Magnetic Ranging and Treatment Facilities for Naval Application
What you should know about us

Activities at SAM Electronics focus on finding sophisticated system solutions in the fields of marine and naval systems, navigation and communication.

SAM Electronics, having become operational in 1998, comprises the former Marine and Naval activities of AEG, MBB and ATLAS Elektronik, carrying on the technology and traditions of the merging partners.

The consideration of mines and mine countermeasures necessarily involves "Magnetics". Expertise and know-how in these disciplines form the link in our activities in the areas of

- Shipborne degaussing systems
- Non-magnetic and low stray field design of equipment
- Systems for magnetic ranging and demagnetization treatment of naval vessels and equipments
- Mine sweeping equipments.

SAM Electronics has many years experience in these areas. This experience has been proven in large scale projects of the Federal German Navy, in addition to many projects for overseas navies. This brochure deals with our activities in the areas of

- Magnetic ranging of ferromagnetic vessels
- Magnetic ranging of non-magnetic vessels
- Magnetic ranging of components
- Magnetic treatment of vessels and equipments

Major areas of SAM Electronics naval activities linked by magnetics
Introduction

For about a hundred years sea mines have been an established element in naval warfare. By far the most important step in their development was the invention of the magnetic influence firing principle, which utilizes the magnetic interference field of passing ships.

Sea mines with magnetic fuzes are effective, inexpensive, easy to deploy in large numbers and a formidable weapon both physically and psychologically. Thus extensive measures are provided to protect naval vessels against the threat from sea mines. Due to the decrease of a vessel’s interference field with the distance in accordance with an exponential law, there is only a limited area under and around a ship, in which it will activate a sea mine. The boundary of this area of endangerment often referred to as danger depth, is defined by an assumed mine sensitivity. Ships are vulnerable to sea mines only, when their danger depth extends into the sensing area of the mine. For this reason all protective measures for vessels are aimed at a reduction of their “danger depth”. Instead of a danger depth the maximum admissible magnetic interference field of a vessel at beam depth, i.e. the water depth equal to the vessel’s beam, is often specified to define the degree of protection required by a vessel for the fulfillment of its operational role.

Reduction of danger depth and area by protective measures
Protective Measures for Vessels against Seamines

Conventional protective measures, either active or passive, are used to reduce the magnetic signature of a vessel.

Active protective measures comprise the installation of shipborne degaussing systems. Passive protective measures are those aimed at minimizing the effective permanent magnetic content of a ship. This is firstly achieved by appropriate design and secondly by a demagnetization treatment of the entire vessel. Design measures may comprise the use of non-magnetic material for hull and equipment and the layout of the electrical plant.

Major combat vessels are normally fitted with shipborne degaussing systems for compensation of permanent and induced magnetic interference fields. Demagnetization treatment is often used as a supportive passive protective measure. For ferromagnetic vessels not fitted with a shipborne degaussing system, the magnetic treatment offers the only means of protection, by a reduction of the vessel’s magnetic interference field caused by permanent magnetization. Compensation of their induced interference fields is possible to a limited extent.

Due to their operational role mine countermeasure vessels demand an extremely high level of active and passive protection. For this reason Mine Countermeasure Vessels (MCMVs) are generally built as non-magnetic vessels and fitted with degaussing systems which compensate permanent and induced interference fields. In addition, eddy current fields are sometimes compensated. In general, MCMVs also require magnetic treatment or non-magnetic design of components, intended for installation on board.

Submarines are constructed either as ferromagnetic or non-magnetic vessels. They use the same protective measures as surface vessels, depending on their type of construction. It is obvious that there is a need for facilities for magnetic ranging and treatment where the different types of vessels present in a fleet can be monitored for their magnetic signature, where protective measures can be carried out and their efficiency assessed.
Magnetic Ranging and Treatment Facilities for Vessels

Essentially magnetic ranging facilities for vessels consist of submerged field probes and evaluation equipment which measure the magnetic interference field of the vessel at a specific water depth. In addition, auxiliary sub-systems may be required.

In practical use two measuring range configurations have proven their value:
- Overrun ranges
- Stationary ranges

The type of a vessel and the protective measures applied determine the range facility required for a specific job.

Overrun magnetic measuring ranges are predominantly used for ranging of ferromagnetic vessels and submarines. In a maximum configuration they consist of probe rows aligned in the magnetic north-south and east-west direction. This arrangement is an optimal solution to separate the permanent and induced magnetization of the vessel and to determine the distribution of the induced magnetic field in the ship.

The vessel to be surveyed moves over the probe arrays at a constant speed and on fixed headings. As the ship passes, the probes are scanned at regular intervals so that a grid of measurements is obtained. A complete set of measurements comprises the results of overruns on two fixed headings and in both directions.

The composition of the fleet may require two separate overrun ranges, one each for small and large ferromagnetic vessels to comply with the requirements of adequate measuring depth. Standard measuring depth is 9 m and 18 m respectively.

The following tasks are performed on a typical overrun range:

For ferromagnetic ships equipped with shipborne degaussing systems
- Check ranging to assess the actual danger level
- Calibration of the permanent and induced channels of the shipborne degaussing system on the basis of data acquired by the ranging procedure.
- Check ranging to confirm improvements made on the vessels magnetic signature due to calibration of the degaussing system.

For ferromagnetic ships not fitted with a degaussing system
- Check ranging before and after magnetic treatment to confirm improvements made.

The overrun range for small ferromagnetic vessels can also be used for check and calibration ranging of non-magnetic vessels and submarines. Stationary magnetic measuring ranges are mainly used for ranging of non-magnetic Mine Countermeasure Vessels.

Typical tasks comprise:
- Check ranging
- Calibration of the permanent and induced channels and, if applicable, also of the eddy current channel of the shipboard degaussing system
- Measurement of the magnetic stray field
- Check ranging to confirm improvements made by calibration of the degaussing system.

In contrast to the overrun method, stationary measurements are carried out whilst the ship is moored over an array of probes. The probes are arranged along the longitudinal and transverse axis of the vessel and thus allow the interference field to be sampled at various points beneath the ship.

Standard measuring depth for ranging of non-magnetic vessels is 9.0 m. The essential feature of stationary magnetic ranging is the possibility also to measure the ship’s interference field caused by eddy currents. Since this effect occurs only during the rolling motions of a vessel, modern ranges for non-magnetic vessels allow roll simulation with the aid of vertical and horizontal magnetic fields generated by a coil system installed on the sea bed.

Another important feature of a stationary range for Mine Countermeasure Vessels is the possibility to directly measure and assess stray fields. Though small by comparison to other sources of ships magnetism, these fields caused by currents in the electric plant of a vessel require attention in MCMVs, due to their low overall magnetic signature.

Illustrations:
Magnetic ranging tasks and range configurations for various types of vessels.
See appendix, page 16

Probe and coil arrangement for a combined overrun range and magnetic treatment facility (figure shows E-W overrun course).
See appendix, page 17

Probe and coil arrangement for a stationary range.
See appendix, page 17
Magnetic Ranging Facilities for Components Mine

Countermeasure forces in the fleet necessitate a magnetic range for components where equipment such as diesel engines, generators etc. can be monitored for their magnetic condition prior to installation on board.

The tasks performed on a component range comprise:
- Check ranging in order to confirm that the magnetic interference field limit values are not exceeded
- Ranging and subsequent procedures for compensation of interference fields by means of permanent magnets and calibration of degaussing coils if fitted.
- Check ranging in order to confirm the results of magnetic treatments.

A ranging system for components comprises the following main assemblies:
- Magnetic probe array
- Overrun rail track with measuring trolley
- Data acquisition and evaluation equipment
- Coil system for generation of magnetic fields

The component to be surveyed is mounted on the measuring trolley which is then moved over the magnetic probe array. The acquisition of the magnetic field data is controlled by a computer system which also evaluates and displays the results. The coil system allows separation of the permanent and induced magnetization of the components which cause the interference field.

The same concept of roll simulation measurements which is employed with MCMVs is also used for components. The component is held stationary above the probe array and the roll movements are simulated by artificial magnetic fields generated by the coil system. Control of this process is also performed by the computer system.
Magnetic Treatment Facilities for Vessels

The magnetic treatment in its various modes is widely used as a supportive means of mine protection on ferromagnetic naval vessels equipped with a shipborne degaussing system. For all other ships not equipped with a degaussing system, magnetic treatment provides the only possibility to improve their protection against sea mines.

The magnetic treatment is characterized by the exposure of the vessel to strong alternating magnetic fields pulsating at low frequency. The magnetic fields are generated by a demagnetization coil system. A second coil arrangement provides compensation of the earth’s field and generation of an additional stationary field in order to allow the demagnetization process to take place in a magnetically defined environment.

Two methods are generally used:
- Stationary treatment, i.e. coils wrapped around the moored ship. Because of the attachment of the coils this method is very time consuming, in particular for large vessels. Prerequisite for this method is that a sensor array is provided at site which allows alternate checks and treatments. The procedure is often referred to as "Deperming".
- The overrun treatment method which SAM Electronics proposes for demagnetization of vessels – is characterized by coil systems installed on the sea bed which the ship overruns at low speed on a fixed course. During overrun each section of the vessel gradually comes under the effect of the demagnetization field. Having reached a maximum in a vessel’s section the demagnetization field declines to zero with the progress of the vessel. This “section-alized” demagnetization provides an effective treatment in a considerably shorter time, thus giving the range a higher capacity in comparison to the deperming procedure. This concept also offers the additional advantage of using a combined coil system for ranging and magnetic treatment.

Ferromagnetic vessels not equipped with a shipborne degaussing system often make use of a variant in the magnetic treatment. Though demagnetization generally does not affect the induced components of the ship’s magnetic signature, it is possible to partly compensate the vertical induced interference field by an impressed permanent magnetization in the inverse direction. SAM Electronics supplies magnetic ranging and treatment facilities of various configurations either as "stand alone" or integrated facilities, comprising individual ranges for various applications.
Major System Components for a Magnetic Ranging and Treatment Facility

On the basis of the measurement and treatment tasks defined for various types of vessels the magnetic ranging and treatment systems can be broken down into the following main subsystems:

- Magnetic field measuring systems
- Electronic data processing systems for data acquisition, evaluation and presentation
- Coil systems for compensation of the earth's magnetic field and for generation of magnetic fields for roll simulation and demagnetization treatment
- Power supply and control equipment for the coil systems.

Magnetic Field Measuring System

The magnetic field measuring system comprises – in its most simple configuration – a single axis magnetic probe array and magnetometers for the unidirectional sensing of the magnetic field strength at the location of the array.

In practice – for ranging of entire vessels – single, double or triple axes sensors arranged in arrays are used together with multi-channel magnetometers.

The probes supplied by SAM Electronics are passive measuring devices, based on the fluxgate measuring principle. The magnetometer control electronics generates a signal for excitation of each sensor. A response signal corresponding to the magnetic field intensity is transmitted back to the magnetometer where it is converted into a field proportional DC signal for further processing in the computer system.

In addition to the vessel’s magnetic interference field, other static magnetic fields such as the earth’s field, interference fields resulting from magnetic anomalies and alternating fields attributable to roll simulation are prevalent at the probe location. Those have to be eliminated to obtain the vessel’s interference field alone. This can be achieved by:

- Generation of compensation fields at the location of the sensor
- Installation of neutralization circuits in the probe
- Subtraction of undesired field components from the aggregate field signal in the data processing area by means of a software program.

The Integral Magnetometer Concept introduced by SAM Electronics uses the latter method for application in magnetic field measuring systems. It avoids the disadvantage of additional highly accurate hardware for elimination of undesired field components by using software programs for compensation. Only the alternating roll simulation field is compensated in analog mode by a neutralization coil within the probe.

Illustration:

Probes and magnetometers for application in ranging facilities for vessels and components

See appendix, page 19
SAM Electronics’s Integral Magneto-meter Concept uses standard hardware and thus allows application in both magnetic ranges for vessels and for components.

**Data Processing System**

The data processing system is a key component in every magnetic ranging and treatment facility. Because of the large amount of data to be handled, extensive data processing is required to perform ranging and magnetic treatment efficiently and economically. Automated measuring and analyzing procedures and clear presentations of measuring results support the range operator.

SAM Electronics provides efficient computer hardware and extensive software programs for a variety of processing tasks related to:

- Data acquisition and correction
- Data evaluation and analysis
- Data presentation and archiving.

**Data Processing System Tasks**

Ranging and treatment procedures for various classes of vessels and for equipments are reflected in the data processing tasks effected by the computer system.

**Check ranging**

Check ranging is normally effected on overrun ranges before and after magnetic treatment and/or calibration of shipborne degaussing systems.

Data processing tasks include:

- Data acquisition and correction.
  The data acquired from the magnetic field measuring system are converted into a ship coordinate related data field. The scan error due to overrun, probe offset and amplification factor are determined before each overrun and accounted for in the computer system. For measurement on stationary ranges the acquired data are corrected for probe offset and amplification factor only.
- Data presentation and archiving.

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**Illustration:**
Principle of SAM Electronics’s integral magneto-meter concept. See appendix, page 19
Data presentation is effected on monitors, printers and plotters. The field values are presented for each overrun:

- As line diagrams of all probes as longitudinal or athwartship shots (magnetic profile in longitudinal and athwartship direction) in a common presentation
- As line diagram for each probe as longitudinal shot
- As isomagnetic lines for an overview of the vessel’s magnetic status

The operator checks the vessel’s magnetic signature for compliance with limit values. The results are stored on a floppy disk memory for archiving.

**Calibration ranging**

Calibration ranging is made for adjustment of shipborne degaussing systems. Permanent/induced channel calibration is generally performed on overrun ranges for ferromagnetic vessels and on stationary ranges for non-magnetic vessels.

Data processing tasks are:

- Data acquisition and correction as with check ranging
- Display of field data as an intermediate step in the form of longitudinal and transverse magnetic profiles and of isomagnetic lines.
- Data evaluation and analysis.
  The computer system performs the separation of the permanent and induced components of the ship’s magnetic interference field and displays them separately. Based on the results of the P/I separation the computer calculates the amptturn setting of each sectional degaussing coil. Calibration of the degaussing system is an iterative process. Repeated adjustments derived from previous ranging bring the residual magnetic field to within specified limits.
- Presentation and archiving.
  Data presentations are given for measured data as for check ranging, and in addition for processed data of the vessel’s magnetic fields. As a final activity the operator initiates archiving of the final magnetic ship’s data as well as the final settings of the shipborne degaussing system on a floppy disk memory.
- Calibration of the eddy current channels of a degaussing system is performed on stationary ranges, equipped with facilities for roll simulation.

Data processing tasks are:

- Data acquisition and correction as described with check ranging
- Presentation and archiving.
  Data presentations are given for measured data as for check ranging, and in addition for processed data of the vessel’s magnetic fields. As a final activity the operator initiates archiving of the final magnetic ship’s data as well as the final settings of the shipborne degaussing system on a floppy disk memory.
- Calibration of the eddy current channels of a degaussing system is performed on stationary ranges, equipped with facilities for roll simulation.
Data evaluation and archiving.
On the basis of the data derived from the computer in various presentations, the operator works out the adjustment data for the eddy current channel. Subsequent roll check simulation is performed to confirm the improvements made by the calibration. The operator initiates archiving of final status data on floppy disk memory.

Stray field ranging
Ranging of static magnetic stray fields is performed on stationary ranges for non-magnetic Mine Countermeasure Vessels to determine the effects of magnetic stray fields caused by the vessel’s electrical plant.

Data processing tasks include:
- Data acquisition and correction.
  Data acquisition and correction are performed similarly as with check ranging on stationary ranges. However, the data are derived from measurements of the vessel with and without energized stray field emitting components or circuits.
- Data presentation and archiving.
  Data of the signature of the interference field caused by the vessel’s stray field are presented. The operator monitors stray field data for compliance with limit values with the aid of the presentations and initiates archiving on floppy disk memory.

Supportive tasks
The data processing system accomplishes tasks for the support of measuring procedures and for operator assistance. They are partly aimed towards automation of routine jobs, another part is directed at creating and maintaining a data base for the range.

Supportive tasks include:
- Probe calibration check. The data processing system automatically calibrates and functionally checks the magnetic probes to be used. Defective probes are identified for further action.
- Provision of data
- Ship’s data for description and identification of vessels
- Environmental data, such as water depth and relevant meteorological data prevalent at the time of ranging
- Information on a ship’s magnetic condition. Relevant data on the magnetic history of all vessels in the fleet such as previous magnetic treatment and ranging, as well as major overhauls are recorded in a ship’s catalogue.
Data Acquisition and Evaluation System

SAM Electronics provides two systems to implement the ranging tasks associated with different classes of vessels and components, the Magnetic Ranging Systems MARAS 1000 and MARAS 300.

- The MARAS 1000 system is employed for multi-purpose ship’s magnetic ranges e.g. ranges having both overrun and stationary measuring facilities, permitting rapid processing of large quantities of data.

Maras 1000 electronic data processing system
The MARAS 300 system is employed for data acquisition and evaluation in magnetic ranging facilities for components. It is also suitable for single overrun ranges or small stationary ranges.

System Hardware

Both systems use modern highly sophisticated computers and peripheral equipment:
- Computers for control of the entire system: CPU with 16 bit or 32 bit architecture, extendable memory from 750 Kbyte to 2 Mbyte or 7.5 Mbyte capacity depending on the system.
- Graphics terminal as dialog oriented man machine interface with a wide range of graphics capability.
- Magnetic Disk Unit (Winchester drive) for storage of application software programs and ranging data: 10 -130 Mbyte capacity, magnetic back-up tape unit for securing data and programs.
- Flexible disk unit for archiving ranging and ship specific data: Drives for all standard available disk sizes and formats, single or dual drive, up to 1.2 Mbyte capacity per drive.
- Printer for hardcopy documentation with Graphics capability.
- Plotter for hardcopy documentation with two to eight separately addressable pens and high resolution CI Multicolor presentations.
- Data acquisition unit as interface between computer and magnetic system with processor control, high resolution, high speed A/D converter, analog channel multiple xer and digital in/outputs.

System Software

Both MARAS systems use extensive software programs for processing data derived from the ranging and magnetic treatment of vessels and components, structured into computer software and application software.

Computer software essentially comprises compiler-interpreter-editor and debugging programs together with extensive diagnostic software routines for self test of the computer hardware assuring fast and reliable system maintenance.

They are structured into
- Data acquisition and correction programs
- Data evaluation and analysis programs
- Data presentation and archiving programs
- Utility programs

The programs allow interactive communication between operator and computer which assures that all ranging tasks specified before can be implemented with maximum speed and accuracy. The modular configuration of the application software assures economical adaption to customer specific requirements.

Coil Systems and Power Supply

Magnetic ranging and treatment facilities require extensive coil systems for generation of artificial magnetic fields. Adequate power supply is needed to energize them. These coil systems are composed of individual coil arrangements for:
- Generation of a vertically effective magnetic field
- Generation of a horizontally effective magnetic field
- Generation of a slowly pulsating magnetic field for demagnetization treatment
- Generation of a superimposed static magnetic field in vertical direction for use in special variants of the magnetic treatment.

The individual coil arrangements can be used in various combinations and in different modes, to suit all ranging and treatment requirements. While check ranging of ferromagnetic vessels can be performed without the need for artificial magnetic fields, generated by the coil systems, ranging for calibration of degaussing systems normally necessitates coil systems for compensation of the vertical and horizontal component of the earth’s magnetic field. This allows separation of the permanent and induced ship’s magnetic field by over-runs on opposite headings. For the magnetic treatment the same coil systems provide the magnetically neutral environment by earth field compensation, while according to the process selected, the other two coil systems generate the necessary magnetic treatment fields.
Overrun ranges used for ranging and calibration of degaussing systems as well as for magnetic treatment thus require installation of all 4 coil systems. Stationary ranges used for calibration ranging of non-magnetic vessels require artificial magnetic fields for roll simulation. For this purpose, horizontal and vertical effective coil arrangements are energized such that the resultant vector simulates roll angles and roll velocities typical for mine countermeasure vessels, to allow the measurement of the vessel’s eddy current fields. A prerequisite both for magnetic ranging and for the magnetic treatment is sufficient homogeneity of the magnetic fields generated by the coils, necessitating complex coil designs. A special computer aided design program is available at SAM Electronics for this purpose.

SAM Electronics’s concept of coil arrangement is characterized by the exclusive use of bottom coils, located on coil supports on the sea bed. This is a particularly economical solution since heavy supports for the horizontally active (vertically arranged) coils are avoided. It also allows the unassisted overrun of vessels during ranging and magnetic treatment. The physical dimensions of the individual coils and the required field strength at the respective water depth prevailing at the site determine the power demand. SAM Electronics supplies the entire electrical installation for magnetic ranging and demagnetization facilities. Apart from the coil systems these are:

- Switchgear and related control and monitoring equipment.
- Converter sets comprising AC drive motors and connected DC generators which allow individual control of coil currents.

SAM Electronics also supplies the high and medium voltage power transformers and switchgear for connection of the ranging and treatment facility to the public utility power grid and diesel alternator sets for alternative or back up power supply.
Integrated Logistic Support

The Integrated Logistic Support (ILS) constitutes an essential part of SAM Electronics’s system responsibility for magnetic ranging and demagnetization facilities. Integrated logistic support includes:

Documentation

Extensive hardware and software documentation is provided to SAM Electronics’s military oriented company standards.

Material Support

Detailed catalogues for spare parts, special tools and test equipment and their long term supply form the basis for life cycle support provided by SAM Electronics.

Training

SAM Electronics’s well proven training concept includes comprehensive training of operators, maintenance engineers and technicians as well as training courses for the customer project management personnel and system engineers. The training concept of SAM Electronics provides a high degree of “know how” transfer. It assures efficient operation and high availability of all systems.

Project Management

The vast experience in large scale naval projects allows SAM Electronics to offer systems for magnetic ranging and treatment of ships and components on a turnkey basis. The assumption of the full system responsibility for a project on a turnkey basis includes the participation of local resources, which may contribute to the work in various work packages.

Major work packages for implementation of a magnetic measuring and demagnetization range are:

- Site investigation
- Realization proposal for the whole project
- System design
- Equipment production
- Planning and drafting of civil construction works
- Construction of civil works installation of equipment
- Commissioning and setting to work
- Logistic support.

SAM Electronics’s project management will guarantee the interfacing of all work packages monitoring the project under technical and economical aspects, thus ensuring the user is supplied with mature systems in full compliance to contractual specifications.

Illustration:

Major work packages for implementation.

See appendix, page 20
Appendix: Illustrations

Magnetic ranging tasks and range configurations for various types of vessels.
Probe and coil arrangement for a combined overrun range and magnetic treatment facility (figure shows E-W overrun course).

Probe and coil arrangement for a stationary range.
Diesel engine undergoing check ranging on a component range.
Major system components for a magnetic ranging and treatment facility

Principle of SAM Electronic’s integral magnetometer concept
Major work packages for implementation.
Schematic layout for a magnetic ranging and treatment facility.