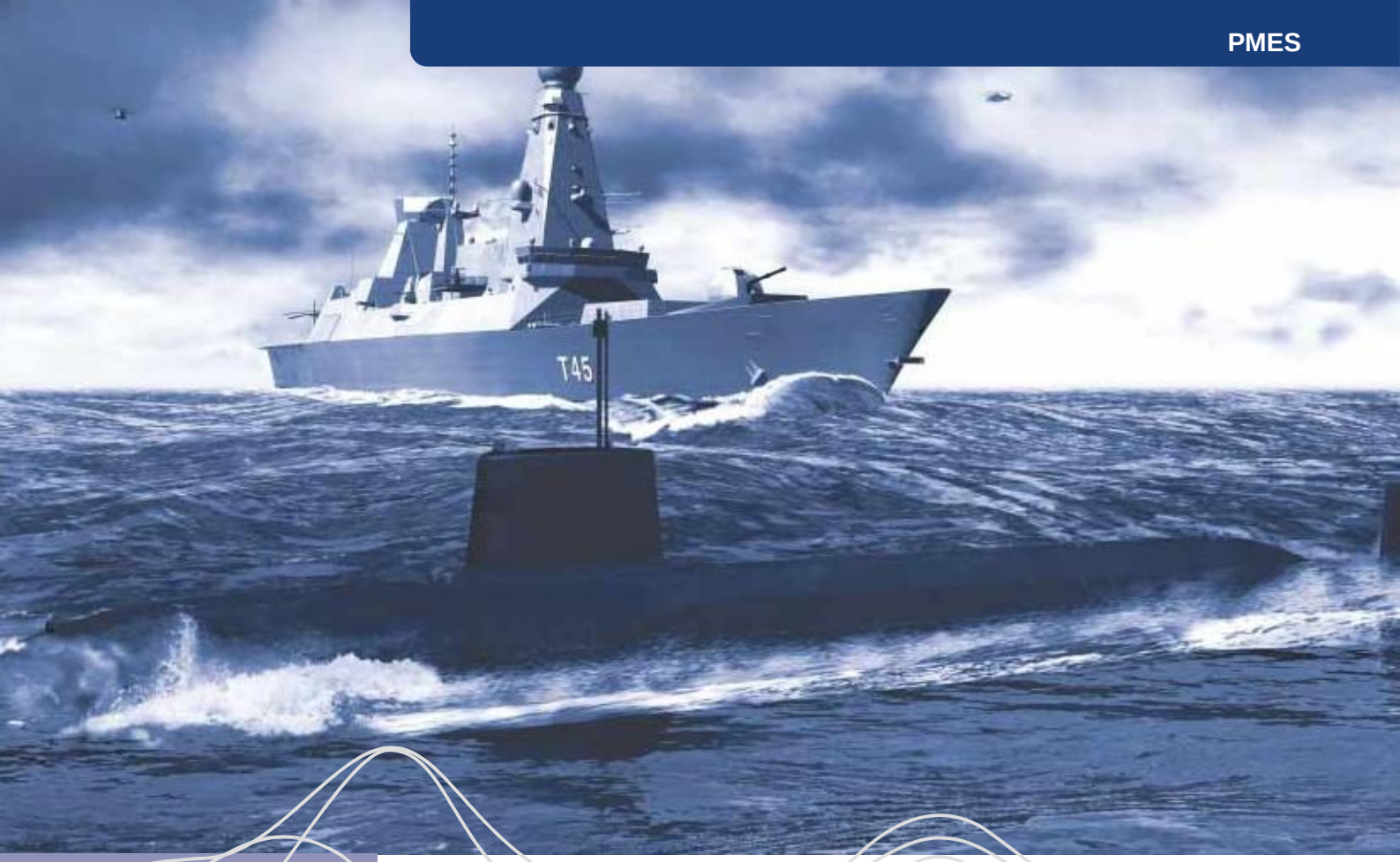


Magnetic Treatment & Deperming

Signature Reduction for Surface Ships and Submarines

Ultra Electronics PMES offers over 40 years experience in the design and manufacture of magnetic treatment facilities (MTF) and measurement ranges. To date over 60 underwater signature measurement ranges and magnetic treatment systems have been provided for the UK Royal Navy and Navies worldwide with significant experience of submarine treatment gained in the last 20 years.

Ultra Electronics PMES key experience encompasses

- Magnetic treatment design consultancy
- Detailed design and manufacture
- Proven through-life magnetic signature reduction capability for surface ships and submarines
- Drive-In, Close Wrap and Over-Run Systems
- Transportable Close-Wrap systems for temporary use at any site
- Independent containerised power supplies (optional)
- Signature analysis and modelling
- Installation, commissioning and acceptance
- Training, documentation and In Service Support

Ultra Electronics PMES also, specialise in the design and manufacture of underwater Signature Measurement and Management systems including:

- On-board degaussing systems (OBDG)
- Transportable and fixed multi-influence underwater measurement ranges

Treatment of a vessel can be used in conjunction with OBDG to reduce onboard vessel power requirements.

Ultra ELECTRONICS

Magnetic Treatment Facilities Overview

This overview describes the general principles of operation, the basic elements of magnetic treatment facilities and the principal types of Magnetic Treatment Facilities available: 'Drive-In', 'Over-Run' and 'Close-Wrap'.

General Principle of Operation:

High DC currents are applied to the magnetic treatment coils to create large magnetic fields within the vessel under test that reduce the permanent magnetic field of the vessel being treated. Magnetic fields are in general simultaneously applied in a minimum of two coil direction axes.

The Range Control Office contains a console to allow operator configuration of the power system and applied current. It also permits the reporting of status information on the power supplies.

Magnetometers stationed along the seabed monitor the treatment process thereby providing magnetic signatures to the treatment officer. An operator console provides a graphical interface to allow analysis of the measured signature data. Recommendations of the current pulse magnitudes to be applied are provided by the software to assist the Operator.

The vessel's position is tracked by high accuracy RTK GPS to enable an accurate signature to be provided to the Operator.

Treatment Coils:

Coils comprise waterproof high current cables. The coils are oriented to generate fields in the ship's co-ordinate frame; that is to say in the Longitudinal, Athwartships and Vertical directions. The currents flowing in the coils are of up to several thousand Amperes in magnitude. Depending on the treatment protocol the individual coils are either used to generate 'shaking' fields to alter the vessel's magnetisation or static fields to back-off the static Earth's field or influence the final magnetisation state.

The coils generally identified as follows:

- 'X' axis coils for generating a longitudinal field
- 'Y' axis coils for generating an athwartships field
- 'Z' axis coils for generating a vertical field

For Drive-In or Close-Wrap systems, if the vessel is treated when moored on a magnetic North / South alignment then there is no requirement for a 'Y'coil. However, if the vessel needs to be moored on a different heading then the field created by the 'Y' coil will compensate for this.

Power Supplies:

Each of the three coils will be powered from separate power supplies where each power supply is capable of precise control over the magnitude and current of the power applied.

The power required for the MTF will depend on the type of steel from which the vessel is built, the level of signature reduction required, the configuration of the coils and the cross sectional area of cable which determines the resistance and the operating current. The overall design will aim to minimise the power required subject to the cable size, the coil support structure and overall treatment time.

As an example for a close wrap system:

- The high power levels require a 3 phase 415V 50/60 Hz dock yard mains supply. The AC power is converted into DC power using Transformer Rectifier Units (TRU). Alternatively, in the case of a transportable MTF power and control can be provided by ISO containerised diesel generators and TRU's.
- For Drive-In or Close-Wrap system where a 'Y' coil power supply is required it is a much lower power unit than the 'X' and 'Z' coil drivers and a commercial unit may be used.
- The generators are provided with a local control panel to permit manual start and stop, synchronising and breaker closing. These functions will also be available via an operator console. Metering to show output voltage, current and frequency is provided and duplicated at the operator console.
- The system design incorporates the latest power conversion techniques. For example TRUs may be either six or twelve pulse phase controlled units and may be either diode or thyristor based and capable of providing a controlled current output in the range 0 to 100% of the full scale.
- Generators and TRUs are fitted with emergency stop and protection systems.

Magnetic Treatment Facilities Overview

Magnetic Sensor Array:

An array of 3-axis magnetometers are installed on the sea bed. These sensors measure and monitor the signature of the vessel being treated. The data from the sensors is collected by a data acquisition system and is processed by a control computer situated in a control office.

As an example for a Drive-In or Close-Wrap system:

- The sensors are normally sited under the keel line of the vessel to be treated.
- Vessel signature data is processed and displayed to enable the required treatment current values to be determined and monitor the progress of the treatment process.
- The depth of the magnetic sensors is measured by using a pressure sensor. This is used to measure tidal changes, and hence changes in vessel to sensor separation distance. An atmospheric pressure indicator is fitted in the control office to correct the sensor depth measurements brought about by changes in air pressure.
- A shore interface unit provides the power supply to the magnetic / depth sensors and a Data Converter for the sensor array and interfaces to Control and Analysis computers.

Positioning:

The vessel is tracked by high accuracy RTK GPS to enable the modelling of the signature and the highest performance signature analysis to be provided to the Operator. The MTF range system requires the location of the vessel in relationship to the sensors to be measured such that when the signature is measured at the relevant points of the treatment process.
The sensor array is positioned at the seabed at a depth of between typically 9m to 15m.

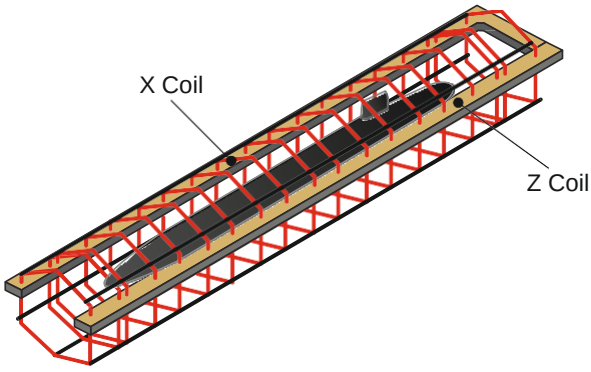
An RTK DGPS position measurement system consists of 2 rovers, mounted at the bow and stern of the vessel and a base station in the control office is used to determine the precise position of the vessel with respect to the measurement range sensors. The X and Y locations of the vessel bow and stern in relationship to the sensors need to be established to an accuracy of better than ±20 cm.

Vessel position data together with the outputs from the sensor array are used to produce a magnetic model which predicts a keel line magnetic signature. Signature measurements are taken at various points in the treatment process and are used to determine the required treatment setting and to confirm the success of the procedure.

Different Types of Magnetic Treatment Facilities (MTF)

Drive-In Type Systems

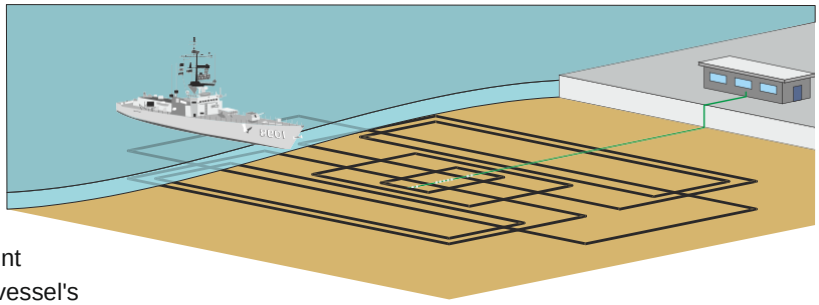
A 'Drive-In' MTF comprises a fixed construction with the treatment coils permanently installed. The vessel to be treated enters the facility from one end and is moored in situ. The vessel is magnetically treated using high magnetic fields, then is unmoored and exits on completion.
This type of facility provides for a very fast set up time and treatment of vessels. Construction and power supply costs are the highest of all the available type of MTFs.



Drive-in submarine treatment system designed by Ultra Electronics PMES

Different types of Magnetic Treatment Facilities (MTF)

Fixed Over-Run System



An Over-Run MTF has a set of treatment coils permanently installed on the seabed. These coils produce a large magnetic field which de-perm the vessel as it transits over the MTF in a succession of runs.

The greater the depth of water the greater the current required to achieve the magnetic field levels at the vessel's hull necessary to modify the magnetisation and provide the required level of signature reduction.

The Over-Run MTF is the simplest method of treating a vessel as there is no requirement for mooring or berthing the vessel although treatment can still take many runs over the coils for some vessels. Whilst less expensive than the Drive-In MTF, it is still an expensive system and the sea-bed installed coils and sensors can be susceptible to damage from dredging, trawling or anchorage.

Close Wrap Systems

Close-Wrap systems have configurable coils sets to treat both ships and submarines and can be supplied in various formats from fixed, permanent systems to fully portable systems with floating coils with independent power supplies. The treatment has a long lasting effect for all vessel types.

The 'Close-Wrap' MTF requires a set of X Coils to be wrapped directly around the vessel to be treated. The cables are specially designed for each vessel. A floating Z-coil is also provided.

A portable version of the treatment system is available which allows the system to be used in several different locations or put into storage when not in use thereby freeing up the dockyard and jetty space.

The main differences between a fixed and portable close wrap MTF are that with the fixed arrangement the Z Coils and sensors are permanently installed whereas with the portable systems the Z Coils are free-floating and hence removable. Ultra can also offer options that include fixed seabed sensor mounts for ease of deployment, transportable power system and offices. Treatment power can be supplied by containerised diesel generators and transformer rectifier units (TRUs) and therefore fully independent of dockyard and grid power supplies.

Ultra Electronics PMES - Design Tasks

Ultra are able to offer the following magnetic design consultancy to Navies and Main Contractors.

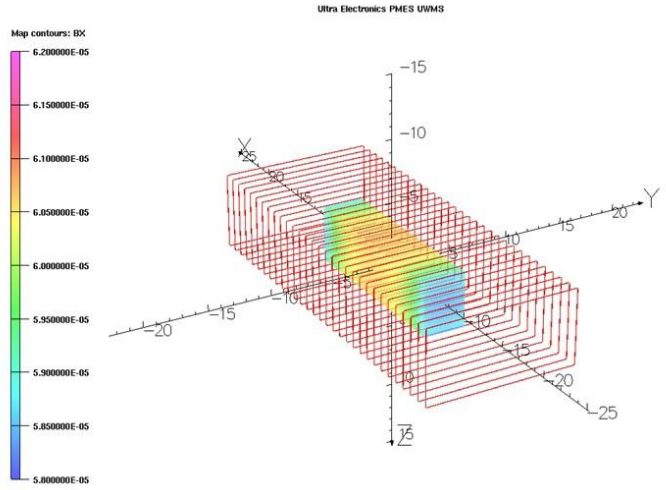
Magnetic Design:

This approach has been proven by Ultra on a number of treatment systems:

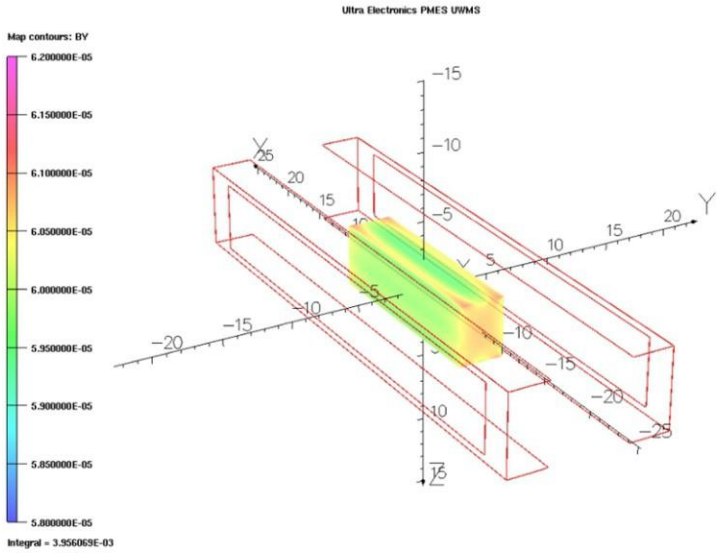
- Use of mathematical modelling techniques to design the coil shape and dimensions
- Use of finite element models and information from the Ship Classes to be treated to calculate the effect of the ship on the generated magnetic fields
- Definition of coil location and current and power requirements
- Optimisation of coil design
  - Optimisation of field uniformity for minimum coil size
  - Cost versus performance and power trade-off
  - Maximise ease of access for ships
  - Uniformity of field

Ultra Electronics PMES - Design Tasks

Examples of 'Drive-In' Coil Design:



'L' coil (in red) showing the field uniformity at the ship's location (approximately 5% uniformity)



A complex 'Y' coil (in red) designed for high magnetic field uniformity at the ship's location

System Design:

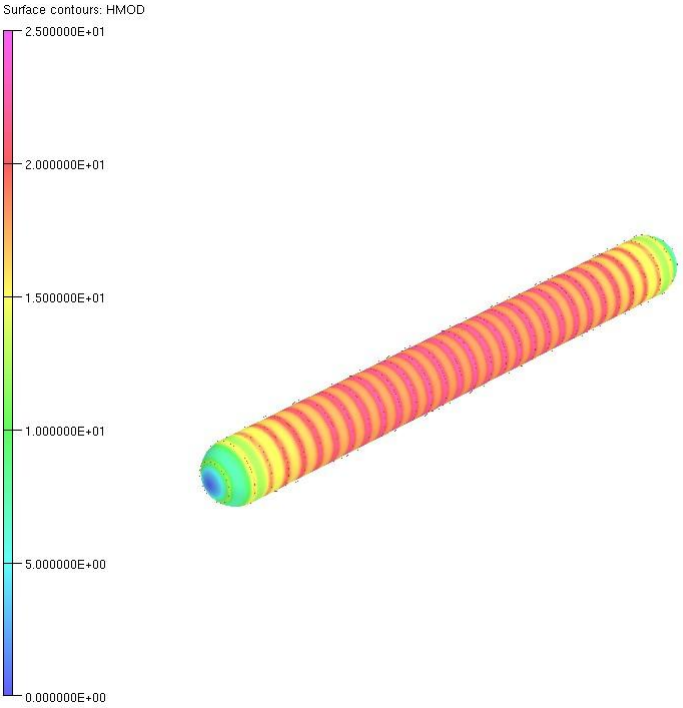
- From coil sizes and cable lengths determine cable cross-sectional area and required drive
- voltage Determine number and rating of power supplies
- Structure of coil mounting frame

Ultra Electronics PMES - Design Tasks

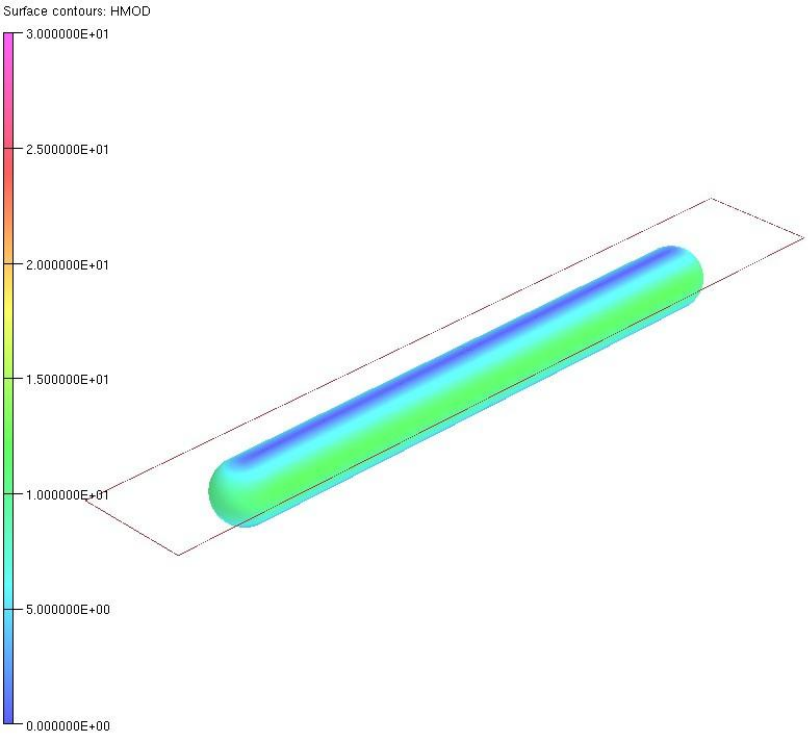
Examples of Redeployable 'Close-Wrap' Coil Design

In this case study the treatment system was supplied with two sets of coils to enable treatment of a submarine and a surface ship. In each case the vessel was fitted with a close wrap X coil and surrounded by a floating Z coil. The ship was also fitted with a Y coil to compensate for a non-ideal heading of the vessel during treatment.

In the first stage of the treatment the shaking field facilitates a change in the permanent magnetisation of the vessel in the direction of the Z bias. In the second stage of the treatment the Z bias is set to zero and the shaking pulses in the X direction are offset from zero to remove the longitudinal permanent magnetisation.



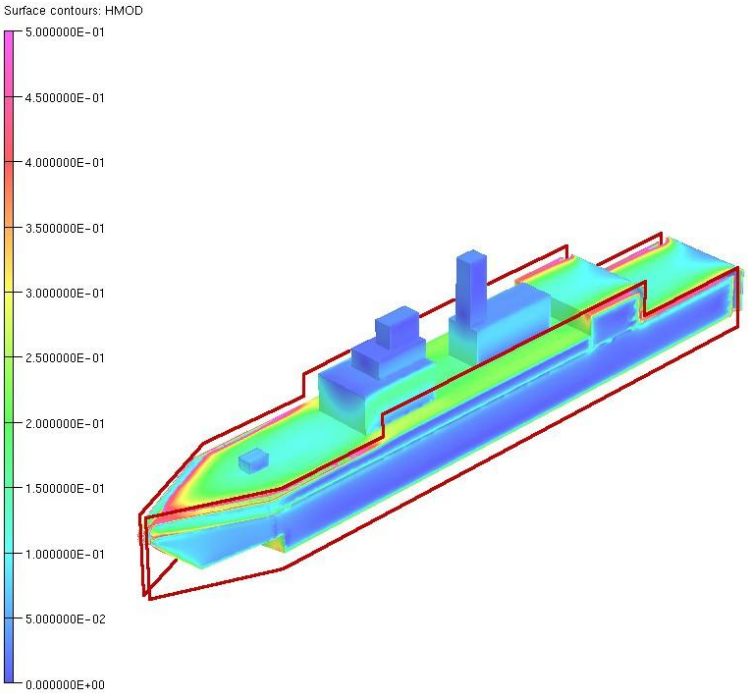
Uniform magnetic field of an X coil (in red) designed for a close wrap treatment of a submarine



Uniform magnetic field of an Floating Z coil (in red) designed for a close wrap treatment of a submarine

Ultra Electronics PMES - Design Tasks

Examples of Redeployable 'Close-Wrap' Coil Design



Uniform magnetic field of a Special Y coil pair (in red) designed for close wrap treatment of a surface ship treated on a non-ideal heading

Ultra Electronics PMES - Power - Operator Interface and Control

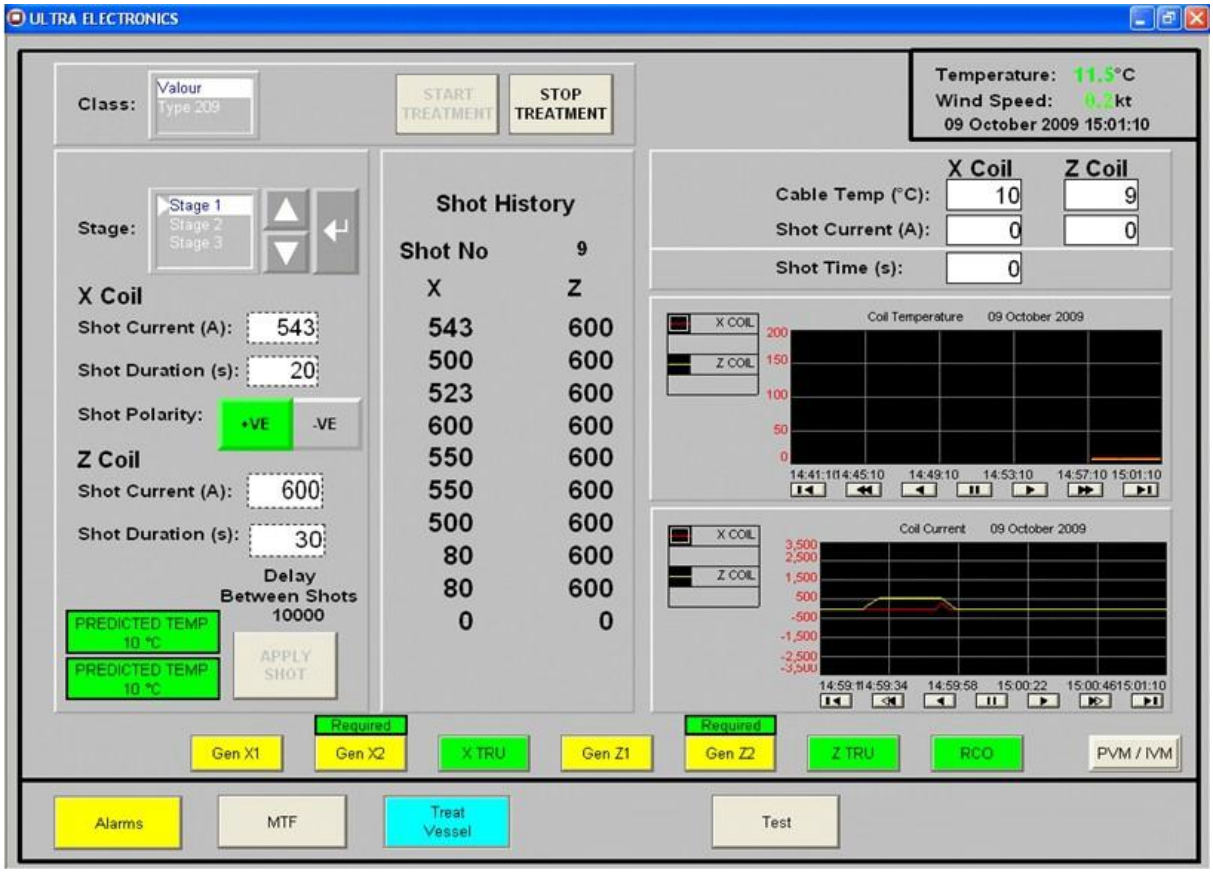
An operator console provides a graphical interface to permit the reporting of status information on all the plant items and to allow operator input of system values.

The power system is operated from the Range Control Office (RCO). In the case of a 'Close-Wrap' transportable system this would comprise a standard ISO container fitted out with air conditioning, desks and used to house the shore side equipment supplied for magnetic measurement and analysis. A separate area will be included for the operator of the MTF to control the power system. For 'Drive-In' and 'Over-Run' MTF systems the RCO is normally a permanent building.

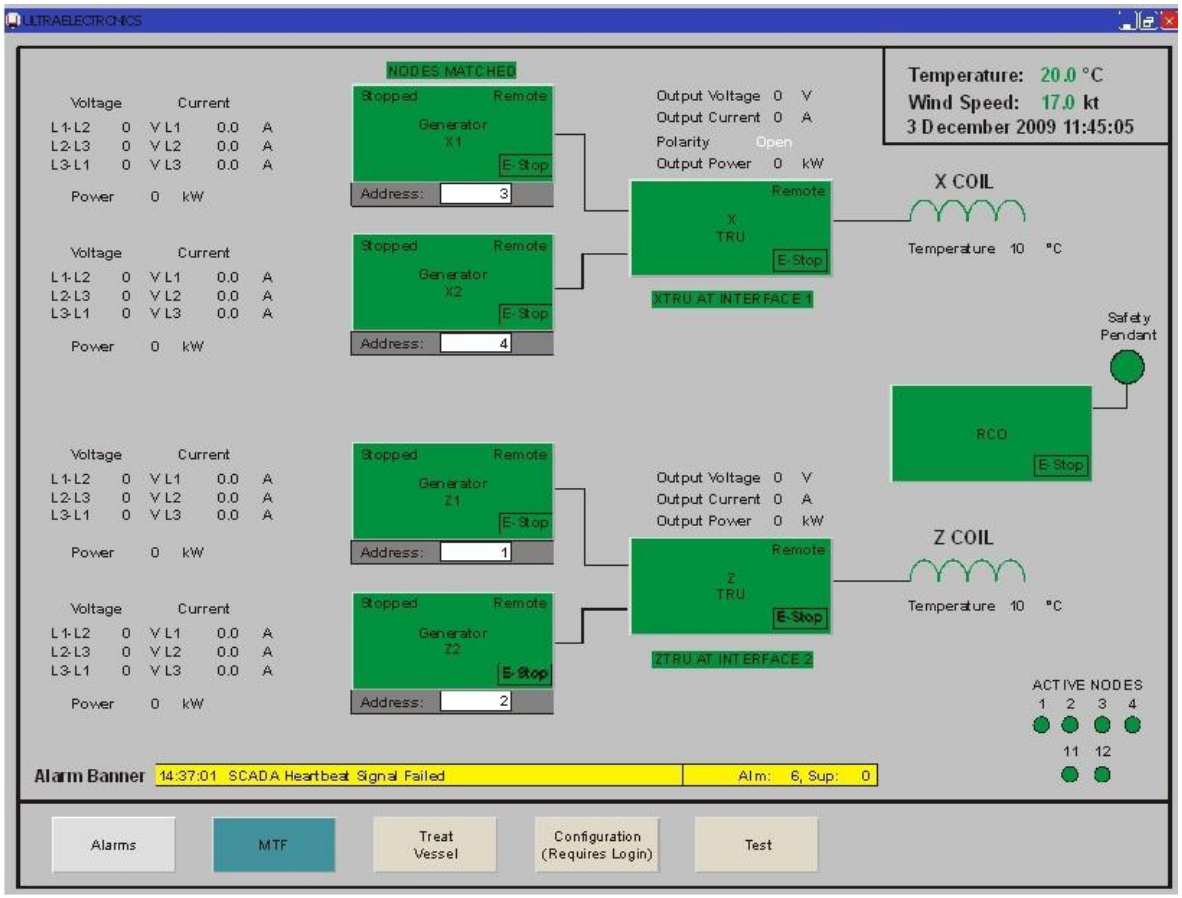
The operator interface is a graphical display used for both display of status information and entry of user commands.
The general requirements are as follows:

- Display voltage, current and power status for each power source
- Display TRU parameters, Voltage, current, polarity and power for each TRU
- Start & Stop of each power source
- Set output current and polarity for each TRU
- Start & Stop treatment pulse for X and Z coils
- Set output current for Y coil PSU (if fitted)
- Display real-time coil current profile
- Display feeder cable temperature for X and Z coil
- Display required inter shot cooling period, estimated from feeder cable temperatures and rate of change information
- Display magnitude and polarity of all shots in treatment sequence on request

Operator Interface Screen Displays



Main Control Panel showing the Treatment Pulse Sequence



Control Panel Showing the Currents Applied

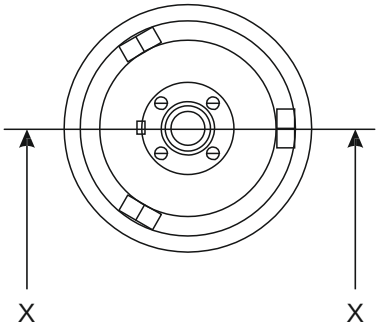
Ultra Electronics PMES - Sensor Solutions and Data Acquisition

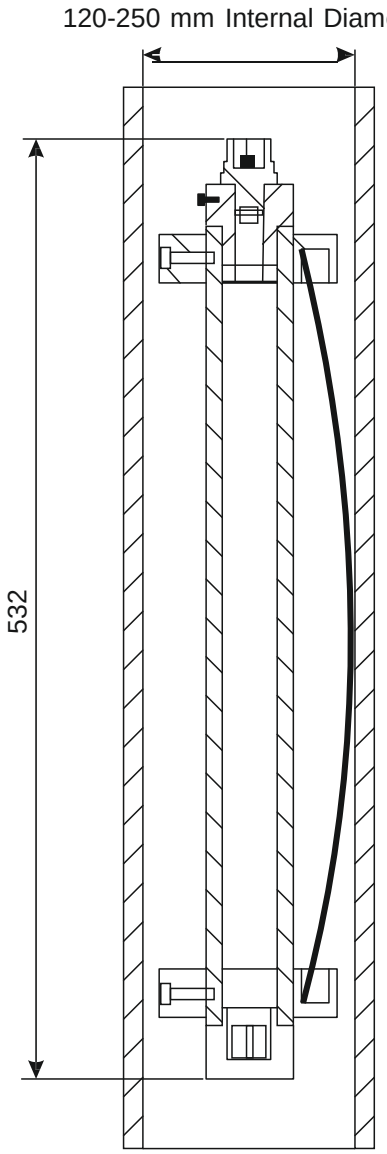
Sensor Solutions

Ultra offer a tri-axial fluxgate magnetometer solution specifically designed for treatment applications. The sensor accuracy is not affected by the large applied fields arising from the magnetic field coils during the treatment process. The very low self-noise, high accuracy, low hysteresis and excellent long term stability make this product an ideal choice for ship magnetic signature measurement.

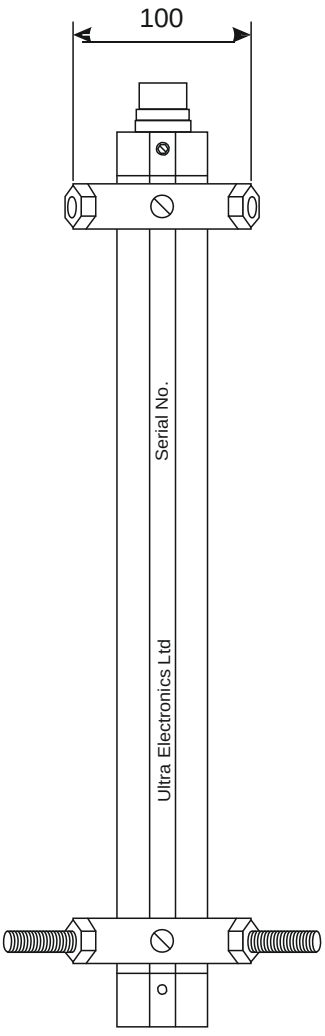
The standard sensor range is ±200 µT full-scale. The position of the three sensor axes are co-incident.

The sensor is supplied with a bow-spring mounting arrangement suitable for mounting in a vertical seabed cylinder.





SECTION X-X



Ultra Electronics PMES - Sensor Solutions and Data Acquisition

Sensor Solutions

The magnetometer requires approximately one watt of power from a 15-30 V supply and has a ±10 V full-scale (±200 µT). The internal supply is electrically isolated and causes no current to flow in the cable shields. Surge arrestors are fitted across all lines within the magnetometer to protect against damage by electrical discharge.

A Built-In Test (BIT) facility, activated by a remote contact gives assurance of correct functioning by creating a precise magnetic flux change within each axis. The BIT user interface is fully implemented allowing the Operator to validate the performance of each magnetic axis of every sensor.

A separate tilt sensor is also provided. Test screens are also provided to allow the sensor tilt to be determined.

Each sensor is marked with a serial number and full scale measuring range are engraved along the enclosure to Support Quality Assurance.
A fully assembled and tested polyurethane-jacketed marine telemetry cable can be supplied in lengths up to 1 km.

The 'wet-end' connector is an underwater mateable connector fitted to a 5 m pigtail.

Diagram shows a 3-axis magnetic sensor viewed from inside the sensor mounting tube. The sensor mounting tubes are sunk into the sea bed and the magnetic sensor positioned in the tube.

The tilt angle of the tubes can be measured at installation and compensated for within the modelling software.

For a Close-Wrap or Drive-In system, an array of magnetic sensors is positioned under the centre line of the keel of the vessel being treated.
For an Over-Run facility the sensors are arranged in a linear array at right angles to the vessels' track.

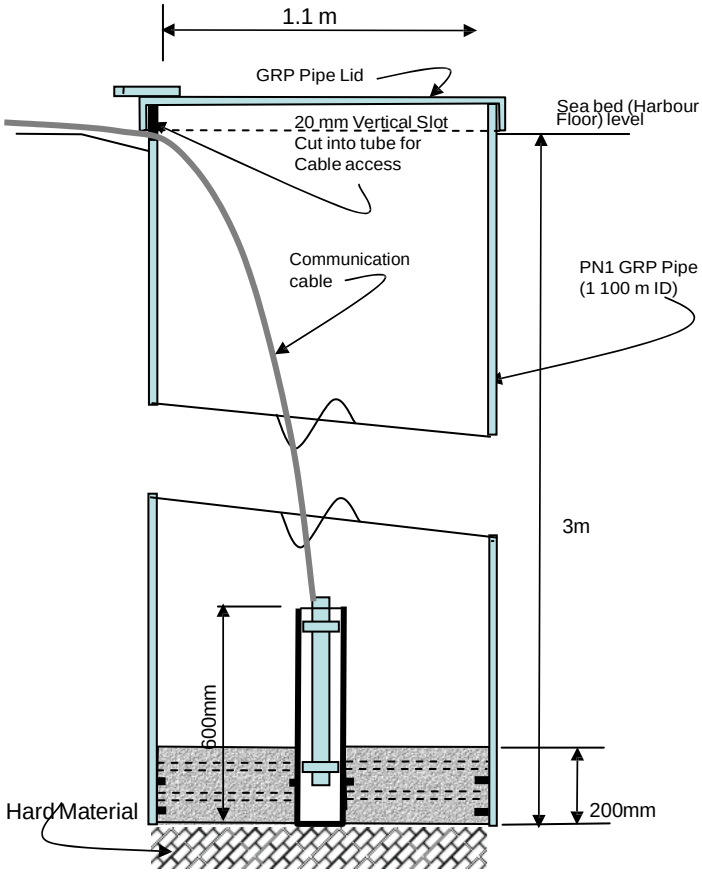


Diagram shows a cross section through the sensor mount.

This solution allows removal of the 3 axis magnetic sensor (shown in the middle of the lower tube) to prevent damage when the MTF is not in use.

Data Acquisition Systems (Drive-In and Close-Wrap Systems)

The data acquisition system will measure the field from the 3-axis sensors in a line approximately beneath the keel of the vessel. The position of the vessel as determined from the RTK DGPS tracking system is also recorded.

A versatile, multi-sensor data acquisition system is used consisting of analogue conditioning, A/D converters and a built-in PC. This provides sampling, recording, processing and display of measurements from a wide range of sensors in one, self-contained unit.

The data acquisition unit supports three-axis Magnetic Field Sensors and a depth/pressure sensor.

The system is supplied in a portable COTS 19-inch rack-style case, containing COTS A/D conversion modules and with a programmable Analogue Interface Module. The data acquisition unit rack has the capacity to support up to 40 three-axis magnetic field sensors.

The Data Acquisition Unit has comprehensive ESD surge protection on each of the sensor inputs.

Data Acquisition systems (Over-run Systems)

The data acquisition system will measure the field from the 3-axis sensors in an array orthogonal to the vessel's track. The position of the vessel as determined by the RTK DGPS tracking system is also recorded.

A typical versatile, multi-sensor data acquisition system is used consisting of analogue conditioning, A/D converters and a built-in PC. It provides sampling, recording, processing and display of measurements from a wide range of sensors in one, self-contained unit as described above for the Drive-In and Close-Wrap Systems.

Ultra Electronics PMES - Signature Processing Software

Data acquisition software collects data from the sensors, the DGPS tracking system, an underwater pressure sensor and a shore air pressure indicator. The signature data is saved in an Ultra proprietary ASCII file format in the ship's frame of reference.

The data is accessed and processed by proprietary Ultra 'Transmag' software which provides the user with various displays to enable the calculation of the required treatment currents. For Drive-In or Close-Wrap facilities, the system can calculate suggested treatment currents based on either 'Flash D', anhysteretic deperming processes or a user defined process. Alternatively the operator may use his judgement to calculate the next pulse current.

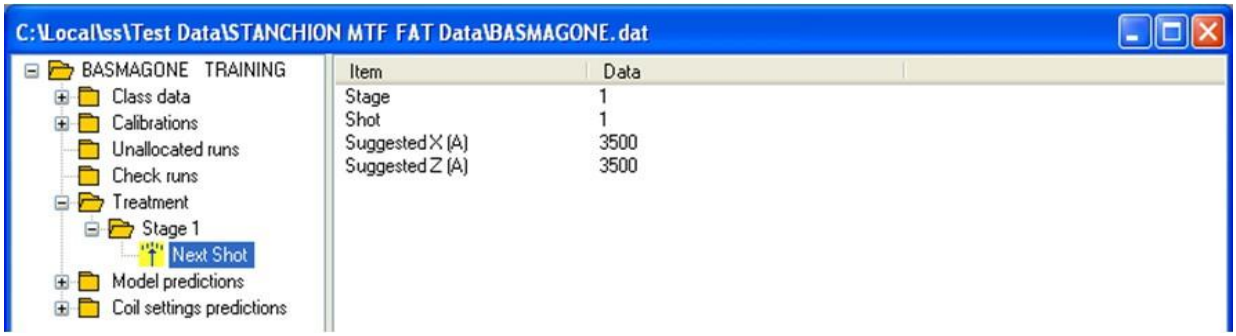
The vessel should be trimmed to be level such that no data correction is required to the vessel signature.

Treatment Data Analysis Software (Drive-in and Close-Wrap Systems)

Ultra proprietary 'Transmag' application software is used for analysis of both magnetic deperming and vessel ranging. The 'Transmag' software recommends the current pulses that are to be applied during treatment.

Suggested shot currents are displayed in a Next Shot object in the Treatment runs folder of the Tree View. Up to three stages of treatment can be defined.

Following each shot, the acquired data will be modelled to allow signature prediction at the standard depth. To verify the progress of the treatment process and to allow changes to be made where necessary, the required signature component, e.g. vertical magnetisation, will be plotted after each shot alongside that of previous ship states.



Analysis Software User Interface showing Treatment Data Folder and Predicted Treatment Shots for Drive-In and Close-Wrap systems

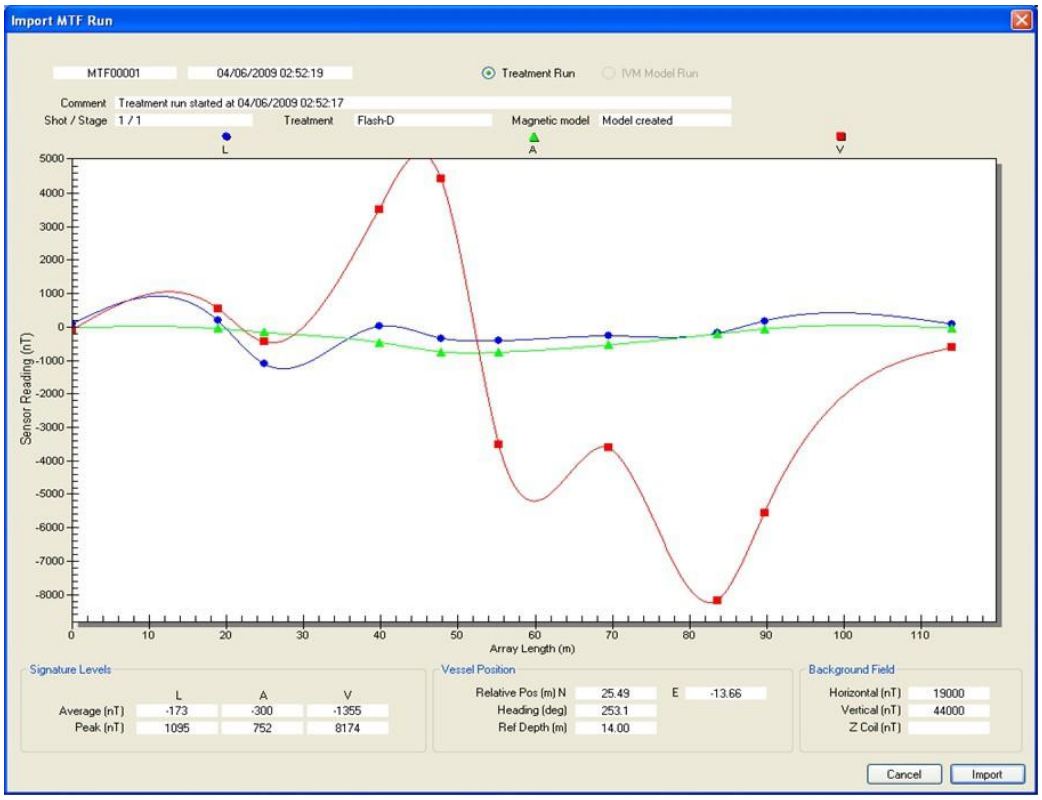
Ultra Electronics PMES - Signature Processing Software

Treatment Data Analysis Software (Drive-in and Close-Wrap Systems)

Once a power pulse (shot) has been made the 3-axis raw signature can be displayed.

The 3-axis magnetic signature can be displayed in ship's coordinates.

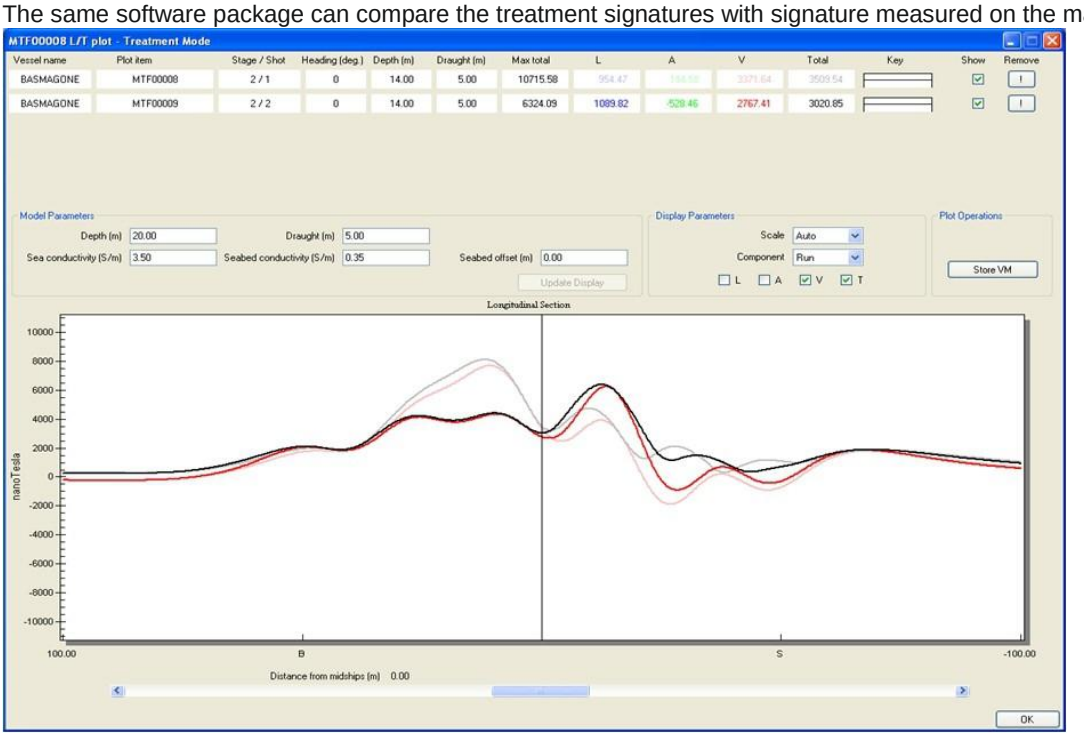
The raw signature is modelled and can be compared to the signature of the present and previous current pulses (up to 10 signatures may be displayed).



Raw Data Signature Display

The signature may be compared to any other signature; for example the initial signature at the start of the present treatment process or the signature at the end of the previous treatment..

The same software package can compare the treatment signatures with signature measured on the magnetic range

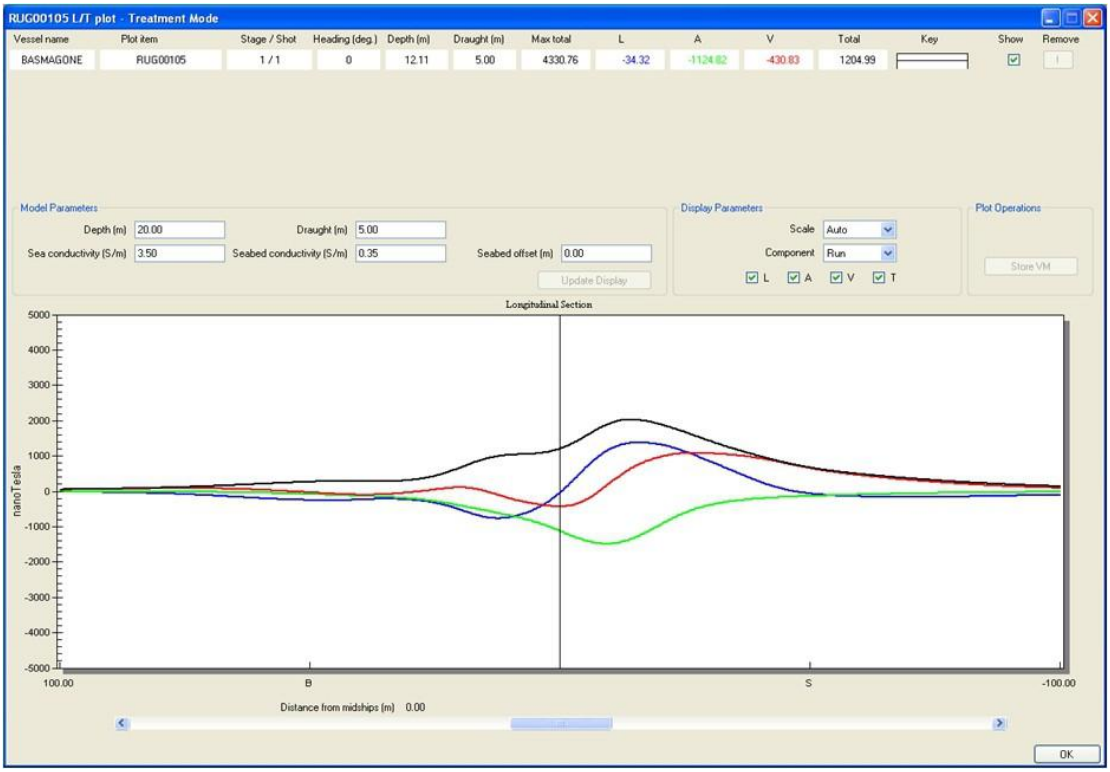


Comparison of the signatures measureed with the previous pulses (Drive-In or Close-Wrap) or transits (Over-Run)

Ultra Electronics PMES - Signature Processing Software

Treatment Data Analysis Software (Drive-in and Close-Wrap Systems)

The signature of the vessel at the end of any treatment shot or transit is modelled and can be predicted to any threat depth.



A vessel signature predicted to the 'Threat Depth'

The treatment is complete when the vessel reaches its required signature target level.

Treatment Reporting

The 'Transmag' application software features 'Cut and Paste' functionality which allows any signature to be included in an End of Treatment report. This would normally include initial and final signatures which can be displayed at measured or threat depth. The Current Pulse History may also be exported for Flash D and other pulsed treatments.

Signature results can be imported into the optional Ultra Signature database.

Data Transfer between Multi-Influence Ranges and Treatment Facilities

Data may be transferred between multi-influence ranges and magnetic treatment facilities to improve performance capability of both systems.

Horizontal induced magnetisation signatures from magnetic sea ranges may be imported to assist in signature analysis.

Vertical induced magnetisation signatures may be transferred to a magnetic sea range to improve worldwide signature prediction capability.

Ultra Electronics PMES - Site Suitability

The chosen site for the Magnetic Treatment Facility (MTF) must not be contaminated with ferromagnetic materials. Any ferromagnetic material in the area where the ship is to be depermed will affect the signature calculations. Such materials can be detected with a magnetic survey; magnetic surveys are available as an Option on request.

Typical MTF Equipment Specifications

Magnetometer Specification:

Measuring range	±200 mT
Scale factor	50 mV/mT
Zero field offset error	±60 nT
Hysteresis (when powered)	
Within measuring range	£1 nT
Beyond measuring range	10 nT @ 1 mT as standard (options available)
Stability	High temperature and zero field stability
Internal noise	<20 pT rmsÖHz @ 1 Hz
Built-in Test (BIT)	BIT generates -1 mT ±10% magnetic field in each axis (test data supplied for each sensor). Graphical user inteface
Linearity error	<0.0015%
Calibration accuracy	±0.5% DC
Orthogonality error (all axes to reference face)	<0.2°
Supply voltage	15-30 V polarity protected
Supply current	50mA @25 V (surge current 83 mA at switch on)
Analogue output	±10 V differential (full scale)
MTBF	75000 hours

Depth/Tilt Sensor Specification:

Depth	Sensor
	Full scale range
	2 bar minimum (relative)
Resolution	<0.01 bar
Gain error	±0.2% of full scale
Offset	±0.01 bar
Sample rate	<1 Hz

Tilt	Sensor
	Full scale range
	±10° min wrt vertical
Resolution	0.05°
Axes	2 axis <±1.0° orthogonal error
Error	±0.2% of full scale
Sample rate	<1 Hz
Offset	±0.05° max

Environmental Parameters	
Operating temperature	Air: 0°C to +40°C
	Water: +10°C to +25°C
Storage temperature	-10°C to +55°C
Pressure	4 bar max
Dimensions	Same dimensions as the magnetometer
Immersion	Suitable for indefinite immersion in sea water to a depth of 30 m

Shore Interface Unit

The shore equipment will provide the signal and power interface to the magnetic sensors and the depth / tilt sensor. The unit will include the interface hardware/software to connect to a stand alone PC running Windows XP to enable data collection from the sensor array under user control. The system will operate from a mains supply.

Environmental Parameters	
Operating temperature	
+20°C	±5°C
Storage temperature	-10°C to +55°C

Typical MTF Equipment Specifications

Examples of a Coil/Rectifier specification for a Close-Wrap system - Frigate and Submarine

Coils

An example of an X coil specification is given below. Note that a Z coil will also be provided. A Y coil is only provided if the vessel's heading is not on a North-South alignment.

X- Coil

	Frigate	Submarine
Connection	Insulated terminals	Insulated terminals
Size (approximate length)	Dependant on the size and construction material of the vessel	Dependant on the size and construction material of the vessel
Power (inductive):	2.2 MW	1.0 MW

X-Loop Rectifier

	Frigate	Submarine
Type	Thyristor	
Environment	Sheltered. Temperature -10°C to +40°C. Humidity 5% to 95%	
Input Power frequency	60 Hz, 6 phases, fed from external transformer (delta-wye)	
Output current	Typically up to 4000 A	
voltage ripple	Ripple <14%	
Set Point Accuracy	1% of Full Load	
Control	In-built PLC	
Protection	Overload, short circuit, open circuit, over voltage, control failure, thermal, load resistance change	
DC circuit breakers	Provided	

Other Products

Ultra Electronics PMES offer a range of other products including:

- Multi-influence measurement ranges
  - SM & AM magnetic
  - SE & AE electric
  - Acoustic
  - Pressure
  - Seismic
- Signature analysis software
- High performance magnetic sensors
- High performance electric field sensors
- Underwater electro-magnetic sensor packages
- Magnetic heading sensors
- Magnetic measurement ranges
- Land range systems
- Roll and stray field ranges
- AUV/USV/ROV ranges
- Mine sweep ranges

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