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**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.
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.

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.

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>INCIDENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>perinatal asphyxia</td>
<td>between 2 – 47 per1000</td>
</tr>
<tr>
<td>hypoxemic-ischemic encephalopathy</td>
<td>between 3 – 8 per 1000</td>
</tr>
<tr>
<td>moderate-to-severe cerebral palsy (post neonatal)</td>
<td>between 1 – 3 per 1000</td>
</tr>
<tr>
<td>periventricular white matter injury</td>
<td>240 per 1000 (for gestational age &lt; 38 weeks)</td>
</tr>
</tbody>
</table>
**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 $< 10 \text{ fT}/\sqrt{\text{Hz}}$ for the detection coils.
- BabySQUID® has an order of magnitude better sensitivity to neuronal sources than conventional whole-head MEG systems. Sensitive enough to measure spontaneous neuronal activity and evoked activity of the cortex of the newborns in real time without signal averaging. 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 makes 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.
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 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.
Mapping of sites and dynamics of sensory functions – auditory, somatosensory, and visual modalities.

**SYSTEM COMPONENTS**

- Sensor/Cradle/Bed on mobile cart – easily accessed height
- Power supplies and computer on companion mobile cart to minimize noise
- Subject Tracking – optical tracking system updates 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 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 headrest.
- Allows simultaneous measurement of the occipital area and parietal and temporal areas
- Includes position tracking device and software, permitting measurements during sleep or relatively quiescent wakefulness
- The measurement cradle and companion electronics cart are portable and can be wheeled in and out of elevators, obstetric suites and neonate 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 β-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 β-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.
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).

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.
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 coil-in-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
- Magently 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.
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.
The Tristan MAGView™ 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/√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/√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
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System information and advantages

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- Because of the superconducting nature of SQUID measurements, true dc response and flat phase response are available.

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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.

![Diagram of gradiometer response](image)

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

For 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.

   \[
   \begin{align*}
   \text{Current:} & \quad 10^{12} \text{ampere/Hz} \\
   \text{Magnetic Fields:} & \quad 10^{17} \text{tesla/Hz} \\
   \text{dc Voltage:} & \quad 10^{14} \text{volt} \\
   \text{dc Resistance:} & \quad 10^{-12} \Omega \\
   \text{Mutual/Self Inductance:} & \quad 10^{-12} \text{Henry} \\
   \text{Magnetic Moment:} & \quad 10^{-10} \text{emu}
   \end{align*}
   \]

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

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:

   Tristan HTS SQUID gradiometer in flight
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.

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
Magnetoencephalography (MEG) is an ideal technique for measuring brain activity. MEG is based on the detection of magnetic fields generated by neuronal activity. These magnetic fields are measured using superconducting quantum interference devices (SQUIDs). This allows for a non-invasive and non-contrast imaging method to be used for studying brain function. MEG has several advantages over other imaging techniques, such as fMRI, including higher spatial resolution, better sensitivity to fast transient events, and the ability to detect single-neuron activity. It is widely used in research and clinical settings to study brain function in healthy individuals and in those with neurological disorders.
Tristan Technologies, Inc.

Tristan Model 619

The Model 619 is a read measurement system, with built-in data-acquisition capabilities and intermittent or continuous data acquisition. It is designed to provide reliable and accurate measurements, with internal memory for data storage and easy-to-use interfaces for user input.

System Features:
- Built-in software for real-time data analysis and reporting
- Intuitive user interface for easy operation
- Internal memory for data storage
- Easy-to-use interfaces for user input

Applications:
- Blood hemoglobin levels
- Fetal heart rate
- Intestinal gas volume
- Nerve function
- Intestinal lumina

Measuring Liver Iron Stores

The Tristar is a device that is specifically designed for measuring liver iron stores. It is non-invasive and can be used on a wide range of patients, from newborns to adults. The Tristar can provide accurate measurements of liver iron stores, which is important for assessing the risk of developing liver disease.

Tristan Model 607

The Model 607 is a complete and economical laboratory system with 7 taps. It includes a variety of features, including:

- Interchangeable taps for different measurement requirements
- Internal memory for data storage
- Easy-to-use interfaces for user input

Applications:
- Blood hemoglobin levels
- Fetal heart rate
- Intestinal gas volume
- Nerve function
- Intestinal lumina

Custom Features:
- Real-Time Data Monitoring
- Subject Positioning
- Reference Arrays
- System Reduction
- Hardware and analysys software
- Aunt and document quality
- Matlab and analysis software
- Matlab documentation and analysis

About Tristan Technologies

Tristan Technologies is a company that specializes in the development and production of high-quality laboratory equipment. They offer a wide range of products that meet the needs of various industries, including medical and research institutions. Tristan Technologies is committed to providing reliable and accurate measurement systems that are easy to use and maintain.
The DRM-300 Rock Magnetometer, with its closed cycle refrigerator, allows for measurements in cryogenic environments without the need for liquid helium. This makes it ideal for studying Earth's magnetic field and other magnetic phenomena. The system is equipped with a SQUID sensor housed in a cryostat, enabling sensitive magnetic field detection.

**Features:**
- Three orthogonal detection coils
- SQUID detection circuitry
- 10^-9 Am² 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 modulation coils

**System Specifications:**
- **SENSOR:** Three Superconducting Quantum Interference Devices (SQUID) sensors
- **SENSITIVITY:** 10^-9 Am²/sec, annual white noise
- **DYNAMIC RANGE:** 10^-10 (10^-6, higher range)
- **CRITICAL TEMPERATURE:** 4.01 K
- **CRITICAL FIELD:** 120 G
- **HOLD TIME:** Infinite, 2r: days He Cryo Water off

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- Automated Sample Insertion Stage
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**Model SMM-401 nanoSQUID**

**Features:**
- 100 pm spatial resolution
- 1.4 pT/Hz field sensitivity
- Room temperature sample
- 25 ± 1 gap between sensor and sample
- Non-magnetic scanning stage
- Low helium consumption

**Specifications:**
- **DIMENSIONS**
  - 1.41 ± 0.01 mm
- **POWER:**
  - 1.5 kW (1500 VA) at 220 V, 50/60 Hz
- **SHIELDING:**
  - Metal shielding
- **HOLD TIME:**
  - Infinite, 2r: days He Cryo Water off

**Options:**
- Further customization and enhancement for the DRM-300 system is possible through the offered options.

**Vibration isolation system**

- The DRM-300 is designed to be mounted on a vibration isolation stand to minimize environmental noise.

**External Magnetic Shield options**

- The system can be equipped with an external magnetic shield to enhance magnetic field detection capabilities.

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The DRM-300 system is ideal for researchers studying Earth's magnetic field and other magnetic phenomena, providing high sensitivity and precision in measurements.

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**Options:**
- Further customization and enhancement for the DRM-300 system is possible through the offered options.
The Tristan model SMM-601 Magnetic Scanning system is designed to measure magnetic fields with a spatial resolution better than 300
m. It can be used to image diverse objects such as:

- subsurface cracks and flaws
- embedded magnets
- corrosion sites
- hidden or exposed
- impurities in metals and ferromagnetic materials

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

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

## SQUID Magnetic Scanner

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

The SMM-770 can also be configured to detect:

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

## Options and Accessories

The SMM-770 offers a variety of options and accessories to enhance its capabilities:

- **Sample Scanning Range:**
  - Adjustable to accommodate various sample sizes

- **Can Step Size:**
  - Customizable for precise sample scanning

- **Phase Response:**
  - Adjustable for optimal image processing

- **Field Response:**
  - Adjustable for better image quality

- **Field Strengths:**
  - Adjustable to accommodate different sample materials

- **Image Processing:**
  - Customizable for improved image quality

- **Temperature Control:**
  - Adjustable for optimal sample conditions

- **Data Collection:**
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## Conclusion

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Magnetometers for Geophysics

Superconducting magnetometers and gradiometers offer several advantages. The following are some of the most notable:

- **Constant Sensitivity**: From dc to 10 kHz
- **High Magnetic Field Resolution**: 10^-4 T
- **Low Noise Level**: < 1 fT/Hz

Tristan offers several models to meet these requirements. The T857 Tensor Gradiometer, for example, is designed to measure magnetic and electric fields and their gradients for geophysical surveys. It is a valuable tool for:

- **Magnetotellurics**
- **Controlled Source Magnetotellurics**
- **Magnetotellurics Measurements (TEM)**
- **Unexploded Ordnance (UXO)**
- **4 Magnetic Anomaly Detection**
- **Environmental Waste Detection**

**T877 Tensor Gradiometer**

The Tristan model T877 SQUID tensor gradiometer is designed to measure magnetic and electric fields and their gradients for geophysical surveys. It is a valuable tool for:

- **Magnetotellurics**
- **Controlled Source Magnetotellurics**
- **Magnetotellurics Measurements (TEM)**
- **Unexploded Ordnance (UXO)**
- **4 Magnetic Anomaly Detection**
- **Environmental Waste Detection**

**The T877 model**

The T877 model is a high-performance, high-sensitivity superconducting SQUID magnetometer with an advanced design for geophysical exploration and measurement.

**Specifications**

- **Model**: T877
- **Squid Technology**: SQUID magnetometers
- **Field of View**: 360°
- **Sensitivity**: 10^-4 T/Hz
- **Noise Level**: < 1 fT/Hz
- **Frequency Range**: DC to 10 kHz
- **Temperature**: 4.2 K
- **Cryogen**: Liquid helium

**Operation Principle**: The T877 uses a SQUID magnetometer to measure the magnetic field. The SQUID is a superconducting quantum interference device that can detect tiny changes in the magnetic field. The T877 is designed to be compact and portable, making it ideal for field use. It can be used in a variety of environments, including remote locations.

**Applications**

The T877 is ideal for geophysical surveys, including magnetotellurics, controlled source magnetotellurics, and environmental waste detection. It is also useful for exploring new areas, identifying mineral deposits, and assessing the safety of underground facilities.

**Technical Specifications**

- **Model**: T877
- **Sensitivity**: 10^-4 T/Hz
- **Noise Level**: < 1 fT/Hz
- **Frequency Range**: DC to 10 kHz
- **Temperature**: 4.2 K
- **Cryogen**: Liquid helium

**Contact Information**

Tristan Technologies
San Diego, CA 92121
Tel: (619) 226-1290
Fax: (619) 226-1291
E-mail: info@tristantechnologies.com
Website: www.tristantechnologies.com
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.

**BLS Methodology**

BLS (Biomagnetic Liver Susceptometer) elucidates the effects of magneto and superconfinement in biological tissues. It measures iron stores in the liver and spleen non-invasively by destroying magnetism and superconducting behavior. While units and blood tissue are in metal, superconfinement is determined (superconducting femtomagnetic Potatrons) in which a nickel and steel are used to intercept it. The blood fields of the patient are generated by a superconducting magnet and a superconducting SQUID detection system gives an accurate measurement of iron concentration in the liver and spleen for adults and children.

In the BLS method, a weak magnetic field is installed within the body. Different external superconducting fields cannot be used in the MRI scanner. For this reason, we used a 0.5 Tesla superconducting magnet as a SQUID Biomagnetic Detection/Interference Detector. The SQUID 0.5 Tesla ranges across it, thereby up to 1.0000 MHz mandating use of a non-titanium head.

What an organ, such as a human liver, placed in a magnetic field, is notՌեոր, abruptly the applied field. If the organ is normal or abnormal, the local field will be encharged slightly. It is shown in the diagram elsewhere.

**Site Requirements**

- Liquid helium capacity 2.0 L.
- Liquid helium Capacity 2.0 L.
- Liquid nitrogen capacity 1.0 L.
- Liquid nitrogen capacity 1.0 L.
- Non-invasive
- Replaces Surgical Biopsy, for iron Measurements
- Eliminates Diacronies/Th1 and Th2
- Allows Pediatric Measurements
- Direct Measurement Method
- Accurate and Reproducible

**Optics**

For researchers interested in extending measurement capabilities, a Terahertz offers the following optimizers:

- A High Resolution Channel
- A Low Resolution Channel
- A High Resolution Channel
- A Low Resolution Channel

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- A High Resolution Channel
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- A High Resolution Channel
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**Specifications**

- Magnetic Yield 32.0 mT at cut load

**BLS Methodology**

- Measurement Time Under 19 Minutes
- Rapid Results
- Allows Frequent Serial Measurements
- Accurate and Reproducible
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- Eliminates Discomfort and Risk
- Replaces Surgical Biopsy, for Iron Measurements

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**Specifications**

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Clinical Relevance

The standard method for iron measurement on non-invasive has involved a gold, or needle free, that is used to obtain results. It also assumes that the blood is evenly distributed throughout the body. In addition, the needle is inserted below the skin, which can be painful. However, the graph shows that serum ferritin levels alone do not predict iron stores accurately. Instead, the results are typically correlated with liver tissue levels, which are determined by BLS (bone). Measurement of liver tissue T2 (BLS) has long been regarded as a predictor of actual iron stores, but for some patients, it may not be as sensitive.

Measurement Protocol

1. The patient is positioned on the table. The patient is then automatically lowered into the bed until the pattern is aligned with the detector and the detector is filled with water.
2. With the patient in the correct position, the computer immediately analyzes the data and displays the result as soon as the bed is fully lowered. The bed is then raised until the pattern is aligned with the detector.
3. The table is then automatically lowered into the bed until the pattern is aligned with the detector and the detector is filled with water.
4. The patient is then automatically lowered into the bed until the pattern is aligned with the detector and the detector is filled with water.
5. With the patient in the correct position, the computer immediately analyzes the data and displays the result as soon as the bed is fully lowered. The bed is then raised until the pattern is aligned with the detector.

Applications

The standard method for iron measurement on non-invasive has involved a gold, or needle free, that is used to obtain results. It also assumes that the blood is evenly distributed throughout the body. In addition, the needle is inserted below the skin, which can be painful. However, the graph shows that serum ferritin levels alone do not predict iron stores accurately. Instead, the results are typically correlated with liver tissue levels, which are determined by BLS (bone). Measurement of liver tissue T2 (BLS) has long been regarded as a predictor of actual iron stores, but for some patients, it may not be as sensitive.
Tristan offers a variety of fully configured system packages based on the iMAG series or SQUID components. These range from basic single/fleet magnetometer systems to instruments for specific applications. They include systems for biomagnetic, geophysical exploration, nondestructive testing of materials, magnetic microscopy and studies of rock magnetism.

For applications that require applied fields, Tristan can supply superconducting magnets with custom-designed field profiles and shapes. Tristan's SQUIDs are available in both high temperature and low temperature systems. Standard product data sheets and application notes are available to ensure compatibility with your equipment.

**SQUIDS**

- Model LS0310 LTS do SQUID Sensor
- Model HTM-100 LTS Magnetometer
- Model LT-100 LTS Gradiometer
- Model HT-100 MRT-miMAG

**PROBES**

- Model ST Standard Cryogenic Cable
- Model 1M External Feedback Probe
- Model MFP Multi-Focus/Distance Probe

**NII series of drawer inserts for FITS SQUID sensors**

- Model MPS Multi-Purpose System

**CR Y O G E N I C**

**PROBES** for the laboratory

- Tristan's cryogenic probes and cables are the heart of any SQUID based measurement system. They provide a flexible transmission line for long distances in the laboratory. All cables are designed and manufactured to meet the requirements of the specific application.

- In all Tristan probes, construction details are non-magnetic and carefully planned to minimize heat, EMF, and other noise sources. All cables are designed to minimize the effects of noise and interference in the laboratory. Each cable is individually designed to meet the specific needs of your project.

**TRISTRAN LABORATORY SYSTEMS**

Tristan offers a flexible line of SQUID measurement systems. These systems can be combined with either the magnetic or Tristan-supplied cryogenic to give you the most versatile measurement capabilities possible.

**N D E** measurements by your laboratory

**TECHNICAL FEATURES**

- Model SPM: Working Temperature: 0 - 7 K (LSO/SHM sensor only)
- Model AMP: Working Temperature: 0 - 7 K (LSO/SHM sensor only)

**CRYSTAL TECHNOLOGIES**

- Model MPS: Multi-Purpose System: This system is a low impedance ac bridge system for extremely sensitive resistance and inductance measurements. Resolutions of 10-14 ohm and 10-17 henry are readily obtained. The Model MPS also has the combined capabilities of

- Model MEPS: Multi-Purpose System: This system is a very sensitive magnetometer for measuring magnetic fields with resolutions of 10-14 tesla and 10-17 henry. It is suitable for use in a wide range of applications, including geophysical exploration, non-destructive testing, and magnetic microscopy.

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SQUID ELECTRONICS

Thetan iMAG 303 SQUID controller features the benefits of a powerful and flexible measurement system. Its three-channel capability accommodates nearly all of the SQUID applications without requiring the size or complexity of eight-channel design. A unique feature of the Thetan controller is its ability to simultaneously control both LTS and HTS devices. For the experienced user, the Thetan MultiChannel Controller offers manual control of all SQUID parameters, including bias dc offset, modulation amplitude, ‘noise’ level, and flux level in the SQUID (offset), heater and integrator read. All parameters are easily adjusted using the microwave coupled and a convenient menu-driven interface that allows users to build a fully automated system with the built-in touch-screen capability that rapidly and reliably optimize the level of all critical parameters.

High-resolution ND converters and the standard IEEE-488 bus make the IMAG controller ideal for use with commercial data acquisition. Use the main panel connections to monitor the high-level analog outputs. A “Touch” channel input allows you to simultaneously display your own signal along with the three SQUID signals using the controller's internal X-Y converter. Labview software drivers are also available.

FLUX-LOCKED LOOP

iMAG FLLs are offered in both HTS and LTS versions. The LTS version uses an advanced binary thermal technique that effectively reduces low-frequency noise in HTS SQUIDs without introducing spikes visible in the output spectrum. This less-expensive and higher-response SQUID is 10 Hz to 100 KHz.

The Model 301 series DNO lock-loop (DLO) provide superior performance under a wide range of operating conditions. The Thetan design features a W22 as close as practical to the SQUID sensors and eliminates noise by the 1/f noise and high-frequency noise over long periods. High-level current is applied directly to the FLL, allowing the compact FLL unit to be conveniently mounted near the dewar, but not as the liquid output signal transfer line to the MSQ-303 controller is made via a composite cable.

COMPOSITE CABLE

Thetan advanced design provides superior radiated-field (RF) rejection and allows for long cable runs, even in hostile environments. It is a simple matter to locate the FLL inside a shielded room and operate it using an iMAG MultiChannel Controller located outside the room.

The connection between the controller and flux-looped signal is via the CC series composite cables. Low level (60 Hz) power one the high level analog input is transmitted by the liquid nitrogen dewar. All SQUID parameters in cores, plotted by single button push, or alterations made is easily done by remote link.

DEWARS

Tristan’s MAAS SQUID electronics have been designed for the user who wants performance and flexibility, editing/correction-easy hierarchical front-panel menus allow fast setup for both LTS and HTS SQUXD research. Multiple slew rates, gains and bandwidths allow the user to fine tune the measurement process. Individual tuning of each channel can optimize performance in multichannel configurations. When you need the best in SQUID electronics, look for the iMAG series to satisfy your needs.

IN1AS Controller Model N0.3431

Number of Channels: 3 SQUID channels 2nd interface to both LTS and HTS FLUX-LOCKED LOOP (FLL) controller can operate any combination of LTS or HTS SQUXD; and can have noise rejection using the appropriate FLLs. An auxiliary channel is selected for typical data applications. FLLs have been approved for use with HTS and LTS dewars.

Auxiliary 2/0: One auxiliary analog input (100 Hz) (100 Hz) and 500 Hz) is provided for 10-11 gain 4.5 V FS range is selectable to be x1, x2, x5, 100, or 500.

User Interface: Interactive user interface via large LCD display and membrane keypad. Special function keys and menus provide friendly operating and setup environment.

Remote Interfaces: Both 3W, 480 and RS-232 remote control interfaces are standard. All control settings may be input and all instrument data may be output via these interfaces. Total maximum data rate via the AUX and FLL interface is 16 kbps for a single channel, or 5 kbps for all three SQUID channels plus the auxiliary channel.

Sample Output: 4 async outputs (SO4D) provided on the front panel for the 3 SQUID channels and the auxiliary analog input.

Autotuning of all SQUID parameters in cores, plotted by single button push, or alterations made is easily done by remote link.

FLL Reset: Any channel may be reset manually or automatically at any user selectable output voltage.

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INFOMATION

DEWAR DIMENSIONS

Dewar

Dewars

DEWAR

Metallic

Non-Metallic

CONSTRUCTION TECHNIQUES AND MATERIALS

All Thetan dewars are Cryogenics International’s FreezePoint design. The FreezePoint design incorporates cast-iron, low-carbon, high-strength material which eliminates “cold-shots” and makes the dewar structurally rigid. Standard dewars are designed to meet world class standards for environmental and electromagnetic compatibility. Coned dewars are built to meet the requirements of any test environment. All Thetan dewars have been leak tested and are designed to meet the requirements of any test environment.

The use of super-insulation and one or more super-insulating sheets must allow free vapor space. The Thetan dewar with its FreezePoint design and the coned dewars with the FreezePoint design are designed to meet the requirements of any test environment. All Thetan dewars have been leak tested and are designed to meet the requirements of any test environment. All Thetan dewars are designed to meet the requirements of any test environment. All Thetan dewars have been leak tested and are designed to meet the requirements of any test environment. All Thetan dewars are designed to meet the requirements of any test environment. All Thetan dewars have been leak tested and are designed to meet the requirements of any test environment. All Thetan dewars have been leak tested and are designed to meet the requirements of any test environment. All Thetan dewars have been leak tested and are designed to meet the requirements of any test environment. All Thetan dewars have been leak tested and are designed to meet the requirements of any test environment. All Thetan dewars have been leak tested and are designed to meet the requirements of any test environment. All Thetan dewars have been leak tested and are designed to meet the requirements of any test environment. All Thetan dewars have been leak tested and are designed to meet the requirements of any test environment. All Thetan dewars have been leak tested and are designed to meet the requirements of any test environment. All Thetan dewars have been leak tested and are designed to meet the requirements of any test environment. All Thetan dewars have been leak tested and are designed to meet the requirements of any test environment. All Thetan dewar
do SQUID SENSORS

The low-temperature LSTS SQUIDS operate in liquid helium and are fabricated using a niobium/aluminum all-thermometer technology that combines durability with high sensitivity. They feature symmetric integral signal and modulation coils that eliminate output variations with varying input loads. The niobium-aluminum package comes with some terminals ready to accept your custom input circuit. Tristan can also provide the thin-film integrated LTC SQUID magnetometers with state-of-the-art performance. The Tristan Model 1112S is a new design using the Model SP Cryogenic Cables. Cable for ultra-low-noise currents of current measurements of current (e.g. TESAM) and magnetic fields (T Ferris). In conjunction with the Model SP and SQUID-Cryogenic cables, it can measure a much wider range of electromagnetic properties in magnetic fields as high as 1 tesla to 1 TST with a Cryogenic Probe denoted as "... Information."

The high-temperature (11-111) SQUIDSC are used in liquid nitrogen at 77 K and are offered in magnetometer or gradiometer configurations. They feature TSCD pick-up coil patterns on the chip and a tough sacrificial layer for protection from moisture and oxygen. All SMM-1000 sensors use a common connector to attach them to the Model SP Cryogenic Cables. They can be easily interfaced to provide alternative pick-up coils and different sensitivity levels. We can guarantee magnetometer performance better than 10 nT/Hz. For customers who need even lower noise levels and performance in magnetic fields we can provide a 100 kA improvement in sensitivity over other cryogenic sensors.

Besides measuring magnetic fields, the SMM-1000 can also be configured to detect:
- transient magnetic properties
- motions that are too fast for AC coupling

The SMM-1144-1000 US coil is a proprietary intrinsically stable in the array of Superconducting Quantum Interferometers. (SQIs) to map the magnetic field from small samples. The use of liquid helium SQUIDSS provides a 100 fold improvement in sensitivity over other SQUID-based detectors and allows high-resolution mapping of eddy currents and magnetic sources located beneath the chip surface of the sample. The SMM-1144-1000 US coil measures the magnetic field from small samples, allowing high-resolution mapping of eddy currents and magnetic sources located beneath the chip surface of the sample.

The SMM-1000 achieves micro resolution by the use of small 8 µm diameter coil and merge gain feedthrough the coils are the object(s) being carried.

The sample is mated with an ml change gas on the lateral end of a cryogenic probe. This house all or the large proportions of the SMM and, being a small size, is ideal with a range of temperatures. The sample to place on the sample, and the sensor is attached. Then the probe can be lowered to the sample area and armed. A 10 kHz, 100 nanometer magnetic field is selected for measurement. The standard 1112S Version 9.1 is available, or contact the factory for additional options.

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