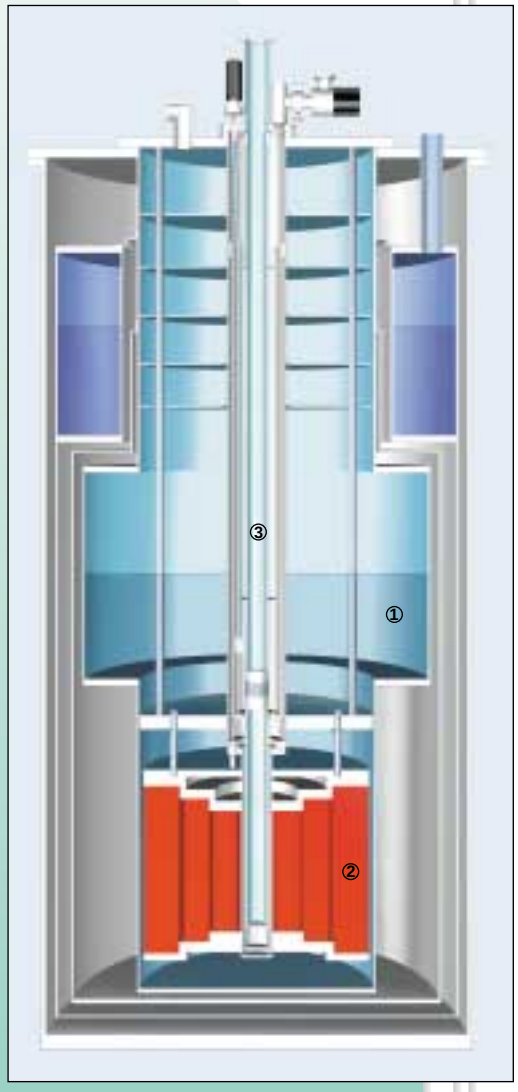
Liquid Helium Cooled Research Systems

- An improved choice of cryogenic and magnet systems offering access to the highest magnetic fields and a wide range of temperatures from 800K to the millikelvin region.
- A modular range of sample inserts, cryostats and magnets built around standard, well-proven designs.
- Improved dual temperature control for samples in the range 1.6-320K giving a more rapid response with millikelvin precision.
- A new ^{3}He insert for temperatures down to 0.3K.
- Dilution Refrigerator Units for ultra-low temperatures.
- Automated operation using computer control of magnetic field and temperature as well as experimental data acquisition.

CRYOGENIC
CRYOGENIC LIMITED

"The Better Choice"

Introduction



19/20 Tesla cryomagnet system with VTI installed.

Research into the properties of materials and experiments in the fundamental sciences often require access to strong magnetic fields and temperatures over the widest range.

Cryogenic has been well known for many years as a leading supplier of advanced superconducting magnets. To compliment its range of powerful magnets Cryogenic has introduced a new range of superior cryostats and variable temperature inserts offering sample temperatures from 700K down to the millikelvin region.

With proven experience over many years in building low temperature equipment and magnet systems, Cryogenic can offer the best solution for every type of research. Our standard magnet systems provide fields from 1 to 20 Tesla and with HTS conductors it is possible to exceed 22 Tesla.

All our magnet systems are designed to be compact and user friendly with cryogenic systems to match. The company also provides fully automated measurement systems with the full function of the cryogenic magnet and experimental measurement electronics under computer control.

Superconducting magnets can nowadays be operated without liquid helium. Our Cryogen Free magnets are widely used and are especially suitable for parts of the world where helium is expensive or not readily available. However, for many applications liquid helium still offers many benefits. It provides very stable conditions with accurately controlled temperatures and freedom from any mechanical vibration. This brochure describes our liquid helium filled research systems.

A typical system is shown in the diagram. It consists of a cryostat containing a pool of liquid helium① to cool the superconducting magnet② and an insert③ which controls the temperature of the sample. The most common insert is a VTI (Variable Temperature Insert) for the range 1.6K to 320K. Other options include room temperature anti-cryostats for work at ambient temperature and small heated ovens or furnaces for higher temperatures.

For lower temperatures Cryogenic supplies ^{3}He inserts covering the range 0.3K to 100K and Dilution Refrigerator Units for the lowest temperatures down to the millikelvin region or lower using nuclear demagnetisation.

In addition to the standard modular range the company produces many more specialised cryomagnets. These include low loss systems where the magnet is permanently welded into the cryostat and a range of optical and beam-line magnets.

Cryostat

Cryogenic supplies both stainless steel and glass fibre aluminium cryostats for use with magnets and inserts for all research applications. They are designed to be robust, reliable and efficient in operation.

Stainless steel is preferred by many customers for its very reliable and easily serviced features. For complex one-off designs with demountable cold flanges, stainless steel fabrication is usually the preferred choice. Glass fibre has the attraction of being non magnetic and electrically insulating. It offers a robust structure with thick walled low thermal conductivity tubes that can withstand internal vacuum. Glass fibre structures are also non resonant and give very good acoustic damping, a feature which is of benefit for mechanically sensitive applications, such as SQUID Magnetometers or Atomic Force Microscopy.

The standard range of cryostats offered have neck diameters in the range 100mm up to 500mm and have either a straight sided bucket shaped helium space or an expanded reservoir volume to give greater helium capacity.

The neck diameter is chosen to be just large enough to allow the magnet and experiment to be installed. To further reduce helium consumption a nitrogen reservoir is offered as an option.

Extra long cryostats and other special low loss cryostats are produced to special order.

All cryostats are fitted with a tail thermometer and a heater mounted at the bottom of the helium space. The thermometer is useful for monitoring transfers of helium and liquid nitrogen during pre-cooling. The heater is used to evaporate the liquid nitrogen used to pre-cool the apparatus.

Three standered cryostats (back) and a low loss ESR cryostat (front).

The Ultra Compact Range of Superconducting Magnets

Cryogenic produces solenoid magnets to the highest magnetic fields available and split pairs for use where access to a transverse field is required. Magnets are made from filamentary superconductor to give reliable performance with low remanent field. Solenoids are produced to standard designs in the range 1 to 20 Tesla with NbTi and NbSn conductors. Fields in excess of 20 Tesla are under development using insert coils made from HTS conductors which at 4.2K remain superconducting to very high fields. Solenoids provide the highest field and superior homogeneity in the most cost effective and efficient manner. Split pair magnets because of their geometry have a higher field on the conductor than at the central sample area and are less suited for very high fields. All magnets may be fitted with superconducting switches to allow the field to be maintained with high stability when the external power source is turned off.

For a fuller description of the Cryogenic superconducting magnets please see our magnet brochure.

18 Tesla 52mm bore magnet, 17.5 Tesla 52mm bore high homogeneity coil for NMR, 40mm 15 Tesla coil and 1 Tesla mini coil (left to right).

^{3}He inserts for temperatures to 0.3K

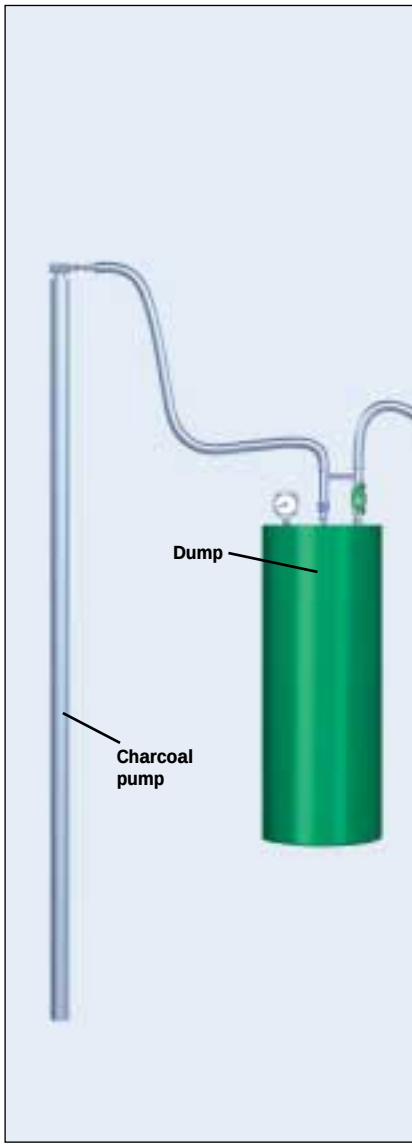
Top loading ^{3}He refrigerator and cryostat.

Cryogenic supplies ^{3}He inserts providing temperatures down to 0.3K to use with superconducting magnet systems.

The ^{3}He inserts can be directly exchanged for the standard Variable Temperature Insert (VTI) as both units are self contained. By this means the same cryo-magnet can be used for experiments over the range 1.6K to 300K with the VTI and 0.3K to 100K with the ^{3}He unit. Using a small dilution unit the temperature can be reduced to a few mK.

The standard ^{3}He insert is supplied with a fixed charge of ^{3}He gas kept in a gas reservoir known as the ^{3}He dump. ^{3}He is a rare isotope and relatively expensive so the insert is designed to recycle and use the same gas over and over again without loss.

A charcoal sorption pump is used to pump the ^{3}He gas to a pressure of 0.01 millibar, sufficient to achieve a base temperature in the liquid of 280 mK. When all the liquid has evaporated from the bath and been absorbed into the charcoal pump, it is necessary to recycle the ^{3}He charge. The charcoal is heated to about 50K releasing the ^{3}He gas which can be



Top loading ^{3}He unit.

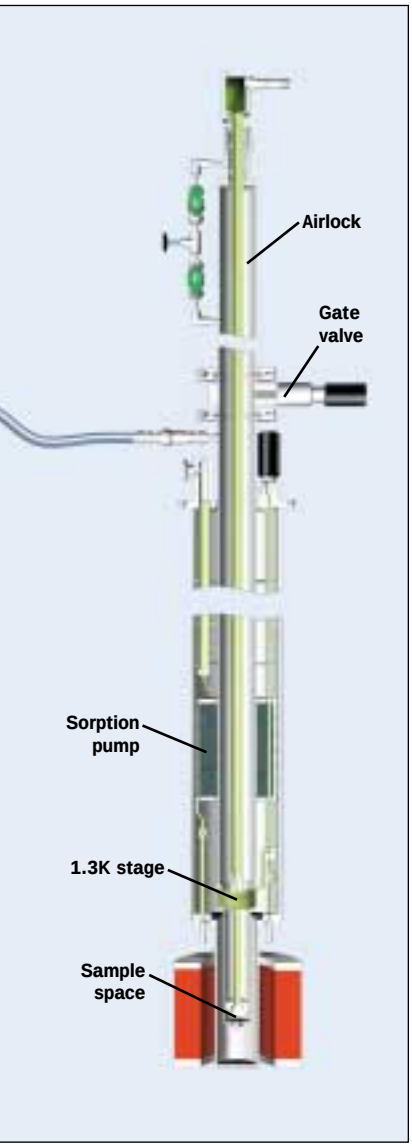
The Variable Temperature Insert

The most commonly used Variable Temperature Insert provides an experimental space with temperatures in the range 1.6K to 320K. The sample space is a thin walled superinsulated tube mounted in an inner vacuum chamber. Samples are mounted on a probe which is loaded through an airlock and gate valve at the top of the insert. This top loading arrangement allows samples to be changed without warming the system or contaminating the VTI with air.

The VTI operates by drawing liquid helium from the main cryostat bath through a filter and a needle valve.

The liquid ^{4}He passes through a heat exchanger into the sample space and is then pumped away by a room temperature vacuum pump. An integral heater and a sensor on the heat exchanger allows the temperature to be set to any value from 1.6 to 320K.

The sample tube is copper plated to give a uniform temperature distribution and a secondary heater is provided to improve the response time.



recondensed at 1.3K. The charcoal is then cooled down again and the experiment can continue. The charge of ^{3}He is sufficient to maintain the lowest temperatures for long periods typically up to 48 hours. Recondensing will take typically 15 to 60 minutes.

The main components of a top loading ^{3}He insert are shown in the diagram. Besides the insert itself there is a separate gas storage dump and a charcoal sorption pump which can be used to extract the last trace of ^{3}He from the insert prior to opening it to atmosphere. At the top of the insert there is a top loading probe, an airlock and a gate valve leading into a central column with the sample space at the bottom. Half way down the column is the charcoal sorption pump and below that the 1.3K stage which is used to condense the ^{3}He into the liquid form. Both the sorption pump and the 1.3K stage are cooled by liquid helium drawn from the main system reservoir.

TWO MAIN TYPES OF HE-3 INSERTS ARE PRODUCED BY CRYOGENIC; In the top loading version the sample is mounted on a long probe which is inserted through the gate valve and an airlock as shown in the diagram. The probe passes right down to the bottom of the insert where the sample sits in a pool of liquid ^{3}He. With this system it is easy to change the sample in the same way as with a conventional VTI.

In the bottom loading version access to the sample space is obtained by lifting the insert out of the cryostat and removing the lower part of the vacuum jacket. Bottom loading inserts are useful because their design is simple, they use very little ^{3}He and they can be built small enough to fit inside small cryostats or storage dewars.

For both systems a thermometer and a heater can be fitted to the sample mount to allow its temperature to be measured and controlled. Temperatures from 0.3K up to 100K can be maintained without excessive heating of the surrounding liquid ^{4}He.

Bottom loading ^{3}He unit.

For the fastest response and the most accurate temperature control of the experiment a two stage control system is used.

The experiment or sample is mounted on a platform surrounded by the gas stream but with its own secondary heater and thermometer. A second control circuit maintains the platform at the exact set temperature. In this way the sample temperature can typically be regulated to 1 mK at 100K and the temperature can be changed rapidly to make a series of measurements at different temperatures.

As an option Cryogenic supplies motor driven needle valves so that the helium flow rate can also be controlled from the computer.

Two types of VTI are produced. Those with radiation shielding between the sample space and the liquid helium outer wall can operate with sample temperatures over the full range 1.6K to 320K. Those without this operate from 1.6K to 150K but do allow a larger sample space inside a given magnet bore.

Specialised Cryomagnet systems

In addition to the range of modular research systems Cryogenic supplies a number of more specialised cryomagnets and cryogenic systems using liquid helium.
There are four main types described below:

8 way optical cryostat (right).

Varitemp cryostat installed in a separate low loss magnet cryostat (far right).

600mm bore 6 Tesla cryomagnet (bottom right).

The Optimag Range

To allow optical, Mossbaüer or beam line experiments in magnetic fields as a function of temperature, Cryogenic supplies a range of Optimagnets with 2, 4 or more optical or other beam-line windows. Magnetic fields ranging from 3 to 10 Tesla are offered as standard. The magnet and the variable temperature sample space are built as a single unit installed into the cryostat but provision is made for ease of disassembly and maintenance such as optical window exchange.

The Varitemp Cryostat

For experiments with an external magnet such as an electromagnet, pulse field magnet, cryogen free magnet or without a magnet at all, Cryogenic produces a small Varitemp cryostat. These cryostats have a helium reservoir of 7 or 15 litres and a built-in VTI which extends into a small tail below the cryostat. Some Varitemp cryostats are provided with optical windows and make a convenient and low cost way of carrying out experiments at low temperatures down to 1.6K.

Ultra Low Temperature Dilution Refrigerator Systems

For research at ultra low temperatures Cryogenic supplies Dilution Refrigerator systems built in collaboration with Leiden Cryogenics, Netherlands.

A complete range is offered from sample inserts that can fit into our standard cryomagnet systems to large high powered machines operating below 5 mK. Magnets for nuclear demagnetisation can be adapted to give experimental access to microkelvin temperatures.
The technology and design of dilution refrigerators has advanced considerably over recent years giving greater reliability and higher performance. Almost all of these systems are built to special order to fulfil customer needs.

Custom Magnet Systems

Cryogenic has many years experience in the design and manufacture of cryomagnet systems. The company is well placed to help customers plan new projects involving magnets and low temperatures. The company designs and builds tailor made systems for many applications. Recent projects have involved magnets for nuclear research, industrial mineral magnetic separation, magnets for MRI and other medical applications. Illustrated is one of the larger horizontal magnet systems, a low loss 6 Tesla 600mm room temperature bore cryomagnet.

SAMPLE MOUNTS

To facilitate measurements a number of specialist top loading probes and sample mounts are provided. These include resistivity, Hall Effect, QHR, van der Pauw and coils for AC susceptibility. Rotating platforms for orientation effects as well as Torque Magnetometers have been produced. High quality wiring to the sample or the measurement system is provided with vacuum tight connections to external circuitry.

DATA ACQUISITION AND SOFTWARE

As part of the Cryogenics' development programme on SQUID Magnetometers and Quantum Hall Resistivity measurement systems for metrology, Cryogenic has developed extensive control software and data acquisition technology.

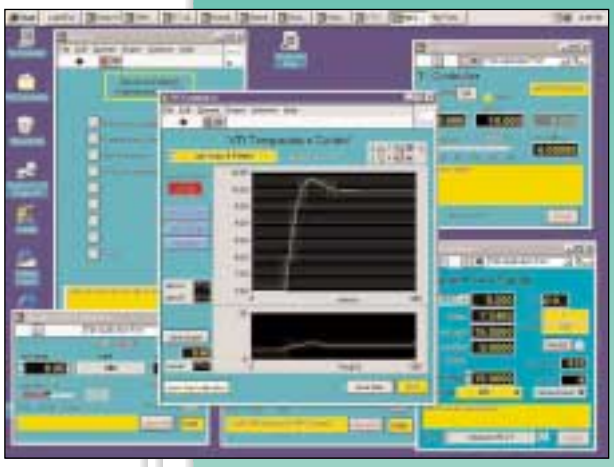
The software has been developed in the National Instruments LabVIEW language, the leading and most flexible programming system. National Instruments digital and analogue cards are used for many applications. They permit fast data acquisition at 16 bit accuracy to over 100kHz. For higher accuracy measurements Cryogenic produces optically isolated 20 bit A/D and D/A converters. They can be used to monitor thermometers or acquire resistivity and other sample data.

Programme development in LabVIEW is through the drawing of new logical structures on the screen rather than writing line by line code. This process is faster and more secure, as well as more user friendly compared to older programming methods. The open software structure allows the researcher to oversee the program and to more clearly control the instruments' operation, reducing the possibility of undetected or systematic errors. All aspects of the experiment can be controlled. The magnet power supply, sample temperature and other instrumentation can be controlled via the IEEE bus. Together with Cryogenics own circuitry a completely automated easy to use measuring system can be provided.

MAGNET POWER SUPPLIES

The SMS series of intelligent magnet power supplies have been developed over many years to meet the needs of magnet operators. They have many unique advantages as well as the standard features expected for driving a superconducting magnet. A smooth linear and precisely controlled ramp of the magnet current and field is provided. A pause function allows the ramp to be interrupted at any time. A SMART current reverse allows the field to be swept linearly through zero. For precise low field measurements a secondary low current source can be provided. The units are fully fail safe and are self protecting in the event of magnet quench or mains power failure. The standard output ranges are from 60 to 300 Amps. All units feature an optically isolated IEEE or RS232 interface. This allows the SMS unit to be linked to read the liquid helium level, provide software control and safe magnet operation.

SMS 120 Amp magnet power supply (left).



VTI temperature control as part of a magnet operating system.

HELIUM LEVEL GAUGE

Standard linear level gauges are provided which use a superconducting wire in a stainless steel tube as the sensing element. The gauge operates in a sample and hold mode to minimise helium consumption.

OVEN AND FURNACES

For experiments above 320K Cryogenic can supply small tubular vacuum insulated furnaces made from stainless steel with a separate heater and temperature controller to heat the sample above ambient temperatures in the cryostat.

A small airlock as illustrated is provided to allow access to the inside of the furnace without admitting air into the furnace sample space. The furnace is normally top loaded into the cryomagnet VTI.

S600X SQUID magnetometer with furnace installed.

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