TRISTAN TECHNOLOGIES, INC

Magnetic and Cryogenic Device solutions

Bio Systems Information Brochure

TRISTAN TECHNOLOGIES, INC.

Bio Systems Information Brochure

6191 Cornerstone Court East • Suite 107
San Diego, CA 92121
Phone 858.550.2700 • Fax 858.550.2799

Table of Contents

System information and advantages

Biomagnetic measurements provide a number of advantages compared to electrical measurements:

- Biomagnetism is non-invasive. The detection system does not contact the subject. The non-invasive nature of biomagnetism makes it an inherently safe procedure and minimizes subject preparation time.
- Insulating barriers such as the skull, varying layers of tissue, anatomical open spaces, do not attenuate or distort magnetic fields. Electrical signals are distorted by the varying resistive layers between the signal source and the surface skin.
- SQUID magnetometers will measure the vector component(s) of the magnetic field. Thus localization is much easier than with electrical measurements, which only measure scalar voltages.
- Magnetic measurements can be made for which there are no electrical analogs. These include measurements of static magnetic fields, measurements of the magnetic susceptibility and measurements where an invasive procedure is not possible (e.g., fetal cardiography).
- Because of the superconducting nature of SQUID measurements, true dc response and flat phase response are available.

Instrumentation

The strength of biomagnetic signals is many orders of magnitude smaller than even the earth's magnetic field, which is 1/2 Gauss or 50 microtesla. The signal strengths associated with biomagnetism (Fig. 1) require the use of extremely sensitive detection systems. The units in this figure are femtotesla, 1 fT = 10-15 tesla. The only instrument with the required sensitivity and bandwidth is the SQUID magnetometer.

The components of a SQUID magnetometer (Fig. 2) typically consist of the following: a detection coil, which senses changes in the external magnetic field and transforms them into an electrical current; an input coil which transforms the resulting current into a magnetic flux in the SQUID sensor; electronics which transform the applied flux into a room temperature voltage output; and acquisition hardware and software for acquiring, storing and analyzing data. Both the SQUID amplifier and the detection coils are superconducting devices. Thus some type of refrigerant (liquid helium or liquid nitrogen) or refrigeration device (cryocooler) is needed to maintain the SQUID and detection coil in the superconducting state. Additional signal conditioning electronics may be needed to improve signal-to-noise.

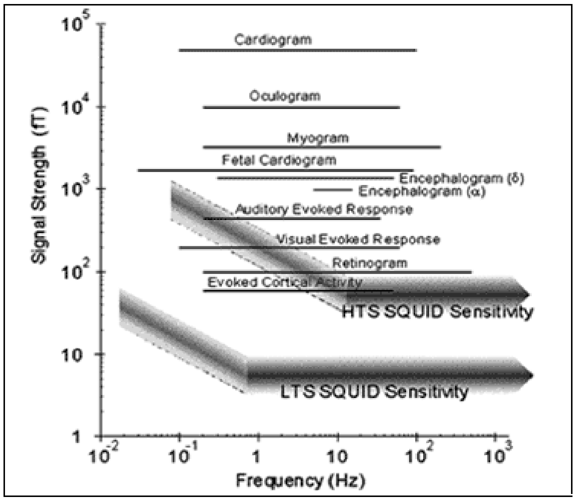


Figure 1: Typical amplitudes and frequencies of various biomagnetic signals. shaded regions indicate the limits of currently available SQUID sensors.

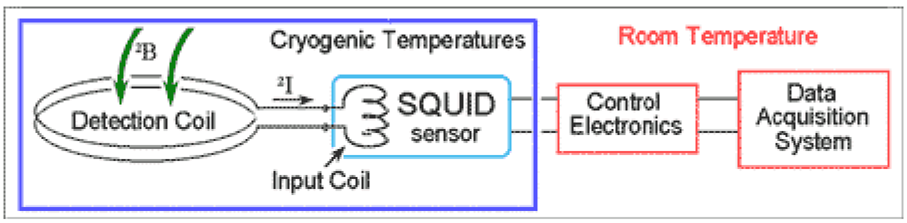


Figure 2: Block diagram of a SQUID magnetometer

The SQUID sensor and electronics package can be considered as a black box that acts like a magnetic field-to-voltage converter and amplifier with extremely high gain. In addition, it offers extremely low noise, high dynamic range, excellent linearity, flat phase response and a bandwidth that can extend from dc to beyond 100 kHz, capabilities that no other single sensor offers.

The type of SQUID sensor and detection coil configuration is dependent on what is to be measured. Figure 1 also shows the capability of both low temperature (requiring liquid helium temperatures, and referred to as LTS) and high temperature (requiring liquid nitrogen temperatures, and referred to as HTS) SQUID magnetometers. Tristan biomagnetic measurement systems make use of either Tristan's LSQ/20 LTS dc SQUID sensor or the HTM-8 HTS dc SQUID sensor. The input coil for an LTS SQUID is normally fabricated from flexible superconducting NbTi wire. The inherent anisotropic nature of HTS SQUIDs requires that the input coils be planar. Typically HTS magnetometers are available only as pure magnetometers.

Another factor to be considered is the detection coil configuration. Conceptually, the easiest input circuit to consider for detecting changes in magnetic fields is a pure magnetometer (Fig. 2). However, magnetometers are extremely sensitive to all magnetic signals in the environment. This may be acceptable if one is measuring ambient fields. However, if the magnetic signal of interest is weak, then environmental magnetic interference may prevent measurements. If the signal source is close to the detection coil, then a gradiometer coil may allow a weak signal to be measured. Figure 3 shows the relative noise rejection for 1st and 2nd derivative gradiometers. The figure insert shows a first order gradiometer, consisting of two coils connected in series but wound in opposite senses, and separated by a distance "b", called the gradiometer baseline. A uniform magnetic field (e.g., from a distant environmental source) would couple equal but opposite quantities of flux into the two coils, resulting in zero net flux in the gradiometer, or zero signal. However, signal sources that are close to the lower coil (relative to the baseline, or separation between coils) would couple significantly more flux into the lower coil than into the upper coil; this would result in a net flux in the gradiometer and hence the signal would be detected.

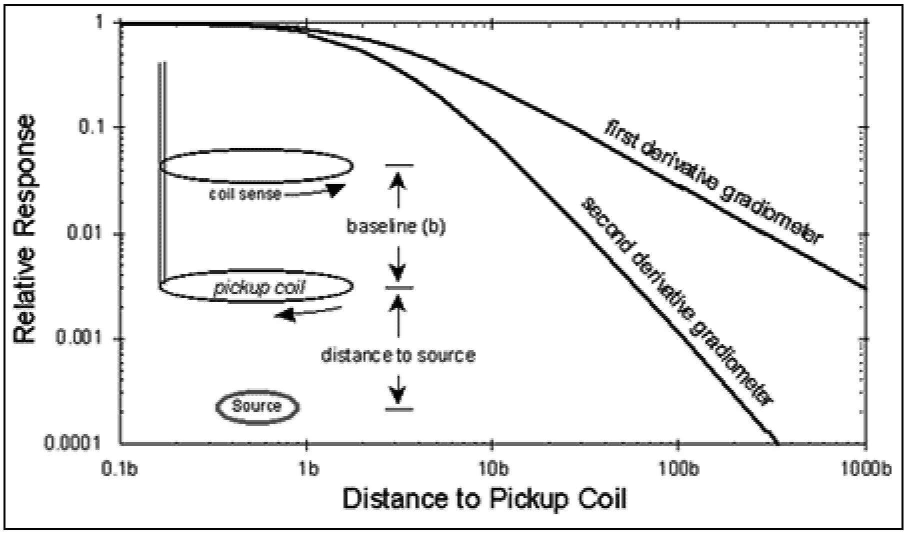


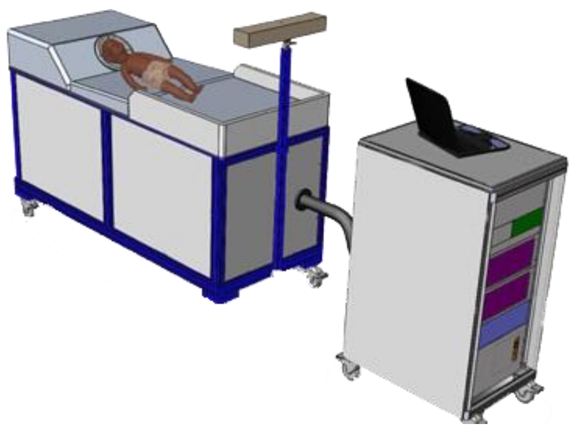
Figure 3: Response of gradient coils relative to magnetometer response (1/r3 suppressed)

For objects objects that are close (relative to the gradiometer baseline), the gradiometer acts as a pure magnetometer, while rejecting more than 99% of the magnetic signals coming from distant objects. In essence, the gradiometer acts as a “compensated” magnetometer.

Normally, SQUID magnetometers (and gradiometers) map the axial (BZ) component of the magnetic field. Obviously, using three sensors, it is possible to monitor all three vector components of the magnetic field. Additional channels of SQUID sensors can be used to provide reference channels for electronic balancing. Portions of the reference magnetometer responses are summed electronically with the detection coil(s) output to reject common mode signals from distant noise sources. Electronic balancing can be used to create an HTS axial gradiometer from two HTS magnetometers.

1. BabySQUID NEONATAL BIOMAGNETOMETER

The BabySQUID Neonatal Biomagnetometer is a new investigational tool for neurological impairments of pre-term and full-term infants. babySQUID® (pdf) measures and maps brain activity non-invasively at the



bedside.

CLINICAL ADVANTAGES of babySQUID®

- Map the sites and dynamics of sensory functions
- Map seizure and inter-ictal activity for epilepsy monitoring
- Assay stages of nervous system development
- Monitor recovery from trauma
- Detect effects of earlier hypoxic and intracranial injury

More newborns survive even with neurological disabilities.

CONDITION	INCIDENCE
perinatal asphyxia	between 2 – 47 per1000
hypoxemic-ischemic encephalopathy	between 3 – 8 per 1000
moderate-to-severe cerebral palsy (post neonatal)	between 1 – 3 per 1000
periventricular white matter injury	240 per 1000 (for gestational age < 38 weeks)

TECHNICAL ADVANTAGES OF BabySQUID®

- Unprecedented spatial resolution and sensitivity.
- A dense array of closely spaced sensors is located just below the outer surface of a headrest.
- The sensor noise is < 10 fT/ÖHz for the detection coils.
- BabySQUID® has an order of magnitude better sensitivity to neuronal sources than conventional whole-head MEG systems o Sensitive enough to measure spontaneous neuronal activity and evoked activity of the cortex of the newborns in real time without signal averaging o Spatial resolution four times greater than existing whole-head MEG sensors
- In comparison, EEG signals are significantly distorted by skull defects (fontanels and sutures) unique to the human neonates. These skull defects can obscure the asymmetry of the signals, especially when the generator is deep, making it difficult to determine the location of the epileptiform tissue when it cannot be easily visualized by CT or MRI.

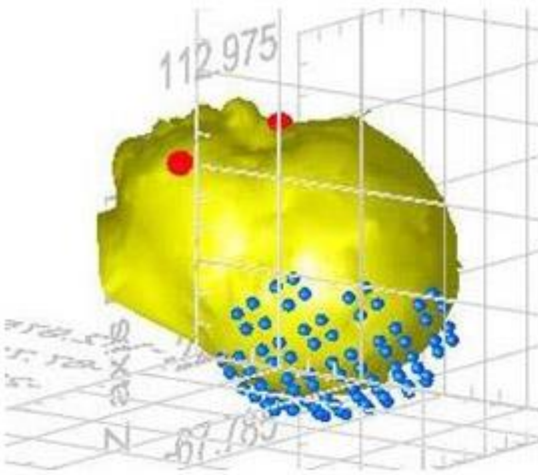
PRINCIPLES OF PRODUCTION

Superconducting amplifiers (SQUIDs) are used to amplify magnetic signals detected by a large array of small detection coils. The detection apparatus is kept at cryogenic temperatures by a vacuum insulated vessel (dewar). Tristan developed fabrication methods allow the detection coils to be placed extremely close to the patient without loss of sensitivity or risk to the patient. Additional information on neuromagnetic instrumentation can be found at Chapt2.pdf. The babySQUID® takes advantage of the fact that the infant’s scalp and skull are thin. This make it possible to measure MEG signals at a distance of only about 5-6 mm from the brain surface. This shorter distance results in a significant increase in amplitude of MEG signals from the newborns, since the magnetic field is inversely proportional to the square of the distance. The shorter distance and the high density of detectors also results in higher spatial resolution.

2. ARTEMIS123®

SYSTEM DESCRIPTION, PRINCIPLES OF OPERATION

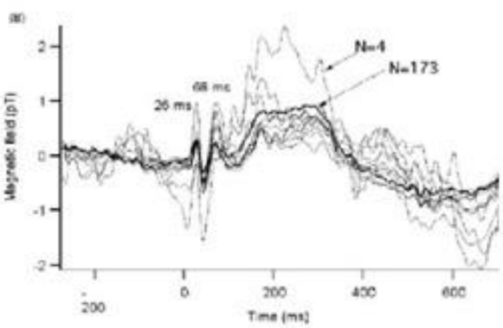
Like adult Magnetoencephalography (MEG) systems, Artemis123® uses superconducting sensors to non-invasively detect and map magnetic fields generated by cortical neural activity. However, Artemis123® takes ad-vantage of the fact that the infant's scalp and skull are very thin. Tristan's fabrication methods put the sensing coils very close to the infant brain's sources of activity, even though SQUIDs must operate in an ultra-cold liquid helium environment. The net result is a significant in-crease in amplitude of neonate MEG signals. Also, the high density of detectors results in higher spatial resolu-tion compared to adult whole-head MEG.



Mapping of sites and dynamics of sensory functions – auditory, somatosensory, and visual modalities.

SYSTEM COMPONENTS

- Sensor/Cradle/Bed on mobile cart – easily ac-cessed height
- Power supplies and computer on companion mobile cart to minimize noise
- Subject Tracking – optical tracking system up-dates movement at 30 Hz with ½ mm accuracy
- Part-wise mapping or optional optical one-click 3D imaging system
- Assay stages of nervous system development



Somatic evoked magnetic field (SEF) obtained from a 7-month old as a function of number of averages from N=4 to 173 epochs. The waveforms are the differences of the SEF at two field extrema. This shows that a small number of averages are needed to acquire SEF data. (data acquired using a Tristan babySQUID® system).

UNIQUE FEATURES OF ARTEMIS123®

- Superior spatial resolution and sensitivity
- Significantly more sensitive to neuronal sources than conventional whole-head MEG systems
- Similar or better spatial resolution compared to existing whole-head MEG sensors
- Better spatial resolution than EEG (EEG signals are distorted by skull defects (fontanels and su-tures), making it difficult localize epileptiform tis-sue

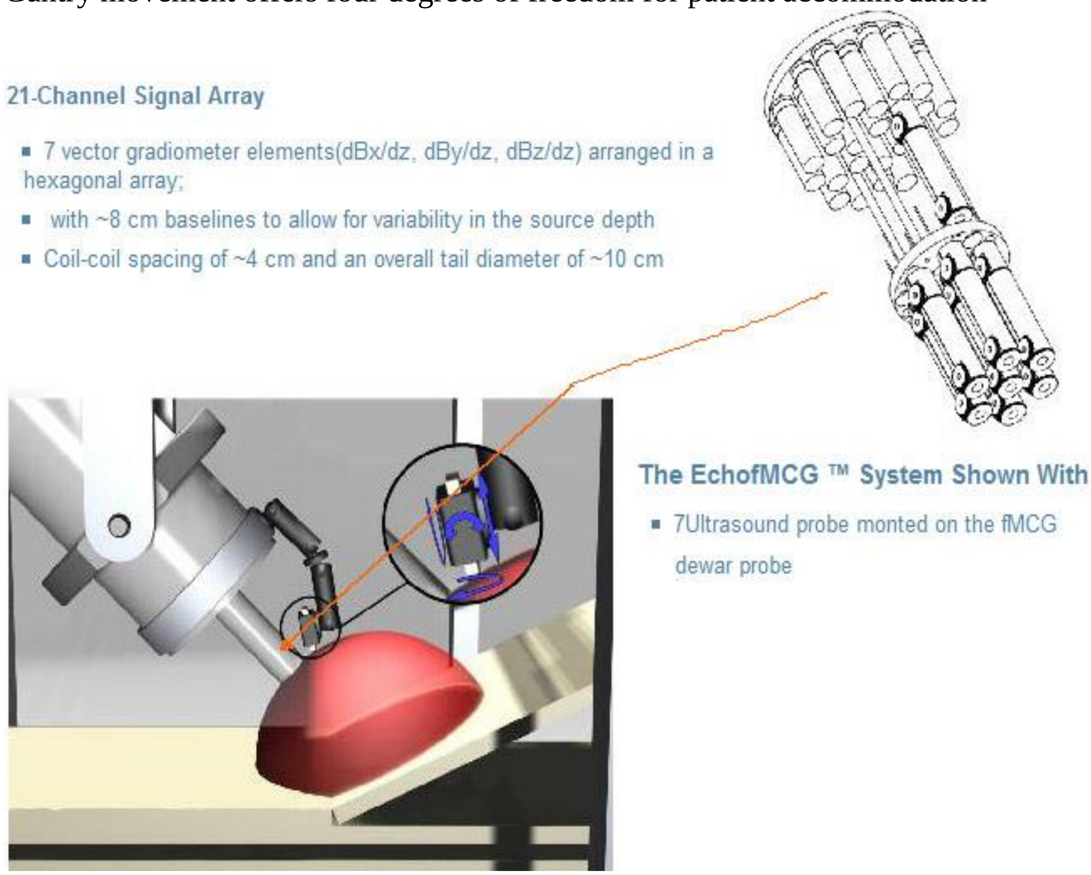
- Rapid scanning: a typical clinical scan can be completed within thirty minutes
- Anti-vibration construction; infant motion will not cause vibrational artifacts
- Sensor noise level < 10 fT/ Hz
- A dense array of closely-spaced sensors located just below the outer surface of a headrest.
- Allows simultaneous measurement of the occipi-tal area and parietal and temporal areas
- Includes position tracking device and software, permitting measurements during sleep or rela-tively quiescent wakefulness
- The measurement cradle and companion elec-tronics cart are portable and can be wheeled in and out of elevators, obstetric suites and neo-nate ICUs

3. A) EchofMCG™ SQUID SYSTEM FOR FETAL CARDIAC MEASUREMENTS

The **EchofMCG ™** is a unique multi-channel vector fMCG system integrated with an echocardiography system, capable of simultaneously performing fetal magnetocardiography (fMCG) and echocardiography (echo/Doppler). Such linking of echo/Doppler and fMCG would allow the clinician to analyze the fetus rapidly for both hemodynamic as well as electrophysiologic abnormalities, such as fetal arrhythmias. This will be the world first clinical modality to provide full characterization of the intrauterine condition of fetuses with life threatening heart conditions.

SQUID = Superconducting Quantum Interference Device.

- Simultaneously detection of both ultrasound and magnetic fields associated with fetal cardiac electrical activity
- Vector gradiometer design to maximize captured fMCG information
- Small probe profile for easy positioning in close proximity to fetus
- Gantry movement offers four degrees of freedom for patient accommodation



EchofMCG™ SYSTEM ADVANTAGES

- Vector field mapping capability.
- Ability for deep source detection
- Synchronized fMCG and fetal ultrasound measurement.
- Advanced data processing based on spatial filtering and ICA.

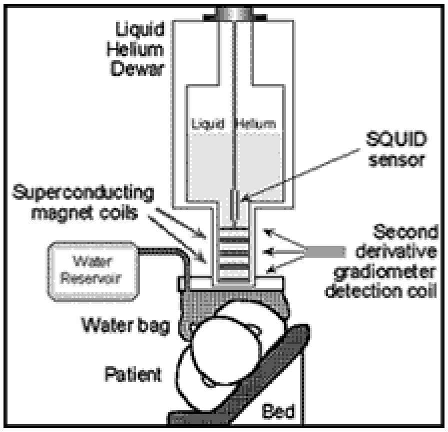
B) TruckSQUID™ SYSTEM FOR MOBILE FETAL MAGNETOCARDIOGRAPHY (fMCG)

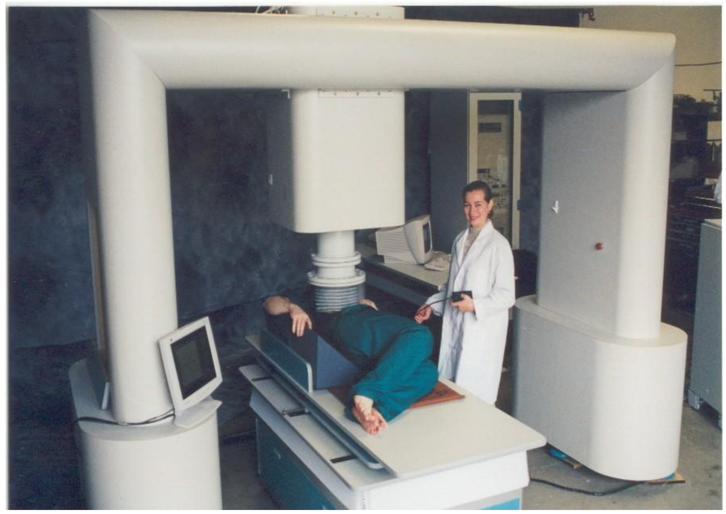
The TruckSQUID ™ is a unique system for fetal magnetocardiography (fMCG) measurements. It allows the clinician to analyze a fetus rapidly for electrophysiologic abnormalities such as fetal arrhythmias. This system is the first clinical mobile system that provides full intrauterine characterization of a fetus with life-threatening heart conditions.

TruckSQUID ™ SYSTEM CHARACTERISTICS:

- Vector field mapping capability
- Deep source detection capability Liquid Helium
- Dewar hold time 5-7 days Windows-based acquisition and display software
- Advanced data processing based on spatial filtering
- ICA optional Ultrasound probe

4. BIOMAGNETIC LIVER SUSCEPTOMETER





The BLS Liver Iron Stores Measurement System is designed for measuring fields from paramagnetic materials in the body, such as hepatic iron stores in the liver. Measurements are made by determining the change in magnetic field at the detector as the subject is moved into and away from the sensitive region of the detector. A small magnetic field is applied during these measurements by a self-contained superconducting magnet. To simulate the presence of the body during the measurements, water approximating the natural diamagnetism of the body is located between the sensor and the body.

The system includes dual channel axial gradiometers (3rd channel optional), superconducting magnet and power supply, a liquid helium dewar and gantry, water bag and reservoir, movable bed, a data acquisition and analysis system, and all necessary accessories. As with all Tristan systems, an on-site training course in the proper use of the system is available.

APPLICATIONS

The most relevant applications of Biomagnetic Liver Susceptometry (BLS) are related to iron overload diseases such as hereditary hemochromatosis and siderosis caused by blood transfusions. To date, the following applications have been demonstrated:

- Monitoring iron overload in patients with transfusional siderosis (genetic ß-thalassemia major and sickle cell disease, or other transfusion dependent anemias) for the onset or intensification of chelation therapy and during this therapy.
- Assessment of iron overload in patients scheduled for Interferon alfa therapy in viral liver infections such as Hepatitis B or C.
- Assessing iron overload in patients with ß-thalassemia scheduled for bone marrow transplantation (BMT) or monitoring iron overload after BMT during iron depletion therapy.
- Assessment of the long-term efficacy of different iron chelators under study.
- Diagnosis of hereditary hemochromatosis and assessment of the degree of iron overload in known hereditary hemochromatosis.
- Monitoring liver iron concentration in the initial assessment and long term phlebotomy therapy of hereditary hemochromatosis.

METHODOLOGY

Non-invasive Biomagnetic Liver Susceptometry (BLS) exploits the effects of magnetism and superconductivity. Biological materials such as ferritin and hemosiderin are weakly attracted to an applied magnetic field (paramagnetic behavior) while water and body tissue are very weakly repelled (diamagnetic).

Ferromagnetic materials e.g., nickel and steel, are strongly attracted to applied fields. No naturally occurring human tissue is ferromagnetic. In the BLS method, a weak magnetic field of 0 - 20 millitesla is generated within the body tissue by an external superconducting field magnet, similar to that used in a MRI scanner, but a hundred times weaker. The applied fields are measured by a superconducting magnetometer known as a SQUID (Superconducting Quantum Interference Device). The SQUID sensing system has the ability to measure distortions in the magnetic field at the part per billion levels.

When an organ, such as the liver, is placed in a magnetic field, it will slightly distort the applied field. If the liver is normal or anemic, the local field will be reduced slightly. If the liver is iron overloaded, the local field will be enhanced. Hence the change in the detected magnetic field is directly related to the iron concentration in the liver. To minimize the body's contribution to the distortion in magnetic field, a small bag of water is placed between the detector and skin surface. Since the susceptibility of body tissue is close to that of water, the resultant measurement is essentially that of a magnetized liver (or spleen) moving in a magnetic field within a uniform (diamagnetic) environment; the only change seen by the detection coils is due to the liver (or spleen) itself.

For higher accuracy, our software removes the actual contribution of overlying tissues (skin, bone, muscle, fat, etc.). This gives the iron concentration of the liver (or spleen) alone, allowing accurate measurements for obese patients and normal patients with atypical liver/spleen depths.

To date, the BLS method has been applied to organs such as livers and enlarged spleens (> 300 ml) with a total error of [Fe] = 0.05 - 0.4 mg/g tissue (wet weight). Repeatability (serial measurements over three weeks) on single subjects of better than 95 % has been demonstrated.

5. INTESTINAL ISCHEMIA SYSTEM

Tristan Technologies fabricates a high sensitivity, multi-channel SQUID magnetometer system for measuring electromagnetic activity in the human intestine. Presently, intestinal ischemia is difficult to diagnose, and is usually fatal. SQUID sensors can detect the magnetic fields produced by the BER (basic electrical rhythm) of the human intestine. The frequency of the BER signals changes under ischemia — the frequency of BER intestinal signals are ~10 cpm (cycles per minute).

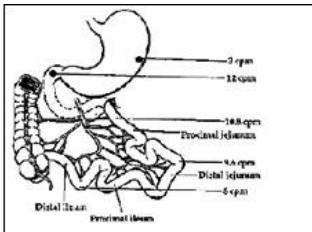


Figure courtesy of Vanderbilt University

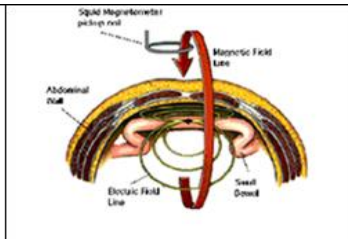


Figure courtesy of Vanderbilt University

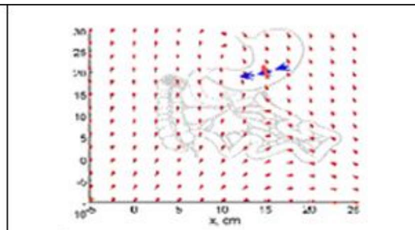
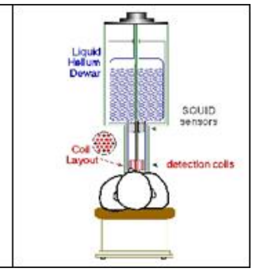


Figure courtesy of Vanderbilt University



Magnetic measurements provide improved signal-to-noise over the currently more typical cutaneous electrode measurements of electric potential. In contrast to the measurements of voltages on the skin surface, magnetic signals are not attenuated or redirected by the multiple layers of varying electrical resistivity tissues separating the intestine from the skin surface. With multi-channel magnetic measurements, vector projection analysis techniques allow focusing on the signals of interest, distinguishing them from the many other biomagnetic and environmental signals present. Other less serious intestinal disorders, such as Crohn's disease, ulcerative colitis, and irritable bowel, are also difficult to diagnose; their diagnoses may be improved with this system.

- Non-Invasive — no contact between instrument and abdominal wall.
- Magnetic measurements superior to electric
- Signals not attenuated or redirected by the multiple layers of tissue separating skin from intestine
- Improved signal-to-noise.
- Detect signal changes before pathological damage.
- Useful information in short time periods — extensive patient preparation or analysis not required.

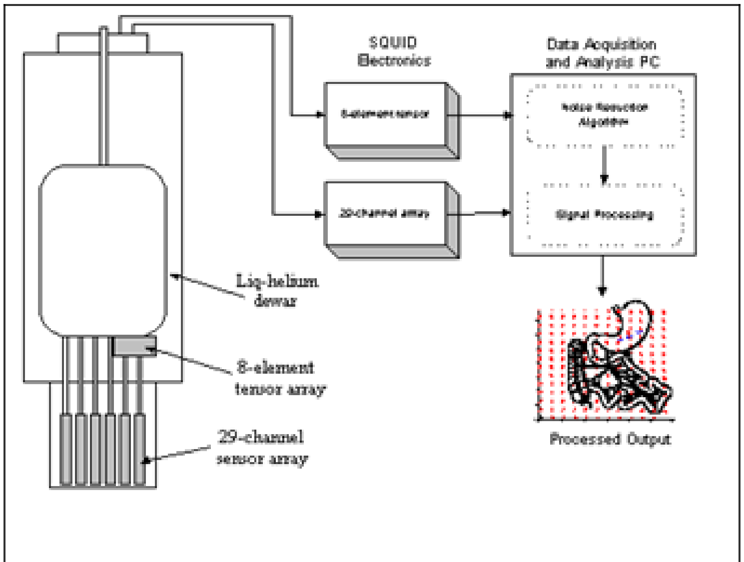
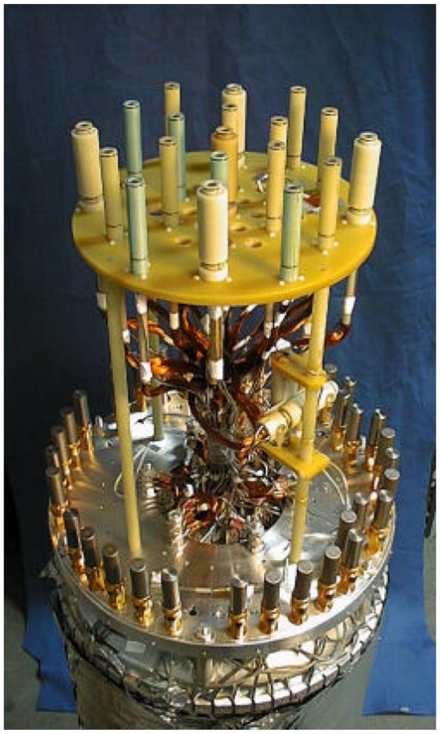


Figure 1. Schematic drawing: Model 637 Intestinal Ischemia System.

ELEMENTS IN THE MODEL 637 INTESTINAL ISCHEMIA SYSTEM

- 29 magnetic field sensing channels, < 20 mm from sensor surface, distributed over
- Large (296 cm2) area of coverage
- Or, intermediate (82 cm2) area of coverage (set at Tristan facility)
- 8 magnetic sensing channels, in a tensor array, monitoring environmental magnetic noise.



This system is a multi-channel system with 29 detection coils (19 axial coils, 10 vector coils) designed to measure the Basic Electric Rhythm (BER) associated with intestinal activity. The specific application is detection of Mesenteric Ischemia, a life threatening condition with no conventional reliable method of diagnosis. Pre-clinical trials in partnership with Vanderbilt University are underway. The system features coilin-vacuum construction and the unique ability to vary the position of the detection coils. This allows the researcher to adjust the spatial frequency measurement capability of the system. Like the model 619, the 'model 637' includes an 8-element tensor noise reduction scheme. Designed to operate in a clinical setting, the model 637 operates in an unshielded environment. Tristan's experience with coil- in-vacuum design is critical for sensors that are both portable and adaptable to measurement at varying orientations.

6. SpineSQUID™ SPINAL CORD MEASUREMENT SYSTEM

Tristan has built and delivered a fully integrated 63 channel magnetic source imaging system for non-invasive measurements of spinal cord activity and source localization. The system is adaptable for humans or animals. Because spinal signals are action potentials, the system is designed to acquire data in excess of 100,000 samples per second on each of its 80 channels (including reference channels), more than an order of magnitude faster than conventional MEG devices. For this project, Tristan devised a novel high speed data acquisition and monitoring system capable of acquiring and storing more than 10 minutes of continuous spine data, and simultaneously retrieving and reviewing a data set collected previously.


ADVANTAGES

- Tailor-made complex shape Dewars Sophisticated cryogenic dewar construction
- Noise reduction software and hardware
- Orthogonally oriented vector (Bx, By, Bz) detection coils Asymmetric gradiometers for improved sensitivity Multi-axis dewar gantries
- Magnetically quiet motorized patient beds Vector and tensor reference arrays for noise cancellation Software for data analysis in LabView™ including FFT, digital filtering and real-time review
- Software compatibility with standard source analysis packages (BESA, EMSE) and with MATLAB.
- Integrated hardware and software for positioning and tracking the subject: including 3D optical positioning camera system.

7. MODEL 601 SINGLE CHANNEL GRADIOMETER SYSTEM

The 601 is a single channel LTS (liquid helium) SQUID gradiometer system. Its components consist of a Cryogenic Probe with liquid helium level sensor, a 1st order axial (dBz/dz) detection coil, iMAG® LTS SQUID and electronics (1 channel) and a Model BMD-6 Liquid Helium Dewar. With a 1 cm detection coil, sensitivities approaching 10 fT/ÖHz are possible. The BMD-6 dewar allows the detection coils to be placed within 10 mm of room temperature. System components:

- 1st order axial detection coil, nominal 1 cm diameter, 2% balance
- Cryogenic Probe with liquid helium level sensor
- Model LSQ/20 LTS dc SQUID
- Model BMD-6 Liquid Helium Dewar
- Model iMC-303 Cryogenic Control Unit
- Model iFL-301-L Flux-Locked Loop
- Model CC-6 six meter fiber-optic composite connecting cable
- Manual and accessory pack

SAMPLE CONFIGURATION

- 2mm diameter 1st order gradiometers with 1 cm baseline.
- 2mm coil to coil separation.
- 2mm offset from room temperature outer dewar surface.

8. INVERTED SQUID MICROSCOPE

Tristan Technologies has developed a prototype Inverted SQUID (Superconducting Quantum Interference Device) Microscope for neuroscience research. The target signal levels are much weaker (100-500 fT, fT = 10-15 Tesla) than signals in the area of non-destructive evaluation (> 1 pT, pT= 10-12 Tesla) where SQUID microscopes have been used previously. The term “inverted” is adopted because the microscope is similar to an inverted optical microscope except the objective lens is replaced by an array of superconducting miniature magnetic field sensing coils.

The microscope is useful for other applications that include measurements of:

- (1) Electrical currents from single neurons and glial cells in culture
- (2) Efficiency of bonding of antigens and magnetically tagged antibodies (immunoassay)
- (3) Movements and conformational changes of a small number of magnetically tagged molecules in a cell for studying signaling pathways.

The inverted SQUID microscope is useful in both academic setting and industry for understanding the electrophysiology of small cells that are difficult to study with electrodes, for drug discovery and for studying second-messenger systems.

9. INFANT MEG SYSTEM- MagView™

The Tristan MAGViewTM Biomagnetometer features whole head coverage for a helmet designed to fit a 50 cm circumference head. It is used to non-invasively measure weak magnetic fields produced by electrical activity from the brain of infants and children. The system consists of the following principal components: the sensor, a mobile patient bed, an electronics cart containing SQUID electronics, an external electronics rack for power supplies and data acquisition hardware, and a computer. The patient bed, sensor, and SQUID electronics rack are designed to fit inside a magnetically shielded room (MSR).

ADVANTAGES

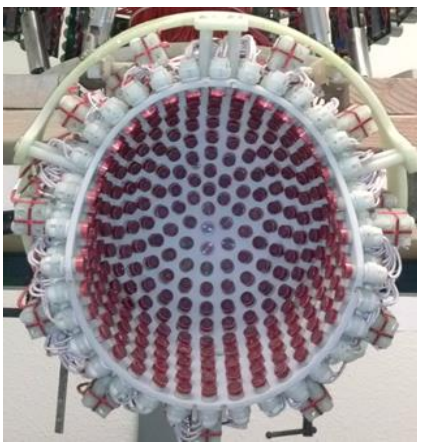
- Superior spatial resolution and sensitivity
- Significantly more sensitive to neuronal sources than conventional whole-head MEG systems
- Similar or better spatial resolution compared to existing whole-head MEG sensors
- Better spatial resolution than EEG. EEG signals are distorted by skull defects (fontanels and sutures), making it difficult localize epileptiform tissue
- Rapid scanning: a typical clinical scan can be completed within thirty minutes
- Anti-vibration construction; infant motion will not cause vibrational artifacts
- Sensor noise level < 10 fT/√Hz
- A dense array of closely-spaced sensors located just below the outer surface of a helmet.
- Allows simultaneous measurement of the occipital area, parietal areas, and temporal areas
- Includes position tracking device and software, permitting measurements during sleep or relatively quiescent wakefulness

SYSTEM DESCRIPTION

Like adult Magnetoencephalography (MEG) systems, MAGView™ uses superconducting sensors to non-invasively detect and map magnetic fields generated by cortical neural activity. However, MAGView™ takes advantage of the fact that the infant's scalp and skull are very thin. Tristan's fabrication methods put the sensing coils very close to the infant brain's sources of activity, even though SQUIDs must operate in an ultra-cold liquid helium environment. The net result is a significant increase in amplitude of neonate MEG signals. Also, the high density of detectors results in higher spatial resolution compared to adult whole-head MEG.

The MAGView™ signal detector channels are specified to have a noise level and sensitivity to magnetic fields of at least 10 $fT/\sqrt{Hz}$ or better on average. Ambient magnetic fields in a typical hospital environment are generally much greater than this sensitivity, and in many cases, the system will be operated within a magnetically shielded room to enable measurements with the full sensitivity capability.

SQUID SENSOR ARRAY



ARRAY ARRANGEMENT WITHIN THE DEWAR

- 200 to 400 channel sensors within the helmet
- Magnetometer detectors
- Reference channels for ambient noise reduction
- Coil-in-vacuum configuration for superconducting coil array and SQUIDs
- Coil-to-surface gap ~ 6 mm
- Average system white noise < 10 $fT/\sqrt{Hz}$ in magnetically quiet environment
- Helmet designed for whole head coverage, with 50 cm circumference
- Helmet positioned at a height between 30-36" from MSR floor
- Subjects measured in a supine position

Non-Bio Systems Information Brochure

TRISTAN TECHNOLOGIES, INC.

Non-Bio Systems Information Brochure

6191 Cornerstone Court East • Suite 107
San Diego, CA 92121
Phone 858.550.2700 • Fax 858.550.2799

Table of Contents

System information and advantages

Biomagnetic measurements provide a number of advantages compared to electrical measurements:

- Biomagnetism is non-invasive. The detection system does not contact the subject. The non-invasive nature of biomagnetism makes it an inherently safe procedure and minimizes subject preparation time.
- Insulating barriers such as the skull, varying layers of tissue, anatomical open spaces, do not attenuate or distort magnetic fields. Electrical signals are distorted by the varying resistive layers between the signal source and the surface skin.
- SQUID magnetometers will measure the vector component(s) of the magnetic field. Thus localization is much easier than with electrical measurements, which only measure scalar voltages.
- Magnetic measurements can be made for which there are no electrical analogs. These include measurements of static magnetic fields, measurements of the magnetic susceptibility and measurements where an invasive procedure is not possible (e.g., fetal cardiography).
- Because of the superconducting nature of SQUID measurements, true dc response and flat phase response are available.

Instrumentation

The strength of biomagnetic signals is many orders of magnitude smaller than even the earth’s magnetic field, which is 1/2 Gauss or 50 microtesla. The signal strengths associated with biomagnetism (Fig. 1) require the use of extremely sensitive detection systems. The units in this figure are femtotesla, 1 fT = 10-15 tesla. The only instrument with the required sensitivity and bandwidth is the SQUID magnetometer.

The components of a SQUID magnetometer (Fig. 2) typically consist of the following: a detection coil, which senses changes in the external magnetic field and transforms them into an electrical current; an input coil which transforms the resulting current into a magnetic flux in the SQUID sensor; electronics which transform the applied flux into a room temperature voltage output; and acquisition hardware and software for acquiring, storing and analyzing data. Both the SQUID amplifier and the detection coils are superconducting devices. Thus some type of refrigerant (liquid helium or liquid nitrogen) or refrigeration device (cryocooler) is needed to maintain the SQUID and detection coil in the superconducting state. Additional signal conditioning electronics may be needed to improve signal-to-noise.

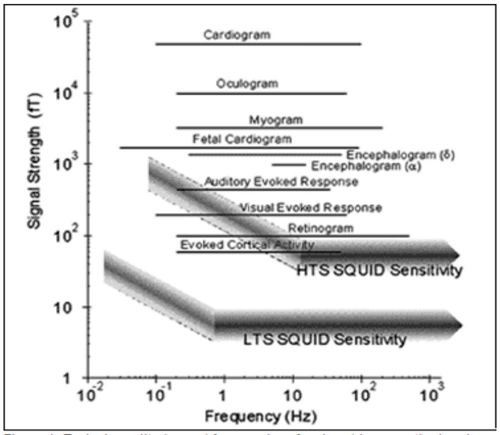


Figure 1: Typical amplitudes and frequencies of various biomagnetic signals. shaded regions indicate the limits of currently available SQUID sensors.

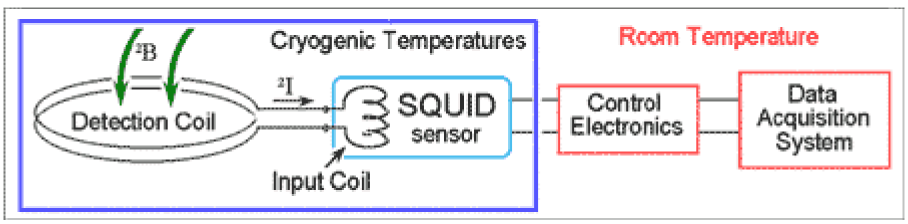


Figure 2: Block diagram of a SQUID magnetometer

The SQUID sensor and electronics package can be considered as a black box that acts like a magnetic field-to-voltage converter and amplifier with extremely high gain. In addition, it offers extremely low noise, high dynamic range, excellent linearity, flat phase response and a bandwidth that can extend from dc to beyond 100 kHz, capabilities that no other single sensor offers.

The type of SQUID sensor and detection coil configuration is dependent on what is to be measured. Figure 1 also shows the capability of both low temperature (requiring liquid helium temperatures, and referred to as LTS) and high temperature (requiring liquid nitrogen temperatures, and referred to as HTS) SQUID magnetometers. Tristan biomagnetic measurement systems make use of either Tristan's LSQ/20 LTS dc SQUID sensor or the HTM-8 HTS dc SQUID sensor. The input coil for an LTS SQUID is normally fabricated from flexible superconducting NbTi wire. The inherent anisotropic nature of HTS SQUIDs requires that the input coils be planar. Typically HTS magnetometers are available only as pure magnetometers.

Another factor to be considered is the detection coil configuration. Conceptually, the easiest input circuit to consider for detecting changes in magnetic fields is a pure magnetometer (Fig. 2). However, magnetometers are extremely sensitive to all magnetic signals in the environment. This may be acceptable if one is measuring ambient fields. However, if the magnetic signal of interest is weak, then environmental magnetic interference may prevent measurements. If the signal source is close to the detection coil, then a gradiometer coil may allow a weak signal to be measured. Figure 3 shows the relative noise rejection for 1st and 2nd derivative gradiometers. The figure insert shows a first order gradiometer, consisting of two coils connected in series but wound in opposite senses, and separated by a distance "b", called the gradiometer baseline. A uniform magnetic field (e.g., from a distant environmental source) would couple equal but opposite quantities of flux into the two coils, resulting in zero net flux in the gradiometer, or zero signal. However, signal sources that are close to the lower coil (relative to the baseline, or separation between coils) would couple significantly more flux into the lower coil than into the upper coil; this would result in a net flux in the gradiometer and hence the signal would be detected.

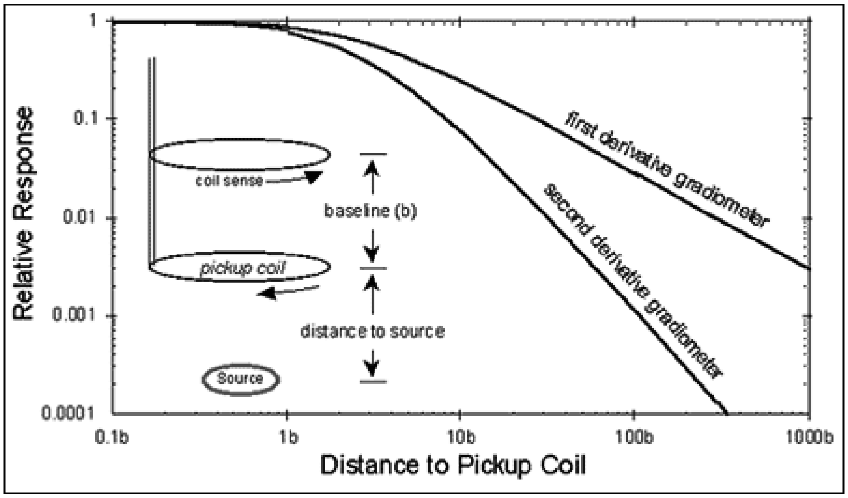


Figure 3: Response of gradient coils relative to magnetometer response (1/r3 suppressed)

For objects objects that are close (relative to the gradiometer baseline), the gradiometer acts as a pure magnetometer, while rejecting more than 99% of the magnetic signals coming from distant objects. In essence, the gradiometer acts as a “compensated” magnetometer.

Normally, SQUID magnetometers (and gradiometers) map the axial (BZ) component of the magnetic field. Obviously, using three sensors, it is possible to monitor all three vector components of the magnetic field. Additional channels of SQUID sensors can be used to provide reference channels for electronic balancing. Portions of the reference magnetometer responses are summed electronically with the detection coil(s) output to reject common mode signals from distant noise sources. Electronic balancing can be used to create an HTS axial gradiometer from two HTS magnetometers.

Tristan and its key personnel have produced a number of measurement systems for a variety of applications. Some of them are listed here:

- Tristan has multiple single- and multi-channel SQUID magnetometers for NDE and paleoarcheology use. These are state-of-the-art systems, some with spatial resolutions approaching 1 µm.
- Multiple single- and multi-channel SQUID magnetometers for biomedical applications for animals and humans. The Ferritometer® is routinely used for clinical assessment of iron overload diseases. This system is a turnkey operation including patient scanning bed, computer control, along with complete data acquisition and analysis software.
- Tristan’s magnetometer systems are based on its iMAG® line of commercial SQUID electronics, which have been supplied worldwide to both end users and OEMs.
- Tristan’s model DRM-300 geophysical rock magnetometer uses closed cycle refrigeration to eliminate the need for liquid helium and reduce operating costs. This technology is available for use on many of Tristan’s products.

Systems built by Tristan’s present personnel during the time period of 1991-1996 include:

- A DC and AC susceptibility variable temperature and field platform. Twelve systems were made. These systems integrated SQUID magnetometers, sample motion control, sub-mK thermal control from 2 – 350 K, variable applied fields to 17 T and truly user-friendly automated control software. This product demonstrated Tristan’s ability to produce state-of-the-art complex analysis equipment with minimal user requirements.

- A six-channel system for Vanderbilt University for general-purpose NDE studies. Comprised of a magnetometer, dewar, electronics, software and multiple magnets, this system has extremely high sensitivity (10-14 tesla) and sub-mm resolution.
- A three-channel Superconducting (SQUID) NDE system for use by a large Japanese steel company, comprising magnetometer probe, dewar, superconducting magnets, custom electronics, and custom software. Using a welding robot, this compact system is scanned over samples.
- A dual-channel magnetometer system for use by a private company to study materials for nuclear-fuel rod integrity. The package includes a magnetometer probe, dewar, computer controlled sample scanner, electronics and software.
- A compact (12") six-channel high sensitivity susceptometer capable of generating tesla fields and operating in both vertical and horizontal orientations. The ultra-compact system, when attached to the end of a robot arm, is used by a large Japanese nuclear reactor inspection company for scanning the interior of nuclear pressure vessels.
- The first commercial scanning magnetic microscope (SMM-1000) to study small electronic circuits and material samples. This comprised a dewar, cryogenic sample handling stage, magnetometer, custom software, vacuum system, and custom electronics. It is comparable to a SEM in complexity. Nine detection coils were fabricated in a linear array with 100 µm coil separation. Spatial resolution was at the µm level.
- A mixed stage (Gifford-McMahon/Joule-Thomson) cryocooler that routinely achieved 2 K.

1. Laboratory Applications include measurements of current, voltage, resistance, magnetization, etc. along with exotic (General Relativity, magnetic monopole) applications.

Current:	10^{-12} ampere/√Hz	dc Resistance:	10^{-12} Ω
Magnetic Fields:	10^{-17} tesla/√Hz	Mutual/Self Inductance:	10^{-12} Henry
dc Voltage:	10^{-14} volt	Magnetic Moment:	10-10 emu

2. Geophysical Applications include oil and mineral exploration, pollutant monitoring, magma flow measurements, rock magnetometry, paleo archeology, etc.

Tristan HTS SQUID gradiometer in flight

3. Non-Destructive Test & Evaluation (NDE)

NDE scanning systems are used for defect detection, corrosion measurement, magnetic microscopy, etc. Some examples of SQUID NDE include:

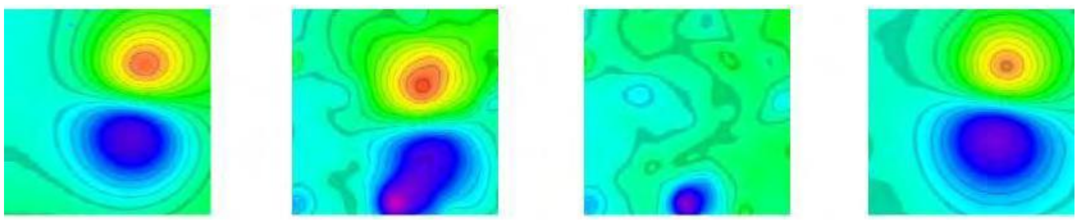
Intrinsic currents measurements, such as:

- Remnant magnetization
- Embedded magnetic sensors (see figure below)
- Flaw-induced perturbations
- Johnson noise in metals
- Eddy currents in an applied ac field (flaws)

Hysteretic magnetization due to:

- cyclic stress (strain)
- simultaneous dc & ac magnetic fields

Magnetization of paramagnetic, diamagnetic and ferromagnetic materials in dc fields.



A B C D

SMM-701 magnetic field scans of an embedded strain sensor under a 4 cm thick concrete overcoating. A: Bare sensor showing dipole characteristics, B: sensor under concrete, C: bare concrete. Image D = B – C is a digital subtraction of B and C showing that it is possible to image objects deep underneath magnetically complex coverings. The scans cover a 6 cm x 6 cm area.

4. Medical Applications

Studies of the Brain- Neuromagnetism

- Epilepsy
- Neonatal and prenatal Brain Disorders Presurgical Cortical Function Mapping Peripheral nerve and spinal cord studies Drug Development and Testing
- Stroke
- Alzheimer's
- Neuromuscular Disorders
- Performance Evaluation
- Animal Systems

Studies of the Heart—Magnetocardiography

- Arrhythmia
- Heart Muscle Damage Fetal Cardiography

Other Medical Applications

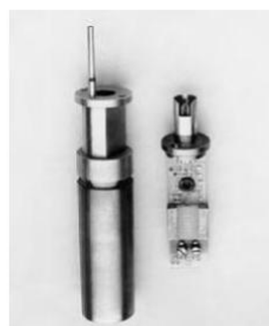
- Non-invasive in-vivo Magnetic Liver Biopsies(Ferritometry)
- Studies of the Stomach—Gastroenterology
- Intestinal and Mesenteric Ischemia

- Lung Function and Clearance Studies
- Peripheral and Single Nerve Studies
- Organ Transplant Rejection Risk
- Blood Flow Disorder

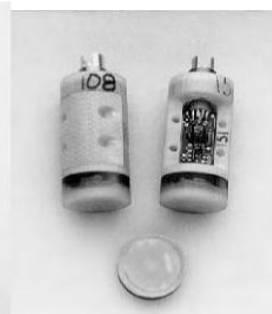
Tristan non-magnetic dewars

Model 607 biomagnetometer

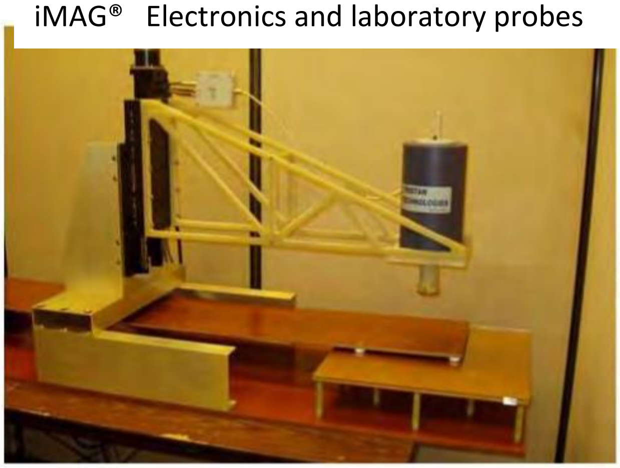
iMAG® Electronics and laboratory probes



LTS SQUID sensor



HTS SQUID sensor



SMM-701 NDE scanning system

Model SMM-770 Scanning SQUID Microscope

Tristan Technologies, Inc.

SQUID Systems for Biomedical Research

Applications

- *Magmbencephalography* (MEG) tar lune·trona imaging
  Mepping GPM.· events and spontaneous rhymms
- *Magnetacardography* OeIGG) Adall
  and fetal magnetocardiography
- SpinePenpheral Nerve Functions· measurements
- Liver Iron (hepatic iron stores) Assessment
- tritestrnal ischemre
- Magnelooneurnography (rung transport mechanisms}

INF] 1.,,,m inert New..

F e a t u r e s

- Safety and Convenience — noninvasive measurements
- High temporal resolution of signals
- Optimum placement. with sensom urine] to sources
- integrated systems,
  ChStOre CleweirS, getle leS, patient beds,

uu J. Sm.. mum noacnr ,Lworpir wompreer 'rah

T e c h n o l o g i e s

- Advanced Josephson Junction TeschnOlOgy
  - Microprocessor-based multichannel control electronics
- Complex Custom Design Coil Arrays *2 mm* to 2 CM diameter detection Pets * magnetometers and grad ornaters (1st and 2nd order)
  - ace] or plane, sworn earn en asymmetric grediometers
- Custom Dewed and Cryoecotea systems
  - adjustable tails tieth coil-to-subject distances lass Than 5 rim', n ultra-low boil off flutter; cryogen free no Gryocoolor assisted
- Custom Elect·arcs and Software
  - electronic noise cancellation hard., and software
  - sophisticated data equation and monitoring software
- Soptrystfrated Modeling
  - finite element analysis for OM·nal coil and dewer deegn
  - thermal analysis for highest tamer performance

*Tristan Technologies, Inc_*

SQUID Magnetometers

Principles of operation

giomagnetic measurements encompass many oohs major organs alto bony, incluoRng heart brain. Hoer, kings end muscles Diagnostic procedures based on Etemagneasm nave enlarged in cardiology end neurchey_ sad are emerging in gaStreenterelegy as web_

Every tripeleclite event MR 9 rneenatic enneg eioinugeetie signed range ar handwirtt ton essontrutlY dc to seven· hens and

SOuilit magnatometer system require the Jollowinft cemPI·nonts

- Deteesion eaglet to sense changes In enamel meg. relic 'held and Lanslorrn hom roto en electrical errant
- Input mal(s) to transform Me resulting current IMO a magnetic flux in The SQUID sewer, ohotrontos to transturat the applied Ito into a roltage output
- A cryogenic regbn to keep he SQUID sensorial and coilfs) superconducting
- Signet omsdnieriirm ckeurronies to convent., '·····nh··he Signme ado ..oliages pea n, p• ,e-norned
- Acquisition hardware end software to ours., store and antayss data

c•zwe
dower
er.r.n
— en.••=r
••••••,••••anneeme
efTeg11110aefifoirebr
OS SOUDasestaele

Pa Zol·feenztre *s.gerff nreeprip fr,N .N,al Ntraflcre· IgaimppLNI* tNiNrrt

tV C..1.04.!RniOna..t.n! firm, TIAllylgrlitlN!

SOUID |_caritrou D a l e M j "

inpui c.ni

My 2 1:CtUll·nteavFNINNowl,.9, Fe no LNNN,neriCeer

&Adam Design System sensilikty is a furionlen el SOLID serrsor sersaikrity leteollon cell diem.,

number of lures, end magnetometer/gala...I design.Dstecton coils may be gm.

ornetem rather than mairelomelers, to reject FiVirdlnent none Sellei.filfii, rU.r of refection channels. arrangonstm and spaung between chem. are all am tailored to ifser arautiOrROna.

Because envirermental noise wn impair del·even/lot learnagnetiv signals, , systems tlf

- O. acquisition and real·lime mendlring system
- TIM party source analysts sal.... eats cornealabolgy with scarce analysis whams

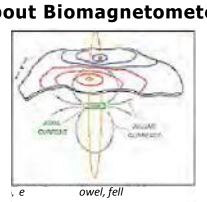
Ft/. 7.0 LOAMY of enMenomeNlal now

Tristan Technologies, Inc.

General Facts about BiomagnetometerApplications

What is measured —bi onnagnetie gelds

Ekinfeeric schtly generates son·expending RI:magnetic (RIM that can he detected with Tristan SQUID magnetoinelers. Arise CT or MRI imaging yield struottnat infernal fiat, demeans.



, e owel, fell

Advantages

SQUI'D based measurements are noninvasive and inner nty sale. The detection system does not conlaci me subject. rind subject preparation is simple and fast. Magnetic adds sutler Stub lass OlaFeken Item 'Maga petenhals. pernatting ORM Seelasilo 14411111040n Insulanng healers (skull Moon scalp, end anatomical open spaces) do not enemata or dorm magnate HAM they az *with* electrical potentlatsMoreover, mere are magnetic mean/semen's. which here m electrical analogs (e.g. stelic magnetic Melds. insomniac suseePotilityl. There era also magnetic measurements where a noninvesivo procedure it 11.P.Sthht lag,, total cardiography). The measurement of a magnet. Hod is a refemnre-free

Etiornodhoel Applienilons

- Brain mapping
  Magnehenwphalograehy ear map mean, end spode How notielly 'MOO severe nekmetets at the Volume at cedes, while distinguishing events separated uy nalisecorels, 111113 prostate fatigue information kcal con ic& comma rice.
- Aqui·Heart
  Magnetocardiography 1MCG• uncladas dynamic metre at heart function, and can he used to nrep salrcea NA rifslinglesh Werean as normal and abnormal events
- Fetal I temt
  The letal. MCC is a unique capabrilly baceusa *the* mos hose nafona Mach mei mentafion mold-no. ENG Offlculf of impos-

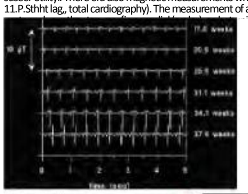
sible Magnetic betas are blookod and fetal abnormalities end arriahrnes can he see, as early as Del wreck el gestanon

- Spinerperipheral function

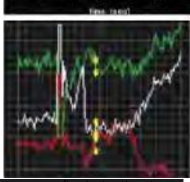
Naive COnarlCSON InVOIIMS rapid axonal spikes, of a duration on the order of 1 refeo Tesiena unique utra Rohspaed system execeeelno.oca sample. per second per channel and can detect a 2-noes change over a 5 an disLmw along a seiner cord er porichera nerve In

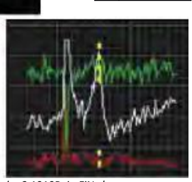
- Detection of Mesenteric IsChen,.

1111eStlei wall necrosis is difficult to dagnose without evasive surgery. Research using glace OW! Ma OrliCeteS thel Sclillas could repls ea:me and esky



over Amen./ Neir ne 17 m





jlto• he, teeeti emote seponnve hy3 ow mwe lOgee, loretorot Joel al.norter ;Nod. .517 sjatou Peat (Orrre)o•NNNy lcor in 2 nFire dime union txlelluthb

he 3 1010Poin FiNc 'pow or Ne.NNN

Tristan Technologies, inc.

Tristan Model 637

The Model 837 Is a hay Integrated rnagneac source reaping system with 37 sensor channel positions. Measurement coverage Is nearly 500 cm', and he array is dense ...CU to oaks imPortaint Nomadic& maps with it single instrument placement over

"""" or ·Fle'Llite Design: Each charnel poekon wn spew·no·wrote from 1 to 3 (a· thogonal) sensors, yleidng up to up to 111 independent sWrces of data. The typlca sensor cote &erneter is t ern In hesagortat dose packed among . Sens, geometries

ten *be* Mitered (a) changed, to idlow he resesadher h adjust he spatial fre-quency measurement eapahuity of he system_ Systems are tailored bus, applicallaff. 1st 021xtemter grerZernoter Optic. tE14.111 to CP. melee. and tooth ol Wm... An &element reference channel system Works to recites the Influence of environmental neft• SOL[12.6.

System testums: Systems typically Include a pantry both e.ya. NIL end rotabon} and adjustable Patent bed along with hardware and software for date acquisition and sepal analysis. The system Matures cairn-yeoman construction.

INg 2 - Ad odylerl 3 posrf, Nprom h, cone Nteernt N mem,' atilt ...... ehamek and N or femme, droanely Ateddcd r i ow. and gartN, oat perm hod ars NhaNNF

Ag ralida hone

- BMapnatoencepherogrephy(MEG) S•noie placement man ot sensory conical swfoe 7.1· abnormal spontaneous event Much as an Inter1.1 epileptic spike or slew wave),
- etwarrlocardiography(MCO; areitertalMCGI YAM a gantry end real-tee data monitoring the user can adjust he system oositho ta recording has, (or fetal hewn data. The 37 channel array la suited for now swum Rhea to separate mammal from Real heart slomm.
- Ass•ss.e..11 of Sp.F.I.Peneh•Tql N,. Fahation Because spinal signals invohm actin potentials, here Is en opthn to new. Man In ascoss et tatopl tOrrpe6 per second per channel This pormits dadeng or ormal events, and allows tracking of vary rapid

minute. characterize intestinal sugnala, which are

associated with intestine! ischemia. Data acquisdion

includas nvisplu tonmoral Stan. and eme-frenuency eiReays that porn& areaud mat ante mateforam

uonw' .ki *Li' tiNl'

f'sri nk/' niip/ wi," wieei

•iga •Ii..: -olFA./ ..i•V Al·t..e'

erºiterAle/ Rilsteo' «''11.,/ -)J.-.." er'

I·W.2:0nm Nene,. (15 rts.ter) port ITIONTli radial Atm. 13 of am 37

r7odfiun.r hope 3 ciats IVAN? vhdtrutelN.

Tristan Technologies, Inc_

Tristan Model 619

Fig 3193enwr poet

The Model .81. a hen ...rated meepurament ewe., with to sensor channel puskam, and can accommodate e ca coy of dense or spatse sunset uacteng. SMISOM are typically 1-cm n diameter. The oneasumment coverage or the standard model 519 is -189 cm" (15 cry diameter). Veda' gradlometers can be used on soma or all

to sancta 11.1 Wale. Yen ali 3.ortegonal

System features, The system Includes hardware aid software for MIS acquisition and mgcal. analysis, system options include

gantry thalh Cit, and root...land adjust...lea...bed. along with hardware and software for data acquisition *end* signal anat..

The soon. 1.1ans eameedien.

ahown,,loruafv rrp riared array Thor loum vhia 1,37 eenrar po.ona

Thal...1610 is ideal for measurements shah es nerve canducticj, (ht.511.14 measures, or fetal cardiography. where 3D source localizations are rata requirement

- Wragnemeneephalography MEG:
- Magnstonardiography 0.100:
- ......legnotoeard.grephydetal **McG**
- SpinaPeriph•ral Name
- Intestinal

The system On be need to measure intestinal iecherrla and is sized to meal cards and fetal candac research requirements

Up,radin, salar,s, anayt
The model DID can also be supplied '0 a 25 em dematter vers.on which can he

eloamOart (..o) Ina

*1'1q 1 19 channel seas, 1trjmn' dfrpluynf*cmTfollai *ong from dripabr*

rmlme bem.114 the rertkr..rxmr roll- ThalmeAwn
and the rime arts on the display van br odfaved

Tristan Technologies, Inc.

Tristan Model 607

The Mann Model 602m a stomped and economical iaboretery system rent 7 sops.

...el on.11.0 ..ch of the channel 0.1.0 can ac.nme.M.te (re. 1 le 3 (d'- Towne. sensors, yielding up Co up to 21 independent sources or data. The 607 comas

with a data acquisilion and 8splay system. and an optlonal ,enii-y. .d *bed.* The

- - (_ _ _ _ _ _ . _ . _ . _
S N E- + - A . .
V •

Applications

- Blair -Megneloenceohelogreohy (MEG}
- Heart • PolapmehMadiogralchy P PACG and I.e. MCGI
- Spine/Peripheral NWV•
- Spinelperipheral nerve function
- Intestinal lucharnia

•no. *3 Carrwur ph. nJ* ittennyJr
porfei. foe OE 7 channel sys wpm qmpling a mail. rreunV cvrand9010VC

,ff TRISTAN

LII: riemNoLom

Ng 2 three gap ',Wel 6074.vsleoli .1- 0.1uni. I. *ilh garrMy in Pe rimorefiœily .4.re 1ded n,am. ..971' J.0*0.k.-uw V.. *.thowe*

Optional Foam..

Anima) Systems

The Mod. MS 607 frthore0(31.110. versoon of tne Model 607 with can be used vin animal preparations and in.. gammas. Tristan's .cluslue dose spacing maroons and materials result in Waalg superconducting sem. less Than 5 rpm from the mono temperature sample. The inetnment can be used with exposed brain or intact animal preparations. and allows noninvasive measuriummts lo be taken In parallel volt electrode recording techniques.

Adjustable Dewar Tall

Tristan's unique adjustable tel technology remits closer spacing between sensor and isolutempuatora *son...* The adjustable tail feature all.ws the real to acsust to tail gep distances For can down end or meeoommeut. adding n factor of sorelv end reltettint.
to sensors. the specifications are custom designed for specific motosteement cp..-

y, , ,,,,,,,,,,,,,, ,,,,,,,,,,,,,, *d*,,,, ...,,,,. 11,,,,

Pons Pom monkey to rat. Or in *vtlro tissue* 5110501-

no,,,rpow. Ow. . &mt.,.

***Tristan** Technologies. Inc.*

Tristan Technologies, Inc.

Measuring Liver Iron Stores

The Ten. Meanest, le a dennos. Instrument emdl measures iron stores moldy and non-nuaswely as wenn... desalt wt. a suPerceeducimq.manot aep SRtIP dolecfio 010101. owes an accurate meatmement of inn uSnamanpon is P. Fiver and suletto Inc an. and children. The measurement is a volumetric techelque, waking average iron concantrasen measured over many milliliters of organ Ussue.01.1 accurately portrays tolablion stems. Atypical needle blopsy removes very small(amounts of Issue and can easily give Wrgr1•01.15 del P *wall. (few* banded gam.-less lbn a refligerata mcgmt) magneto field map elizas the liver and a 8.0.118

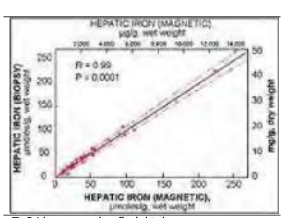
- **Non-Invaelve**

n Replicas sursca biopsy Ter Iron 0.1.881.Menlv

0 El.-mates Discomfort and Risk

- o Allows *P..... M aatnramen.*
- **Direct Measurement Method**
- o*ccwele* end Rnnlydogble O Nowa FF... Social Measure awls
- o Rapid Repulls u MeasurementI1n. Omar in Minutes
- First SOLID based system for clinical measurements
- o Codet-15 year operational period
- o Thousands of patients measured

bollrame ref synear with ism. bed runt com('aaer mum' rAiem Mom ten wx.E.rety



Ft 2 I igure coarieryfl: dnlrt.rharn

Appliendiene

iron ...to amasses seen es genea hemochminelosla and sitter.* ca.ed by tripod transfusions. The loNowing us. have Been ...lashed

- .raskulenal siderosis mem.. 6-11.1asserda •nd sickle cell disease ao othet :rank.. dependent anemias)
- 1-thalassenacs sdoodissd (or bone reauco. anosplantaa. (BAIT} or in ......lesseincs aft. BirAT scheduled for iron depletion therapy
- sal.u.la cnnee.1.1mr ist.1.. thccapy In 'era dam..
- assessment of the long-term efficacy of afferent iron 8slalom render sine,
- (Rogues. and ...email at gene. hemoolortimalceo

'The Feromeee sciefiedaaCiea I insninaeiveldedoeunerseEwoosn commusas dessoliume Grecs. 0.eF.Acereceo. ha seen

a p h e a f o r l s t o u l d n e c o n a d e r e d a n i n e e s i g e m o n a l d e v i c e f o r u . a m e U n i t e d g e t e e

Custom Features

Real-Time Data MonIInrincl System	Subject PositioninotTraching System	Reference Arrays for Noise Reduction
Hardware and proprietary software data amt....n eterfaces pewit the user to monitor and evalunte the quality of data	A combined hardwateXafetrare system mans the 3D ...ice area of the subject and the ltracks position and movements	The ,ariest obstacle to SOLD recautint- moot le mt."al visa exec...eta- ova. ehatnele can be.ad to subtract

- Pikers Lb Filter editors
- Monitoring Displays
- Data Averaging
- Anther Retortion

.1

..!

story ho Vest& ha gran411.1rinkKV) V111. refe.nco location

Mg 3 *Res.1-duse* airopipv.r.... *(man,' seosors relar,e oi. hood Chunging.V. on 0 reftehed al a X lir reile.*

1rg.7.10,111otire liry.e.1 ..4-'' awpfcet Eacil yecannele aolvaina trnqx,ney evuovnl ,'s. iisivit,,, 4

chivineL ....plop

.10 pT
-11a PT
060 **pT** -
le 01
.2on (.1
-210 pT

■sfo'Vo$0.1.•+14"MOlte*Lef'"i10. oP.
\ A, nner 4414YONe2 **.wet**
...2g pT
..1110
r
e \ '+..0.4.Pe ih.. **es 4**
me 10 as **team** 10es 24sec 30

Ng i Nhise redo. pm 640 k' .7.' iF ...1, *pvd* ■*orni. Olv kyntoory alli Mar* 713-P.10.9, o,,,,,e,o,h, 041 ......i *kV* 65, 1 *7(47.71' qtry...11vox .*

About Tristan Technologies

T} tan makes advanced atleemondueling measurement devices and systems based primarily en 312111213. The lechnology lo Woreached in Ile capacity to liked wall etedromegnetic agnate, and its great prordse continues . Impxa new ineenbone end ...kV- menls both within Tristan and on the pat of is academic and commemia/ collaborators.

mascemersam•coon Fast sodleses set rev, CI1121.21 LISA

weavaisteMie.one

DRM-300 Rock Magnetometer

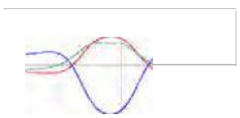
The TrtsAn rrogal DIRM.100 is C mowl and cant 43 um SCUD mennelorreter system or measurement or manna, rragetrixatian of geephrysinal samples. Tie we el SQUID bachreincy *Om unparalleled senalivity. Ginned cycle reldgeralen eliminate, the reed to wester buld rellurn. 16 moll looter/0 niturnizes needed larcrabry sine

Features:

- Three orthogonal detection coils
- SQUID detection circuitry
- 10[1'] Am[t] Sensitivity
- Wide Dynamic Range
- Room Temperature Bore
- Closed-cycle 4-Kelvin refrigeration
- Self-replenishing liquid helium ballast for Quiet Mode operation
- Automated Sample Insertion Stage
- Internal Superconducting and mu-

3La

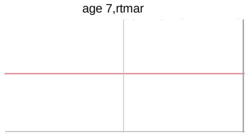
3E4



a

•I1)nn s Ire teem age 7,rtmar

X.E



enliven Youndwar

MM-ate eonl, heraweinruen {'..ryweetir etneetwice weird-vet

Trielerfa model EIRKA 300 Rock Magnetometer otters technical enhancements to ache.e supenor see`wittily and dynamic ranpe without sandrielng merddleb/ilv Cr ease Cr use. SucenmanclOcarg QUantum Interfamme Cede. ISQUICel are mad d dateci and anelify de magnetic moment ot samples placed into the sensitive volume or the detection 0e115. thy change in detected magnelV_otktin is difentlY PmnontoralIn tte nenneho morrent of *Me* sample, The detente. oohs In the Yodel ORM11-300 are Wound In a neirrholizalke conflourahon to provided rage) of undarre serrellovIly al Me renter or each call net Then NM Intim separate delaCtION coil Sets odnfigUred In SnleaseogSly

are the three orthogonal component (13 S Fl4 ride

A GliinrcLfAcktah.n closed cycle reIngenfor Beetles seeseus nelturn b sunray the cryogenic enyvonnent. *The*

dulttlion nuns 9t2Ul0 ammo. and aupintorereling Shailti are kept at operating temperatUra by thermal mniact In a Squid helium ballast reservoir. The clear bore sample tube IS Kept at acorn temperature end bermes narroim as large as 19 rim diameter (Wager sample sees Wallah. on eiteclel order). Ann/organic lernmenalunt oonimlbrencuree mrdlikaltnn subtly or Ire SCilliO sensors. The 'closed cycle ow:outer is mounted far tern sensors to mitirriee ON held along the sample path.

Fel ultimate serstirettst the DR10-300 pan operate with lie cryccooler tined off for pedants or more *Men WA"* days. An °mond VlbraInfr et'lairon stanch 00505 He sysem In ccntinun'clY ePenrite eilhoMsOniticank yumasonally Mdteed fluke freinIteetvocodercorremsactit and NOM fret.,

FOrthert reaction of be ambient tregretk tog cetri ter achieved by Triving the stioenoncluoting niobium aheki above IS bertslacn emPerature tb rein.. arty Rapped

○bowie Reid, in the supemarducting 0Na A cinmegnedamon comic Is stewed elfin all 04210.300 systorro.

Options

Further customization and enhancement for the DRIVI` 3L)0 is possible through the offered options.

- Vibration isolation system

  The 01344-300 Is designed b metal, ohs the cementer lannd of lb' as long as-2-3 days) The debblen colts ZOOID sensors and supolconduclInd shleki am kept et operating uncterature Fly tieimal contact to the !loud he3um tease(reservou. Addltiorwd viaaton Isolation S piny:dad It continuous opera. el to Cr'y.3.010r Is deStiert The Vrtiraliail isttmen 51end (Open 3t/l pnbland tar imee ftem data aommlisKirm during nacencter operalen. The incbpendendy deletion Sobtied and weighted nacre surrourcP the dewar and the murretal shields. 11 tins lts net independent vibration Isolation botpacts which rest directly on the hoe, independent nn the Rest of He tystern

- External Magnetic Shield options

  An optional mu- etas shied Mounted olltside Line devour is catered tar further redaction of externes *Moe.* Frisian man also supply magneficativ shielded moms or Irtmeaxis nancelLation

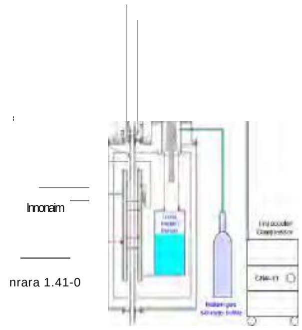
System Specifications

SENSOR.	Three Supercooduchno QUantum Intlarrensme DOVIceS {Slaters) operating ter 4 *K*
SENSITNITY:	10^2Arm' NH, ennui white anise
DYNAMIC RANGE:	10[1] Ant' `(197 dM, higher ranges aYallatttem,speebtor.br
CRYOGEN-RI-M`5C	Not needed - Setbreplentahlre Hebb helium battiest tar Islet Aittxle PpOralloll oozes b.:immoral gratb tehlkonnas cylinders for the process
HOLD TIME	Infinite, 2r days Mb Cry`Wader oft

:

Imonaim

nrara 1.41-0



Orlf.,300 matt (Molloy stiletto static] notebook

Model SMM-401 nanoSQUID

scanning microsoopy for imaging magnetic field distributions

- SMIN-4.01 uses *a* superconduoting 501,14} sensor to

■Iroeide outstanding spatial resclaition and high sensitiVity

Features:

- 100 pm spatial resolution
- 1.4 pThiflz field sensitivity
- Room temperature sample
- 25 am gap between sensor and sample
- Non-magnetic scanning stage
- Low helium consumption

Applications

-he $1414`101 is partic,lanv desire in the areas *where* high consetifties. Bepecially at Ines frequency. aim a reqUiremoml t`iclutilmobloropateontelogy and Diamagnetism

Wpm. Imago cr homoginewsly muse.. 50 tn.. osologi 11,3 sedion token front. Ulan ontnnonoLrymoot nid line snnPOF.

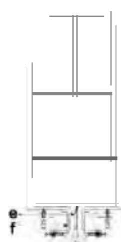
nnotIndInnInd n 0`120 Goan ofF Pointenteslor

ter. ei

Magnetic microscopy image or mm by 2 an by 1 an slice

of martian meteorite ALI'M.400`Y overlayed on top KO a dace' photo of the same slice The mere give the field intensity.

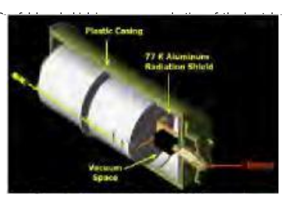
,egh red *and* yellow itArle} Oorreainndion nr're'i' MoVonstiarch magne,izabon. The ruson cost on ihe upper lett clan al Cie 'amok, {visible as a bin black rind in the visum Photograph) has Mee vanagneczal In the Earth's



Oct.0■1 OI Medd SPANN. 00110 aaa dena lwao words,

le) t menhirs lot Yezalan lion mechanism IM, sow nitrogenocoliq

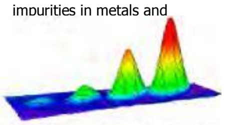
r `ions Id) coldtrmn dal. and Oda n,dadom.



SQUID Magnetic Scanner

The Tristan model SMM-601 Magnetic Scanner is designed to measure magnetic fields with a spatial resolution better than 300 WTI, It can be used to image diverse objects such as:

- subsurface cracks and flaws
- embedded magnetic sensors
- composite structures
- corrosion sites – hidden or exposed
- impurities in metals and



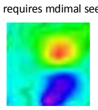
Sesn oil, 3.5 and 10 mm hotea in n meet Wag

Besides measuring magnetic fields, the SMM-601 can also be configured to detect:

+ induced magnetization
4. aging and stress in ferromagnetic materials
- magnetic susceptibility
- eddy currents
- magnetic hysteresis
- Barkhausen effect

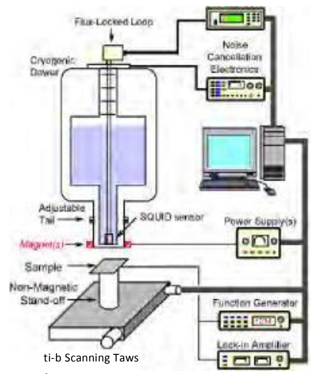
Mode sAlverli Scanning Sales linorossc pe with dc endure big na magnets

- Tiro SMI51-501 in a fatly featured Measurement system that ,Noose the merle mama inagnenc image of the Abject being measured over the untine In — 50 kl'Iz frequency range The adjustable rail viewer the spacing between the detection coil end sample'N.) to he its small as 3 tarn.
- Ice lima frequency Iresponae means large penetration depths (deep penetration). Another advantage of the model SMS1560 i is its ability 10 Olidele hl it'Ein fields. This alleles il 10 Malt SOSCL Mignity measurem.rs on the same suh.rnm spatial resolution scale. In addition, it can operate in ac with do— en td 1n bandwidths for eddy current measurements.
- The shirt eel allows computer controlled scans of objects over a Imhavi (1 K 15 mu) ores with 25 pm slapping amiability
- The USe ofa dc SQUIT) sensor gives it aopatelleled sensitivity Its cal phase response allows bola in-phase and quadmture information to be obtained 5vilhout distention. If ultimate sensitivity is needed, larger demotion roils with resolutions exceeding 5 friV'llz are available, Additional detection coils can he supplied to give vector inlbrrna lion The Shill-601 requires mdimal seep. Automated setup and computer

0  0

glannane add moans of an oneadand strain serisee under al ern thick caner,.

oVerco.g A - baresense, showing uharadvinathys- sensor rider cow., C - berm umcrate. Imsge 0 = 0 —Cis diefial subtraction el D and C shogun taint it la coa lala to Imes ollhiuta deen oni:km 11v



ti-b Scanning Taws

01111,0/1411a Or Ine Mom sigil-hula caller moues, hum. Cassta+.

The stendevd modal eht'ol-801 Is .malgrured lo detect electric cotton, and to measure morlanl magnetic Odds. It Includes a Single.Chunnei scanning SQUID Maarmlornetar Probe. INVaie 551110 Electronics Cristogenie dew, Room Temperature Scanning Stage co-make contiol ore Mtn 011pdelller System, end imaging Sothic.. The model Stall-edi ran ha aummien Mill addeonel capauvitles th extend Its measurement capabilities.

OPTIONS AND ACCESSORIES

Adtlidonal DolooNon Chamois: The model ShIM-Elll's measurement capabilities CIENI be extended le mulli-chennet oapebllatles. This can mean either vector IS, & end By) wpm/Wiles .ar

ndMionW Verli.1 ....re wt. to reduce rmasomMent Coins lodtallan Ch. Meg even NSO tie Odd. fa 60E6 WI,m anteranntentai noise In OkaPiSSIVIL

Wadicaihae rotntl.alrnaaP ilnrllrnInc

Seen Aram Lerner scan areas and higher mann, stepping 125 pni stermard) are available per mowed,

co FINS Capablky.. This option mows a small an t'gellnefic addle he emceed ei the same. Tire Fell is vertical 104 and can have a peak-tapeah magnitude at La 1 oersted This cerrabilty is Cr Whaler interest eyes eddy careni measurements eve desired

NW/A.1W ALPS(B,and 00 Sham Ingham; A lonvlzontal field sheet inducer mach ran apple an ec magnetic field parallel in the teat surface In in.ce a large intended eddy currant in e desired onenteacn. can be used to image cracks cr material Ion Jeep In eunduebee tug., aulmlnbnrl sthicnuies.

as Field Cemponsallon Ebotranica. Men en ac mon. is dimity coupled Into the syglern. the result. signal learn. field colts) may be trot tit lamer than the atonal horn the sample. In the case of a logoureonette materials sunk so carbon steel, The induced MarreilaYalieg (Man Wen n 110011 01 WO Matt in pulp lame and me ripe,. range or he data acumen. mishear Thar not he eilmaysto le track this large signal ahle sal Tasokano the small Nona Awn def.% mine metal.

To rrinlnneo thus, Tu.n t. tuh4y an Jr Compete ellen system to nil Pie as signal in The detection era and erten the irgluctul Venal irt the chest hang me.ured

SPECIFICA77ONS

srAisoR, Lien teissaerhioio suroaamossina woken ieustrareaso d.vt.a IsCesto

SPA77AL RESOLUTION: Getter th. 300 pin

SENSITIVITY, a 10" haelehgte /50 iTivhgl rov 3 mince.

DISTANCE TO SAMPLE Adlnet&h lo 0.1.5 than A MM

OPERATING BANEAMOTH: do - 50 kHz. Measmerrients net be

TRISTAN TECHNOLOGIES

61 IA COMeheleric 00Cril 001, 0010
ids Say, dug, CA 52121
55810511-2706(thig550-2799

Scanning Magnetic Microscope

The Tristan model SMM-770 Scanning Magnetic Microscope is designed to measure magnetic fields above a planar surface with unparalleled spatial resolutions,

Using a liquid nitrogen SQUIB sensor, it can be used to image room temperature objects such as:

+ traces on a circuit board or multi-chip module
- shorts to ground planes

Ma01..11nage Ordollar

- insulators, ferrous and non-ferrous metals to detect cracks, voids and corrosion
- nanciparticle distributions
- flux-motion in HTS materials

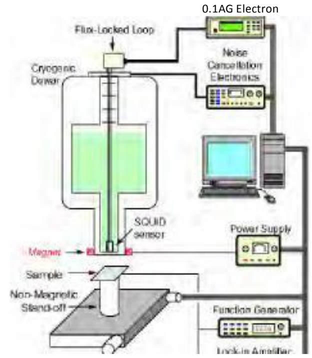
The 0MM-770 can also be configured to detect:

- induced magnetization
- magnetic susceptibility
- eddy currents
- magnetic hysteresis
- micropaleontology

SUMO Microscope Loll o: a nd ac haves mane.

- The Shilv1-770 is a fully lectured measurement system hal allows the user 10 extract a magnetic image of the object tieing measured overlie entire do —10 kHz Erequency range.
- Whether the samples are circuit boards. maltischip modules, steel or aluminum plates, composites or even plastics, the SUM 770 cen measure surface and even deeply embedded sources with a spatial resolution down te 50 strn.
- The ure of a High Temperature Superconducting do SQUID sensor gives it unparalleled sensitivity with the ability to measure fields smaller than 20 pT/Uftz. Tristan's FITS sensors can also operate in applied magnetic fields up to IOW oersteds.
- The Shl M-770 allows computer controlled scans of objects over a large (15 a 15 ch'n area frith 25 Pat stepping capability with sub4incron stepping available-1110user Fee the ability to preprogram the wen ceardinetes.
- The SMM-770 (emigres minimal setup. Automated setup and computer cougall makes Theasurements rapid and repeal able. System sort-were provides the ability to control the critical system components, acquire data from be SQI.(11) lessor(and analyze ilia data no determine the magnetic progenies oitile sample being ineasured. The use of open architecture software allows the user to cusionthae nearly all

0.1AG Electron



X.V Seeming Tattle

an-uo.. of Ma Medal S.1.1.77 eystem Naaudaq, n1 Ill accessories

The Areidand Shlh47T0 is configured to detect elecui entrants and 1111.9011 remnant magnatk Voids. II includes a Sithlo-Channel Scanning shim lelegmbemeter Preto. MAC 501110 ;lactinnias, Cryogenic Vegan Roan Temporal. Lmining Stage. Computer Chantal and Cate Acquisitive System. and Imaging SIAVAIR. The

Stas.770. can be suppled Yeah addittatial capabithies b Whig] 110 1710.nriarisant haepOnlatleei

OPTIONS AND ACCESSORIES

SCAN AREA: Latger.en are. 30 cm a 30 cm) and tighe lesslblon atimp I. (20 um stranded) no ovulat§ upon mallisel..

Sularlitinten OF 1051-1 SQUID Salmon For me.umnauls Maim .1sittvitas significantly Pak. 20 pThilde are needed and ultimate spatial naselliton is nal SO Important. Atkin can substitate the rnadgtHrhalss.or with S sijn&aney law rs semi. deteciSsie °al

with a .thsPivira dc.r than to olio-lo 1-1TMA15 mm carmen with a sensithitv holler than Ong palitht teal:30.711M.

5vvoricaruhivarthertucteinunimaiso mat

Norimmtal Flak, DA add 13a Mae, increco, A horizontal Sail sleet inducer. With can apply an . marmot field parallel to the Wt mitre b inchuct s tinge extended eddy current In a remind enentaiiin. can he wed to inage clacks or malc..1 b. deep in conductive Mg., alurruntirel structures.

as Rent Compensation Elecfronkr When imaging. conductive Materials. il on an signal Is dlnictly coupled Into the system the memo signal tune the held 101151 mss he most lairs then lee signal lam the sernsA. To minimize this. Tristan con supply an ac Co mpererarg n system In nauthe no stroliin the doteagen gni and

eetrant the *0150 mgnal In the object being trairsined

SPECIFICATIONS

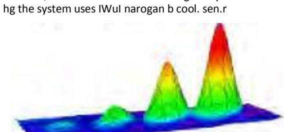
SENSOR 1-1lgh temperature aupornonducting quantum arlorlerenco diets 1500101 op-ember; al 77 K

SPATNUNESOLRTION Reiter than 51 um

SENSMATTV, 2 th 10' trantlA He (20 TSslstri

OPERATING SANDIAIDTM: dc - 10 kHz. Measmamerits can lie made al any Inagua nay. ganderalths shove 20 MFR am available.

CRYOGEN/0 COOLING: To ahead bw tregueirey vett balms 20D hg the system uses IWul narogan b cool. sen.r



Scan of 1, 3, 5, and 10 mm holes in a steel plate

TRISTAN

III TECHNOLOGIES eta,
Cwrea brew Court East, Salle
106 San Ciao, GA 92121

Magnetometers for Geophysics

Mineral surveys, magnetotellurics, magnetic detection of induced polarization, and other magnetic detection methods are important geophysical tools. Superconducting magneto-meters an d gradiemeters offer several advantages over other detectors commonly used for such measurements.

Model G377 three axis magnetometer system

- Constant Sensitivity from de to 10 kHz
- Magnetic Field Resolution of 10'4 Testa
- Gradient Resolution of 10' Testa/meter
- True dc Response
- Flat Phase Response
- Wide Dynamic Range

Tristan manufactures the most complete line of ultresenseive geomagnetic measurement systems available. From compact single and three channel Magnetometers to 8-charnel tensor arrays, Tristan offers a vanety of fully configured system packages for geophysical measurements,

The basic geophysical measurement system offered by Tristan is the model G377 It measures all three vector components of the Earth's magnetic field (By, Br, Bz). The small size and portability of the model G377 makes it convenient for field use. It can also be used with different size dewars for airborne (model NLD-530 dewed and borehole (Model NGD-530 debar) use Planar Gradiometers can also be

Tristan offers three basic sensors for geophysical measurements, the FITM-5 and the higher sensitivity HIM'16 are magnetometers (13, Br, Be)', the optional i-ITG.10B measures planar gradients (d13,Ids).

The modal G377 can be supplied with fewer sensors or a mixture of magnetometers and planar gradometers if needed. The picture below shows a single channel planar radiometer (I' ITG-10R sensor) being used in airborne measurements

Model 701G system mounted at end of boom

r i

.49 Ai

Itoleas.dsermiliv,ties en1r14'15 (SM90703) and HTG-1 (G90126) sem,

Tristan offers variants of the model 0377. The Model 703 is identical to the G377. but uses the smaller 5" diameter Model 530 dewar. The Model 701G uses a single HTG-10R gradlometer in the Model 530 dewar. Tristan can also offer fast 5 usec reset times tor transient measurements. For even greater sensitivity and dynamic ranges, Tristan can supply liquid helium versions of the

orttaNAL 13t5.4145

Nis s

Medal NG0-830 borehole dawn

Model G377

Operation Principle: 3-Axis 77 kelvin do SCIL111:: Magnetometer - Measuring the relative change in magnetic field simultaneously in *O.* B, and 13,, BOORS.

Range: 7`5 PiTh/Hz

serheavkffh: do Iota kHz

wider bandwidths available

Slow Rate' >1 pTrsec speak'to'peek)

SensttivIty: 50 TI7VHz, HTM-13

20 ffNW, HTM-16

1 frrme'Hz: HTG-10R

Cryogen: Liquid Nitrogen

Volume: 7 liters

Hold time: 2-3 weeks

Power. 120 or 240 VAO, 50 Walls

112 Volt Battery Supply Optional)

Outputs: Analog. RS-232 or IEEE-4138
Visual Alphanumeric display
Controller. 321 MM 0 121 nrit X 300 mm (12.6' wide, 4.8" high. 11.8" deep).
Weight: 3.5 kg (8 lbs)

NG13-1030 diewer (7 Hers) *Standard* on G377
406 rem high. 250 mm diameter
OR' high, 9.8' diameter)

T877 Tensor Gradiometer

TRISTAN TECHNOLOGIES

The Tristan model T877 SQUID tensor gradiometer is designed to measure magnetic fields and gradients for geophysical measurements.

It is a valuable tool for:

- Magnetotelludos
- Controlled Source Measurements
- Borehole Measurements
- Transient Electromagnetic Measurements (TEM)
- Unexploded Ordinance (LAO)
- 4 Magnetic Anomaly Detection
- \+ Environmental Waste Detection

Supereonduming magnetometers and gradiometers offer several advantages. over Other detectras mnrenordy *used for Magnetic* Anomaly Detection. MagnutoTellunca, raugnatic ...on of induced polarization, and other geophysical 11.151mEntenle SLIVeronntltmlin detectors' offer constant sengiiivity front In to tens of kHz (or higherl,

tad magnetic field resolution op nT4Γ1z with magnetic' gtedleal resolution up to le ISPft4HA and a elynomie range of i40 dB. Dame systems are well 11.0100 10 ilea oe, bE1ne ilahweight. [suable, fag to set up, and easy to or.

The TS77 masnetometerraradiometrr offers owlsl important advantages over other magnetometers. It is a vector magnetometer, in contrast to the *proton* menasion dem= whwh responds only In the magnitude of the Seat With a three-axes vector inagnercineter, both the magnitude and direction of the Field can l•e determined. With eight sensing elements in s terror conflguranon, the complete magnetic Feld gradient can be &ermined. Its performance is not impaired by the presence of large Asnieres and — unlike Niagara devices — SQUID magnetometers do not saner.. In comparison to large induction the Itor in col awkward or cumbersome Sr deployment and use The T877's be response avoids giving andue emphasis to high frequency phenomena such as the ubiquitous lightning induced stenos.

phaseahifts.

The Tristan Model TS77 is a tiottl-prmoo reglad, highly sensitive superconductin SQUID magamcmcieggradtamMer design.' for geophysical exploration and measurement. With the full tensor configurarion, it iv possible to cloth complete clunacteri.nan of may' erie dipole souroes Sr long nags obtaining kmahmation and cluaitication information_ me has been shown theoretically by Wynn' and demonstrated in rile Feld All pat necessary is knowledge of the magnetic Field compose.. (Hr, *Hr.* Hy) and m< live unique field gradients *(a3agg, PH, 04',*

TO,sOS, Mies) The Tlitt combines etgkl individual magnetometers into anarmy that yields all mummy Odd endTarr BMW, twang gradient components.

For uirhosne operation, Tristan can supply ~~custom dewars including horiso~~ntat or other Wyni, a se', 'Adamed supercandigainneramomatoronbantanshrAnays mats h6ryosig,at praegaspnTectin.s. rEgrTrans cut MasnnOt., t7r1-7711M31

TENSOR CONFIGURATION

- The /neg..: field vector, 1'1, can be expressed he cones of Cartesian CONIFOR015 *If* - For each cumponten, there aie three spaniel derivatives along ortliogonal directions, generating nine components of the noon rank magmelit veld gradient Sera This !woo' can be represented by the Finns.

OH, 614.. 58 *ag,.*

— > 7 c ;

idi• OIL *ahc OR,*

} 7.7 'F.,

- According to Maxwell's equations_ only five of these tensor

I X • 1..1'1-

0 2

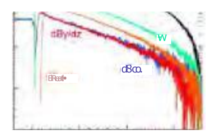
.Ha=Z(2+2"I

- Model *H714-8* HTS or SQUID Magnmemmer Sensors (S)
- Medal NGD.1099 Liquid Nitrogen Dewar avowereui dm 1,0131316 dams e.11.able on 1,1,061
- Model NO1-100 cryogenic insert and oriel:genre robins
- Modal MC-393 IMATS01.11 3 Electronics COMM Soil
- Model iFk-301-liFkre-Locked imps (ri)
- Model CC-09 six meter Itberoptio composes cables (S)
- Masal and accessory perk lira.. *on*

oar of tikm hm,i1 w se

dead,

I



Data from Controlled Source Measuremem cal a 10 an diameter hollow MO me Mica copper sphere showing data hom the foe indoPendont tensor gradients Dale was collectery ea ow Intervals.

SPECIFICATIONS

sENsOn', High temperature superconducting quantum intarlensrm Cana (SCUJIEtst operates 017711

OPERATING RANGE: t 900 nT

DEWAR VOLUME: HOLD TIME'POWER, niters

nominally 2 weeks

129 07240 V..d. 50 Watts Ito Volt Battery Supply Optional)

CONTROLLER: Analog o.3 Volts

DEWAR: 55232 or IEEE-436
41.1.1Alphal,rtleato dienNy 521 rrrn wide, 121 ram Nutt KO rum deep 1125rx 4.6[0] 11 8 0 9.I3 kg (5155)

TRISTAN TECHNOLOGIES

ihSSComerstonn Court Ent, 5,01105
San 0: 0e. G. 92121

Biamagnetio Liver Susceptometer

kieamitortbeat 0 Ow kw %Wu krg lagua0142 Biopsy

The Biomagnetic Liver Susceptometer is a diagnostic instrument which measures iron stores rapidly and non-invasively. Its advanced design with a superconducting magnet and SQUID detection system gives an accurate measurement of iron concentration in the liver and spleen for adults and children.

- **Non-invasive**
  Replaces Surgical Biopsy, for Iron Measurements

  Eliminates Di.scornic7r1 and Risk
- **Allows Pediatric Measurements**
- **Direct Measurement Method**
  Accurate and Reproducible

BLS Methodology

1,01ˉ Snseeptomerty (BLS) ekulorts the effects. of magnousin and supaconel•eus in Biological ma ten Ms such as rennin and honosidenn as mallsartrauled to an molted magnetic field Maracsagedic behmio* while unicr and hod, tissue are,en weak!, tcpched (thanammehel Ferromagnetic Platenals c g, nickel and anal. are shong/4 nthacted n. polled fields No Bengali ly penurring blame Bunn la fmn:tritansatin

In Is BLS method_ a weak magma, NM] nf0 20 Ind litesla is 'tenoned tathin the bed). borate. an external supewconduchnn field manner similar In thra oscd ins MRI scone, bat a hundred trees weaker.The applied fields me =elated M a superconducting magnetometer known as a SQUID ISimeremthaturnQtrantlint Interference Derˉlcc) The 5031' D .raing',stom his Ill, ahility tip F.ASFIFFI'FFFIMM WI* niamitic nold ai the pax no billion heel.

Wiwi, an organ, such as the hoer IF placed Ina mannenc field. ir mill slight', dtsrort the auphed field /Idle [Fuer a normalˉ or samara. the kraal hetet 1611 no redoned slightly. If drainer is Imo

orecloudad, the local field will be enhanced. Hem the pliangt In

Specifications

Magnetic Yield 20 inT el cod Dec. stab& n better than u.I ppndhour. 5 Gauss bins II am rum Jut., lad Detection Coil Sensitivity Intl 174117

Liquid Helium Cenneity 35 1 iters11 ft l,. hpld ham

Parkin Bed Capacity 131 Lg.

Ilhresound 3.5 ',Alia it war array. xia min resolution

Daze Base. Open file stmcbtre with abdip Mauston'". to user pref,reases

'Total System Noise. 00.02 meg 'Fel coucknin wOor (met w111111.. mansinvd Ina 'her phantom el a distance OF 15 rum Illsownement Range 115-30 niwg lwer ucighfl, aril, Diem 10 to 100 mgla (do' weight,

Options

For researchers dmerasted to dvanding measurement capotaline s_Tnsten offers the following ophons•

- Addition," Detcetion channel
  fins iheludm a third delecnon EMI with dtffinent sannial 5G11011,1i
- Atli. NOPISF C-annallition
  Needed For sites with high ent,minnemal poise
- All Fidel Capabilin
  tie-weld modulance of the mannehe field. This can ado. .t.search on alternate malhods of BLS

11. IrjeauvEnx.reronfr LineSer,inner,,elpaifiedaracionwaigariaeol.ir,

rmr,m,r-ronLienr.rmˉ4,easoord.,

and,a,sme, n,1•••11,,'io0ol

,Nowee.nre n,whnl n, ebr, welte,ei wee e

On detected magnnie Enid is 501,0010 mlakd to the troll a:neonˉmoon in the liver

To mina nice the body's contribution In 6c-distortion In magnetic held, a eroall bag of warm is placed hi:hr.:oh the debactur nod dun susfrat. Since the smocedhdityofbad, 01000 • close to Mal of halmˉ. the resultant aoommremenl a msen alt. that of a magnetized 6,1 tor spleen/ moving in a uninnenn field Within I

Ithamattle,ialtrarvirpnment, 410 -only chump Span by the &nation ends Is due to no: liver lot shipenl itself

For higher accuram.. our software removes the annul eon nibunon of nralying tissues (skin hone, =MC lc, iha, Mc.). This gives the lme concentration at the lnes for suieen) alone. allowing ae,mthe Mcasarenˉlintts for obese patients and normal patients 00,11011 1,1011 lirˉmhpken depths

Tn dada die BLS maim/11am hem. applied up orzans. 5redˉi

Inas and enlamot spleens f+300 nith a total orm of

I Fel = 0115 .11 mein tissue (wet weight) Rapeatabi ison al measurements o,ˉcr Max ,.nets/ on stogie stibieets -of beter Mien

O5 0 0, has b,undeinonstru.d.

Site Requirements

The model BLS reamims & Minimum 3.1mvr M1 nix in

r !Tx no Torn] or a.m' n eight os 1_5110 kg Pdwnr teguittment is 7 hVA A tibranion free 111110001 for the gam} or required and the system should he sued rp a magnancaly

quiet cmiwormcni Cont. Tn elan fo discuss site servers for magneto and labwation mosque...Ms. All Tristan ',Enthrals me eoicoed kn. a 1 ear nazrantj. Sorwe contracts may be 511F, heard a pm ide past nurrunt!,. esmage

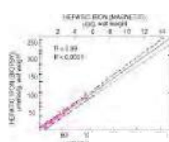
TRISTAN TECHNOLOGIES 1250 Nancy Ridge Drive. Sully 102 San Diego, CA 92121

(95s) 550-2700 /leg] (n13)-550.2799
Int@instantech.aom
httpd/wwW.Inslantech corm

Clinical Relevance

The slandvd nuanh lathe measurement or non shins has meowed a sup.' or needle Ines bmps, Tnis **method requires a physiachernmwd analysis With its assbciateci time dell) nt obtaining results l1' alto assumes that trouts evenly distributed th,ghonl the hoer. In addition. the reedie bilmi gnot lelthent discomfon and, to some cases.significanl** nay **Them.** 00rllmon **.5e.inect ar,rOn store, Is the**

serum ferntm mem irrement suiches have *On n seroni remdb0 piessui emeo Ll la he a pone predictor of actual Iron stores non correlative soclficierlB lnd railing as low . ill for 8- Thalasselne intennedm patients[1] Serum tern tin cstiridnei ea,bo Wm`rod IN as mirth DS 3 taanr**afim **Biornagneti a Liver Suscaptomein [BLS) has long hen reeeign/ed as provLcrz ascorne quail/ Dl,c measurements of iron stores The graph' shows a cOmpanSOu ofhapnliciron COncmirallun determined by BLS (2e-axist and by cheencal analysis or liver tissue LA.` tinned In clinic-elle indicated need, biopsy t`,z■



is,auEa1¢1111=71

With the shill/ 1.0 Use into account the contribuilim of ovedying tissues_ BLS measurements cm *be* **.tended fin adults and children who base wide**

variations in organ depth and CM Another adnantaae of BLS I, flua lb is a vrilinnellic lechnque. giving n avenge iron concentranon measured over many milliliters of organ ussue width ram, accurately portrays total iron stores A nmeal needle Noon' winch removes •ray smart amounts of tissue can ma, gi,e erroneous mud iron stores

Measurement Protocol

Ile *the* **first trun, patient m formation inducting v..' age fiet.ght' wetithl and loud body, fat is taken. The depth and shape of the titer No spleen Pu-reed**

meas by ultrasound and entered into the patient data *base*

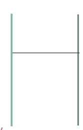
The bed is elmmlad Until the pattern _I int lanches the **detector and the Haler hell." is tilled**

The patient is then automat calk lowered about In nu *over bib* **seconds As the hill 101APTS_ water Bows 1010111e hdlows keening We space Seto eon the pal., and detector tilled**

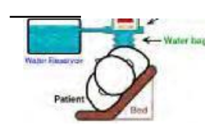
Thu c•`b`I teas tie Field Measured ho 11,, magm1omeueris Fccordad as a frnelion eflho distanced' the liner from the detector cods

The computer immediately analyzes Medal and gi4es a omit mum!' result as soon as the bed [11.1011 stops

The **ineasitreureM Senn•ice Is generalh. maethed 0001 or more limes W i nrprolo moolrecy**



invenee.av aree **Coe♦** **SoulD Arrptifhm.**



ScPernatt ollulajdraunanatams

Applications

The rarest rel., mi appbethen, n1 rhnrtragnehe Linn **S'eswolenanry (BLS/ are related lo iron Overload dtseas,s such as hemdnarY hello& rormaoss and siderosta caused** fits **blood transfusions. To dale, the fellonang appitcarions hare been dervionsirined**

- **Monitoring iron o,n,load in patients with transfusiond** *siklebosis* **(genetic 11-thalassemia moor and sickle cell disease_ or other transihsmo dependent anemia:/ for dm onset or nuensificanon** acltelati **of therapy and dining tam boom**
- **Am....memo! tree[weldedm p.en`Ls,bedaled fir Intaferau elfa th.rn in viral 1'or re,20n5 Sigh**
- **_Assessing ace overload In palm. with 11' thalassend a sdredoled for bona n•rrov. irmsulantation IBINT/ os monnoring iron o0erl oat after BMT during bum depletion therapy**
- **Amessrunol Of the lung`WM' erFen03 0`different iron chelalm, Amdei`**

srudr

- **Diagalrrisnrheredtmn hemochrornalosts and assessment of the degree of ion ovedoad on lam, hereditao, hemochrornalosis**

SYSTEMS

Tristan offers s variety

or **fully configured system packages based on the iMIAG series or SQUID components. These range from basic** singleFenannat magnetometer systems to instruments **for specific applications. They include systems for biomagneesrn, geophysical exploration, nondestructive testing Of** materials, **magnetic microscopy and studies of rock magnetism. For epplicetInne that require applied fields, Tristan can supply persistent superconducting magna e, permanent magnet structures with custom-designed field profile shapes and built-In copper magnets for ac fields.** Tristan's SQUIDs are **available** in both high temperature. IIHTS1 77 K and low **temperature. ILTS] 4.2K veraione. Standard product data sheets and application sheets are available to** merry mr /mos. **comp**lete systems. Contact your Tristan products representative

a Laboratory Applications a
BiOmagnatio Measurements **a**
Geophysical Exploration te
Non-Destructive Evaluation

Y Magnetic Microscopy e
Custom SQUID **Systems**

The basic SQUID system consists of an input circuit connected to a SQUID

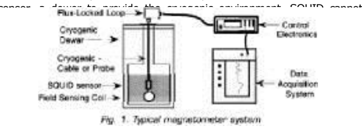


Fig. 1. Typical magnetometer system

Tristan offers complete systems or individual components, according to your needs. Tristan also supplies the Isaac components that can be combined lo form the teas of a SQUID measurement system. Specific inks-maids on individual components **can be** found on their respective data sheets.

SQUIDS

Model LS0120 LTS do SQUID Sensor
Model FITM.100 HTS Magnetometer
Model 1`170-100 HTS Gradarreler
Model H7.100 HTS miriMAG

PROBES

Model SP Standard Cryogenic Cable

Model RMP External Feedback Probe

Model MFP Multi`FdraCtion Probe

NLI series of dewier inserts for FITS SQUID sensors

TRISTAN LABORATORY SYSTEMS

Tristan offers Tie 0051 complete line of SQUID meseura-ment systems available. These systems can be combined with either user- or Trietan-supplied **cryogenics to give** you the most versatile measurement capabilities possible.

For laboratory applications, the LTS SQUID system can he confmured to measure a wide variety of electromagnene signals. VETS SQUIDS are availade as pure magnetometers and planar gradiometers. Typical sensitivities that can be achieved with Tristan SQUID systems are listed below:

a) Current	10`re amphitls
b) Magnetic Fields:	10`re lesIWVHz
c) do Voltage.	10`re volt
dl do Resistance:	**10`to i1**
e) inductance:	1(-4 henry
I) Magnetic Moment:	10-0 emu

Model ISMS Haan Measuring Systems: The Model eMS-H is a HIS SQUID system capable of measuring magnetic Seas approaching 30 lemtotesiarefle (1 fT -4 I0-4 testa). Typically, this system is used in conjunction with a 411.0 series Devar.The BINS-H can also he supplied with a planar grad. meter coil with a gradient sensitivity better lhan 100 fl7cm1H. or a miniMAG sensor with spatial resolution <100 pm.

The Model 5MS-L s a LTS SQUID system capable of mea-suring small electric currents with a better than War 7 X 10` re ampereNFla. With a simple pickup mil, it also can be used far the detection of magnetic fields as small as 1 fT.

Model PM5 Picovolt Measuring System: This cryogenic **dc vellage** amplifier with a gan or 10[4] and a rms noise of less than 10-0 voltsf4H2 is used for measurements of very small voltages and resistances.

Model MPS Multi-Purpose Measurement System: This system is a low impedance ac bridge system for extremely sensitive resistance and inductance measurements. Resolutions of 10`In ohm and 10`ts henry are readily ob-tained. The Model MPS also has the combined capabilities of

TRISTAN

For measurements of external magnetic fields, Tristan offers both liquid helium and liquid nitrogen SQUID measurement systems. Senes 500 LTS systems are designed for the re-searcher sac desires urinate performance from a low to med. um Manna yours SQUID magnetometer or gradameter sys-tem. The series 700 HIS magnetometers offer researchers

interested in HTS nitrogen} SQUIDs a number of con-venient platforms lo pernrm magnetic measurements.

node tyre **eereet** orlenielon

808	170	Out	`1.1.,7;.1`4-`.0-..19.,B,		deft}
612	LTS		inn		
7 0 1			nr		<90 W`N stallfarinst
cos	SITS	3	Pstif 101`1		e1 RNHo

Web the use of discrete detection circuits. Tristan LTS SQUID systems can operate in magnetic holds exceeding 9 rests and sample temperatures ranging From criK to wall above **MOW** temperature. Tristan HTS SQUIDS can operate in fields that can exceed 0.1 testa

TRISTAN CUSTOM SQUID SYSTEMS

Tristan has supplied a wide some/ of unique SQUID-based instrumentatian **for** Laboratory, Barnagnetic. Geophysical, and Non-Destructive Evaluation (ND!) measurements II your needs are unique, canted us to discuss year particular mquirements. Tristan's scientists and engineers 20+ years of experience and an ever-increasing quest for refinement of its product Bea, secures that Tristan can manufacture the ideal SQUID system to suit your needs.

SOSCR..15- nat. caress Acrue.

***riff)* TECHNOLOGIES**

CRYOGENIC PROBES for the laboratory

FEATURES

4 Easy to **install**

Is **Multiple Measurement Capability**

- **irrunersian** cr **Vacuum Operation**

Tristan manufactures three hams SC11.J10 probe. for general

- ***Magnetic Fields end* Raid OraLliente u Static Magnetic Moment and Susceptibility Electric and Magnetic Fluctuations**

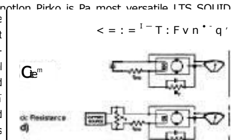
Tr Intents **cryogenic probes** and cables are the heart of any SQUID hosed measurement system. They provide a flexible Fans-mission line funning tram room temperature to either 4 K or 77 K with plug-in connecters at each end. Without restrictions of a rigid probe, a variety of installation options are mailable.

In all Tristan probes, construction matertals are non-magnetic and care-fully seleded to minimize conduction or heal into the cryogenic Path. All probes are **shielded** against d intorlerence and other etecticei transients het may anent the SQUID operation. A mom temperature 0-ring seal al. lows Rowed decor operation Probes are availabre separalely for up. grading older SQUID systems or for expanding the capabilities of a more *r AnAntly* onmhseed system.

The Model SP Cryogenic **Canis is the** probe ol choice ler simple sumoril and megnetc teillMeaSuremen16- Seed with *MD* Model 05009 low lem-

Perdu re ILTS)de sensor, measurements shown In Fig la & tb are possible. Used with the Model HTM•100 high temperature (FITS) do SQUID sensor, measurement contiguretiors shown in rig it are passible.

'vacuum sealed housing. The limper LS0/201ASOUtnt sensor housing accommo-dates a cryogenic nominal hoard Oath the teslalarce And nu dual mdi**mlance** Stan` dards required tor voilege and impedano measure. nerds. Its great versatility makes this the **sconetend. ed probe when a variety of applcalices enerequired.**



et MO

11)

the Modal ***RIAP is* dcaligred elf** *arm* moaner...nests (Fig. le *5 and cantgorelions *ra*

l`eMellif art., I WW1 tr71

TECHNICAL FEATURES

Model **SP:** Waiving Tenwensture) 0 - 77 X !Snows dependent)

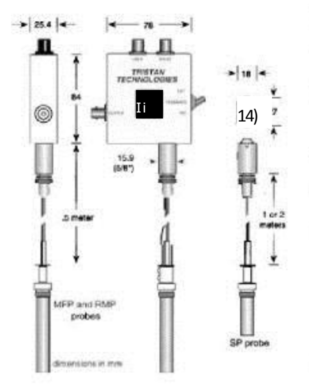
Model AMP; Melting Temperature: 0 - 7 K ELSI7IOVM weeps only)

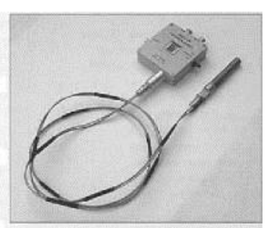
Standard Mutual knuCtandt 0.0 uH (nominal)

Input **impedance capacallva al non-taro frequencies wall Z is 1120** *j to*

Current Leads: d decousted fraung palm rnasirnum Current 0.5 Amperes

Model MS.: Working Temperature: 0 -7 K (LSO/OrM sensor only)





itolltabbne satfactio dote xtflortitts

TRISTAN TECHNOLOGIES

6105 Comererone Caw East** Simile **106** Sim **Dego, C,1 93,21

SQUID ELECTRONICS

Peatnreo:

S Easy Setup

IP Manual end

Auto■Tuning of All SQUID Parameters

I- Multichannel Capabilities

11. Single Controller for LTS and HTS SQUIDS

Tristan's MAAS SQUID electronics have been designed for the user who wants performance and fleslbllty. edlicroprocassor-ekdven hierarchical front panel menus allow fast setup for both LTS and HTS SQUID merseu-s. Multiple stew rates, gains and **bandwidths allow the user to fine one the measurement process. Individual tuning of each channel** ovids **optimum performance in multichannel configurations. When you need the best in SQUID electronics, look** ter thp **iMAG series to satisfy your needs.**

•

Thou Model INIC-3'73 !MAC SQUID controller forms the basis of a powerful and flexible measurement system. Its three channel capability accom-modates nearly at laboratory SQUID applications without incurring the cost or oomplexity of eight-channel designs. A unique Feature of the Tristan controller is its ability to simultaneously control both ITS and PITS devices. For the experienced user, the Tristan Multichannel Controller of-feria complete manual control of all SQUID parameters, including ties led el, modulation amplitude, 'skew" level, de flux level in the SQUID (offset), heater and integrator reset. All parameters are easily adjusted using the membrane keypad and a convenient menu-driven intedece Liners who want **a fully autemaled system** will use the one-touch tuning capability that rapidly and reliably optimize the level at all critical parameterS.

High-resolution ND convertors and the standard IEEE-428 bus make the iMAG controller ideal for use with computerized data acquisition. Use the rear-panel 050 connectors to monitor the high-level analog outputs. A "fourth channel' input allows you to synchronously digitizer your own Mg-nal along with the three SQUID signals using the controllers internal *AA)* convener_ LabViewtu software drivers **are also available-**

FLUX-LOCKED LOOP

MAD FLLs are offered in both FITS and LTS versions. The LTD version uses an advanced bias reversal technique [hal effectively reduces low-frequency noise in HTS SOUIDs without intrOdUting reties spikes in the output spectrum. The less-expansive [TS FLLerovides slightly higher Ire-quarry response.

The Model iFL-301 series IMO tux-locked loops (FLLs) provide superior performance under a wide range of operating conditions. The Tristan design locates the FLL as close as practical to the SQUID sensors and **eliminates the need** to run low-level or high-frequency loads over long distances. A shad Cable connects the FLL to the probe or cryogenic cable, allowing the compact FLL td be conveniently mounted near the dewar, hut net of the way of the liquid cryogen transfers Connection to the WIC-303 COntroller is via a composite cable.

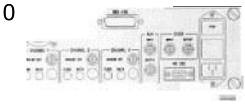
COMPOSITE CABLE

Thetane advanced design provides superior radiefrequency (M) rejection and allows for long cable runs, even in hostile environrneMs. Il is a sim-ple matter to locate the FLL inside a shielded roam and operate it using an iMAG Multichannel Controller located outside the room.

The connection between the controller and flux-locked loop(s) M via the CC Series composite cables_ Low level dc power one the high-level ens-log

IMC-303 SQUID CONTROLLER

0



iNIAS Controller Nadel 00.3431

Number of Channels: 3 SOUID channels Net interlace to both HTS and LTS Flux Looked-Loops (FLLs9Thecontmlier can operate any combination of LTS or HIS SQUIDS simul. laneously using the appropriate FLLs. An auxiliary channel is stippled for synchronous data acquisition (see below)

Auxiliary **I/0:** One auxiliary analog input (10 Oa impedance 50 kHz 0W) is prodded for 16-91 digitedng 01 a user supplied signal for synchronous acquisflion or event trigger ing. Maximum output signal Is 4.5 V FS. Gain Is selectable to be x1, X2, X5, 7010, 020 or X50.

User Interface:Interactive user Interlace vie large LCD display end **membrane keypad. Special** fundion keys and menu-driven software provide friendly operating and **setup** environment_

Remote Interlaces: Both IEEE-4B9 and RS-232 remote control interlaces am standard. All control sethngs may be input and all instrument dale may be output via these inter-faces. Total maximum data rate vie the ILLE-488 interlace is 16 Ices at 20 kHz kr a single channel, or 5 kHz for all three SQUID channels plus the auxiliary channel.

Analog Output.: 4 analog outputs (60962) provided on the back panel for **the 3 SQUID channels and the auxiliary ana-log input.**

Autotuning of all **SQUID** parameters is cocoa, plished by single button push. All **adushnents may alas be made** manually or via the remote intoleces.

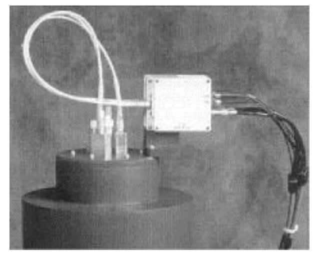
FLL Reset: Any channel may be reset manually or noternahcally et any user seksotable output voltage.

Bandwidth &Gain: Selectable bandwidths of 5 **H.. 509 HZ, 5 kHz & 50 kHz. (4-Pole** Butterworth response). Selectable gains of (1, 2, 5, 10, ..., 500) corresponding to full-scale oul.

Flux Lock-Loop Waded IFL-30`1)

Two versions of the flux-looked loop are available. one for HIS sensors sod one for LTS sensors. The HIS FLL hes a 25 kHz maximum bandwidth (selectable to be 250 Hz from the IMC-303 controller) and uses high-frequency bias reversal to minimize low-frequency noise intrinsic to the HTS sensors_ This bias reversal eons not locreaSe the white noise M the sensors or add any spikes within the specified bandwidth. The LTS FLL has a 53 kHz bandwidth (selectable to be 500 He from the iMC-333 controller) and uses no bias reversal since it is not required by the LTS sensors. Wider benclwidMs **On both** LTS and FITS leapt are available [on] special order.

All FLL functions are controlled remotely by the IMAG IMC-303 Controller. The FLU coenect to the 1MC-393 via a cern-posite cable. To minimize di, even when using very Imo 011. bins, ell high-frequency signals are transmitted by optical fiber between the FLL and Controller.



IIITRISTAN TECHNOLOGIES *al AS Cosiereless*

Court East S,Se 106, Can Grego C.4 *82121*

DEWARS

FEATURES

- **Low scoldgef**
- **Close Tail Spacing**

50 Standard and Custom Designs

•

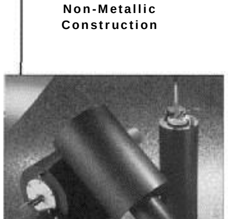
Comp lete

Factory Testing

•

Metall ic or

Non-Metallic Construction



TrIeten lakes special pride in the Wesellve de. nen and constnsmon techniques n free developed. The use of SQUID magnetometers for tlomegnotio or non-destructive lasting and melte. (N010) measurements requires that magnetic signals front a subject al don temperature be coupled IC a superconducting pickup colt In the reels reserved II me dewier. it Is easerreat to use nonmagnetic moindals and to have the smelted posside spacing between the cryogen. reservoir and the outside of me dew.` Tualanis development of adjustable tail dowers have allowed marl was to be less than 2 me

Pl.MCI Series Liquid HIR I IUM **InnuumIrm**

Triaens IA113.10 is a fiberglass worm cosigned Iv: magnetism and Iff DE. The **BMD-101,1 variant is supplied** nor an upper aluminum bowing to resuce weight, nonslruntion CA. end Inerc&so reliability Intended for use with Tristan magnetometer probes. they provide a spacing of leas than 10 mm be tween room temperature and ins kquitl helium. The 6NI610 typically uses 2 **ilteday of liquid** *es* offers longer held timer and room for multimhannel deteceod **Oldle-** Custom deems with different size necks, teils, helium reservoirs or in--vacuum data:ellen coils are available.

NLO Series Liquid Nitrogen Dewar.

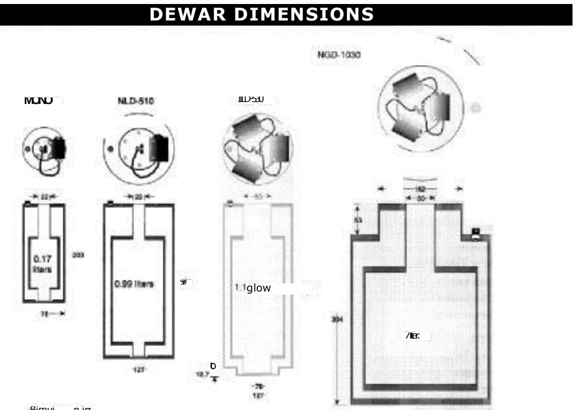
Speckaer aanogned Ion use with HTS sbanu wooer:s`glean **suers swine as-sortment** of standard devrar designs. **These** include toted dervare wily done *access* a the sensors . multi channel dewars, handheld deems pat epee. In *any* ormantim and larger dowers alto more than 30-day hold does Cdnigemo inserts ere **nobble to mount the 50010 cantos rigidly in are dear and provide any performance features required of** rho application eastern dewars wire miteredl size necks, tails, or cryogen reseneous **can be spacial ordered.**

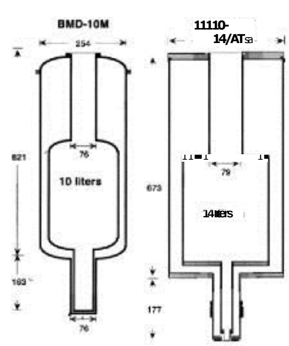
CONSTRUCTICIN TECHNIQUES AND MATERIALS

All "flown down incorporate loot **egad daign cmcnpts** and are assembled cob the highest standards of workmanship. They **are leak tested afar each** *phase* of their construction end are cycled between 100, **temperate** and liquid name:Intorno:rakes macaws long-wen *liability, *A* complete series et tests is made at operating temperature including measurements **of** Ins equilibrium Ouilfoll A lento, led report is supplied with each delver_

The use of super-insulation end one or more vapodnooled shields inlaid alimi news the need or liquid nitrogen in the BMD serres.Tristarns own computer analysis is used to calculate the optimum layer deadly of supreinspetion **In sect fern-arsine moon** and the estaaten In careuhr applied by hand to main.. Ids density, even in thole Penal regions Ouch as corns, clow-spacad Cale or regfone where overtop occurs. Also computed are the number and position of do required ,ecor-cocied shields end, for custom steward the prodded cryogen boiled mi.

DEWAR DIMENSIONS





OPTIONS AND ACCESSORIES

- **Dail-in-Vacuum dewars**
- **Adjustable** ten option for liq-uid helium and NI_D-500 se-nes dewars_ **This option can ale4rail** spacings kassthan 2 mm Iran liquid helium or re-hewn to roan temperature

- tea` Tilt Option for NLD series 310 8 510 dewars
- Cumin designed low-pass (eddy current) filters end dl shields.
- **Mechanical anchoring of the hedum reservoir to theoutside Omar ease is available for appitationS where oadhancal** vibrations and relative mean may introduce noise
- Liquid helium **or nitrogen level**

gauge_ re Flexible metal transfer

tubes wwwww awe *did,[1.7411,141.4*

TRISTAN TECHNOLOGIES

arm Cuweral ns Como East Sofa lee, San Easy. Ca 92121 Tv-*

asS91 0601'00 Ass (SW 550-2 SO Ewer aSpes-eteseAS one

Product of TTi

SQUID iMAG

Features:

- **All Thin-Film Devices**
- **Niobium-Aluminum TH. Pryer Pi-ocean fm Robust LTS Device.**
- **YOCO Step-edge and therystat Junctions fur Robust I-ITS Devices**
- **Symmetric Modulation Coils Eliminate Inductive Loading of Output**

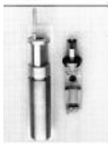
Tristan offers Revere! configurations of love...some SGI-110 oensors which serve as the heart of **our iMAG SQUID systems-**

Address your magnetic ...inning applications with the latest technology in both high-temperature and low.

do SQUID SENSORS

The low-temperature 11TE7 SIMUILlso run in liquid helium and are labricated using a niobium/aluminum all thin-film hl-layer technology that combines durability with high sensitivity They Mature symmetric integral signal and modulation coils that eliminate output variations with varying input loads. The niobium-shielded package comes with screw terminals ready to accept your custom input circuit Tristan can also provide thin-film integrated LTC SCUID megnetornelers with siate-ol-she.art performance. The Tristan Model L50125 can lee used with the Model SP Cryogenic Cable for ultrasensitive measurements of current (< (IT RANH.) and magnetic field to T fthlHz). In conjunction with the Model [IMP and **MFP** Cryogenic Probes, it can measure a much wider range of electromagnetic properties in magnetic fields as high as 0 testa—see Tdstan's Cryogenic Probe den sheet for more Information.

The highrterripereture (11-1T61 SOILPICle run in liquid nitrogen a177 K and are offered in magnetometer or gradio meter configurations They feature YI3C0 pick-up tolls patterned on the chip and a tough passivation layer for protection horn moisture and oxygen. All FITS MAO sensors use a common connector to attach them to the Model SP Cryogenic Cable; they may be easily interchanged to provide alternative pick-up cells and different sensitivity levels. We can guarantee magnetometer performance better than 90 **IT0Hz.** For customers who need even knver noise levels and performance in magnetic fields we can pro-



LTS Sensors

Input doll Incluolanca, TB pH

Noise level <5 a: 10[31]J/Hz

HTS Sensors

Noise IHTM-11309: <90 fIAlHz

01 09-100ti e 10 pT/Hg

Sesides. the Standard LSO/90. Tristan can supply LTS sensors wen longer niobium shield cans such as that supplied with the MFP and RIMP probes (see Probe Sala Sheet for details). We can also supply the bare sensor chip for specialized applications. 1000

The 2 pH input impedance 01 the LSCV20 allows eater matching of input circuit, Unlike asymmetric coil designs, the symmetric con design of the LSID/20 avoids inductive coupling of unwanted signals. Additionally, it exhibits no sensitivity variations with changing input impedances.

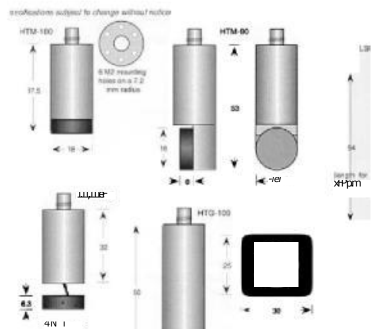
Tristang TITS sensors are the liron commercial devicaa to operate in both ambient and kilograuss environments. Step-edge junctions ensure uniform response Independent of sensor orientation, avoiding the Fraunhofer-like diffraction behavior seen in many monolithic bicrystal junction devices. 700

Tristan's FITS sensors are available in a wide variety of configurations. The standard FITS magnetometer sensor Is available in a 90[9] mounting (Model HTM-80) or Ina flexible end piece (Model HIM-Inaba. The lee-tale section can be as long as 15 our without degrading performance. Pickup col dimensrons other than the standard S mm X El ern are also availeble. The HTo-100 MiniMAG has a 50 in X 50 **gilt** pickup-coil and Is well suttee for magnetic microscopy. The HTM-400's large 16 mm x 15 min detection area gives it the highest sensitivity on any available HTS sensor_ Tristan's gradiorneters are available In either dElearr (shown be low) or cinvidg configurations.

L Mama **M*SO**

resolnann. (H*

A In



TRISTAN TECHNOLOGIES

eves COMersterre Gond *East Suitt* [10]*F. San* cress, **CA** 92121

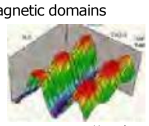
reset asj:2tin pae: gum sso-zees 0.max: ma,eniateroo.ot

rees.enneeen.hsse

Ultra-high Resolution Scanning Magnetic Microscope

The Tristan model SMM-1000 Scanning Magnetic Microscope performs micron level non-destructive analysis of surface and sub-surface material properties using an array of small SQUID magnetometers_ It can be used to Image diverse objects such as:

- micro-current distributions
- vortex motion in superconductors
- traces on a circuit board or multi-chip module
- weak electric currents in semiconductors
- integrated circuits
- magnetic domains



awpm. env dan on me ms Herechmone ea V .6.1.6 or to mane The Ca mums **eel or .rno.iaok** mixing **h 15** rtnoons.pourthey ucsol

Besides measuring magnetic fields, the SMM-1000 can also be configured to detect:

- transient magnetic properties

Model 610.1.1nowSeamumSnll1611.ausem.

- The 65.1114-1000 us CH a proprietary intimated circuit That Incorporates an array of Sugerantducting Quantum Int-Heart.. Ideate. (SOLI Ills) to map the magnetic Cold froin smell samples. 'rite use of liand helium SQUIDS provides a 100 cola improvement in sensitivity over other ClOglISPC detectors and allows high-resolution mapping of elect/to currents and magnetic sources located beneath ***the*** surface of the sample.
- It is a tally Natured measurement system that allows the user to extract a (napet le image of the object being measured Odor die entire dc - 10 kHz frequency range_ Its flat phase response allows both in-phase and anadranne information to be olthined without distortion. Addlliomd detection channels **can** Ire supplied to speed dela acquisition rates.
- It allows computer controlled earns ofobjects over aiarge IS a 5 min) area with 0.17 Lcn stepping capability, The user has the ability to preprogram the scan coordinates.
- Automated setup and Computer control makes measurementa sapid and repeatable. System software provides the ability to control Ike critical system component, acquire data Horn the SQUID sensor, arid analyze the data lo date mine Me aingnaie proportion of the sample being measured. The use of open architecture software allows the user to modify and Customize nearly oil aspects or Operating including image aocessisa.

TRISTAN TECHNOLOGIES

SMM-1000 sample stage

System ***Operation***

The 0INM.1000 achieves micron resolvrion by the use of small ill use deemon coifs and merge gag Fete.en rte coils ate the objeci(s) being canned.

The sample is mended inside an m change gas car et the lamer end of s cryogenic probs. This houses ell or the cryogenic portions of Me SW ant, lass) a measurement, Is Sled with a man amount of he/lenges. The sample to placed on Mesmeric stage and the erotic can etlaoheol. Then IfreeM0.1 Prete Is lowered mu He fined helium dewy Sloe the sample arose Imo armed IO •.2

otos er sq. tower fiv **onusescene** re ren Selectee coil*

System Component's

The standard model **SM51.1000 pdodes a single channel WM** probe nlagnete Onteonen autisertem) end WAG' **891013** e..1'1311.. UMW *p5111.* **measurement end** control **gobygelt,**

Well hem, gear **veil vitromen** stand,onoto wenninis, 31.1 gas dandling states monomer cont. **console and** complete software package for system control, **des** acquisition end dale anilines me model 7011.4111110 on he supplied and additional. capetitillos ...extend Its measurement capabIlities.

OPTIONS AND ACCESSORIES

Addhionie *Defective chgeorteekt* The model ,SPAM-101774 mensuremeal opethiltes can be untended to wfill-channel twprahnew Adrationel mire. (Bit **nenswomell sites** 050 ts3 installed **le** reduce massuremo. ems The stereo. stance beams, the LO118 **is 54 gm. cols** maybe larded IOC pm, 120 rim, or 209 era span at *no* este charge Other *.41* ciameters and nonNituralions are ayseshoe as options.

&piled Feld This option generates a vertical dri,a dc

magnetic Mil on the sample This snows mngrelic ensceplibility meesuremerle on insulators, conductors anal ferrous materials to he endeared.

Variable *swept* rerlper.lll:* The Wandard measurement lerrperatise is 42 IC The varialsla lemoacature °peon elates sample termeratise to Lis vaned between 2K and los s

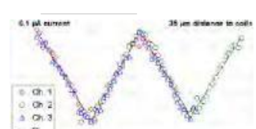
SPECIFICATIONS

SENSOR: Lore tBlelEiBMILNP wreemorshrsling SRIFIFIke, interference device (5121110)Ontratea .92X

SPATIAL RESOLUTION: **I Onto** single spate sources

SENSITAITro leSatits [WC pT.Hr)

OPE/1617HG *NANDI/ADM de* - 10 kHz. M0.1.11.10nrs mn bar *made* at any irecueney.Bandeoidths above to kHz ere avelFeble



e e l

InT

EnT

TRISTAN

TECHNOLOGIES