphical presentation on the screen is always in local coordinates. The printouts however may be in geographical coordinates.*

Transponder modes

Each transponder may be in one of the following modes.

- *SSBL mode.* The transponder enters this mode after power on and after reset. It must be in this mode when being interrogated as an SSBL transponder.
- *LBL calibration mode.* The transponder must be in this mode when performing the subsea range measurements during the Local calibration.
- *LBL positioning mode.* The transponders must be in this mode when measuring ranges from a transducer to the transponders. In this mode, the transponder is interrogated on an LBL interrogation channel, which is usually different from the transponder s channel. The transponder s reply frequency is decided by its channel number. This mode enables all the transponders in an array to be interrogated on the same interrogation channel, while replying on their individual frequencies.

In the LBL positioning mode, the turnaround delay is set individually for each transponder. This possibility is used to prevent the transponder replies being received at the transducer simultaneously.

Cymbal uses LBL and SSBL mode at the same time and is not using the calibration mode.

Operation

The following paragraphs give an overview of the operations without going into details. For detailed description of the operation, refer to the APOS on-line help system.

Measure ranges

The transponders in the transponder array must all be in the Calibration mode before the subsea ranges are measured.

The local calibration is primarily based on range measurements between the transponders. They send the results up to the HiPAP®/cPAP®/HPR system by telemetry. You may choose to request one transponder at a time to measure the ranges to all the others, or you may request all the transponders, one at a time, to measure the ranges to all the others. This operation will last for some minutes, depending upon the ranges and the number of ranges to measure. The second option should only be selected when the vessel has good telemetry communication with all transponders from a single position. In both cases only one telemetry function is performed at any one time in the water.

Execute the local calibration

Once the subsea ranges have been measured, the positions of the transponders in the array can be calculated.

When APOS has completed the calculations, it displays the maximum and the RMS values of the range residuals. These indicate how well the calibrated positions fit with the measured ranges. If you are not satisfied with the residuals, you should identify the ranges contributing the most to the RMS value of the residuals. Ranges with large residuals should be measured again and the calibration calculations repeated. This iteration may need to be performed many times before the resulting residuals are considered to be small enough.

The left part of the screen is normally used to present graphical information. In the LBL local calibration process, it is better to use it to display the ranges. Then the display gives an overview over the ranges, the standard deviations and the range residuals. The ranges and the standard deviations are updated after each range measurement. The range residuals are updated after each local calibration calculation.

Position a vessel or ROV

When satisfied with the result of the local calibration, you can start the positioning operation. First the turnaround delays of those transponders in the array must be decided, then the transponders must be commanded to the LBL positioning mode.

Position a transponder

The transponders are able to measure the ranges to other transponders, and send the result, on telemetry, to the HiPAP®/cPAP®/HPR system. This capability is used in the LBL transponder positioning mode. The transponder to be positioned is called the master transponder, and it is not part of the TP array. The master transponder measures ranges to transponders in a TP array, these other transponders being called the slaves. Up to six slaves may be used simultaneously by one master.

The transponders in the TP array must be in the calibration mode (*not Cymbal*). The master is commanded to be in a special TP range positioning mode, in which it knows the channels of the slaves to which it is to measure the ranges. The positioning sequence is initiated by the HiPAP®/cPAP®/HPR system transmitting a short message to the master on telemetry. The master measures the ranges to the slaves, just as in calibration mode. Only one range is measured towards each slave. When it has finished, the master transmits the ranges, on telemetry, up to the HiPAP®/cPAP®/HPR system, then waits for the next request to measure ranges.

The LBL transponder positioning mode is a flexible and simple solution for many applications. The drawback is the speed. Both the ranges and the request to measure are sent on telemetry and the master transponder measures only one range at a time. The time used for a sequence depends on the number of slave transponders used, and if there are timeouts on the replies from the slaves. The positions may be updated as fast as once every 12 seconds, though more time may well be required, resulting in a slower update rate (*faster with Cymbal*).

Geographical calibration

The geographical calibration requires that you position the vessel in local LBL coordinates and that APOS reads the vessel position from a DGPS receiver simultaneously. An LBL position and a DGPS position, logged simultaneously, are named a position pair.

When logging the position pair, the vessel should be drifting to avoid noise and air bubbles from the thrusters and propellers disturbing the LBL measurements. 8 to 10 position pairs should be logged while the vessel is drifting in one position, then the vessel should be moved to another position and a new 8 to 10 position pairs should be logged. This procedure should be repeated at many positions, evenly distributed, in the area covered by the transponder array. Do not log only while located in the centre of the area as that will give a high uncertainty for the rotation of the local north axis.

When logging position pairs, attention should be paid to the ranges measured and the range residuals calculated. The best results are achieved when the position pairs are logged when many ranges are measured correctly and their residuals are small.

When enough position pairs are logged, the geographical calibration calculation is performed. Some position pairs will often have larger distance residuals than the others. In that case, you may exclude some of the position pairs with the large distance residuals and repeat the calculation. When performing the exclusions, be aware that the position pairs used in the calculation should be evenly distributed in the area.

SSBL PRINCIPLES OF OPERATION

For Super-Short Base Line (SSBL) information please refer to the *HiPAP®/HPR 400 Product description* - section in the APOS HiPAP®/HPR 400 Instruction manual.

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Product description

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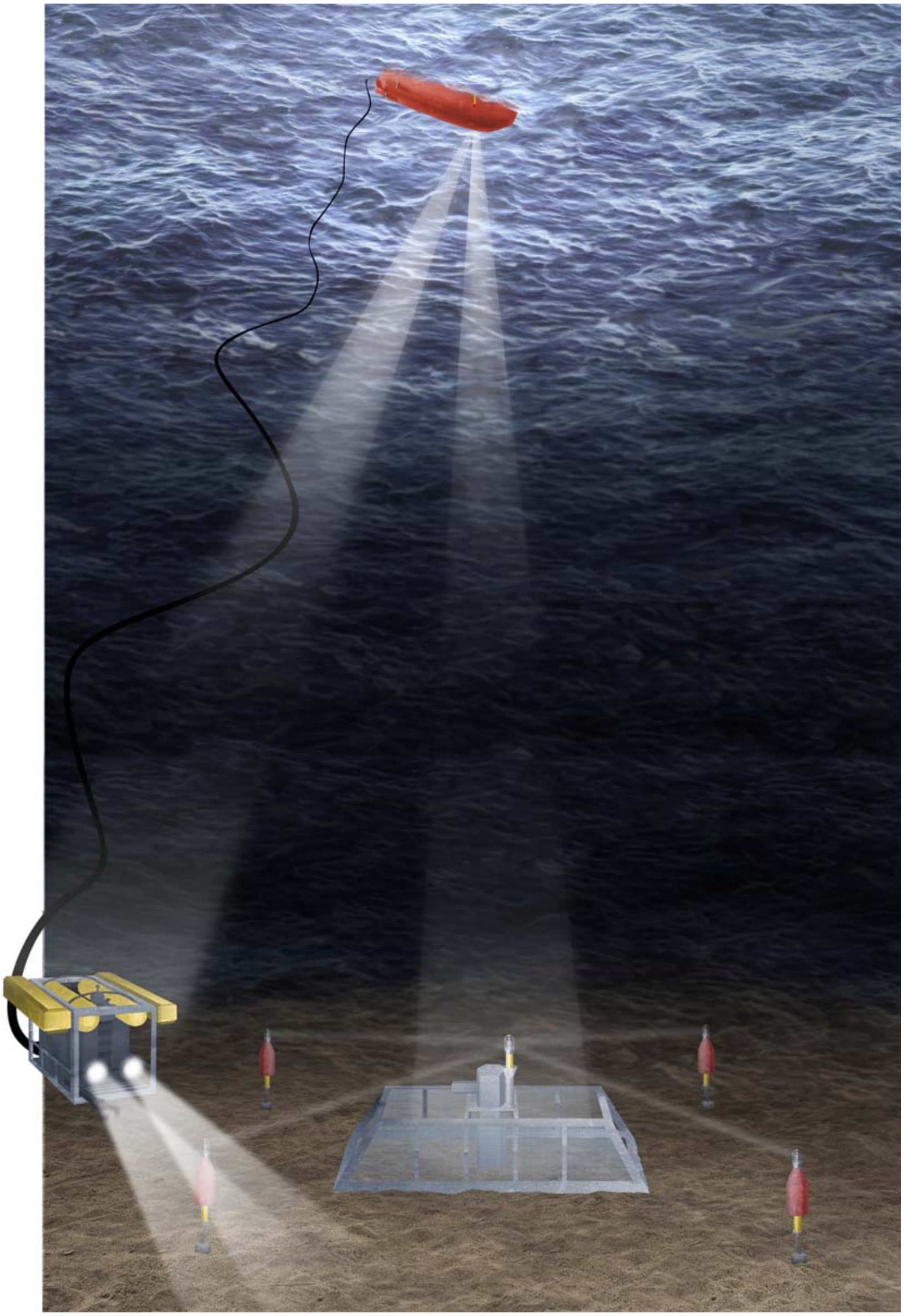
HiPAP®

High precision Acoustic Positioning
Model 501/451/351/101



HiPAP®

High Precision Acoustic Positioning

Model 501/451/351/101

This document describes the High Precision Acoustic Positioning (HiPAP®) systems. The HiPAP® systems are designed for optimal positioning of subsea objects in both shallow and deep water.

The HiPAP® systems have four different models.

The HiPAP® systems use both Super Short Base Line (SSBL) and Long Base Line (LBL) positioning techniques.

Document history

Rev	Date	Written by	Checked by	Approved by
F	18.01.2013	JEF/AJ	SER	JEF
	Removed APC information. Updated drawings.			

Disclaimer

Kongsberg Maritime endeavours to ensure that all information in this document is correct and fairly stated, but does not accept liability for any errors or omission.

Warning

The equipment to which this manual applies must only be used for the purpose for which it was designed. Improper use or maintenance may cause damage to the equipment and/or injury to personnel. The user must be familiar with the contents of the appropriate manuals before attempting to operate or work on the equipment. Kongsberg Maritime disclaims any responsibility for damage or injury caused by improper installation, use or maintenance of the equipment.

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KONGSBERG

Contents

1 ABOUT THIS DOCUMENT

1.1 Contents

This document covers the complete HiPAP® Model 501/451/351/101 systems. It provides a general description of the systems, each module, the functions and technical specifications. It also includes outline dimension drawing of the main units.

1.2 List of abbreviations

ACC	Acoustic Control Commander
ACS	Acoustic Control Subsea
APOS	Acoustic Positioning Operator Station
AUV	Autonomous Underwater Vehicles
BOP	Blow Out Preventer
DP	Dynamic Positioning
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HiPAP®	High Precision Acoustic Positioning
LBL	Long Base Line
MPT	Multifunction Positioning Transponder
MST	Mini SSBL Transponder
MULBL	Multi-User Long Base Line
ROV	Remotely Operated Vehicle
SPT	SSBL Positioning Transponder
SSBL	Super Short Base Line

2 HIPAP® SYSTEM – SHORT DESCRIPTION

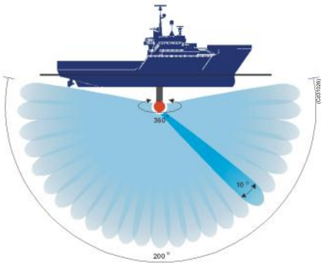
2.1 Systems

The HiPAP® systems are designed to provide accurate positions of subsea objects such as Remotely Operated Vehicles (ROVs), autonomous underwater vehicles (AUVs), towed bodies or fixed seabed transponders. To achieve the accuracy, the HiPAP® system uses unique signal processing techniques. This technique enables narrow transmitter and receiver beams to be generated in all directions within the lower half of the transducer using electronic beam control.
The HiPAP® Model 501/451/351/101 systems are the second generation HiPAP® systems. These models have a new transceiver unit and a new signal processing algorithms for Cymbal processing.
Cymbal is KM’s new acoustic protocol for positioning and communication.

All HiPAP® systems; HiPAP® 501, HiPAP® 451, HiPAP® 351 and HiPAP® 101 have common software and hardware platforms, and thereby offer the same kind of additional functionality and options.

- The HiPAP® 501, HiPAP® 451, HiPAP® 351 systems are medium frequency systems operating from 21 kHz to 31 kHz.
- The HiPAP® 101 system is a low frequency system operating from 10 kHz to 15.5 kHz.

HiPAP® 501

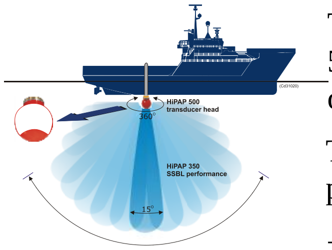


The HiPAP® 501 has a full spherical transducer body including 241 transducer elements. This model has close to full accuracy in the half sphere sector and is the preferred system where the best possible performance is required. The HiPAP® 501 can also track targets above the half sphere sector.
The use of *very narrow beams* provides:

- High accuracy
- Long range capabilities
- Good noise reduction capabilities
- Good multipath suppression

The HiPAP® 500 transducer has a diameter of 392 mm and will be installed with the 500 mm gate valve.

HiPAP® 451



The HiPAP® 450 transducer is the same unit as the HiPAP® 500 transducer. The system has Transmitter/Receiver boards for only 46 elements, similar to the HiPAP® 351 system.

The HiPAP® 451 system has the same operational and technical performance as the HiPAP® 351 system.

→ *Refer to HiPAP® 351 system description on page 4.*

The HiPAP® 451 uses the same hull units as the HiPAP® 501.

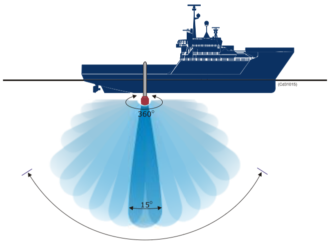
→ *Refer to HiPAP® 501 system description on page 3.*

Upgrade to HiPAP® 501

The HiPAP® 451 can be upgraded to full HiPAP® 501 performance. This is done by:

- Insert 6 additional Transmitter / Receiver Boards in the transceiver unit which is fully prepared for this.
- APOS software upgrade.

HiPAP® 351

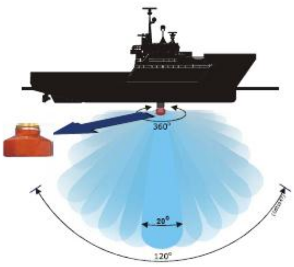


The HiPAP® 351 has a spherical transducer with a cylindrical body including 46 transducer elements. This model has good accuracy in the ± 60º sector and is suited for operations where the major positioning objects are within this sector. The total coverage is ± 80º.
The use of *narrow beams* provides:

- High accuracy
- Long range capabilities
- Good noise reduction capabilities
- Good multipath suppression

The HiPAP® 350 transducer has a diameter of 320 mm and it will be installed with a 350 mm gate valve. Installing the system with a 500 mm gate valve, will enable an easy upgrade to a HiPAP® 501 system.

HiPAP® 101



The HiPAP® 101 has a planar transducer array with a cylindrical body including 31 transducer elements. This model has good accuracy in the ± 60º coverage sector and is suited for operations where the major positioning targets are within this sector.
The HiPAP® 100 transducer has a diameter of 452 mm and will be installed with the 500 mm gate valve.

2.2 Operating modes

- **SSBL** - Positions various targets by directional and range measurements, using a unique processing technique that provides very high accuracy.
- **LBL** - Positions the surface vessel by simultaneously use of combined directional and range measurements to transponders in an LBL array.
- **MULBL** - Positions the surface vessel in an MULBL transponder array.
- **Telemetry** – acoustic communication to:
  - transponders for LBL calibration, metrology
  - measurements and set-up
  - Instrument units and BOP systems.

2.3 APOS

The HiPAP® system is operated from the APOS, which is a Windows based software used to operate the HiPAP® system. The system can be operated from one single APOS station or from a wide number of APOS operator stations connected on a network.

2.4 Sensors

The HiPAP® system has a wide range of interfaces to sensors from different manufacturers.

The HiPAP® system needs high accuracy heading, roll and pitch sensors to be interfaced.
The accuracy of the sensors has direct impact on the position. Examples of search sensors are Seapath and MRU.

3 SYSTEM CONFIGURATIONS

3.1 HiPAP® systems

A HiPAP® system may be configured in several different ways, from a single system to a redundant system with several operator stations. Some configurations are described below.

→ *See the system diagrams with all types of transducers on pages 9, 10 and 11.*

There are two different transceiver types and several different hull units available. The HiPAP® x81 transceiver unit can be used for all HiPAP® transducers, while the compact HiPAP® x21 transceiver unit can be used for HiPAP® 351 and HiPAP®101.

3.2 Single HiPAP® system

The single HiPAP® system has one transceiver and hull unit, but it may have one or more operator stations.

→ *See the system diagram on pages 9 and 10.*

3.3 Redundant HiPAP® system

The redundant HiPAP® system has two or more operator stations and two or more transceivers and hull units. All transceivers are accessible from all operator stations. The redundant system will operate with 2 transponders, one on each transducer, or two LBL arrays. The redundant system shall still be operational after one single failure in the system.

→ *See the system diagram on page 11.*

3.4 Dual HiPAP® system

A dual system applies for the HiPAP® 501 only. HiPAP® is designed to operate two sets of transceivers / transducers, both operated from the same operator station(s).

→ *See the system diagram on page 11.*

The dual system uses both transducers to measure the position of one single target (transponder / responder) by controlling beam forming and directional measurement separately for each system in parallel. This means that both systems will measure and calculate a position for the same reply pulse from the transponder.

If the signal is lost due to noise or air bubbles on one of the transducers, it may still be possible to receive it on the other one.

A position estimator will use the position information from both systems to estimate one optimal transponder position. Each system calculates a variance for its measurements, determined from the known system accuracy and the standard deviation of the measurements. The position estimator receives the position and the variance from the two systems, and calculates the weighted mean of the two positions. The variances are used as the weights.

The quality control function uses variance data, standard deviation and position difference to perform a quality control of the position. If the variance and the position difference are outside a pre-set limit, a warning will be displayed for the operator.

For the dual configuration, a synchronisation line between the transceivers is required.

The following paragraphs indicate the benefits of a dual system:

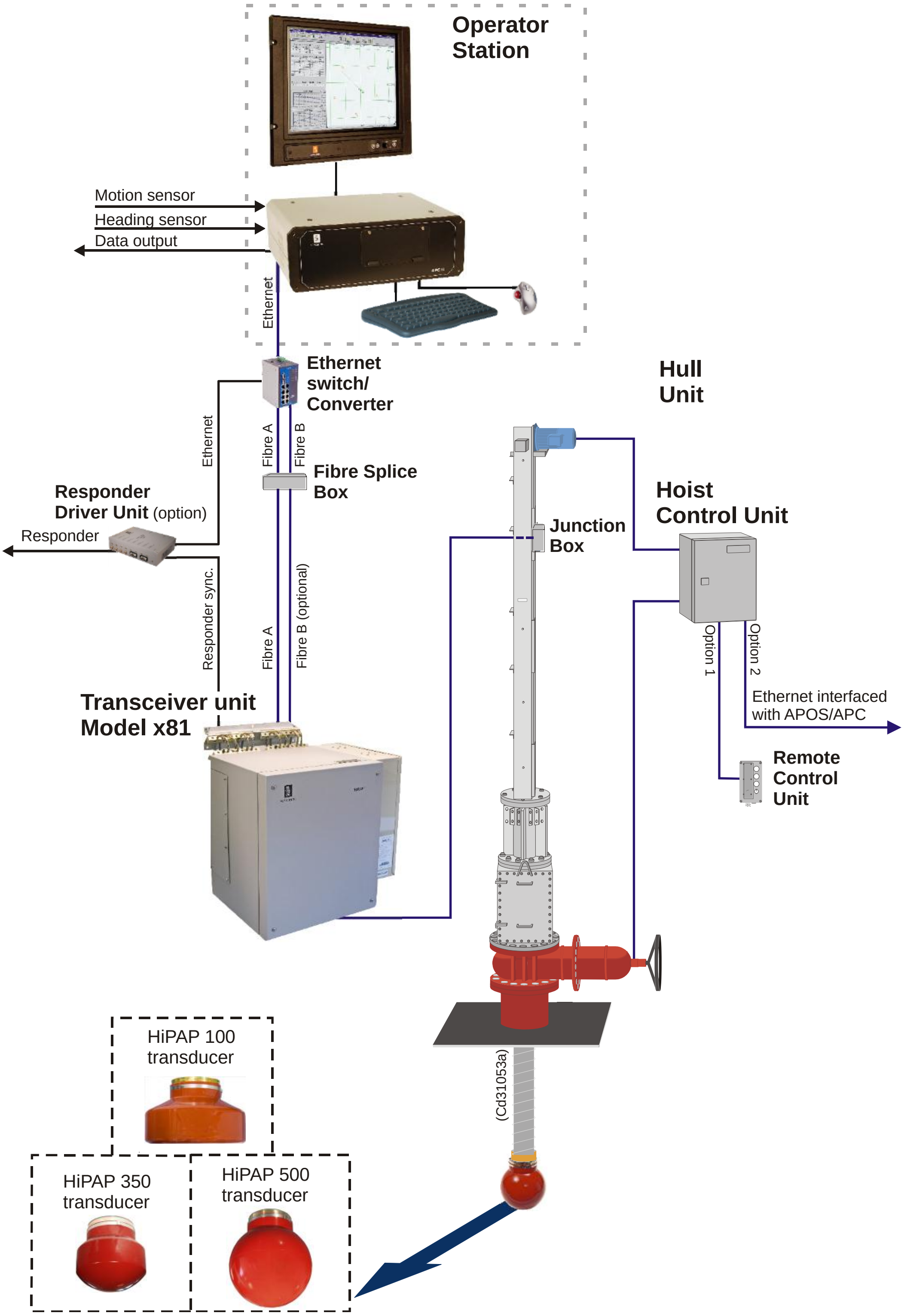
Accuracy improvement

The improvement factor from 1 to 2 transducers is $\sqrt{2}$. This is based on the statistical improvements when using two independent systems.

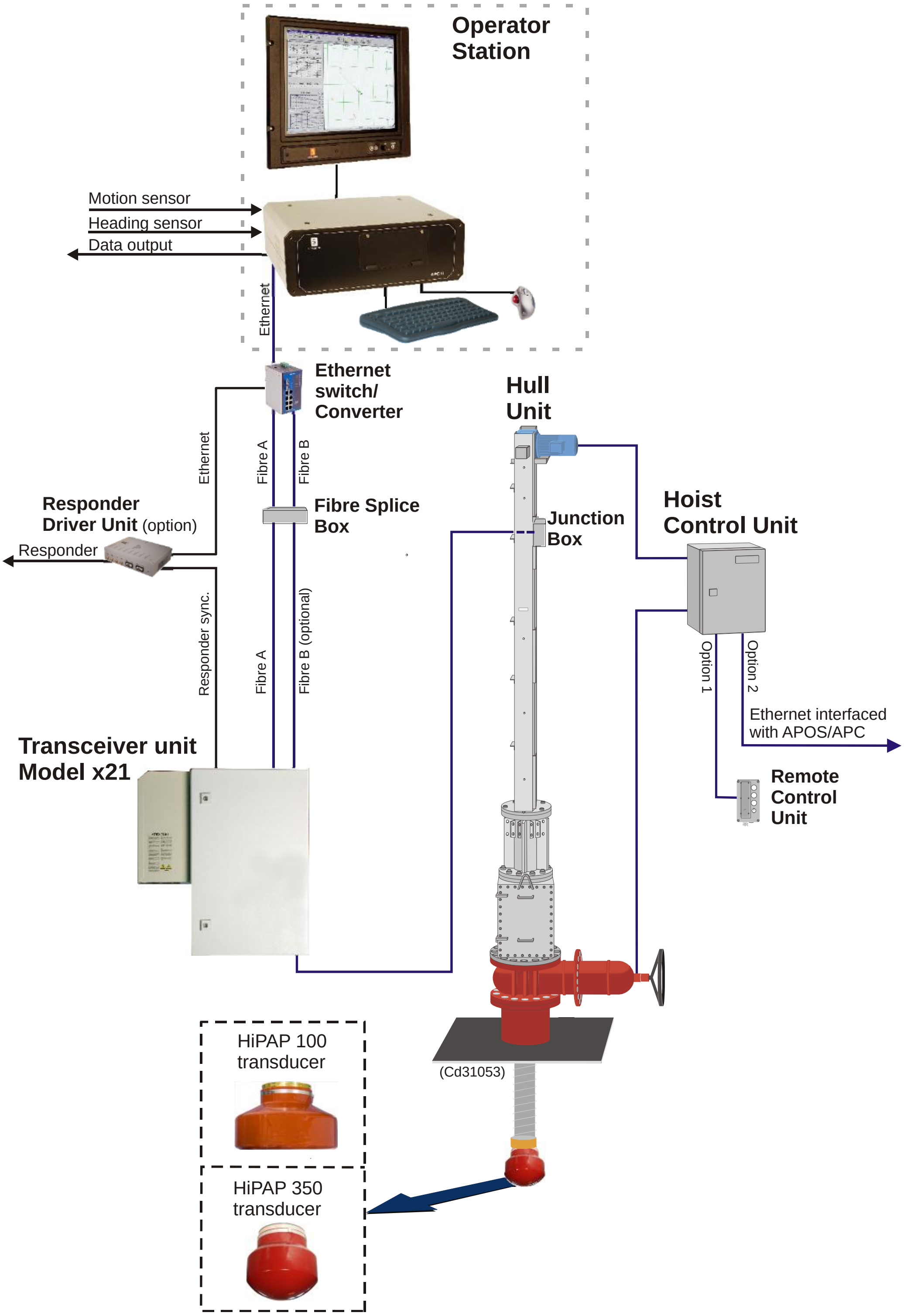
Redundancy improvement

The two transducers will normally be installed at different locations onboard. One transducer may then have a better location with respect to noise environments and reflections than the other. The computed position will be a weighted mean of these two measurements, if one of the systems fails to receive a reply, the other system may still receive it and the position will still be computed.

HiPAP with Transceiver unit Model x81

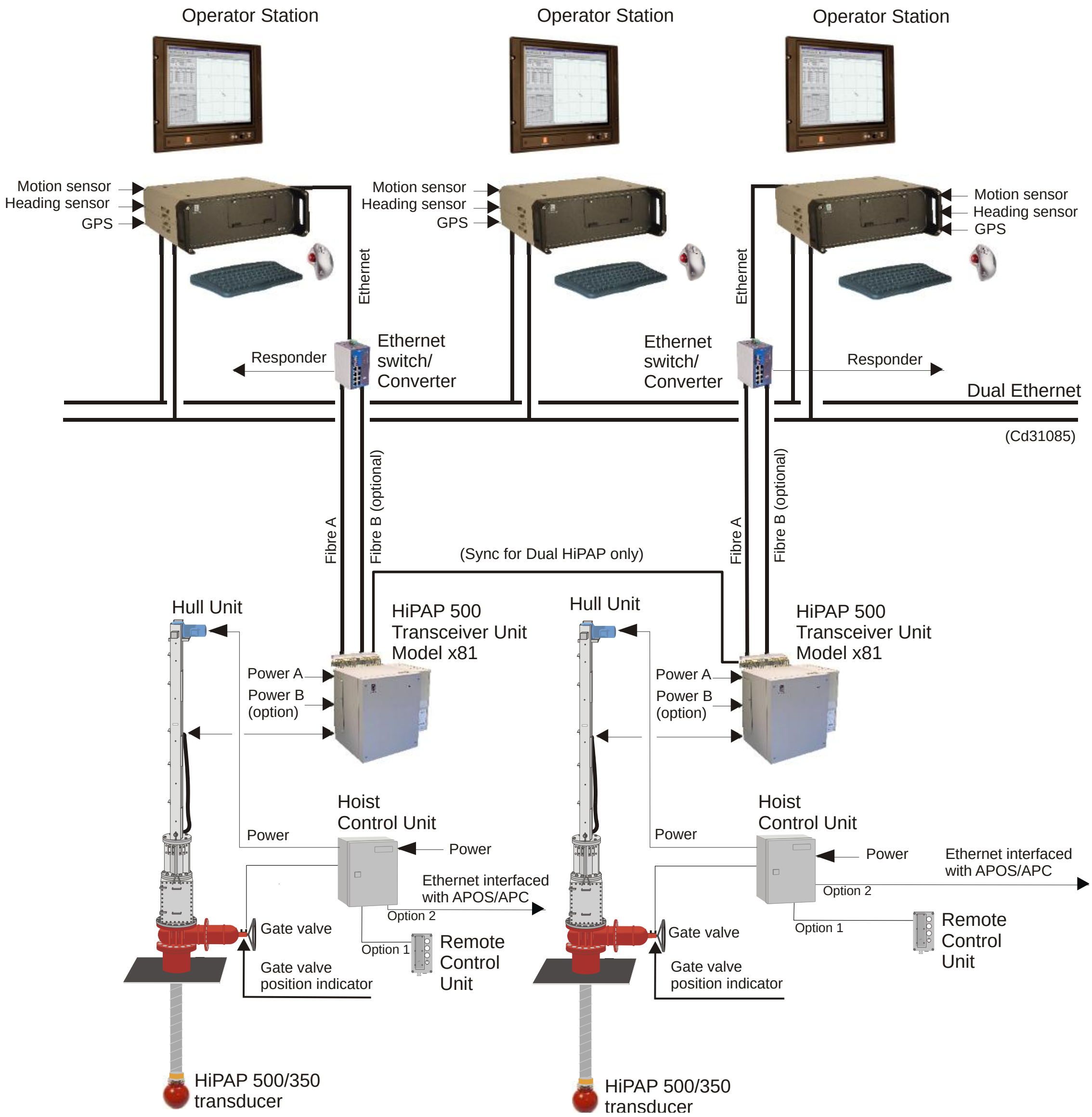


HiPAP with Transceiver unit Model x21



HiPAP redundant system

This illustration shows an example of a HiPAP redundant system.



4 SYSTEM FUNCTIONS

A HiPAP® system consists of a wide range of functions. A function is selected by the operator. The basic systems have standard functions included, to ensure normal operation. The systems may be delivered with additional options selected from the system option list.

4.1 Main functions

The main functions in the HiPAP® system are described below. The system may be configured with one or several of these functions. They will appear in the systems main menu.

List of main functions

The list below shows which functionality each of the function includes. The "Reg. No." (Registration Number) is the unique identification for this function.
Example; the Reg. No. for APOS Base version is 886 - 212745.

HiPAP® system software

Description	**Reg. No.**
APOS Base Version Base for running all applications, including: • Sound velocity profile function • Ethernet interface for position data • Serial line, RS-422 for transceiver interface • Serial line, RS-422 for position data Transponder telemetry for SPT/MPT transponders including: • Set transmit power level • Set receive sensitivity • Set Pulse length • Change channel • Enable/Disable	886-212745

Description	Reg. No.
• Transponder release • Read battery status • Read sensor data Position and angle alarm APOS software for HiPAP® or HPR 400 providing alarm for transponder position and riser angle alarm APOS Depth sensor interface APOS software for interfacing a depth sensor for depth compensation of position. Suitable for ROV or Tow fish positioning GNSS Interface APOS software with interface to GNSS for geographical data on transponders and vessel positions. Also used for SSBL and LBL array calibration. The APOS clock may be synchronised to 1PPS from the GNSS receiver. HiPAP® - Emergency channels A&B The HiPAP® transceiver can use emergency channels A and B used on diving bells. Position and angle audible alarm APOS software for HiPAP® providing alarm for transponder position and riser angle alarm. Gives an audible alarm using the PC sound output. An external PC loudspeaker is required.	
HiPAP® 501 SSBL function NOTE: Export license is required. APOS software for HiPAP® SSBL operation including: • Transponder positioning • Responder positioning • Serial interface for gyro and VRU or attitude sensor (maximum 3 units total) • SSBL simulator for training	886-212746

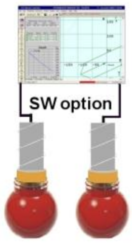
<table>
<tr><th>Description</th><th>Reg. No.</th></tr>
<tr><td>HiPAP® 451 SSBL function
NOTE: Export license is required.
APOS software for HiPAP® 450 SSBL operation including:
Transponder positioning
Responder positioning
Serial interface for gyro and VRU or attitude sensor (maximum 3 units total)
SSBL simulator for training
Upgradeable to full HiPAP® 501 SSBL function by installing software functions in existing operator station and controller and hardware units as described below.</td><td>886-220734</td></tr>
<tr><td>HiPAP® 351 SSBL function
NOTE: Export license is required.
APOS software for HiPAP® SSBL operation including:
Transponder positioning
Responder positioning
Serial interface for gyro and VRU or attitude sensor (maximum 3 units total)
SSBL simulator for training</td><td>886-214927</td></tr>
<tr><td>HiPAP® 101 SSBL function
NOTE: Export license is required.
APOS software for HiPAP® SSBL operation including:
Transponder positioning
Responder positioning
Serial interface for gyro and VRU or attitude sensor (maximum 3 units total)
SSBL simulator for training</td><td>334043</td></tr>
</table>

Description	Reg. No.
HiPAP® 351P SSBL function NOTE: Export license is required. APOS software for HiPAP® SSBL operation including: • Transponder positioning • Responder positioning • Serial interface for gyro and VRU or attitude sensor (maximum 3 units total) SSBL simulator for training	356186
HiPAP® Cymbal acoustic protocol function New acoustic protocol used for both positioning of subsea transponder in SSBL/LBL modes and data communication to and from transponders. The Cymbal technology utilizes Direct Sequence Spread Spectrum (DSSS) signals for positioning and data communication. The data communication speed is variable and can be adapted to the acoustic communication conditions; noise and multi-path. DSSS is a wide band signal. Due to the higher energy in its acoustic pulses the Cymbal protocol provides: • Higher position accuracy • Extreme accurate range measurements • Longer range capabilities • Higher data rate communication	347211

Description	**Reg. No.**
LBL function APOS software for Long Base Line operation using HPR 408/418 or HiPAP®, including: • Calibration of transponder array in local grid • Positioning of vessel/ROV in LBL array • Necessary transponder telemetry • LBL simulator for training • Geographical position output if transponder locations/origin are entered in geo co-ordinates This function requires that the system already has the "APOS Base Version", reg. no: 212745 and "HiPAP® SSBL function" Reg. No.: *Dependant on model.* Positioning of an ROV in LBL requires an HPR 400S unit. NOTE: Requires export license.	886-212748
HiPAP® MULBL function APOS software for HiPAP® MULBL operation including: • Calibration of transponder array in local grid • Positioning of vessel in MULBL array • Necessary transponder telemetry • Setting of fast LBL update rate through the master transponder This function requires that the system already has both the HiPAP® SSBL and LBL functions, Reg. No.: 212746 and 212748	886-212750
MULBL transponder array data APOS files containing transponder array data for MULBL	886-212751

Optional HiPAP® system functions

Description	**Reg. no**
Beacon Mode APOS software for HiPAP® or HPR 400 beacon and depth beacon operation	886-212752

Description	Reg. no
Inclinometer Mode APOS software for HiPAP® or HPR 400 inclinometer transponder operation	886-212753
Compass Transponder Mode APOS software for HiPAP® or HPR 400 compass transponder operation	886-212754
GEO LBL Calibration APOS software for HiPAP® or HPR 400 for calibration of LBL array in geographical co-ordinates. In positioning mode the position may be reported in geographical co-ordinates.	886-212755
LBL Transponder Positioning mode APOS software for HiPAP® or HPR 400 for use of MPT transponders to be positioned in an LBL network. (old name was "Transponder Range Positioning") This mode requires that the system already has the LBL function: 212748	886-212757
SAL Reference APOS software for HiPAP® or HPR 400 for calculation displaying a vessel's distance (numeric value) relative to a known coordinate in a UTM coordinate system.	334053
Dual HiPAP® Increased SSBL Accuracy function APOS and HiPAP® software for enabling increased SSBL accuracy in dual HiPAP® configurations. Provides simultaneous measurement of transponder position by use of two HiPAP® transducers. Provides two separate and one integrated position Requires two complete HiPAP® transceivers/ transducers, and HiPAP® SSBL function	886-212758 
APOS Additional Operator Station Function Software and hardware for allowing several Operator Stations for HiPAP® and HPR 400 systems.	886-212759
APOS Upgrade software Upgrade from HSC400 software to APOS software, including old functionalities. This upgrade may require a new monitor and a new computer and keyboard (will be additionally priced).	886-212760

Description	Reg. no
APOS External synch APOS software for synchronising HiPAP® or HPR 400 transceivers to external equipment.	886-212761
APOS ACS BOP function APOS software in the HPR or HiPAP system for telemetry to ACS 4xx / ACS 3xx system used on BOP. Telemetry to ACS 300 only available on HPR 400 systems.	886-212765
APOS ACS OLS function APOS software for telemetry to ACS 300 system used on OLS. Telemetry to ACS 300 only available on HPR 400 systems.	886-212766
APOS STL function APOS software for HiPAP® or HPR 400 systems for STL fields special functions including: • Scanning of up to 9 MLBE depth and position • Positioning of STL buoy • Scanning of transponder battery status • Graphics showing STL connection point	886-212767
HiPAP® Transponder Relay Function Enables use of relay-function, relay-transponder frequency allocation, operator interfaces and displays functionality.	886-215837
SAL Tension & Yoke monitoring For Single Anchor Loading stations. APOS software HiPAP® or HPR 400 systems for showing Tension and Yoke including: • Graphical presentation of yoke-angle • Graphical presentation of tension • Table for converting inclination angle to tension (this option is field dependent).	886-215939
APOS Field transponder array data APOS files containing transponder array data for offshore loading fields. Price is per upgrade.	886-212768

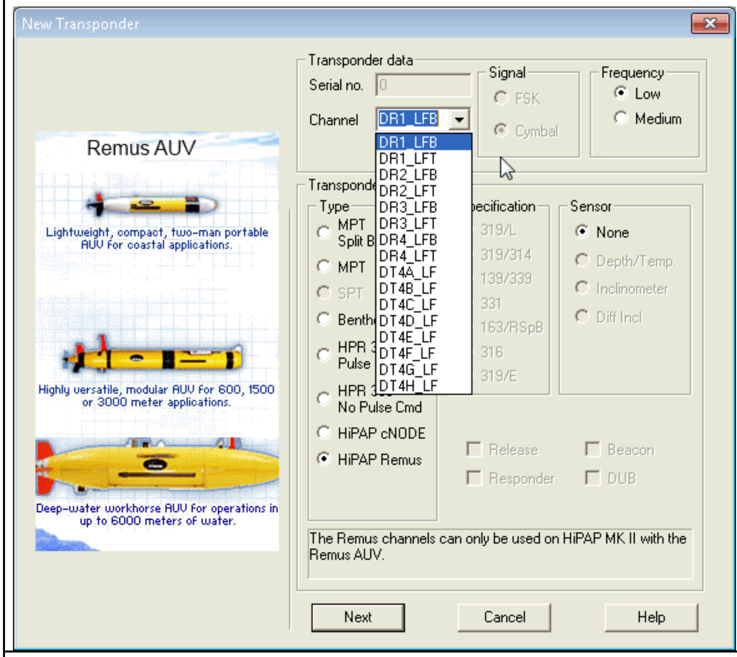
Description	Reg. no
APOS Remus SSBL Function APOS software for HiPAP® SSBL positioning of REMUS AUV transponders. This function requires that the system already has both the HiPAP® SSBL function (reg. no.: 212746 or 886-214927 or 886-220734 or V101010) and the HiPAP® Cymbal acoustic protocol function (Reg. No.: 347211).	356185
APOS Trainer - HiPAP® The product is suitable for training, planning and demonstration purposes and consists of: A CD containing full APOS software with all options except OLS. Defined with one HiPAP® and one HPR 400 transceiver. APOS Instruction Operating Manual 319957 (one binder of paper). Includes Sound velocity ray-trace calculation and displaying of deflection based on velocity profile input. Includes Long Base Line array planning tool. Includes data output for testing telegram interfaces to external computers (transmits standard HPR/HiPAP® telegrams). The APOS can be operated as a normal HiPAP® and a simulator replaces transceiver and transponders. The program requires a computer with CD-ROM player, a running Windows NT / Windows 2000 / Windows XP program, a monitor with minimum 800x600 resolution, a network card, and a TCP-IP protocol needs to be defined.	881-217543

<table>
<tr><th>Description</th><th>Reg. no</th></tr>
<tr><td>

APOS Remus SSBL LF Function

APOS software for HiPAP® SSBL positioning of REMUS AUV transponders. This option is for positioning Remus low frequency wide band transponders.

This function requires that the system already has both any of the HiPAP® SSBL functions (for HiPAP 101) and the HiPAP® Cymbal acoustic protocol function.



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APOS Benthos SSBL LF Function

APOS software for HiPAP® SSBL positioning of Benthos low frequency transponders. The interrogation is 16kHz and the transponder replies are 7.5-12.0kHz with 0.5kHz step.

This function requires that the system already has both any of the HiPAP® SSBL functions (for HiPAP 101) and the HiPAP® Cymbal acoustic protocol function

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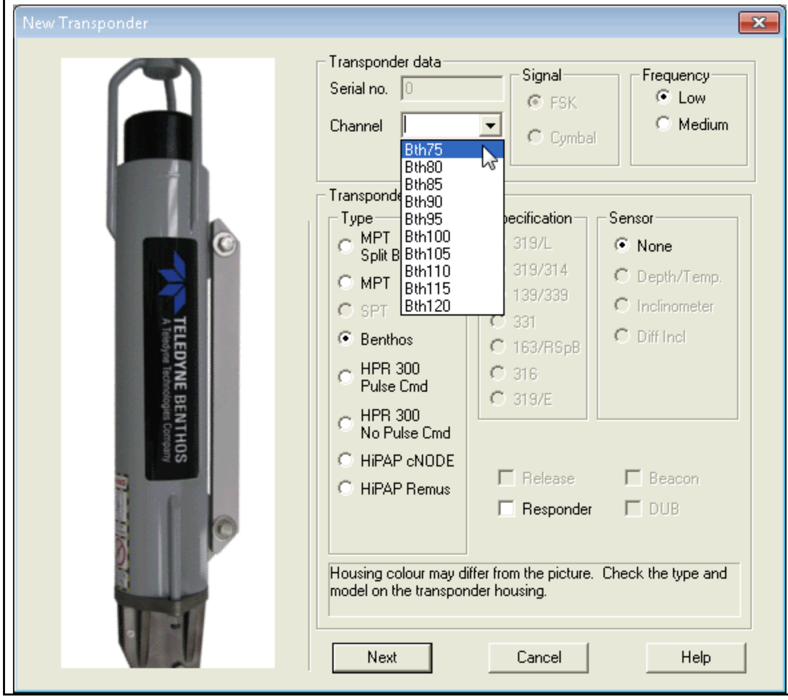
Description	Reg. no
	

5 SYSTEM UNITS

A HiPAP® system consists of the following main units:

- Operator station
- Transceiver unit
- Hull unit with transducer and hoist control
- Gate valve and mounting flange

Each transducer requires a dedicated hull unit arrangement and transceiver unit. One operator station can control several transceiver units.

5.1 Operator station

The HiPAP® system is operated from one or several operator stations, depending on the actual system configuration. The operator station is identical for all HiPAP® models. One station can operate several HiPAP® transducers and of various types.

The Operator station comprises of:

- Computer
- Keyboard
- Trackball
- Display

The computer runs on the Microsoft Windows operating system. The user interface is a graphical user interface, designed as a standard Windows application.
A Keyboard and trackball is used to operate the system.
The screen is divided into 3 windows in which the operator can select several different views. Typical views are graphical position plot, numerical data, inclination and roll, pitch and heading. A normal display configuration is shown in the following figure.
One system may have one or several operator stations, which communicates on an Ethernet. One of the operator stations will be the Master. This is selected by the operator(s).

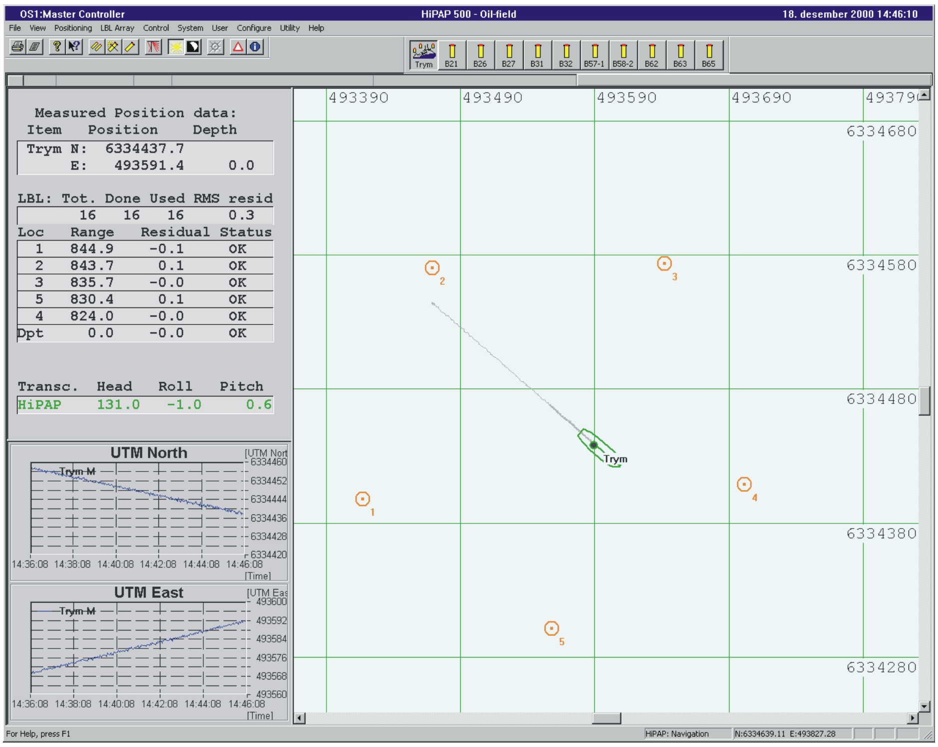


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Figure 1 APOS presentation

Operator Station configuration

A HiPAP® system may be configured with the Operator Station in two ways:

- Stand-alone computer, monitor, keyboard and trackball.
- Operator console, integrated with the Dynamic Positioning (DP).

Standard operator station

Computer

The HiPAP® Operator Station contains computer hardware as processor, hard drive, DVD-RW player and external interface boards. The computer is continuously being updated with new hardware.

The computer may be mounted on a desktop attached to the colour monitor, or in a 19” rack.

Display
The colour display, the flat-screen 19” TFT is a general purpose, micro-processor based and digitally controlled display unit. The display can be installed in several ways; desktop, roof, panel or 19” rack.

Keyboard
The keyboard is a PS/2 keyboard. It has US layout and includes back-lighting. The keyboard can be mounted on the computer or be placed on a desktop.

Trackball
A standard off the shelf unit is used.

Operator console

If the HiPAP® system is delivered together with a Kongsberg DP system the operator station may be a standard Kongsberg DP console.

5.2 Ethernet switch/Converter

The Ethernet switch/Converter has the following functions:

- Interface Optical fibre to transceiver
- Responder Driver Unit
-

5.3 Fibre Splice Box

Fibre Splice Box with up to eight (8) ports. This box is used to splice the system fibre-optic cable.

5.4 Transceiver units

Two types of HiPAP® transceiver units are available:

1 HiPAP® x81 Transceiver Unit, for HiPAP® 501, 451, 351 or 101

2 HiPAP® x21 Transceiver Unit, for HiPAP® 351 or 101

The transceiver models have identical function. The x21 can be used for HiPAP® 351 and HiPAP® 101, while x81 can be used for all models. The unit contains power supplies, transmitter and receiver boards and interface to the optical fibre link.

The unit is designed for bulkhead mounting close to the hull unit.
The transceiver units are equipped with different filter boards for HiPAP® 100 and HiPAP® 501/541/351.

5.5 Responder Driver Unit (option)

The Responder Driver Unit provides responder trigger signals to responders.
The unit can be used for HiPAP® transceiver unit x81 and x21.
The Responder Driver Unit is a stand-alone unit.
The unit is interfaced to the HiPAP® system via an Ethernet, and to the HiPAP® transceiver unit for sync. The APOS controls which drive is being active while the sync/timing is received from the HiPAP® transceiver.

5.6 Transducers

HiPAP® 500 transducer

The HiPAP® 500 transducer has a full spherical transducer body including 241 transducer elements, the elements covers its entire surface area except for a small cone around the ”north-pole”. The large number of elements enables narrow receiver beams to be generated. The transducer is mounted on the hull unit.

HiPAP® 450 transducer

The HiPAP® 450 transducer is the same unit as the HiPAP® 500 but only the 46 lower sector elements of the sphere are “activated” and in use.

HiPAP® 350 transducer

The HiPAP® 350 transducer has a spherical transducer with a cylindrical body including 46 transducer elements, the elements covers its' +/- 60° cone pointing downwards. The large number of elements enables narrow receiver beams to be generated. The transducer is mounted on the hull unit.

HiPAP® 100 transducer

The HiPAP® 100 transducer has a planar transducer array with a cylindrical body including 31 transducer elements. This model has good accuracy in the ± 60º coverage sector and is suited for operations where the major positioning targets are within this sector.

5.7 Hull units

The HiPAP® hull unit enables the transducer to be lowered, by either local or remote control, through the vessel's hull to a depth sufficient to minimise the effects of noise and air layers below the vessel. The hull unit is installed on top of a gate valve, which can be closed during maintenance (cleaning) of the transducer.
The hull unit also holds the guide-rail arrangement for keeping the transducer exactly aligned with the vessels reference line.

A complete specified HiPAP® hull unit depends on:

- **Type of transceiver unit**
- **Type of hull unit**
- **Type of transducer**

The following are available:

Type of transceiver unit (available types)	Type of hull unit (available types)	Type of transducer (available types)
Model x21 Model x81	HL 2180 HL 3770 HL 4570 HL 6180 (The numbers indicates the hoist length in mm)	HiPAP® 500/450 (same transducer) HiPAP® 350 HiPAP® 100

→ *An overview of available HiPAP assemblies, see table on page 57.*

A HiPAP® hull unit is equipped with the following sub units:

Gate valves

There are two different gate valves available, one with 500 mm aperture and one with 350 mm aperture. The valve is hand-wheel operated, delivered with electrical interlock for prevention of lowering the transducer into the gate.
As an option the gate vale can be delivered with an electrical actuator (electrical gate valve operation).

Mounting flange

There are two different flanges available one with 500 mm aperture and one with 350 mm aperture. Standard height is 600 mm. Optional length is available on request.

Hoist Control Unit

This unit holds the power supplies and control logic for the hoist and lower operation of the hull unit. It also has a local control panel for local control of the hoist / lower operation.

Hoist Control Unit with Ethernet interface

APOS and HiPAP® mk II support remote control of the Hull Unit Hoist and the Gate Valve. A new control unit for the hoist control and/or the gate valve is required. In addition this must be enabled in the HiPAP® program.

Remote Control Unit

This unit is normally mounted close to the display unit in the operation room. It allows remote control of the hoist and lower operation of the hull unit.

6 EXTERNAL INTERFACES

6.1 Position outputs

The HiPAP® system can be interfaced to other computers allowing them to process the position data for various applications. The system is flexible in the way it interfaces other computes. Several binary and ASCII formats are available on serial line and Ethernet using UDP protocol.
A dual Ethernet is available for secure DP operations.
An accurate time-tagged position output is available if the system is interfaced to a GNSS and synchronised to 1PPS.

→ *Refer to the NMEA 0183 sentences description on APOS online help.*

6.2 Surface navigation

The HiPAP® system can be interfaced to a surface navigation system. As standard the system uses Global Navigation Satellite System (GNSS). When GNSS is interfaced, a number of features will become available; UTM grid on display, UTM position of transponders, transducer alignment and geographical calibration of LBL arrays.

6.3 Motion Sensor Unit

The motion sensor unit is interfaced to the HiPAP® system transceiver unit. The system can thereby automatically compensate the transducer position, for the vessel's roll and pitch movements. The HiPAP® system can use the same as the Dynamic Positioning (DP) system (if one is fitted).
The sensor may or may not be a part of the Kongsberg Maritime delivery. In any case, the unit is documented separately by the applicable manufacturer.

6.4 Heading sensor

The heading sensor (gyro compass) provides the HiPAP® system with the vessel's heading relative to north. The HiPAP® system may then provide transponder coordinates relative to north. It is also used to update the position filter and tracking algorithms as the vessel changes heading.

6.5 Attitude sensors

These sensors integrate rate gyros, accelerometer and GPS to provide an accurate roll, pitch, heave and heading output. These sensors are superior to traditional gyros and motion sensor. The HiPAP® system may be interfaced to such sensors.

6.6 Interface specification

The HiPAP® system has several interface formats available. These are described in the *Attitude formats description* document.

→ *Refer to the Attitude formats description, on APOS online help.*

7 TRANSPONDERS

The position calculation is based on range and/or direction measurements from the onboard transducer to the subsea transponder(s). For the HiPAP® system, there is a wide range of transponders available. The various transponders models have different depth rating, source level, lifetime, beam pattern and function.

There are two main transponder series:

- cNODE® series which are using Cymbal acoustic protocol.
- MST series which are using traditional frequency shift (FSK) modulation technique

More details are described in section on page 40.

For details, please see the *Product Specification* for each of the transponder models.

7.1 cNODE® series

The cNODE® series consist of three main models:

- **Maxi transponder** - a full size transponder with large battery capacity well suited for seabed deployment and long life operation.
- **Midi transponder -** a short transponder with good battery capacity well suited for installation on structures etc.
- **Mini transponder** - a small sized transponder suited for ROV mounting.

The cNODE® transponders have a flexible design based on a standard housing which can have various transducers, release mechanism and sensor modules attached.

Maxi Midi Mini

7.2 MST series

The MST is an SSBL mini transponder suited for ROV operation and where the size of the transponder can be a limiting factor. The transponder models cover various water depths. The MST series consists of the following models:

- **MST 319** - rated for 1000 m water depth
- **MST 324** - rated for 2000 m water depth
- **MST 342** - rated for 4000 m water depth

All units have a rechargeable battery, can operate in responder mode and can also be externally powered.

(Cd6424b)

8 POSITIONING PRINCIPLES AND PROCESSING

The HiPAP® system uses two different principles for positioning; the SSBL and the LBL. These two principles have different properties that make the system flexible for different applications.

- The SSBL principle is based on a range and direction measurement to one transponder, while the LBL principle is based on range measurements to minimum three transponders on the seabed.
- The position accuracy in SSBL is proportional to the slant range to the transponder, while the LBL accuracy is determined by the geometry of the seabed transponders array and the vessel that is being positioned.
- The SSBL principle, due to its simple operation, is the obvious choice if the accuracy is good enough for the application performed. The LBL principle is the obvious choice if the SSBL accuracy is not good enough for the application performed, though it requires a more complex operation.
- Cymbal is a signal processing technique used for all positioning modes. Cymbal utilizes Direct Sequence Spread Spectrum (DSSS) signals for positioning and data communication. DSSS is a wide band signal. The Cymbal protocol provides new characteristics for both positioning and data communication.

8.1 SSBL positioning

In SSBL, the system calculates a three-dimensional subsea position of a transponder relative to a vessel-mounted transducer. The position calculation is based on range and direction measurements to one transponder. The onboard transducer transmits an interrogation pulse to a subsea transponder, which then answers with a reply pulse. When using a responder the interrogation is replaced by a hard wire trigger connection.

- The onboard system will measure the time from the interrogation to the reply pulse is detected and use the sound velocity to compute the range.

- The transponder position is presented both numerical and graphically on the operator station. Only one onboard SSBL type transducer is necessary to establish this position.

Using a pressure sensor in the subsea transponder can increase position and depth accuracy. The pressure is measured and transmitted to the surface HiPAP® system using acoustic telemetry. The depth is then used in the algorithms for establishing the 3D position. The system can also read the depth via a serial line input from a pressure sensor. Simultaneous use of many transponders is made possible by using individual interrogation and reply frequencies.

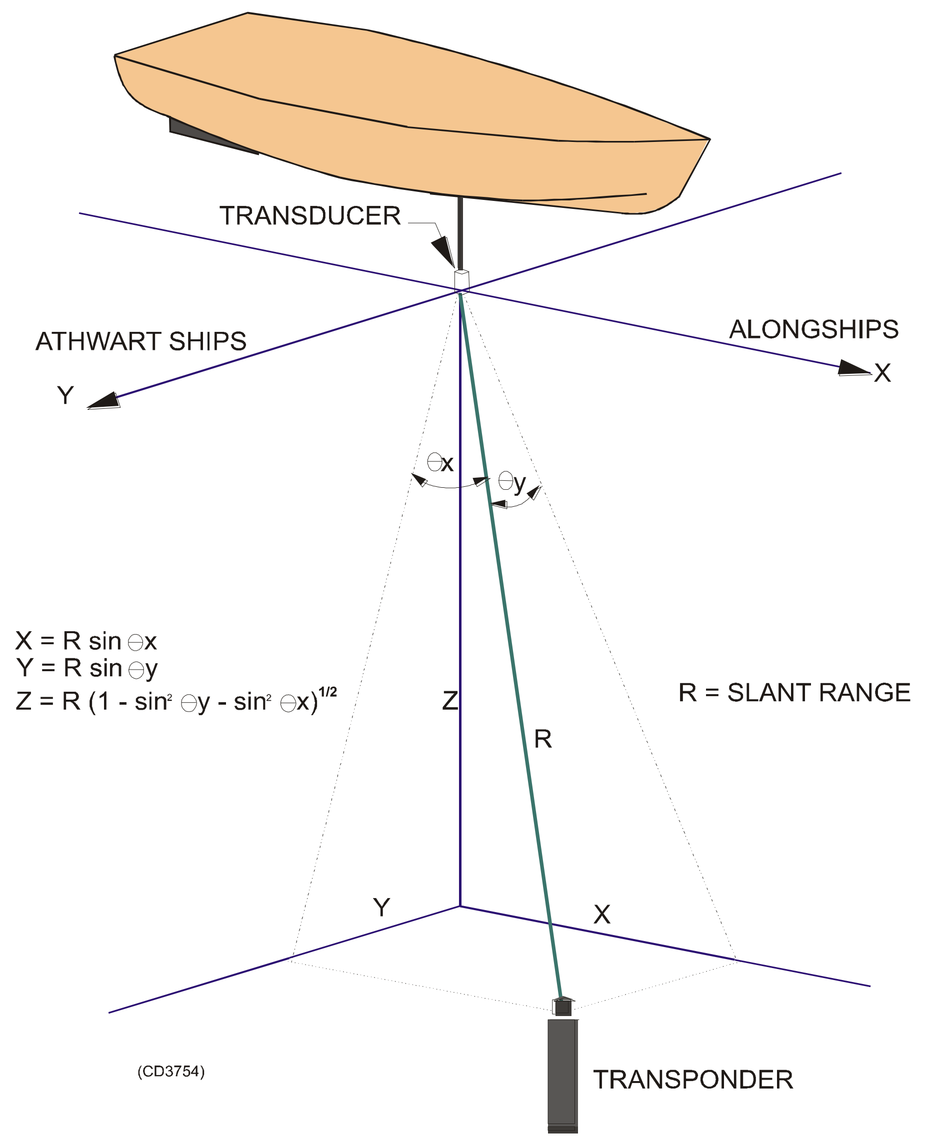

Figure 2 SSBL principle

8.2 LBL positioning

Calibration

The LBL principle is based on one vessel-mounted transducer, and normally 4 - 6 transponders on the seabed. This seabed transponder array must be calibrated before LBL positioning operations can begin. The calibration shall determine the transponder's positions in a local geographical co-ordinate frame.

The HiPAP® system supports two calibration techniques:

1. Baseline measurements
This technique uses automatic calibration functions in the HiPAP® system. This allows all the ranges to be measured and made available by acoustic telemetry communication between the transponders and the vessel's system. Based on the baseline measurements and initial positions of the transponders, the calibrated transponder positions are computed.

2. Runtime calibration
To use this technique, the system is run in LBL positioning mode, using the SSBL positions of the seabed transponders for the vessel LBL position calculation. The runtime calibration function logs the measurements. Based on this, new optimised seabed transponder positions will be computed. This technique makes the baseline measurements redundant. If the baselines measurements are done, they are also used in the calculations. The calibration is performed only once prior to positioning operation, since the transponders will remain in the same location during the operation.

Positioning

When the transponder positions are known, positioning of the surface vessel can begin. All the seabed transponders will be interrogated simultaneously, and each will respond with its specific reply signal. The LBL system will then calculate the ranges from the individual transponders. By using the calibration data together with the calculated ranges in software algorithms, the vessel or an ROV can be positioned. ROV positioning requires an HPR 400S transceiver to be mounted on the ROV.

- The system can take the depth from an ROV-mounted pressure sensor via a serial line. By using this depth in the computation, it will increase the position accuracy of the ROV.
- The range capabilities of a medium frequency LBL system will be approximately the same as those of an SSBL system.
- LBL positioning will give better position accuracy at greater water depths, but is more complex to operate, and it needs more transponders than the SSBL.
- LBL TP positioning method uses one transponder to measure the ranges to the transponders in the array and telemetry the data to the surface vessel, which computes the position of the transponder.

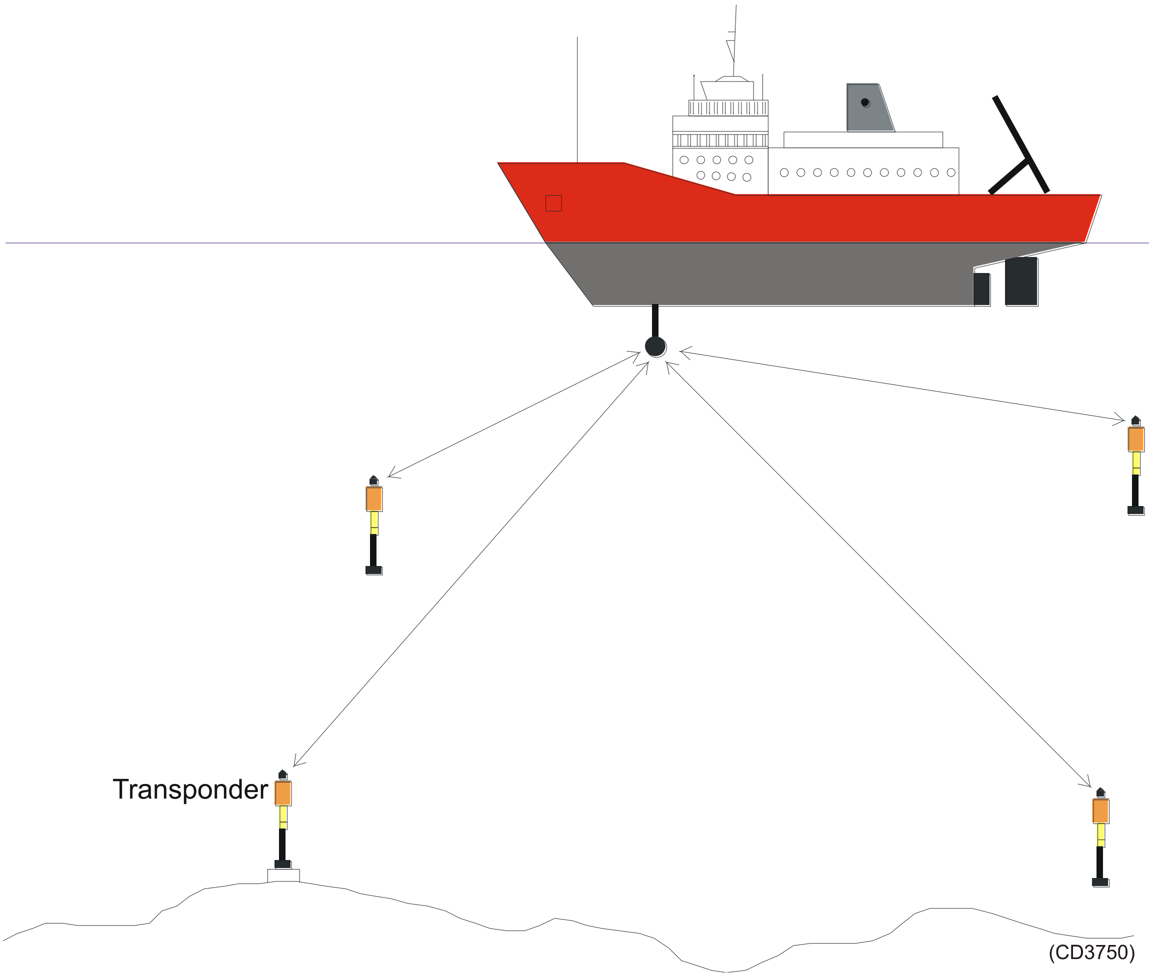

Figure 3 LBL principle

Multi-User LBL positioning

Several individual vessels and ROV units can now position themselves using the same seabed transponder array. The system and principle has the following main advantages:

- Provides high position accuracy
(comparable to standard LBL).
- A small number of transponders serve all vessels and ROVs.
- Secures high position update rate (down to approx. 2 seconds), which is essential in DP operations.
- Avoids transponder frequency collisions when vessels are working in the same area (all vessels are “listening” only).

A transponder array is deployed and calibrated by use of subsea baseline measurements. One transponder is used as the Master in the positioning phase. The other transponders are called the Slaves.
The Master transponder acts as a beacon. It starts a positioning sequence by doing the steps described below. This is done regularly with an interval set by telemetry from one of the vessels.

- The Master interrogates the Slaves.
- The Master transmits its individual transponder channel to be received by the vessels/ROVs positioning in the array.
- Each Slave transponder receives the interrogation from the Master and transmits its individual reply channels after a turnaround delay.

A MULBL system positioning in the array listens for the individual channels transmitted by the master beacon, and by the Slave transponders. When they are received, the system uses its knowledge about their positions in the TP array to calculate the differences in range to the transponders in the TP array. The time difference between the Master interrogation and the start of the reception of the pulses at the system is unknown. It has to be calculated together with the position of the vessel or ROV.
All vessels to use the MULBL array need the coordinates of the transponders and the channel numbers, which will be distributed of a file.

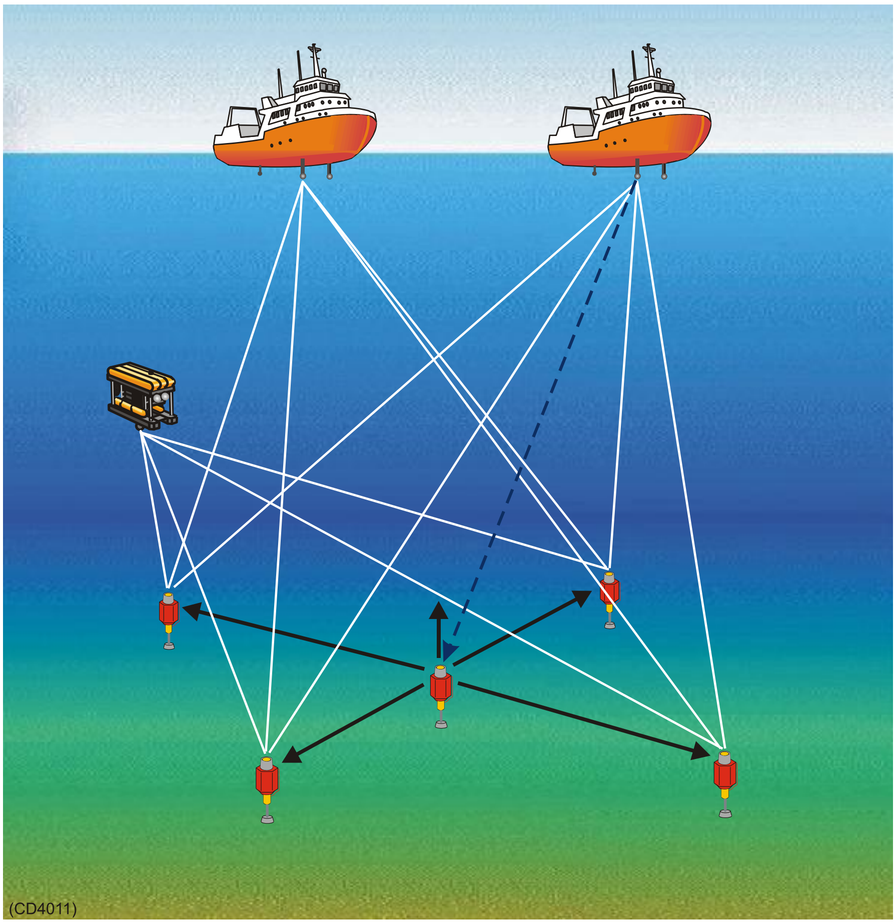

Figure 4 Multi-User LBL positioning

8.3 Combined SSBL and LBL positioning

The combined SSBL/LBL system uses an onboard multi-element transducer. The system may operate as an SSBL system and as an LBL system simultaneously.

As an example, the vessel may be positioned relative to the seabed using LBL while an SSBL transponder/responder on an ROV is positioned relative to the vessel. The vessel is displayed relative to the array origin and the ROV relative to the vessel.

The combined system will also use the measured directions in 2D together with the measured ranges in the LBL positioning. The combined measurement gives a robust system with increased accuracy. An LBL solution is achievable when only two transponder replies are detected.

8.4 HiPAP® processing

HiPAP® SSBL processing

- The HiPAP® system determines the position of a subsea target (transponder or responder) by controlling a narrow reception beam towards its location. The system uses a digital beam-former, which takes its input from all the transducer elements.
- The system uses a number of wide fixed beams to generate an approximate position for the target. Once this is achieved, it uses data from all the elements on the hemisphere facing the target to compute the narrow reception beam and optimise the directional measurement.
- The range is measured by noting the time delay between interrogation and reception. The system will control the beam dynamically so it is always pointing towards the target. The target may be moving, and the vessel itself is affected by pitch, roll and yaw. Data from a roll/pitch sensor is used to stabilise the beam for roll and pitch, while directional data from a compass is input to the tracking algorithm to direct the beam in the correct horizontal direction.
- The HiPAP® transceiver can operate with up to 56 transponders simultaneously. The data is sent to the computer.

HiPAP® LBL processing

- This mode is similar to the HiPAP® SSBL processing, but the transceiver positions up to 8 LBL transponders for each single LBL interrogation. Both ranges and directions to the transponders are measured.

HiPAP® MULBL processing

- This mode is similar to the HiPAP® LBL processing, but the transceiver does not interrogate the MULBL transponder array, it only listen for the replies from the array. The transceiver can listen for to 8 LBL transponders. The direction to the transponders and the time difference between the received replies is transmitted to the computer.

HiPAP® Telemetry processing

- The unit transmits acoustic telemetry messages, and receives and decodes the acoustic telemetry message from the transponder. The data is sent to the computer.

8.5 Cymbal acoustic protocol

Cymbal is the new acoustic protocol used for both positioning of subsea transponder in SSBL/LBL mode and data communication to and from transponders.

Technology

Cymbal utilizes Direct Sequence Spread Spectrum (DSSS) signals for positioning and data communication. The data communication speed is variable and can be adapted to the acoustic communication conditions; noise and multi-path. DSSS is a wide band signal.
The Cymbal protocol provides new characteristics for both positioning and data communication.

Range capability and reduced impact from noise

Cymbal protocol can transmit more energy in each positioning pulse. Compared to the current HiPAP® 500 this extra energy will provide higher position accuracy at low signal to noise ratio. It will also provide longer range capabilities. This improvement in energy is 5dB.

Range accuracy

The Cymbal signal gives range accuracy in the order of 0.01 m. Error contribution from sound velocity and ray bending not included.

Directional measurements

In SSBL operation, the accuracy of directional measurement is the main contributor to the position accuracy. The HiPAP® 501 has new and improved algorithms for directional computation when using Cymbal. At low signal to noise ratio the system will be more robust.

Number of channels

The Cymbal protocol has increased number of unique codes for transponder channels compared to the current system. At present there are 50 unique transponder channels.

Multi-path capability

The Cymbal protocol is designed to have good multi path properties. The processing technique allows signals to and from the transponder to overlap and still be able to have a correct detection.

Position update rate – MultiPing

New function that allows higher position updates rate in SSBL mode. Details not defined.

Power management – lifetime

The Cymbal protocol has a power management function that can command the transponder to adjust transmit power to save batteries. This is done automatically by the system.

Data Link with variable data rate – adaptable

The Cymbal protocol supports variable data rate and high reliability level. The obtainable data rate is defined by the signal to noise level and multi-path conditions. By default the system uses data rates that will secure long range and high reliable communication.

Integrated navigation and data link

Data that needs to be sent to and from a transponder will be interleaved between the positioning signals. The cNODE® transponder can any time send status and data to the HiPAP® and the other way around. If the cNODE® transponder detects low battery level, this can be directly sent to HiPAP® and displayed to the operator

cNODE® - Modeless transponder

The Cymbal protocol is able to use transponders in SSBL and LBL mode without changing the mode of the transponder. A transponder in an LBL array can by the operator be deselected from the LBL positioning and directly be used in SSBL mode. No data telemetry is required.
The cNODE® transponders can simultaneously listen for a Cymbal and an HPR400 channel interrogation. By this, vessels not having Cymbal protocol can use the same transponders

9 MEASUREMENT COMPENSATION

9.1 Roll - pitch - heading compensation

In order to compensate for the vessels roll / pitch / heading movements, vertical reference sensors and heading sensors are interfaced. Data from these sensors are used to compute position data that is relative to horizontal level and to north.
The absolute accuracy and the standard deviation of the position are very dependent of the roll / pitch / heading sensors performance. Especially when working at great water depths the roll / pitch / heading error contribution is significant and when working at long horizontal range the heading error contribution is significant. This compensation is used in all positioning modes.
The accuracy of the attitude data is of crucial significance for the total accuracy of the HiPAP® system, and the error from the attitude sensor will add to the error of the HiPAP® system.

Example:
A roll or pith error of 0.25 degrees will give an error of 4.4 m at 1000 m depth, and an error of 13 m at 3000 m depth -
while a roll or pitch error of 0.05 degree will give respectively 0.9 m and 2.6 m.

9.2 Ray bending compensation

Positions calculated from the raw measurements are influenced by variable sound velocity through the water column. The variable sound velocity causes an error in both range measurements and the angular measurements. By use of a sound profile, the system can correct these errors.

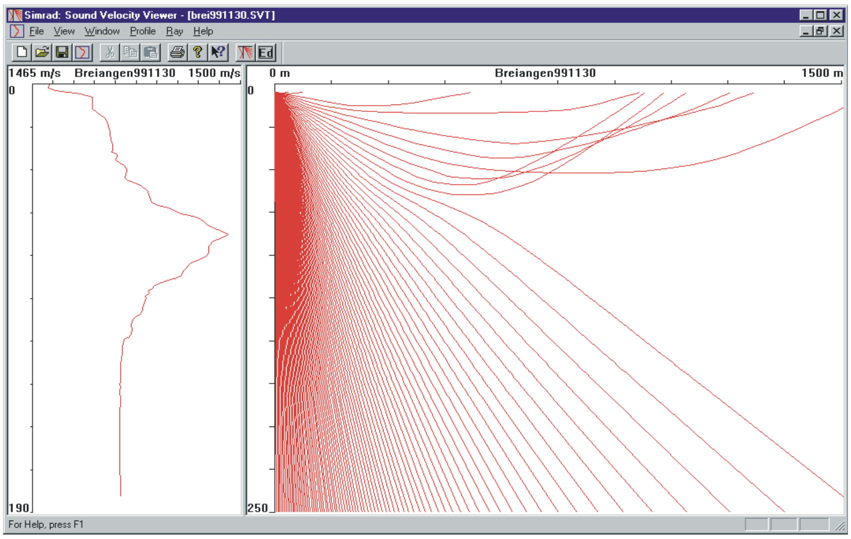

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Figure 5 Sound profile - APOS presentation

The sound velocity values may be measured by a probe and transferred to the system. If the depth of the target (transponder) is known either by depth sensor in the transponder or by an ROV depth sensor, these data can be transferred to the system and they will be used in the compensation.
The range calculation is compensated for the error caused by different sound velocities in the water column, and for the extra propagation path caused by the ray bending. The angular measurements are compensated for the ray bending.
The compensation is used in all positioning modes.

9.3 Transducer alignment

After a HiPAP® installation, it is necessary to determine a number of offsets between various sensor reference points and axes. These are:

Vertical angular The offset between transducer axis and roll / pitch sensor axis.

Horizontal angular The offset between roll / pitch sensor and heading reference.

Horizontal distance The offset between transducer location and reference point.

The principles for these alignment adjustments are based on the position of a fixed seabed transponder relative to the vessel and the geographical position of the vessel.

In order to simplify and improve the quality of the alignment scenario, the alignment function in APOS is used. By logging the vessel position from GNSS along with the measured HiPAP position of a seabed transponder, the program computes the alignment parameters. The normal procedure is to locate the vessel at four cardinal points and on top of the transponder with four headings.
Immediately the alignment parameters can be computed and automatically be transferred to the APOS alignment parameters. No manual transfer is needed. The results from the alignment are shown both numerical and graphically on the APOS.
An example is shown in the two figures below.

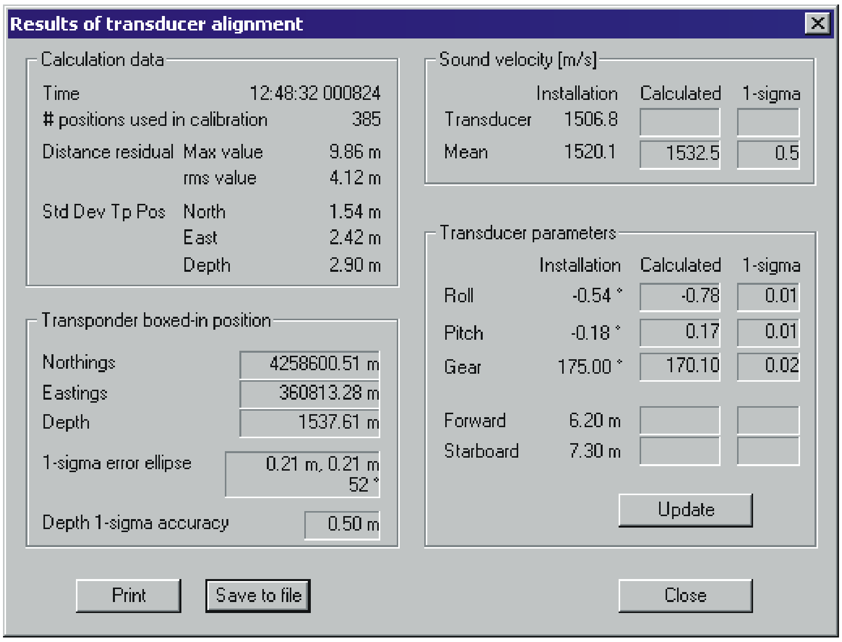

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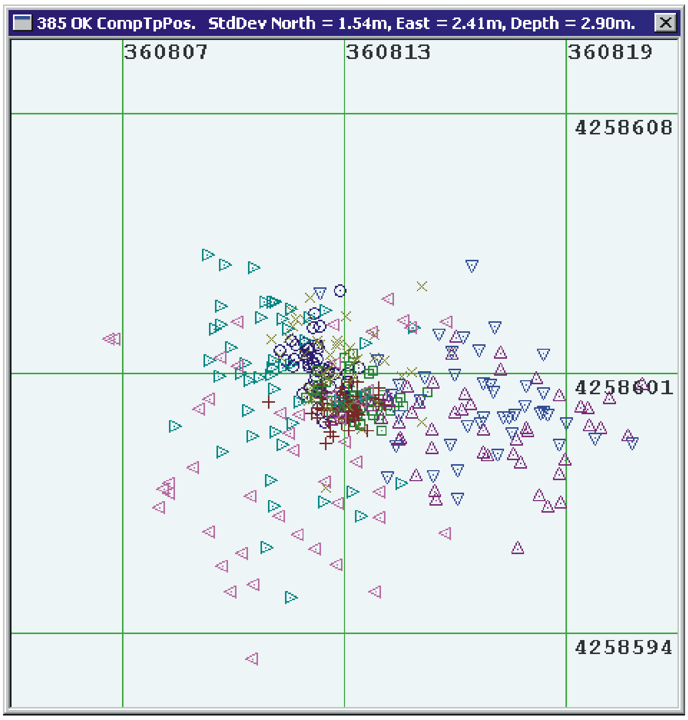
Figure 6 Result of transducer alignment - APOS presentation



(Cd5885)

Figure 7 Transponder positioning - APOS presentation

The figure shows the positions at the seabed transponder in UTM co-ordinates after the compensation values are determined and applied. The various symbols are used so readings from different locations easy can be separated from each other.

10 APPLICATIONS

10.1 Dynamic Positioning (DP) reference

The position data can be used by a DP system as the reference signals for keeping the vessel in the desired position. High position accuracy and reliability ensure a secure and stable reference input to the DP systems. SSBL and LBL systems may be used.

10.2 Subsea survey and inspection

Positioning of ROVs carrying instruments for survey and inspection is another important application for the HiPAP® system. The ROV position relative to the vessel is integrated with the position from surface navigation to provide a geographical position of the ROV. In this application, a responder is suitable.
Tracking towed bodies for similar applications may also be done. In survey applications, a best possible geographic position is wanted. To obtain this, sound velocity and depth (pressure) sensor input to the HiPAP® system may be used.

10.3 Rig and Riser monitoring

The HiPAP® system can be used to monitor the drill rig position relative to the well/Blow Out Preventer (BOP). It can also be used with inclinometer transponders to monitor the BOP and riser inclination. For HSC 400, interface to electrical riser angle measurement is available. Used with the Acoustic Control Subsea (ACS 400) it can be used for BOP.

10.4 Acoustic Blow Out Preventer (BOP) control

The HiPAP® system is also used for transmitting and receiving acoustic telemetry command with high security. This is used for acoustic BOP control, which includes BOP valve operation and monitoring critical functions by reading subsea status information and sending this information to the operator onboard the vessel.
A separate unit, the ACS 400, is required on the BOP stack. The ACS 400 contains electronics and batteries for interfacing the BOP.

A portable control unit, the Acoustic Control Commander (ACC 400), is also available. The ACC 400 contains electronics and batteries for operating the BOP functions.

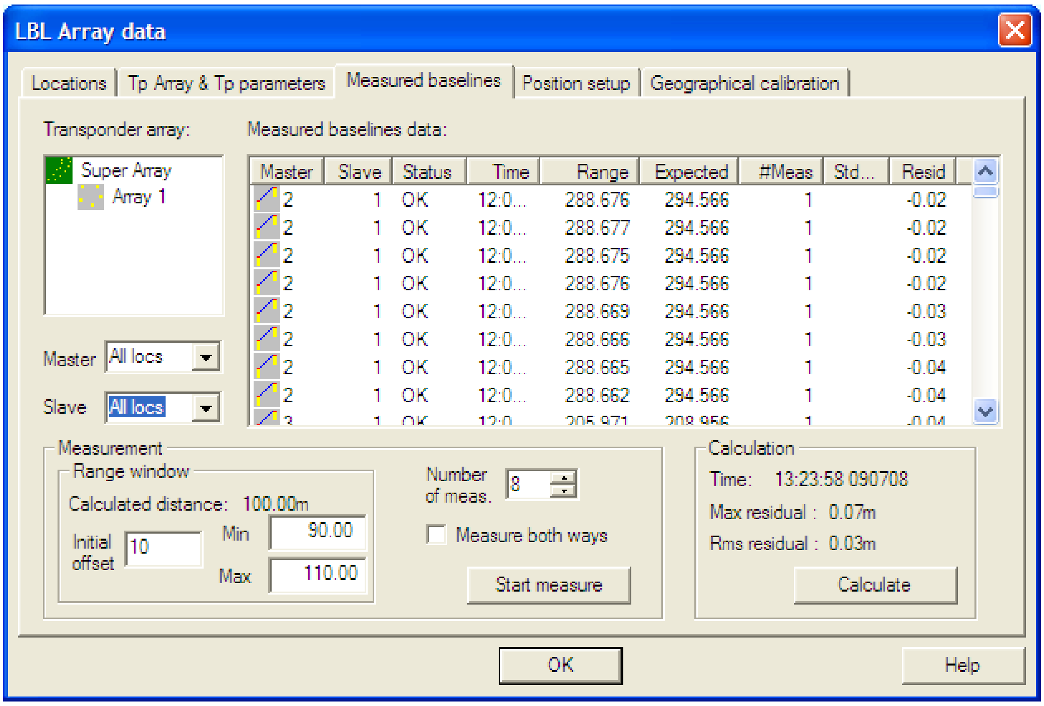
10.5 Construction work and metrology

The HiPAP® system forms a powerful platform for performing several tasks for positioning and acoustic data communication for construction and metrology work:

- LBL array calibration
- Box-in of locations
- Telemetry of sensor data
- Highly accurate baseline measurements

The cNODE® transponder has high performance range measurement and data communication capabilities. A variety of sensors are available for cNODE® and the sensor data is available to the operator from the HiPAP® system.

The accuracy of baseline measurements obtained by use of cNODE® transponders can be in the order of 0.01 m. However, to obtain this kind of accuracy it is essential that the operator has full control of the sound velocity. The figure below shows an APOS screen dump showing the statistics from a LBL calibration. The RMS residuals are calculated to be 0.03 m. There were 7 transponders in the array.



11 TECHNICAL SPECIFICATIONS

11.1 SSBL accuracy

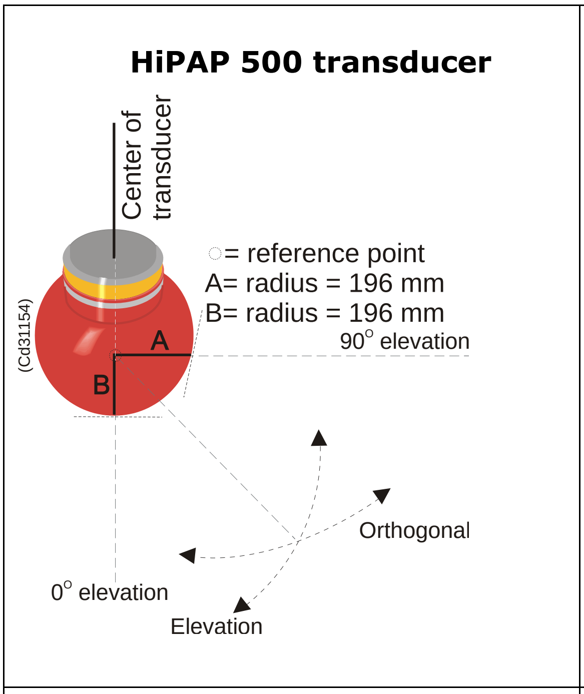
The angular figures are errors in both axis, elevation and orthogonal.

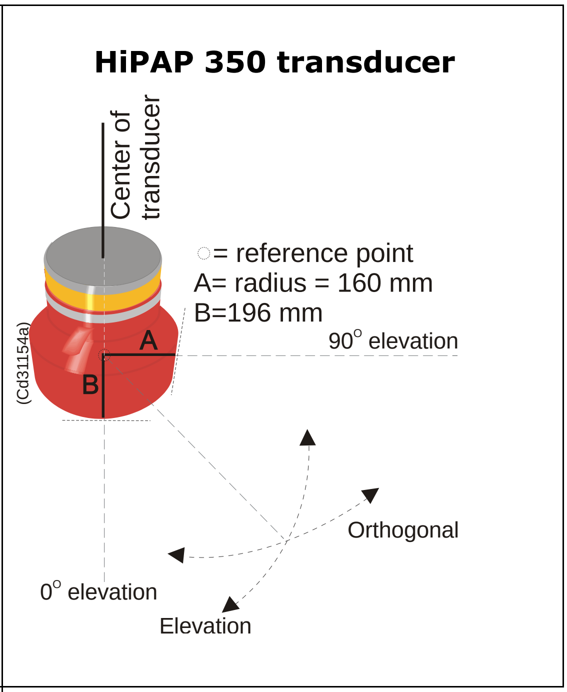
The specification is based on:

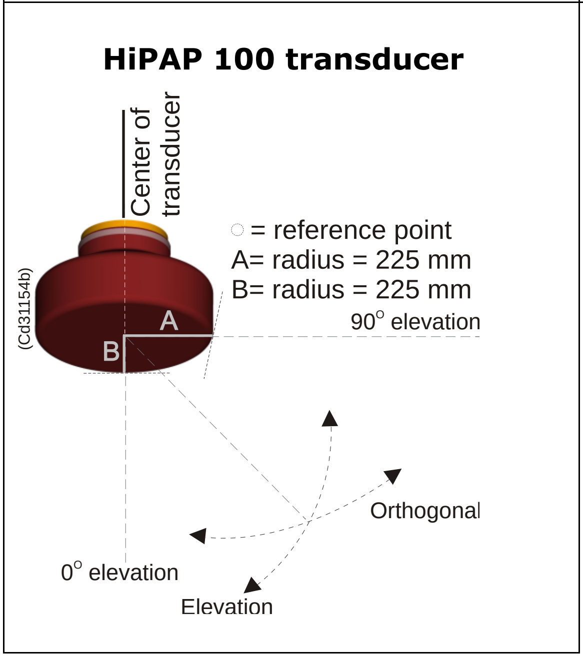
- Free line of sight from transducer to transponder.
- No influence from ray-bending.
- Signal to Noise ratio in water in the 250 Hz receiver band.
- No error from heading and roll / pitch sensors.

Transducer reference point

The reference points shown below are the origin for the position measurements.
The elevation and orthogonal angles are used in the accuracy curves.



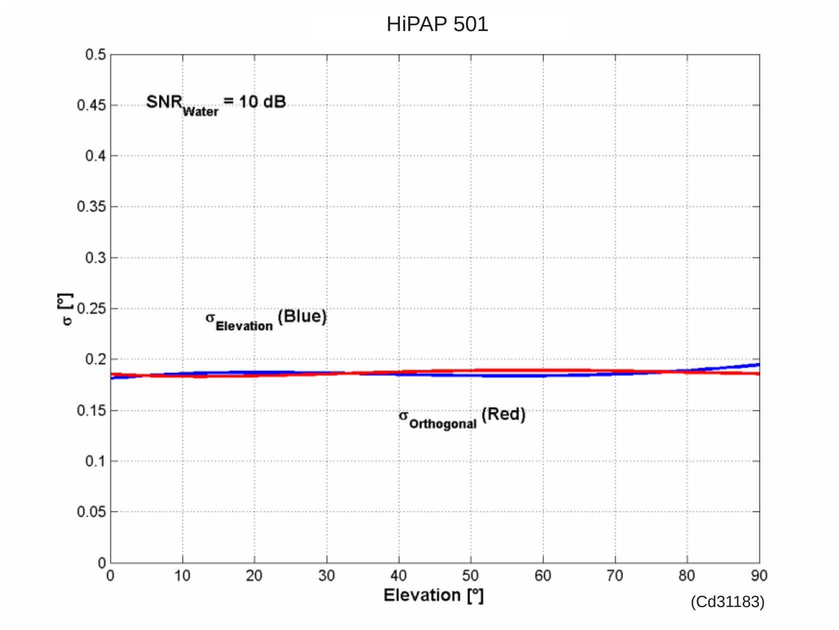




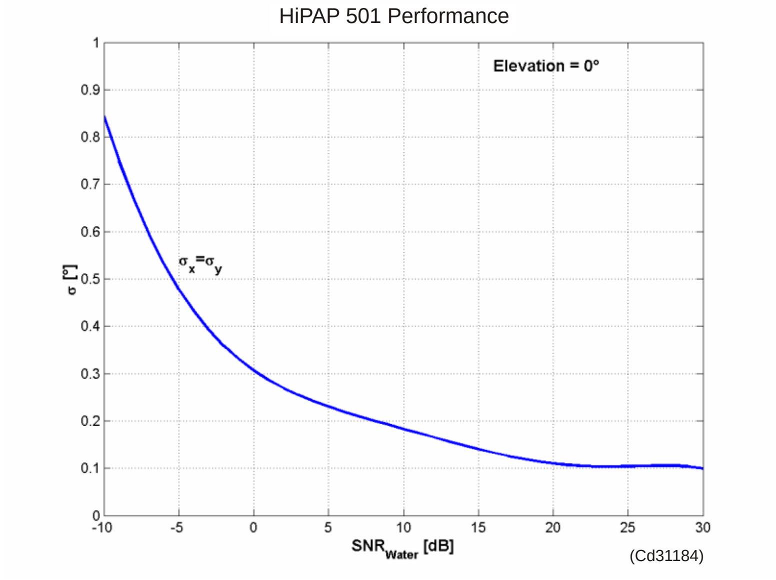
HiPAP® 501

	HiPAP 501 Single system			HiPAP 501 Dual system		
	S/N [dB rel. 1µPa]			S/N [dB rel. 1µPa]		
	20	10	0	20	10	0
Angular Accuracy [°] (At 0° elevation)	0.12	0.18	0.3	0.085	0.13	0.21
Range Accuracy [m]	0.1	0.1	0.15	0.1	0.15	0.15
Cymbal Range Accuracy [m]	0.02	0.02	0.02	0.02	0.02	0.02
Receiver beam [°]	10			10		
Coverage [°]	+/-100			+/-100		

Accuracy curves – HiPAP® 501



The figure above shows the accuracy as a function of elevation angle. The signal to noise ratio of 10 dB is in the bandwidth.



The figure above shows the accuracy as a function of signal to noise ratio. The elevation and the orthogonal angles are 0° (at vertical).

HiPAP® 451

The HiPAP® 500 transducer is used, and it has the same technical performance as the HiPAP® 351.

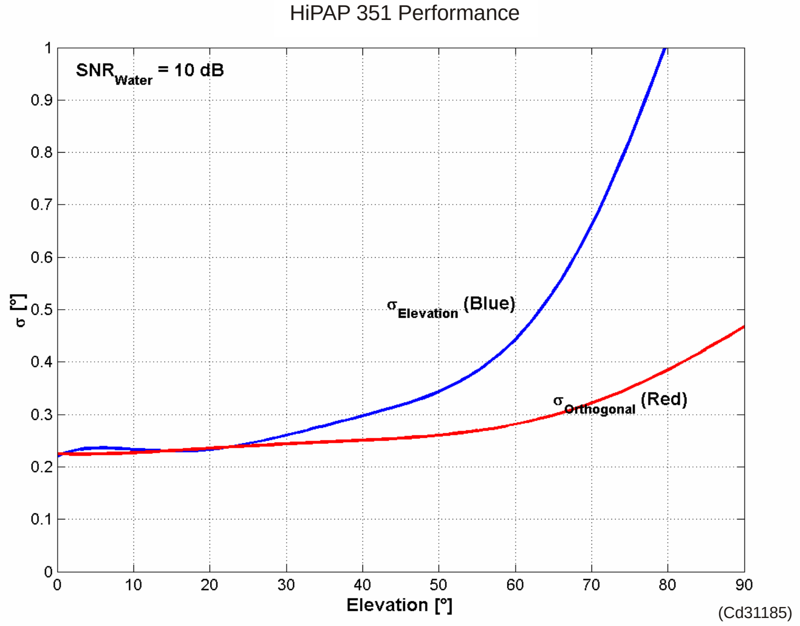
→ *Refer to HiPAP® 351 SSBL accuracy.*

HiPAP® 351

HiPAP® 351/451 Single system	**S/N [dB rel. 1μPa]**		
	20	10	0
Angular Accuracy, 1σ [°] (At 0° elevation)	0.18	0.23	0.4
Range Accuracy, 1σ [m]	0.1	0.15	0.2
Cymbal Range Accuracy, 1σ [m]	0.02	0.02	0.02
Receiver beam [°]	15		
Coverage [°]	+/-80		

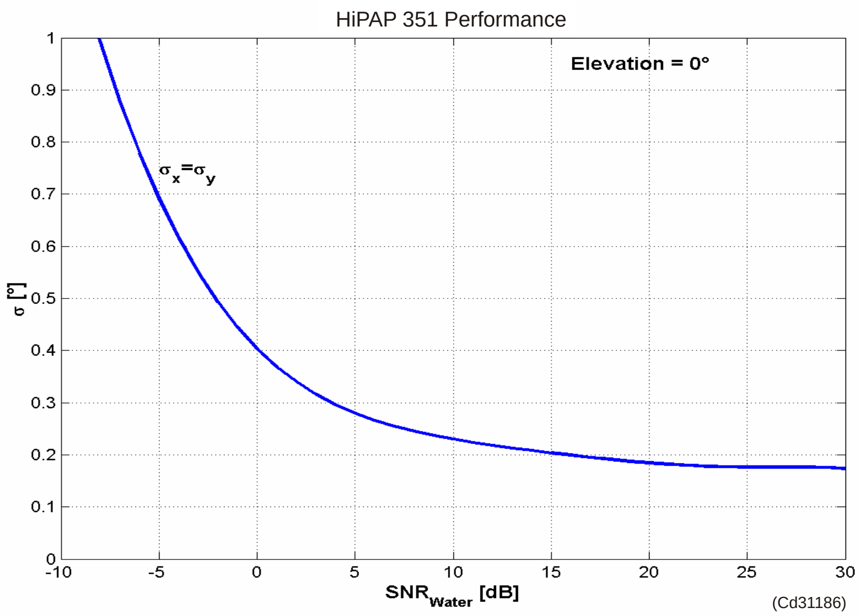
The elevation and orthogonal angles are used in the accuracy curves.

Accuracy curves – HiPAP® 351



(Cd31185)

The figure above shows the accuracy as a function of elevation angle. The signal to noise ratio 10 dB is in the bandwidth.



(Cd31186)

The figure above shows the accuracy as a function of signal to noise ratio. The elevation and the orthogonal angles are 0° (at vertical).

HiPAP® 101

HiPAP® 101 system	**S/N [dB rel. 1μPa]**
	20
Angular Accuracy, 1σ [°] (At 0° elevation)	0.14
Range Accuracy, 1σ [m]	0.2
Cymbal, Range Accuracy, 1σ [m]	0.02
Receiver beam [°]	15
Coverage [°]	+/-60

11.2 LBL accuracy

The position accuracy for LBL operation depends on the transponder array geometry, sound velocity errors and signal to noise ratio. Range accuracy's down to a few centimetres can be obtained, while ROV and vessel positions can be calculated to within a few decimetres.
Table 1 and Figure 8 show acoustic parameters and position accuracies that are achieved in deep waters when using an array with four transponders at water depth 3000m.

Source of random error	1-sigma CW	1-sigma Cymbal
Range reception with 20 dB S/N	0.15 m	0.02 m
Range reception in the transponder	0.15 m	0.02 m
Range error due to transponder movements	0.01 m	
Range error due to rig movements	0.05 m	
HiPAP® Angle accuracy	0.15°	

Table 1 Sources of random errors on the acoustic measurements

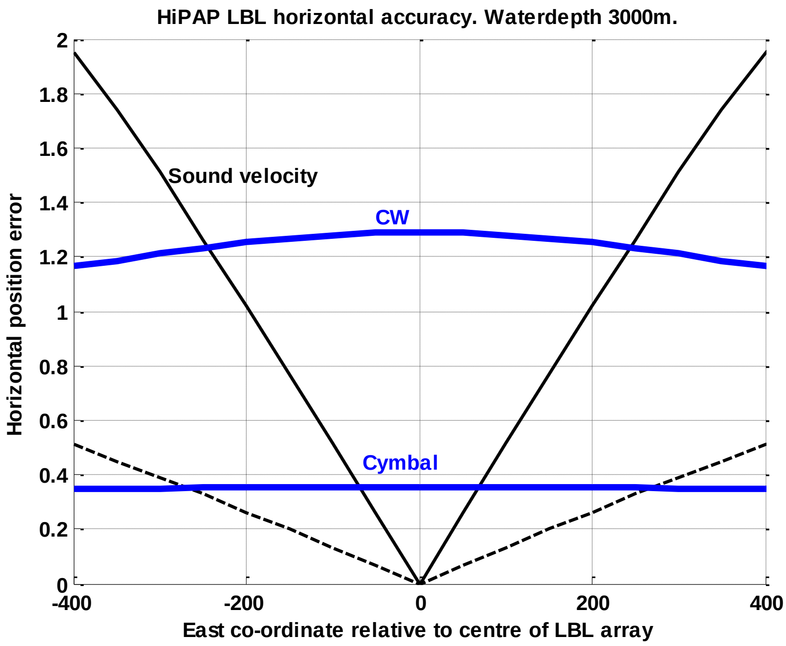


Figure 8 LBL position error in the horizontal plane as a function of the East co-ordinate. The North co-ordinate is zero. The blue lines show random error due to acoustics. Black line is systematic error due to 1 m/s wrong sound velocity settings.

The blue lines in Figure 8 show the random error in the horizontal position when the rig moves within a transponder array with 4 transponders placed on a circle with 500 m radius at water depth 3000 m. The lower line shows the expected error when the Cymbal acoustics is used and the upper line when the CW acoustics is used.

The black line shows the systematic error when the sound velocity is set 1 m/s wrongly in APOS. This error is zero in the centre of the array due to the symmetry. The LBL run time calibration should be done when the rig is in the centre of the array. Then the effect of a wrong sound velocity setting in APOS is strongly reduced, as shown with the dotted black line.

11.3 Range capabilities

The range capabilities of an acoustic system are dependent of the vessels noise level and attenuation of the transponder signal level due to ray bending. The transponder source level and the signal to noise ratio are crucial factors for calculating maximum range capability. The below figures are recommended guideline for maximum operating range.

Please also be aware of:

- The figures are valid for HiPAP® 501/351/451
- Figures for cNODE® are when used in Cymbal mode (Wideband)
- The HiPAP® system will in many cases have longer range capabilities that specified below due to its narrow receiving beam.
- The figures are approximate values for guidance.
- Ray bending can limit the maximum range
- Ray bending normally not a problem for vertical positioning operation

Transponder	Transponder source level (dB rel.1µPa ref. 1 m)	Max Range (Typical, m)
cNODE® 180° transducer	190	2000
cNODE®, 40° transducer	203	3000
cNODE®, 30° transducer	206	4000
MPT/SPT 319	188	1500
MPT/SPT 324	195	2000
MPT/SPT 331	206	3000

The specification is based on:

- Free line of sight from transducer to transponder
- No influence from ray bending
- Signal to Noise ratio ≥ 12 dB. rel. 1µPa

HiPAP units/transducer cables

Hull unit	Part no.	Transceiver cable / Transceiver unit	Part no.	Transducer	Part no.	Service dock	Part no.
HL 2180							
Hull Unit HL 2180 (TD cable is included part no. 306057)	306080	Patch cable HL 2180 HiPAP® 500/450 For x81 TU	306068	HiPAP® 500	100-103315	Service dock 500	499-089777
		Patch cable HL 2180 HiPAP® 350/100 for Model x81 TU	306071	HiPAP® 350	100-103317	Service dock 500	499-089777
						Service dock 350	499-210007
				HiPAP® 100	100-103318	Service dock 500	499-089777
		Patch cable HL 2180 HiPAP® 350/100 for x21 TU	306076	HiPAP® 350	100-103317	Service dock 500	499-089777
Drawing:						Service dock 350	499-210007
316242				HiPAP® 100	100-103318	Service dock 500	499-089777
HL 3770							
Hull Unit HL 3770 (TD cable is included part no. 304105)	305427	Patch cable HL 3770 HiPAP® 500/450 For x81 TU	304106	HiPAP® 500	100-103315	Service dock 500	499-089777
		Patch cable HL 3770 HiPAP® 350/100 for x81 TU	306072	HiPAP® 350	100-103317	Service dock 500	499-089777
						Service dock 350	499-210007
				HiPAP® 100	100-103318	Service dock 500	499-089777
		Patch Cable HL 3770 HiPAP® 350/100 for x21 TU	306077	HiPAP® 350	100-103317	Service dock 500	499-089777
Drawing:						Service dock 350	499-210007
316243				HiPAP® 100	100-103318	Service dock 500	499-089777
HL 4570							
Hull Unit HL 4570 (TD cable is included part no. 306058)	306081	Patch cable HL 4570 HiPAP® 500/450 For x81 TU	306069	HiPAP® 500	100-103315	Service dock 500	499-089777
		Patch cable HL 4570 HiPAP® 350/100 for x81 TU	306073	HiPAP® 350	100-103317	Service dock 500	499-089777
						Service dock 350	499-210007
				HiPAP® 100	100-103318	Service dock 500	499-089777
		Patch Cable HL 4570 HiPAP® 350/100 for x21 TU	306078	HiPAP® 350	100-103317	Service dock 500	499-089777
Drawing:						Service dock 350	499-210007
316244				HiPAP® 100	100-103318	Service dock 500	499-089777
HL 6180							
Hull Unit HL 6180 (TD cable is included part no. 306059)	306082	Patch cable HL 6180 HiPAP® 500/450 For x81 TU	306070	HiPAP® 500	100-103315	Service dock 500	499-089777
		Patch cable HL 6120 HiPAP® 350/100 for x81 TU	306075	HiPAP® 350	100-103317	Service dock 500	499-089777
						Service dock 350	499-210007
				HiPAP® 100	100-103318	Service dock 500	499-089777
		Patch Cable HL 6120 HiPAP® 350/100 for x21 TU	306079	HiPAP® 350	100-103317	Service dock 500	499-089777
Drawing:						Service dock 350	499-210007
316245				HiPAP® 100	100-103318	Service dock 500	499-089777

Note:
Patch cable = Transducer cable Y^2
TD = Transducer
TU = Transceiver Unit
Service dock 500 requires 500 mounting flange w/DN 500 Gate valve
Service dock 350 requires 350 mounting flange w/DN 350 Gate valve

11.4 Computer

Degree of protection:	IP 22
Weight:	approximately 17 kg

→ *Outline dimensions - see drawing in the Drawing file chapter from page 65.*

Power

Voltage:	115 / 230 Vac
– Selector-switch beside power connector. – The power supply must be kept within ± 10% of the unit's nominal voltage (90-132 VAC / 180-264 VAC). – The maximum transient voltage variations on the main switchboard's bus-bars which could occur (except under fault conditions), are not to exceed -15% to +20% of the nominal voltage.	
Frequency:	50-60 Hz
Maximum current drawn:	5 A
Normal current drawn:	0.5 A
Nominal:	80 W

Environment

Operation temperature:	0 to 55° C
Storage temperature:	-40 to +70° C
Storage / operating humidity:	95% / 85% relative

Vibration

Range:	5-100 Hz
Excitation level:	5-13.2 Hz ±1.5 mm, 13.2-100 Hz 1 g

11.5 Keyboard

Degree of protection:	IP 64
Weight:	0.5 kg
Cable length:	1.5 m

→ *Outline dimensions - see drawing in the Drawing file chapter from page 65.*

11.6 Trackball

A standard off the shelf unit is used.

11.7 Display

→ *Outline dimensions - see drawing in the Drawing file chapter from page 65.*

→ *For more information, refer to separate manual supplied with the display.*

11.8 Responder Driver Unit (option)

Degree of protection:	IP 44
Weight:	2.8 kg
Dimensions:	LxWxH (280x 200x 73) mm, without connectors
Power:	230 VAC, 150 mA

Environment

Operation temperature:	0 to 55 °C
Storage temperature:	-40 to 75 °C
Humidity:	15% - 95% (non condensing)

Responder Driver Unit kit

Part no.:	317925
Includes: - Responder Driver Unit - Power cable - Ethernet cable - D-sub connectors - Mounting screws w/nuts (4)	

11.9 Fibre Splice Box

Eight (8) ports MX-WFR-00024-02.

11.10 Transceiver units

Common data

This data is the same for both transceiver units.

Degree of protection:	IP 44

Power

Voltage:	230 Vac
– The power supply to a HiPAP® transceiver unit must be kept within ±10% of the unit's nominal voltage (180-264 VAC). – The maximum transient voltage variations on the main switch- board's bus-bars which could occur (except under fault conditions), are not to exceed -15% to +20% of the nominal voltage. – 110 VAC to 230 VAC transformer (option) For installations where only 110 VAC is available, an external transformer from 110 VAC to 220 VAC must be installed on the main power line to the transducer unit.	
Inrush max:	35 A Ac
Nominal:	2.1 A Ac
Frequency:	50 - 60 Hz

Environment

Operating temperature:	0 to +55 °C
Storage temperature:	-20 to +65 °C
Humidity:	15% - 95% (non condensing)

Heading reference

- Serial RS-422 SKR format
- Serial RS-422 STL format
- Serial RS-422 NMEA format
- Serial RS-422 Seatex MRU or Seapath
- Serial RS-422 DGR format (Tokimec DGR 11)
- Serial RS-422 NMEA HDT, VHW
- Serial RS-422 SKR format
- Roll and pitch reference (both models):
  Serial RS-422 Seatex MRU or Seapath

Model x81

Weight:	approximately 80 kg (depending on number of PCBs fitted)

→ *Outline dimensions - see drawing in the Drawing file chapter from page 65.*

Main power supply

Input:	230 VAC
Output:	24 VDC, 12 VDC, 6 VDC, 5 VDC, 3.2 VDC
Input:	230 VAC
Output:	48 VDC

Model x21

Weight:	approximately 35 kg (depending on number of PCBs fitted)

→ *Outline dimensions - see drawing in the Drawing file chapter from page 65.*

Main power supply

Input:	90 VAC - 264 VAC
Output:	48 VDC, 24 VDC, 12 VDC, 5.4 VDC

11.11 HiPAP® hull units

→ *HiPAP® HL 2180 - dimensions on page 76*

→ *HiPAP® HL 3770 - dimensions on page 77*

→ *HiPAP® HL 4570 - dimensions on page 78*

→ *HiPAP® HL 6120 - dimensions on page 79*

The following specifications are common for all HiPAP® hull units.

Degree of protection:	IP 54

Environment

Storage:	-20° C to +60 °C

Operating:	0° C to +55 °C
Storage / operating humidity:	90% / 80% relative

Power supply

Voltage:	230/440 VAC 3-phase
Frequency:	50-60 Hz
Consumption max:	1100 W

11.12 Mounting flange

Certificates - Lloyd's and DNV certifications are standard, others on request.

Specifications	DN 500 mm mounting flange	DN 350 mm mounting flange
Type:	DN 500	DN 350
Standard height:	600 mm	200 mm
Optional height:	Specified by customer	Specified by customer
Diameter Internal / Flange:	506 mm / 670 mm	350 mm / 505 mm
Wall thickness:	20 mm	20 mm
Weight (standard):	Approx. 90 Kg	Approx. 70 Kg
Securing bolt holes:	Quantity: 20 Diameter: 26 mm	Quantity: 16 Diameter: 22 mm
See also drawing:	on page 72	on page 73

11.13 Gate valve

Certificates - Lloyd's and DNV certifications are standard, others on request.

Specifications	DN 500 gate valve	DN 350 gate valve
Type:	DN 500	DN 350
Height:	350 mm	290 mm
Weight:	500 kg	225 kg
Material case:	670 mm Nodular cast iron	670 mm Nodular cast iron
Material gate:	Bronze	Bronze
Length (from centre):	1335 mm	940 mm

Specifications	DN 500 gate valve	DN 350 gate valve
Diameter Internal / Flange:	500 mm / 670 mm	350 mm / 505 mm
Securing bolt holes:	Quantity: 20 Diameter: 26 mm	Quantity: 16 Diameter: 22 mm
See also drawing:	*on page* 72	*on page* 73

11.14 Raise and lower motor

Motor type:	SEW EURODRIVE S62 DT80N4BM/HF
Degree of protection:	IP 54
Input voltage:	230/440 VAC
Phase:	3 Phase
Rated power:	750 W
Speed:	1500 RPM
Timken OK Load, ASTM D2509	Lb 40

11.15 Hoist Control Unit

Degree of protection:	IP 54

Dimensions

→ *Outline dimensions - see drawing in the Drawing file chapter from page 65.*

Power

Voltage:	230 VAC / 440 VAC, 3 phase
Frequency:	50 – 60 Hz
Power consumption:	750 – 1100 W depending o application

Environment

Storage temperature:	-20 to +65 °C
Operational temperature:	-0 to +55 °C
Storage / operating humidity:	90% / 80% relative

11.16 Remote Control Unit

Degree of protection:	IP 54

Dimensions

→ *Outline dimensions - see drawing in the Drawing file chapter from page 65.*

Power

Voltage:	24 VDC (from HCU)
Power consumption:	6 W

Environment

Storage temperature:	-20 to +65 °C
Operational temperature:	-0 to +55 °C
Storage / operating humidity:	90% / 80% relative

11.17 Transducer units

→ *Weight - see drawing in the Drawing file chapter from page 74.*

Model:	**HiPAP® 500 transducer**	**HiPAP® 350 transducer**	**HiPAP® 100 transducer**
Diameter:	392 mm	320 mm	452 mm
Shape:	Spherical	Spherical w/cylindrical body	Cylindrical body

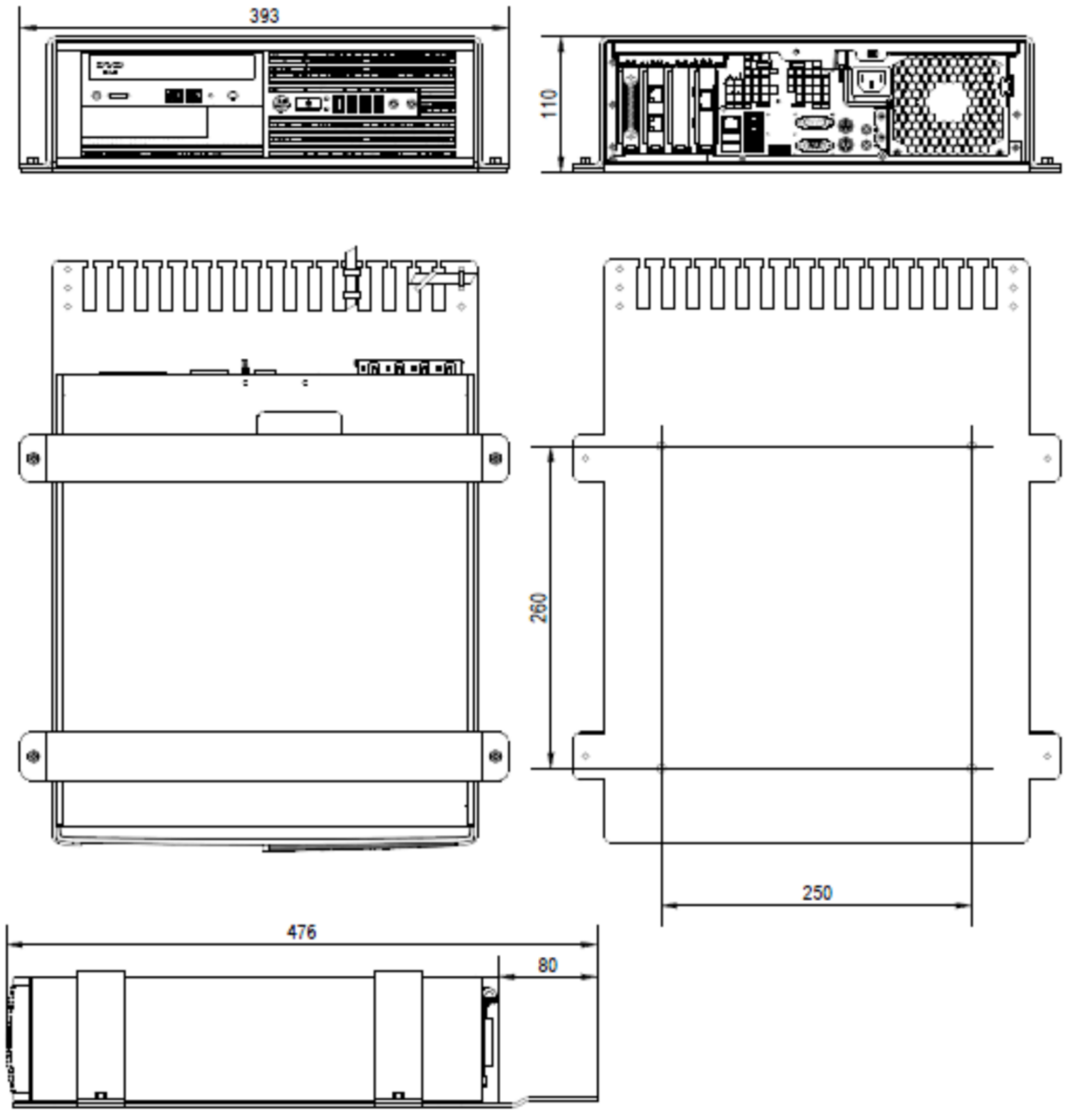
12 DRAWING FILE

12.1 Outline dimensions

The outline dimensions shown in this section are for information only and must not be used for installation or manufactory purposes.

Part No.	Rev.	Description	Ref.
Outline dimensions			
365290	B	Computer	on page 66
N/A	N/A	Keyboard	on page 67
N/A	N/A	Display	on page 68
316067	A	Responder Driver Unit (option)	on page 69
308630	B	Transceiver Unit Model x81	on page 70
304659	C	Transceiver Unit Model x21	on page 71
830-083045	H	DN 500 mounting flange w/gate valve	on page 72
830-214043	E	DN 350 mounting flange w/gate valve	on page 73
830-102887	D	Hoist Control Unit	on page 74
830-103012	B	Remote Control Unit	on page 75
316242	A	HiPAP® HL 2180	on page 76
316243	A	HiPAP® HL 3770	on page 77
316244	A	HiPAP® HL 4570	on page 78
316245	A	HiPAP® HL 6120	on page 79

Computer –desktop mounting and outline dimensions



Note:
The drawing is not in scale.

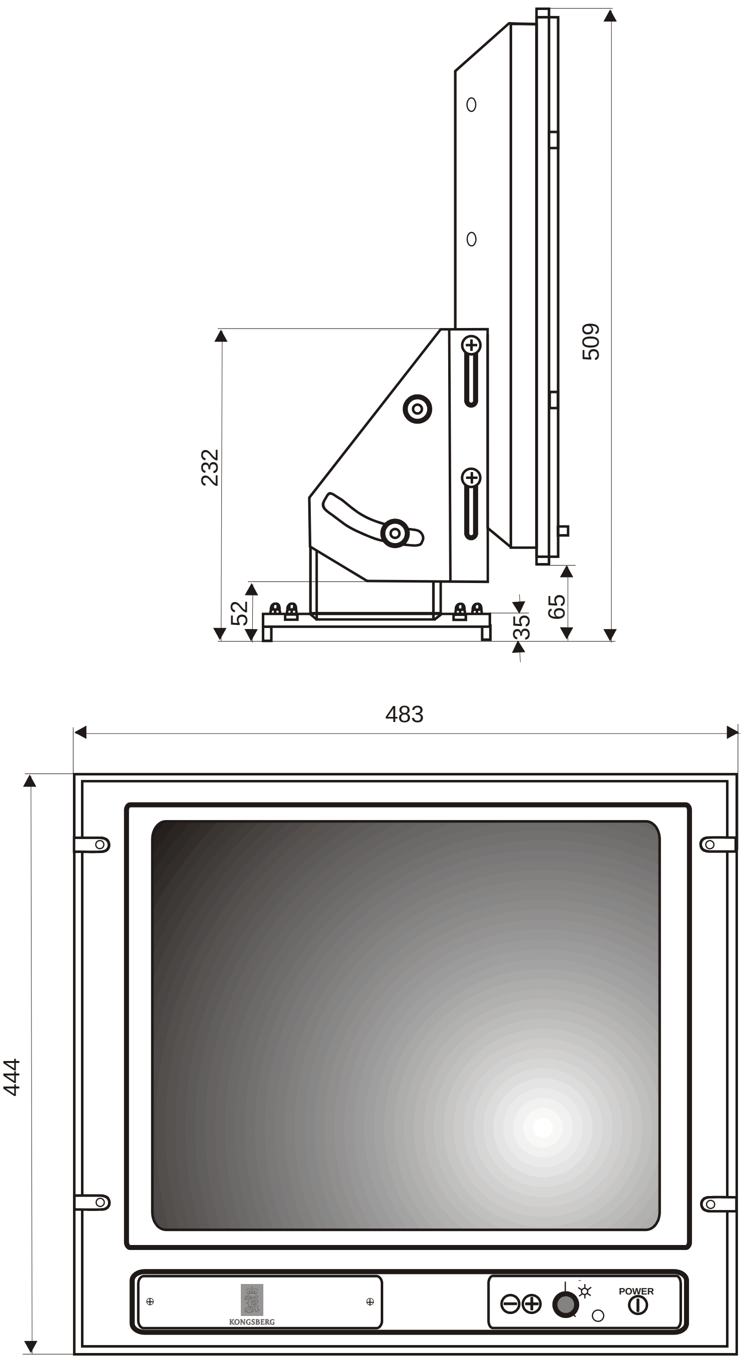
Cd31249 Page 1
365290 Rev. B

Keyboard

(Cd31406)

Note:
All measurements are in mm.
The drawing is not in scale.

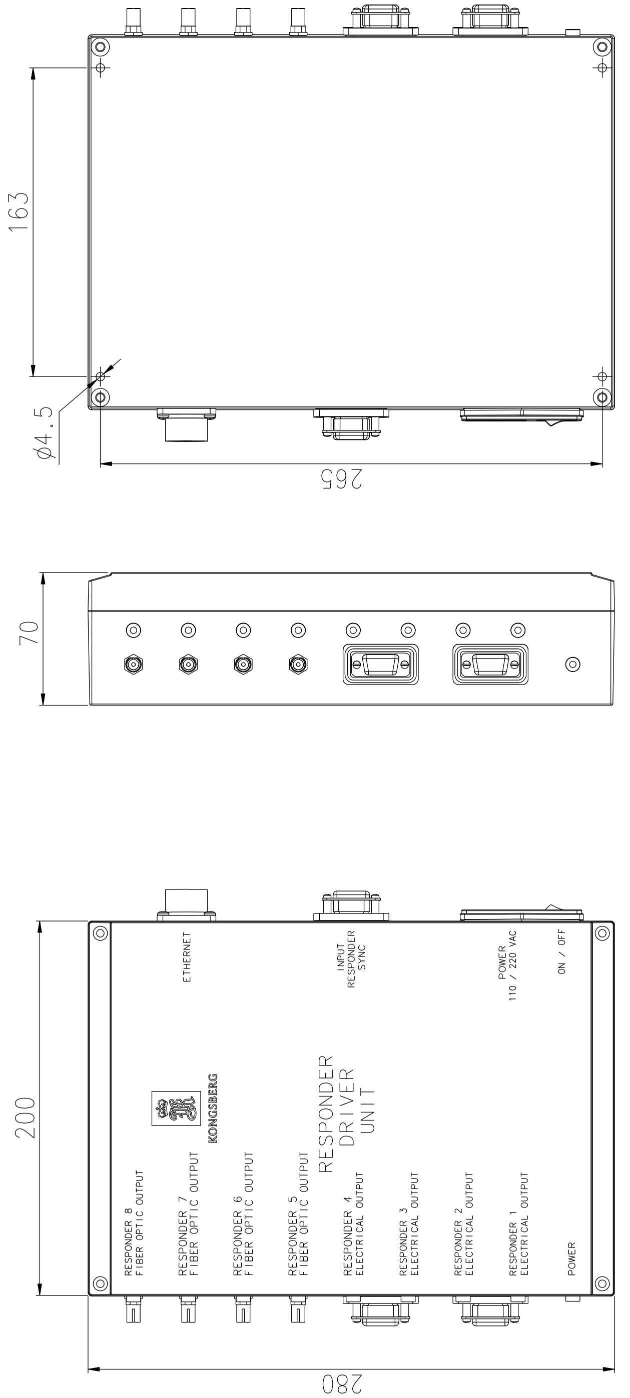
19" Display



Note:
All measurements are in mm.
The drawing is not in scale.

Cd31022x Page 1 o 1

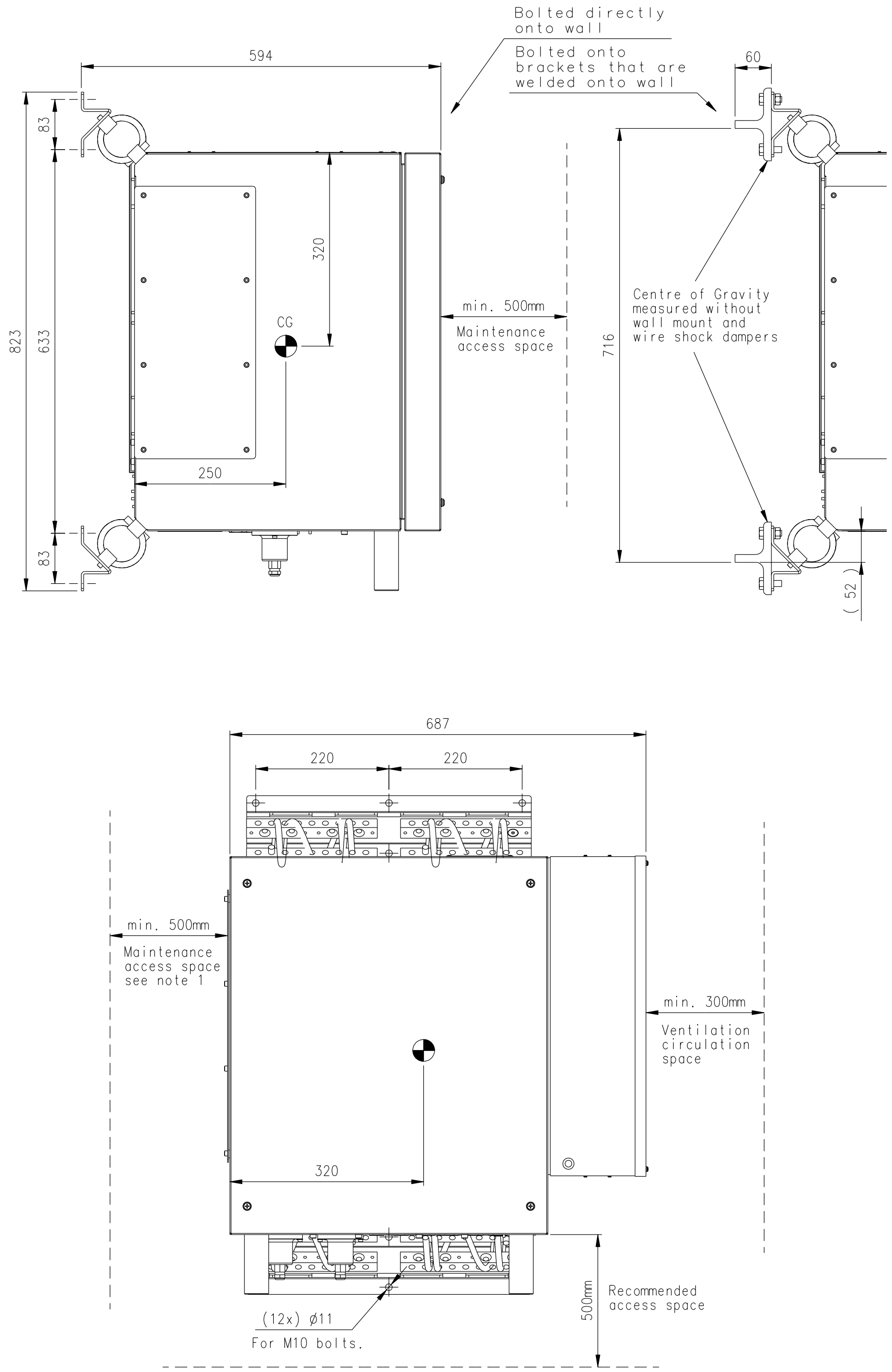
Responder Driver Unit (option)



Note:
All measurements are in mm.
The drawing is not in scale.

Cd31148 Page 1 of 1
316067 Rev.A

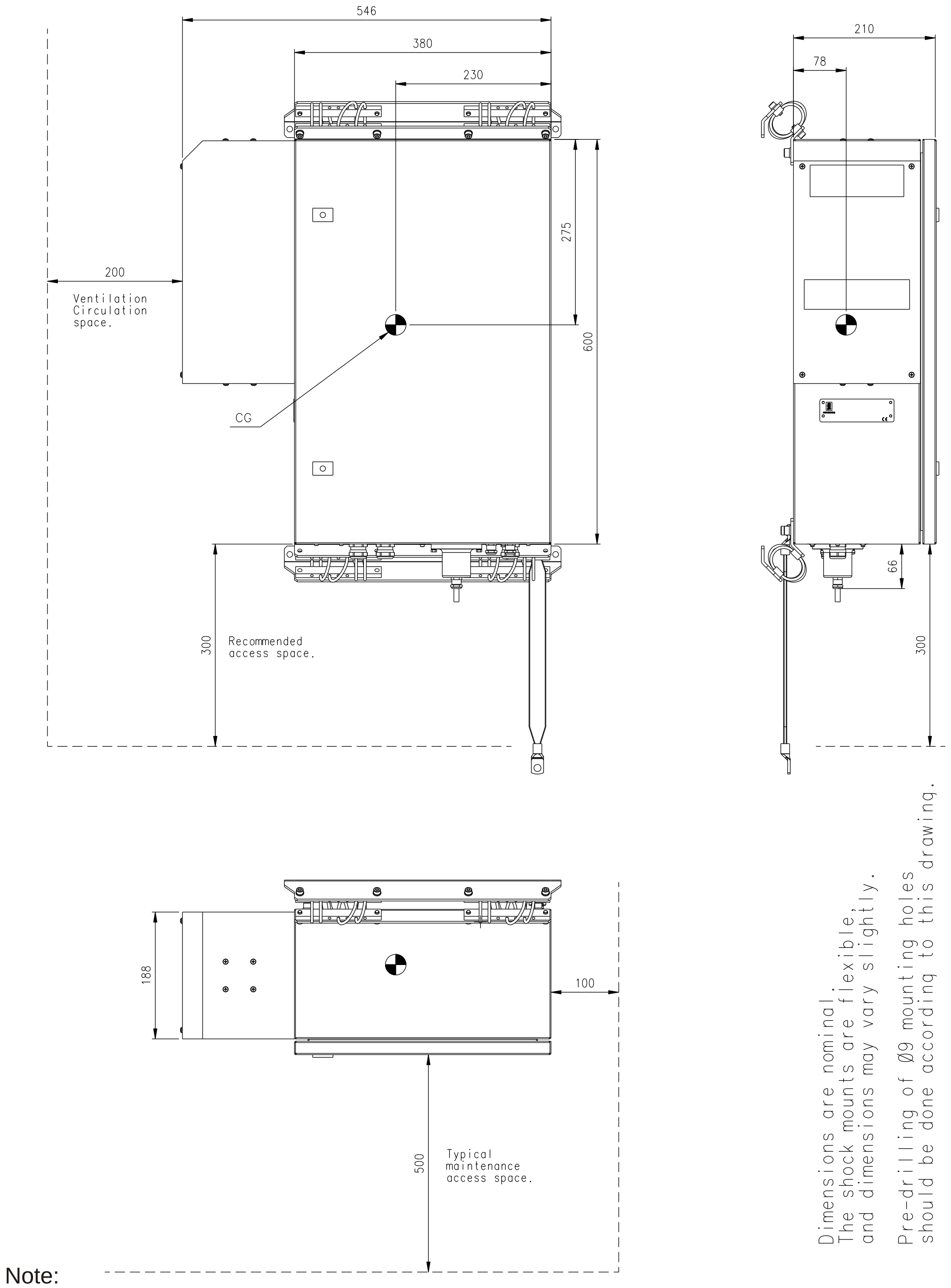
Transceiver Unit Model x81



Note:
All measurements are in mm.
The drawing is not in scale.

Cd31093 Page 1 of 2
308630 Rev.B

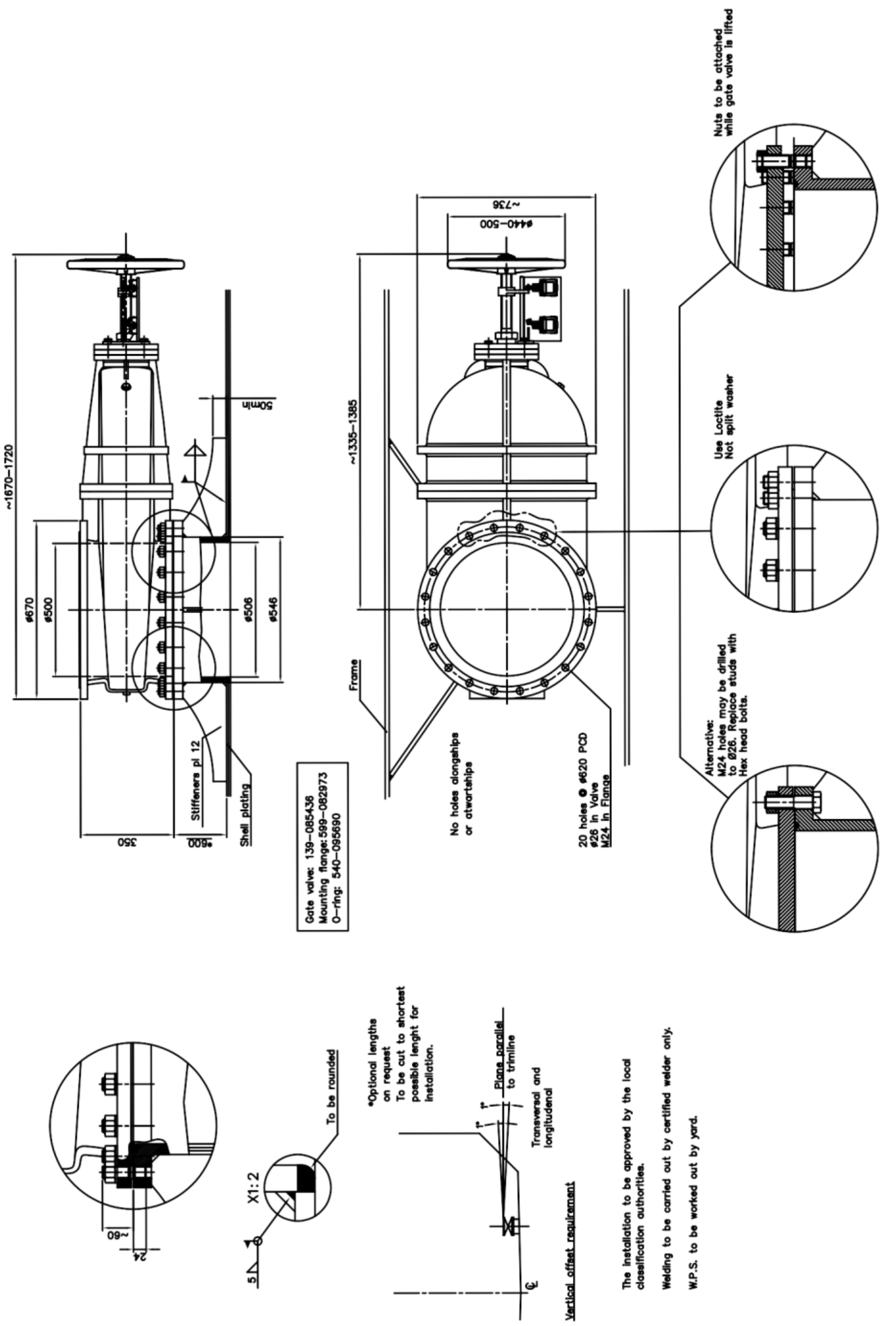
Transceiver Unit Model x21



Note:
All measurements are in mm.
The drawing is not in scale.

Cd31071 Page 1 o 2
304659 Rev.C

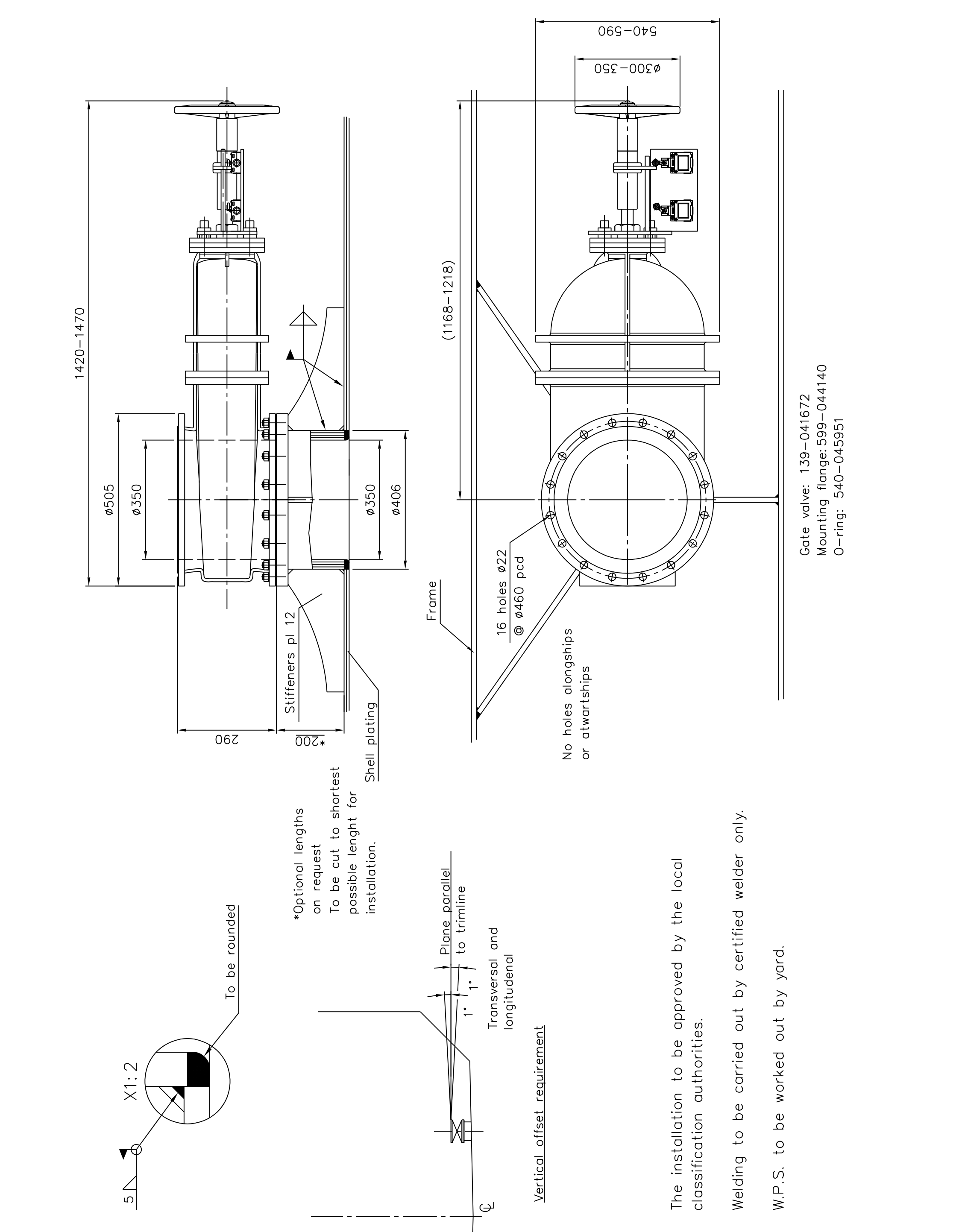
DN 500 mounting flange w/gate valve



Note:
The drawing is not in scale.

Cd31126b Page 1 of 1
830-083045 Rev. H

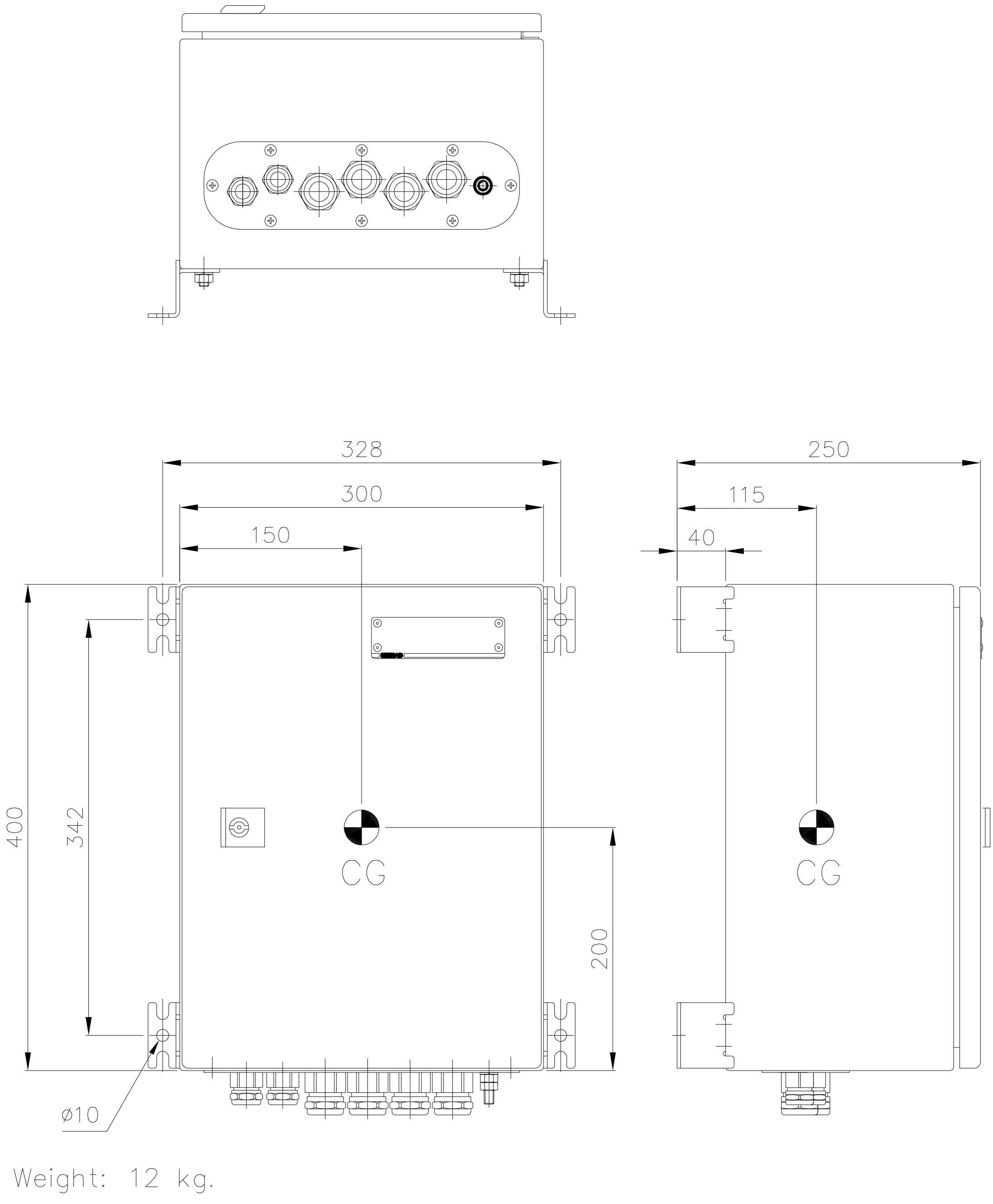
DN 350 mounting flange w/gate valve



Note:
The drawing is not in scale.

Cd31124a Page 1 of 1
830-214043 Rev. E

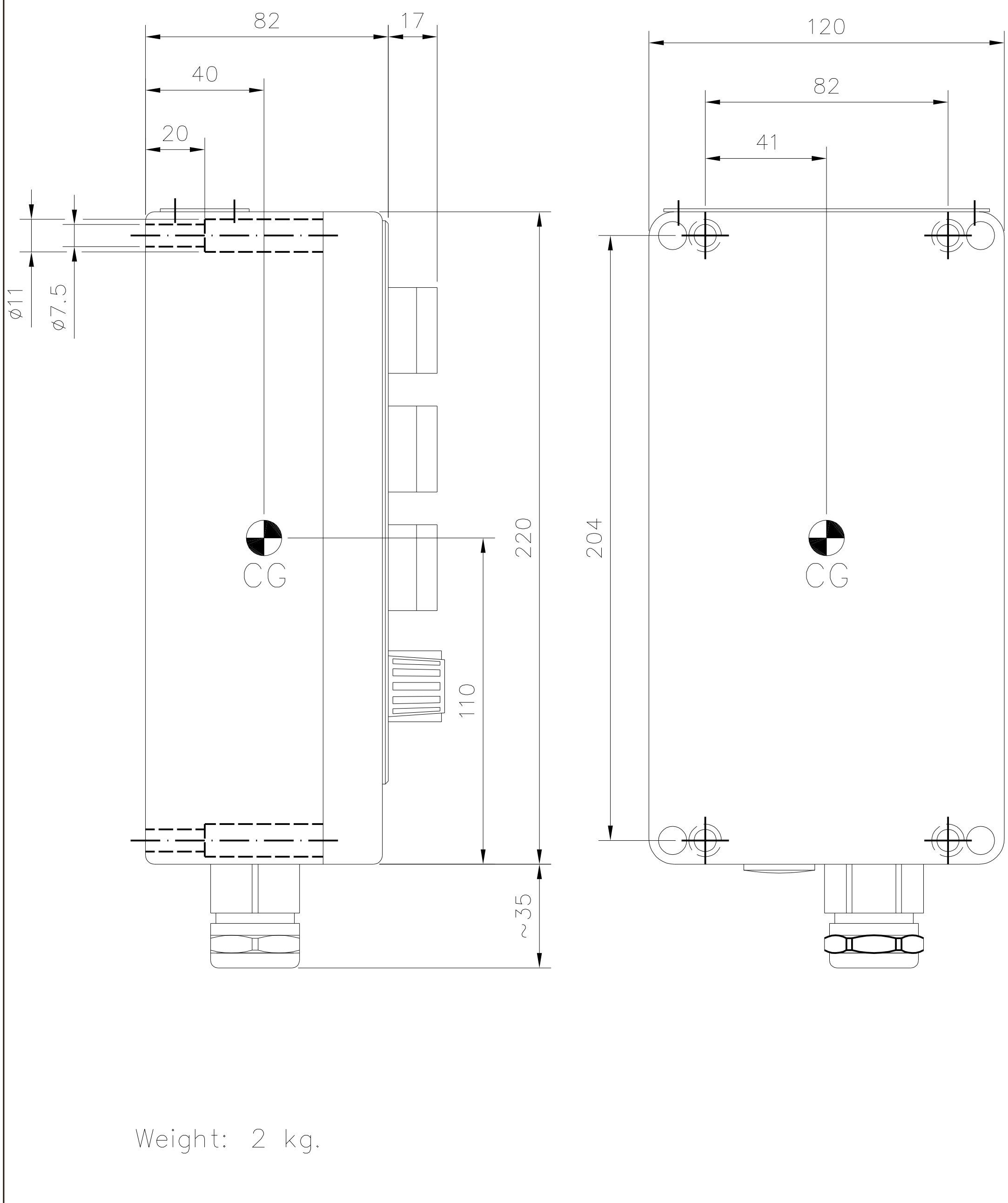
Hoist Control Unit



Note:
All measurements are in mm.
The drawing is not in scale.

Cd31028 Page 1 of 1
830-102887 Rev.D

Remote Control Unit



Note:
All measurements are in mm.
The drawing is not in scale.

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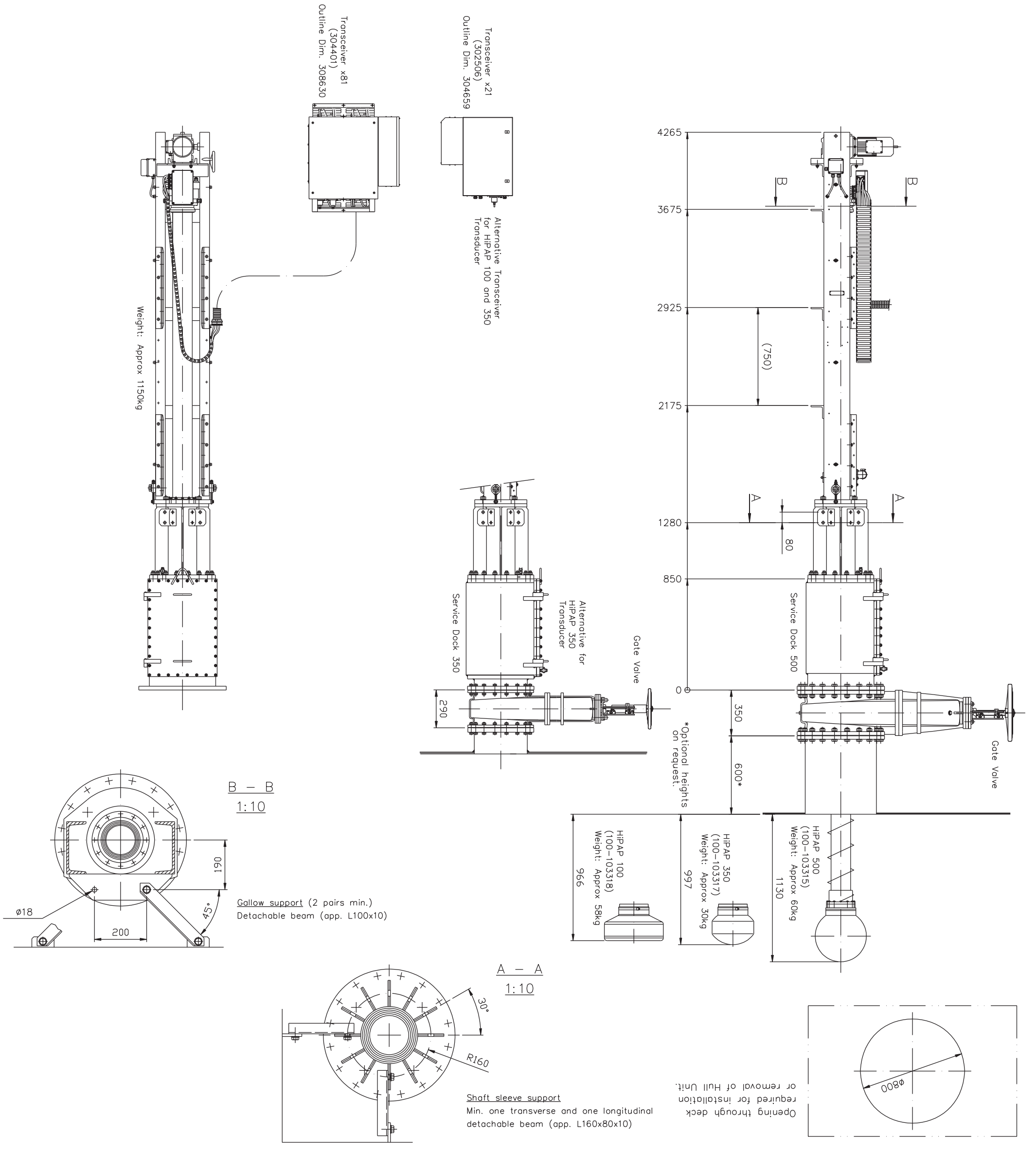
830-103012 Rev.B

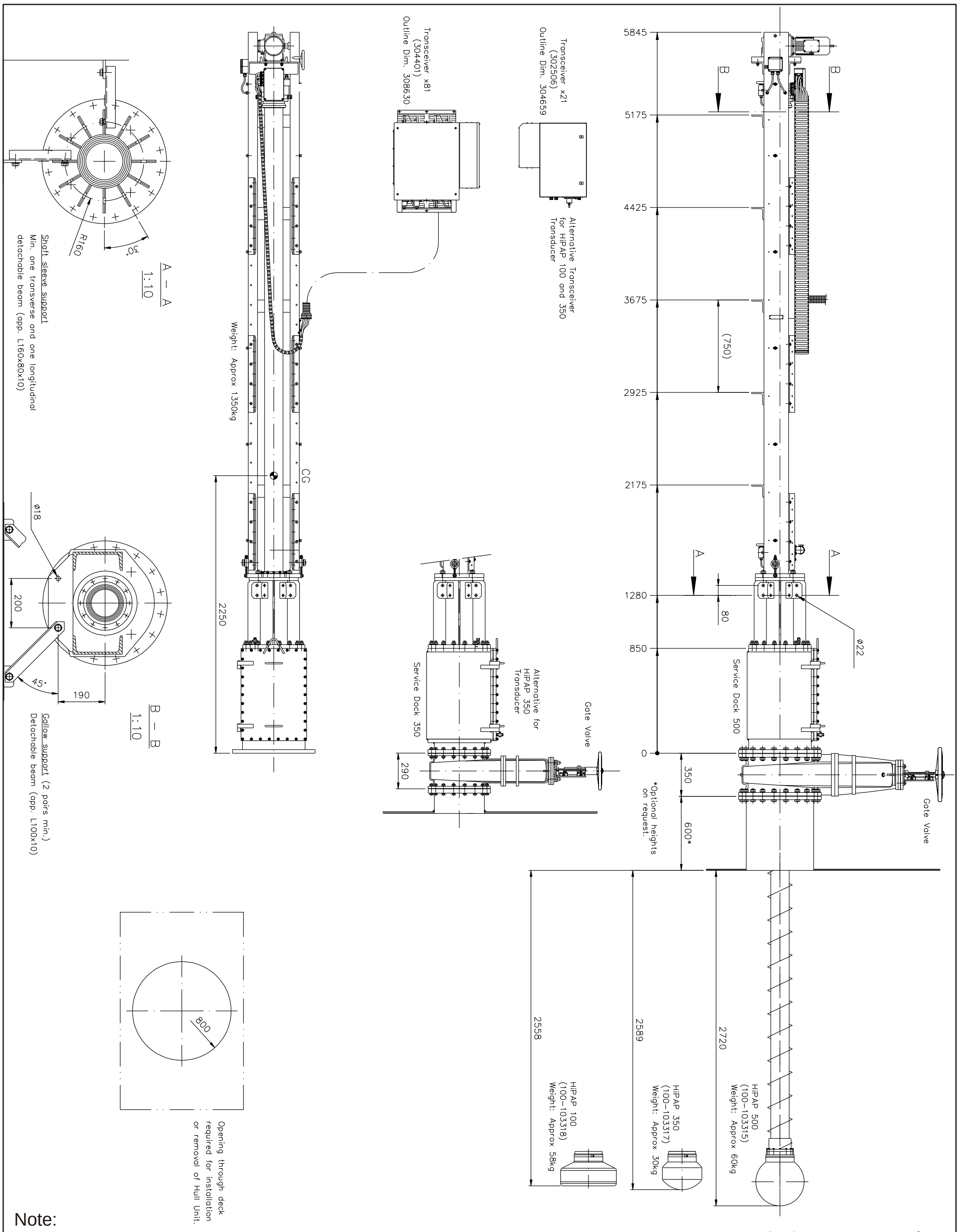
HiPAP® HL 2180



Note:
All measurements are in mm.
The drawing is not in scale.

CD31140 Page 1 of 1
316242 Rev.A

HiPAP® HL 3770



Note:
All measurements are in mm.
The drawing is not in scale.

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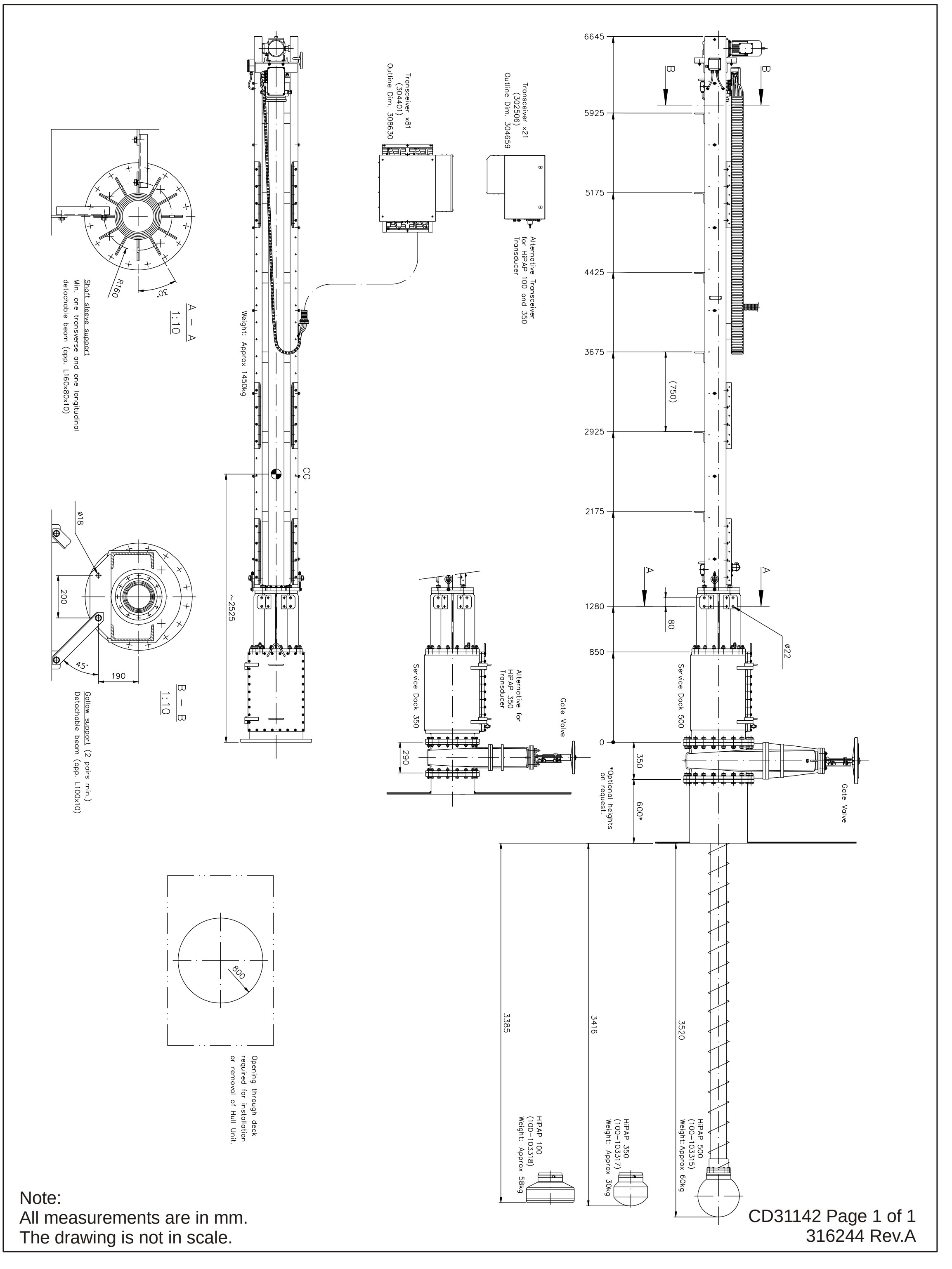
316243 Rev.A

HiPAP® HL 4570



Note:
All measurements are in mm.
The drawing is not in scale.

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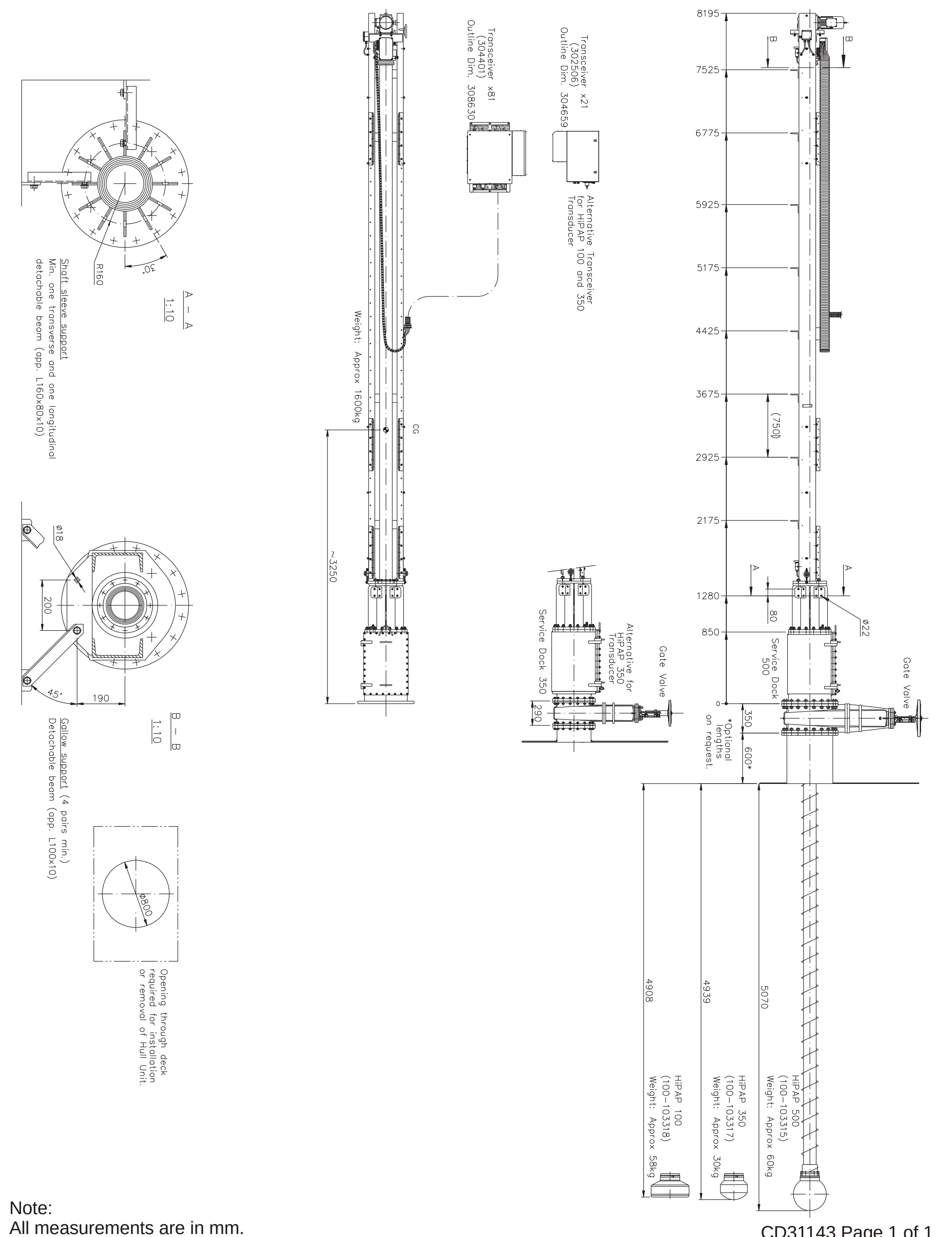
316244 Rev.A

HiPAP® HL 6120



Note:
All measurements are in mm.
The drawing is not in scale.

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316245 Rev.A

APOS for HiPAP® Instruction Manual

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