# Triton$^{200}$ Cryofree® Dilution Refrigerator

*Operator's Handbook*

Issue V2.0

*The Business of Science*®

OXFORD INSTRUMENTS

# System test data

| | |
|---|---|
| Supplied to: | Enrique Diez<br>Universidad de Salmanca,<br>Espana |
| Project Number: | 39954<br><br>Please Quote this number whenever you contact the factory. |

## Guaranteed System Specifications

| | | | |
|---|---|---|---|
| Base Temperature (no customer wiring) | < | 10 | mK |
| Cooling power at 20mk | > | 3 | μW |
| Cooling power at 100mk | > | 200 | μW |
| Cooling Power at 120 mK (no customer wiring) | > | 300 | μW |

Base temperature shall be confirmed using nuclear orientation thermometry. In general we use a $^{60}$Co<u>Co</u> nuclear orientation thermometer below 50 mK and resistance thermometers above 50 mK.

As the performance of resistance thermometry at ultra low temperatures is influenced strongly by the experimental environment, and RF pickup in particular, we are unable to guarantee the performance of any resistance thermometer at temperatures below 50 mK.

## *Cooling Power Tests*

### 300 μW cooling power

Here the other system parameters were:

| | | |
|---|---|---|
| Mixing Chamber temperature | 119.9 | mk |
| Electrical power applied to still | 22 | mW |
| 100mK plate temperature | 188 | mK |
| Still temperature | 0.69 | K |
| Condenser pressure | 0.69 | bar |
| Flow | 695 | sccm |

### 200 μW cooling power

Here the other system parameters were:

| | | |
|---|---|---|
| Mixing Chamber temperature | 84.5 | mk |
| Electrical power applied to still | 22 | mW |
| 100mK plate temperature | 153 | mK |
| Still temperature | 0.7 | K |
| Condenser pressure | 0.66 | bar |
| Flow | 685 | sccm |

### 3 μW cooling power

Here the other system parameters were:

| | | |
|---|---|---|
| Mixing Chamber temperature | 17.2 | mk |
| Electrical power applied to still | 5 | mW |
| 100mK plate temperature | 100.4 | mK |
| Still temperature | 0.68 | K |
| Condenser pressure | 0.51 | bar |
| Flow | 423 | sccm |

## *System Mixture*

The total quantity of mixture used in the system is: 75 Ltrs.

This comprises:

| | | |
|---|---|---|
| 15 | Ltrs | $^3He$ |
| 60 | Ltrs | $^4He$ |

The dump volume is approximately 100 Ltrs.

## *Cooldown Time*

Time taken for the system to cool from room temperature to below 10 K (when condensing of the mixture can commence) and from 10 K to below 100 mK:

| | | | |
|---|---|---|---|
| 300 K to < 10 K | < | 18.25 | hours |
| 10 K to < 100 mK | < | 3.5 | hours |

## *Pulse Tube Temperatures*

Temperatures of the first (PT1) and second (PT2) stage of the pulse tube cooler when:

| | | | |
|---|---|---|---|
| System is at base temperature: | PT1 | 50 / 59 | K |
| | PT2 | 2.6 / 2.7 | K |
| System running at maximum 100 mK cooling power: | PT1 | 50 / 60 | K |
| | PT2 | 2.6 / 2.8 | K |

## *Temperature Control*

The table below summarises the results of the temperature control tests using the Lakeshore bridge:

| Settings | Gains | | | Results | |
|---|---|---|---|---|---|
| Set Point [K] | P | I | D | Temperature [mK] | Stability [mK] |
| 0.065 | 5 | 300 | 0 | 64.5 | +/-0.3 |
| 0.150 | 5 | 300 | 0 | 149.7 | +/-0.3 |
| 0.5 | 5 | 300 | 0 | 497 | +/-4 mk |
| 30 | 5 | 300 | 30 | 30K | +/-0.1K |

# Test Results

## *Throughput Tests*

The rate of pressure rise in the still line with valve shut at the back of the turbo pump

| | | |
|---|---|---|
| 300 K | 2.9 | mbar / min |
| < 10 K | 40 | mbar / min |

## *Still Temperature and Flow*

The measured Still temperature and $^3He$ circulation rate as a function of the electrical power applied to the Still heater with the system near base temperature.

| Still Power [mW] | Still Temperature [K] | Condenser Pressure [bar] | Flow [SCCM] |
|---|---|---|---|
| 2 | 0.64 | 0.42 | 310 |
| 3 | 0.65 | 0.44 | 345 |
| 4 | 0.67 | 0.47 | 385 |

## *Base Temperature and Temperature Stability*

System run at base temperature for at least eight hours with no electrical power applied to the mixing chamber. The base temperature measured was:

| | | |
|---|---|---|
| Base Temperature | 8.55 | mK |

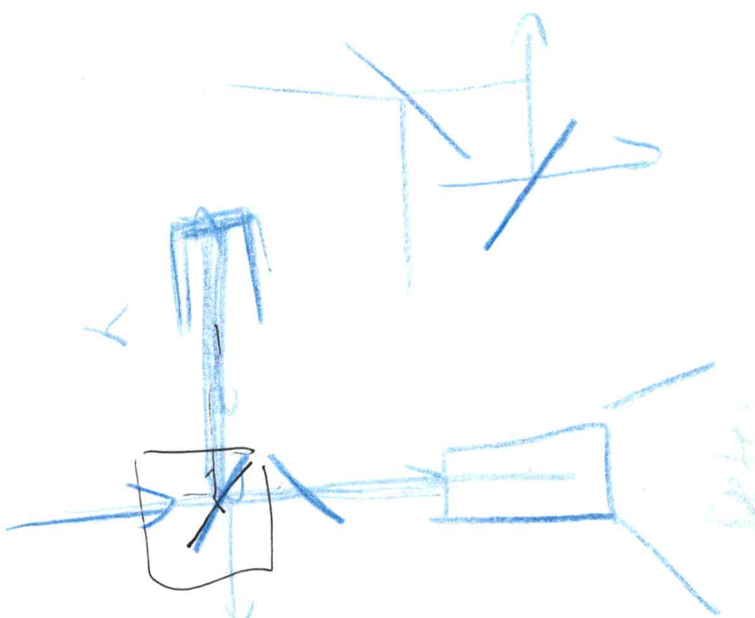
Here the other system parameters were:

| | | |
|---|---|---|
| Electrical power applied to still | 3 | mW |
| 100mK plate temperature | 97 | mK |
| Still temperature | 0.65 | K |
| Condenser pressure | 0.45 | bar |

Details of system temperature control will be given in a later section.

# Triton High-Temperature Operation

## Manual Addendum





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# Preparation for running at high-temperatures

The Triton range of cryogen-free dilution refrigerators are capable of running at elevated temperatures whilst in continuous operation.

Control at lower temperatures ($T < 2$ K) can be accomplished by simply choosing the appropriate control set-point and heater range in the Triton System Control software.

Prior to attempting control at higher temperatures ($T > 2$ K) the following steps should be taken:

1. Switch off the turbo pump
2. Switch off the still heater
3. Ensure V9 is closed
4. Ensure V4 is open
5. If necessary, ensure the heater control channel is set to the correct sensor.

This procedure lower the 3He circulation rate in the system and will buffer the condenser line with the volume of the mixture tank ensuring that the condenser pressure can never rise above ~ 0.75 bar.

The required temperature set-point and heater range can then be selected in the Triton System Control software.

# Returning to normal mixture circulation after high-temperature operation

The most efficient method of returning to normal operation after control at higher temperatures will depend on exactly how high the mixing chamber temperature was raised during the high-temperature operation. After running your system you will gain experience of exactly which procedure is the optimum in your experimental set-up.

However, these approximate guidelines will always operate correctly.

**Recovering from temperature control at T < 10 K**

- Select the "Start the condensing" automation from the "Refrigerator" menu of the Triton Software Control front panel.

The system will then automatically run back to base temperature.

**Recovering from temperature control at T > 10 K**

In this case it is probably more efficient to use the pre-cool loop to cool the mixing chamber back to ~ 10 K:

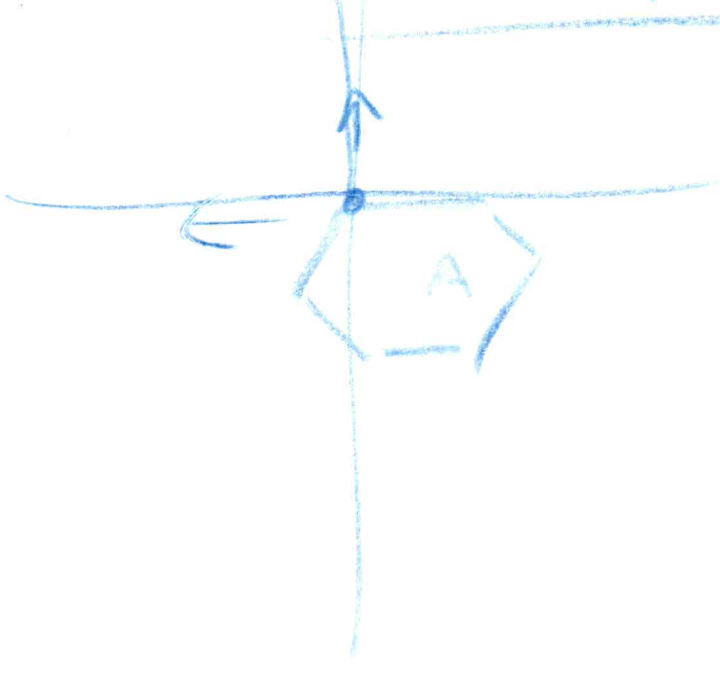
- Select the "Collect the mixture" automation from the "Refrigerator" menu of the Triton Software Control front panel.
- When this automation has completed, select the "Full cool down" automation from the "Refrigerator" menu of the Triton Software Control front panel.

The system will then automatically run back to base temperature.

Trilayer

ABC

Graphene

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| 30 | 5 | 300 | 30 | 30K | +/-0.1K |

Still | Mixing

0 - 100 mK heater at 3,16 mA range

0 - 400 mK " " 10 mA "

30

Operator's Handbook

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Issue 2.2

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## Technical and Customer Support

Contact details for Technical and Customer Support can be found on page 111.

**Oxford Instruments NanoScience**
Tubney Woods, Abingdon, Oxon, OX13 5QX, England
Tel: +44 (0)1865 393 200
Fax: +44 (0)1865 393 333
E-mail: nanoscience@oxinst.co.uk
www.oxford-instruments.com

## Contents

# *Welcome*

Thank you for choosing your equipment from Oxford Instruments, a company dedicated to providing world-class products and customer support. Our highly trained teams are available to help you with all your queries relating to your order, delivery or technical issues.

As an Oxford Instruments customer, you have access to a worldwide service and support package providing telephone and on-site technical and repair services. In the unlikely event that your product should require repair, our technicians will initiate service under the terms of your Oxford Instruments warranty.

At Oxford Instruments we know that your expectations are at the highest level. We aim to meet and exceed those expectations in the service that we provide, and in the quality you will see when you use Oxford Instruments equipment.

We are delighted you selected Oxford Instruments as your supplier and wish you success with your new equipment.

**Jim Hutchins, Managing Director, Oxford Instruments NanoScience**

# 1. Introduction

## Scope of this Manual

This manual contains user and technical information for the Triton200 Dilution Refrigerator. It also contains reference information and includes details of key contacts at Oxford Instruments who are available for help on repair matters and service. Please keep all the manuals supplied with your system and make sure that you incorporate any amendments that might be sent to you. If you sell or give away the product to someone else, please give them the manuals too.

## Abbreviations and terms

| | |
|---|---|
| DR | Dilution Refrigerator |
| GHS | Gas Handling System |
| DC | Direct Current |
| IEC | International Electrotechnical Commission |
| IP | Internet Protocol |
| M/C | Mixing Chamber |
| OI | Oxford Instruments |
| OS | PC operating system |
| OVC | Outer Vacuum Chamber |
| PC | Personal Computer |
| PID | Proportional, Integral and Derivative |
| PT(R) | Pulse Tube (Refrigerator) |

## Documents supplied with the system

The following documents are supplied with the Triton$^{200}$ system depending on options ordered (either hard copy or electronic on PC or CD):

- Triton$^{200}$ operator's manual (this document)
- Safety Matters
- Practical Cryogenics
- Pulse tube refrigerator and compressor manuals; either VeriTube with Leybold compressor or Cryomech or Sumitomo
- LakeShore 370 Resistance Bridge manual
- Multiple pressure transducer manual
- Turbo pump manual
- Fore pump manual
- Toshiba motor drive controller manual (for VeriTube 0.5 Watt systems only)
- Thermometer calibration data
- System cryogenic performance datasheet.

If the system is supplied with a superconducting magnet the following are also provided:

- Magnet power supply manual
- Magnet performance and characteristics datasheet.

# Disposal and recycling instructions

Before disposing of this equipment, it is important to check with the appropriate local organisations to obtain advice on local rules and regulations about disposal and recycling.

You **must** contact Oxford Instruments Nanoscience Customer Support (giving full product details) before any disposal begins.

# 2. Safety Issues

**Safety procedures are vital to prevent**

- **Serious injury or death**
- **Serious damage to the equipment.**

**Before you attempt to install or operate this Triton$^{200}$ system, please make sure that you are aware of all safety precautions listed in this document together with the warnings and cautions set out in other documents supplied with the system.**

**All cryogenic systems are potentially hazardous and you must take precautions to ensure your own safety.**

The general safety precautions required when working with cryogenic systems and superconducting magnets are given in the **Safety Matters** booklet.

Note that Chapter 3 of Safety Matters (Operating Cryogenic Systems) is mostly concerned with the handling of liquid cryogens. In this system, the use of potentially hazardous liquid cryogens is restricted to the nitrogen cold trap and optional liquid nitrogen pre-cool.

***Special precautions against asphyxiation are required when using the pre-cool line, as described in chapter 3 of Safety Matters.***

***Des précautions spéciales sont nécessaires contre l'asphyxie lors de l'utilisation du pré-cool ligne tels que décrits dans le chapitre 3 de la sécurité.***

The Triton$^{200}$ consists of a pulse tube refrigerator (PTR) and compressor with a dilution refrigerator and cryostat. The separate **PTR and compressor manuals** contain essential information and detailed recommendations about precautions that you should take relating to these units.

Safety information that applies specifically to the DR, GHS, control electronics and cryostat are provided in **this manual**.

If the Triton$^{200}$ system has been supplied with a superconducting magnet system, you should read the additional safety precautions supplied in **this manual**.

All gas pumping circuits for the Triton$^{200}$ are sealed, recirculation systems. Consequently, no gases are released into the environment.

## Safety symbols used in this manual

Symbols are used in this manual to draw your attention to safety procedures that you must follow to protect yourself or the equipment. There are two types of hazard symbol used in this manual:

***Warning: The warning triangle highlights dangers which may cause injury or, in extreme circumstances, death. Warnings and cautions must be followed to ensure your own safety.***

***La triangle d'avertissement accentue les dangers qui peuvent causer des dommages ou, dans des circonstances extrêmes, la mort. Les avertissements et les messages de prudence doivent être suivis pour assurer votre propre sûreté.***

***Caution: The general caution symbol highlights actions that you must take to prevent damage to the equipment. The action is explained in the text.***

***Attention : Le symbole général d'attention accentue les mesures que vous devez prendre pour empêcher des dommages à l'équipement. L'action est expliquée dans le texte.***

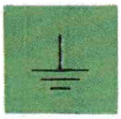
Additional safety symbols include:

***This symbol indicates that protective goggles or (for cryogenic use) a face mask should be worn.***

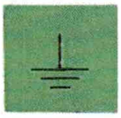
***Ce symbole indique que des lunettes de sécurité (pour l'usage cryogénique) ou un masque de protecteur devraient être portés.***

***This is the symbol for protective earth (also known as rack ground).***

***Symbole de la terre protectrice.***



***This is the symbol for functional earth (also known as measurement ground).***



***Symbole de la terre fonctionnelle (également connue sous le nom de mesure rectifiée).***

## Disclaimer

Oxford Instruments cannot accept responsibility for damage to the system caused by failure to observe the correct procedures laid down in this manual and the other manuals supplied with the system. The warranty may be affected if the system is misused, or the recommendations in the manuals are not followed.

## Warnings

Warnings and cautions must be followed to ensure your own safety.

***It is your responsibility to ensure your own safety and the safety of the people working around you (use hazard warning signs to make sure that anyone approaching the system is aware of the potential hazards). You must read all manuals supplied with the system and follow the recommendations contained in the manuals. This includes the manuals for parts of the system not manufactured by Oxford Instruments – this is important as not all warnings and operational instructions relevant to these parts are duplicated in this manual.***

***Il est de votre responsabilité d'assurer votre propre sûreté et la sûreté des personnes travaillant autour de vous (utilisez des panneaux d'avertissement de risque d'utilisation afin de s'assurer que les personnes qui s'approchent du système se rendent compte des risques). Vous devez lire tous les manuels fournis avec le système et suivre les recommandations contenues dans les manuels. Ceci inclut les manuels pour les composants du système non construits par Oxford Instruments - c'est important car tous les avertissements et instructions opérationnelles concernant ces pièces ne sont reproduits dans ce manuel.***

***All users of the Triton$^{200}$ must read the manuals supplied with the system including the Oxford Instruments booklet Safety Matters.***

***Tous les utilisateurs du Triton$^{200}$ doivent lire les manuels fournis avec le système incluant le livret " Safety Matters" d'Oxford Instruments.***

***If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.***

***Si l'équipement est utilisé d'une manière non recommandée par le fabriquant, la protection fournie avec l'équipement peut malfonctionner.***

***The Triton$^{200}$ system contains high pressure helium gas. The equipment should be handled with great care to avoid mechanical damage to any of the component parts.***

***Le système Triton$^{200}$ contient du gaz à haute pression d'hélium. L'équipement doit être manipulé avec grand soin pour éviter les dommages mécaniques des composants.***

***Do not tamper with any of the pressure relief devices fitted to the system or attempt to modify or remove them. Also ensure that the outlets of the relief devices are not obstructed. The correct operation of these relief valves is critical to the safety of the system.***

***Ne dérégler pas les dispositifs de décompression adaptés au système ou n'essayez pas de les modifier ou enlever. Assurez-vous également que les sorties des dispositifs de décompression ne sont pas obstruées. Le fonctionnement correct de ces soupapes de sécurité est critique à la sûreté du système.***

***The Triton$^{200}$ system must be kept vertical at all times.***

***Le système Triton$^{200}$ doit être maintenu vertical à tout moment.***

## Pressure relief valves

All closed vessels in the system are protected by pressure relief valves

## Safety and Superconducting Magnets

This cryogenic system may include a superconducting magnet operating at a very high field. This section describes additional hazards that must be taken into account. There are several references to Safety Matters, where further information will be found.
Extensive studies continue into the direct effects of magnetic fields on health (especially in relation to clinical MRI, where patients are necessarily exposed to very high fields for diagnostic imaging – see www.MRIsafety.com). The current recommendations are summarised in sections 4.4 and 4.5 of Safety Matters.
Far more hazardous are the indirect effects on stray ferromagnetic objects (including everyday items such as hand tools, keys and coins) and instrumentation and the results of a magnet quench.

***Consider the following hazards (at least):***

***Considérez les risques suivants (au moins) :***

- Magnetic items may move suddenly and uncontrollably towards a magnet. Most tools are magnetic.
- Someone could be trapped between a large magnetic item (such as a gas cylinder) and a cryostat, resulting in severe injury or death
- Medical electronic implants (such as pacemakers) may be affected by a magnetic field
- The magnetic field is three dimensional so the field may affect rooms on the floors above and below your laboratory, as well as on the same floor. Use the stray field map supplied with your system and determine whether steel reinforcement in floors and walls could be magnetised.
- Magnets may suddenly quench and release their stored energy as heat into the magnet support structure.
- Magnetic data on credit cards, disks and other magnetic storage media may be corrupted.

Every magnet site should be reviewed individually to determine precautions to be taken against these hazards and it is strongly recommended that a formal site survey be carried out; contact Oxford Instruments Nanoscience.


**Before you start to energise a magnet:**

- Ensure that all loose ferromagnetic objects are secured or moved to a safe distance. These will normally be safe outside the 5 gauss field contour (see your stray field map).
- Connect one ground wire between the earth points on the cryostat and the power supply and a second wire between the same cryostat earth and a laboratory earth point; refer to your installation manual for details. Note additional information in section 5.4 of Safety Matters.
- Check that there is an insulating rubber cover fitted over the current lead terminals.
- Display warning signs (preferably illuminated) at all the laboratory doors, to remind people that the magnet is operating.
- Display warning signs giving notice of the possible presence of magnetic fields and of the potential hazards in all areas where the field may exceed 5 gauss.
- Ensure that all electronics and interfacing equipment are removed to areas where the field level is sufficiently low; some guidelines are provided in Table 1 but you may need to refer to individual instruction manuals.
- Assess the safe working field level of all other equipment and take appropriate action.

**While the magnet is at field**

While the magnet is at field make the following checks regularly:

- Check that the warning signs are still in place: restrict access to unauthorised personnel.
- Do not bring magnetic objects close to the magnet. They should normally remain outside the 5 gauss limit. **Never attempt to check for the presence of a magnetic field with a ferromagnetic object such as a standard tool. You are risking serious injury or damage to equipment or personnel (see Figure 14 of Safety Matters.**
- Only use non-magnetic storage/transport dewars and non-magnetic trolleys for liquid helium and liquid nitrogen. This system does not require the use of liquid helium; liquid nitrogen is required for the cold traps and may be used for pre-cooling.
- Use non-magnetic tools to work on a system if the magnet is energised.
- Remember that even non-magnetic electrically conductive materials may experience a force or resistance to motion due to field induced eddy currents

- Give a verbal warning to people entering the room; remember that keys and coins are often magnetic.

### Effects on personnel and instrumentation

Other equipment may be directly affected by the presence of large magnetic fields. The field may cause permanent damage or it may only have a temporary effect until the field is removed. Use a stray field map of your system and Table 1to provide guidance.

***Personnel must be restricted so as to prevent access to areas with fields greater than 5 gauss; warning signs should be erected.***

***L'acces au personnel doit être restreint afin d'empêcher l'accès dans les secteurs avec des champs de plus de 5 gauss ; metre des panneaux d'avertissement dans ces secteurs.***

| Safe working field | Equipment or restriction |
|---|---|
| 1 gauss | Image intensifiers<br>Electron microscopes<br>Accurate measuring scales<br>Graphics terminals<br>Nuclear cameras |
| 5 gauss | Pacemakers<br>Public access without warning signs<br>Cathode ray tubes |
| 10 gauss | Computers<br>Watches and clocks<br>Credit cards |
| 20 gauss | Magnetic storage media |
| 50 gauss | Magnet power supply |

**Table 1 Guidelines for safe location of some sensitive equipment.**

### Medical implants

The operation of medical electronic implants, such as cardiac pacemakers, may be affected by static or changing magnetic fields.

***Erect suitable notices to warn visitors and make sure that none of your staff is vulnerable.***

***Redigez des notices appropriées afin d'avertir les visiteurs et de s'assurer qu'aucun membre de votre personnel est vulnérable.***

Pacemakers do not all respond in the same way or at the same field level. You may not know that one of your visitors has a pacemaker so it is important to erect suitable signs to warn them of the danger. The stray fields caused by your magnet in other surrounding rooms may be enough to affect them.

Other medical implants, such as aneurysm clips, surgical clips or prostheses, may contain ferromagnetic materials. Therefore they may experience strong forces near the magnet which could result in injury or death.

### Superconducting magnet quenches

***In the event of a magnet quench (either spontaneous or induced) the magnetic field will rapidly fall to zero. This may affect objects present in the room.***

***En cas de quench de l'aimant (spontané ou induit) le champ magnétique tombera rapidement à zéro. Ceci peut affecter les objets présents dans la piéce.***

There is always the risk of a quench, even in a very reliable and stable magnet. External factors can affect the stability of the magnet so you should always be prepared. There are two effects that must be considered; the collapse of the field and the possible generation of high voltages. Magnets cooled by liquid helium and nitrogen will experience a sudden release of cryogens as gas; **this does not apply to cryofree systems**.

If you are using an Oxford Instruments Nanoscience power supply for your magnet the output current will automatically be switched off safely.

Actions that should be taken following a quench are described in Section 5.

# 3. Description

## System Overview

**Figure 1 Components supplied as the Triton^200 dilution fridge.**
**(Exact components, configuration and colouring may vary depending on options)**

Figure 1 shows a complete Triton$^{200}$ system. The main components are as follows:

- Cryostat (cooling unit and superconducting magnet, if applicable)
- Control cabinet
- Compressor for PTR
- Compressor for $^{3}He/^{4}He$ gas mixture
- Ancillary pumps.

This chapter will briefly describe how the system works before identifying important components and how they function together.

### The Pulse Tube Refrigerator

The cooling engine of the Triton$^{200}$ cryogenic refrigeration system is based on a closed-loop helium expansion cycle. The PTR consists of three major components:

- the compressor package, which compresses refrigerant and removes heat from the system

- the rotary valve, which periodically switches the cold head helium connection between the high-pressure and the low-pressure level of the compressor
- the cold head itself, which takes refrigerant through one or more additional expansion cycles to cool it down to cryogenic temperatures.

The refrigerant gas used in the cooling systems is 99.999% pure helium. Flexible stainless steel lines (flex lines) carry compressed helium from the compressor via the rotary valve to the cold head and carry low-pressure helium back.

The compressor package works as follows. The compressor compresses the pure low-pressure helium that is returned from the cold head. The heat of compression is removed via a heat exchanger, and the oil from the compression process is removed in a series of oil separators and absorbers. The compressed helium is then fed to the cold head via the high-pressure helium flex line and the rotary valve.

In the cold head, adiabatic expansion of the helium and further heat removal allows cooling to cryogenic temperatures. The low-pressure helium then returns to the compressor package via the rotary valve and the low-pressure helium flex line.

### The $^3He/^4He$ mixture Condensing Circuit

Condensing the helium gas mixture into liquid requires sufficiently high pressures and sufficiently low temperatures.
In a traditional dilution refrigerator the pre-cooling of the helium gas is accomplished by a separate pumped $^4He$ stage. This is unavailable on a "cryo-free" system. Instead, the returning helium is first pre-cooled on the first and second stages of the PTR (see Figure 5) before undergoing isenthalpic expansion through a Joule-Thomson (J-T) impedance. This expansion results in cooling provided the gas entering the J-T stage has been sufficiently well pre-cooled. The returning helium then undergoes heat exchange with the still where any remaining gas is liquefied before entering the rest of the Dilution Unit.

### Dilution Unit

Below the J-T stage, the dilution unit is standard, consisting of

- heat exchangers (continuous and step), to pre-cool the incoming mixture
- a mixing chamber where cooling is obtained from the enthalpy of mixing of the two stable isotopes of helium
- a still where $^3He$ is preferentially evaporated to be circulated by the pumping system.

### Cryostat

The cryostat is an evacuated enclosure that protects (thermally and mechanically) the cold parts of the system (the refrigerator). An overall view is shown in Figure 2 and the main items identified.

The cryostat top plate is the boundary between the room temperature parts of the system (above the top plate) and the cold parts of the system (below the top plate). The cryostat must be supported from an adaptor plate in a rigid frame, usually constructed by the user to suit the laboratory. This frame isolates the cryostat from vibrations transmitted through the floor and allows essential working access below.

The rotary valve may be mounted separately on the support frame, close to the cold head.

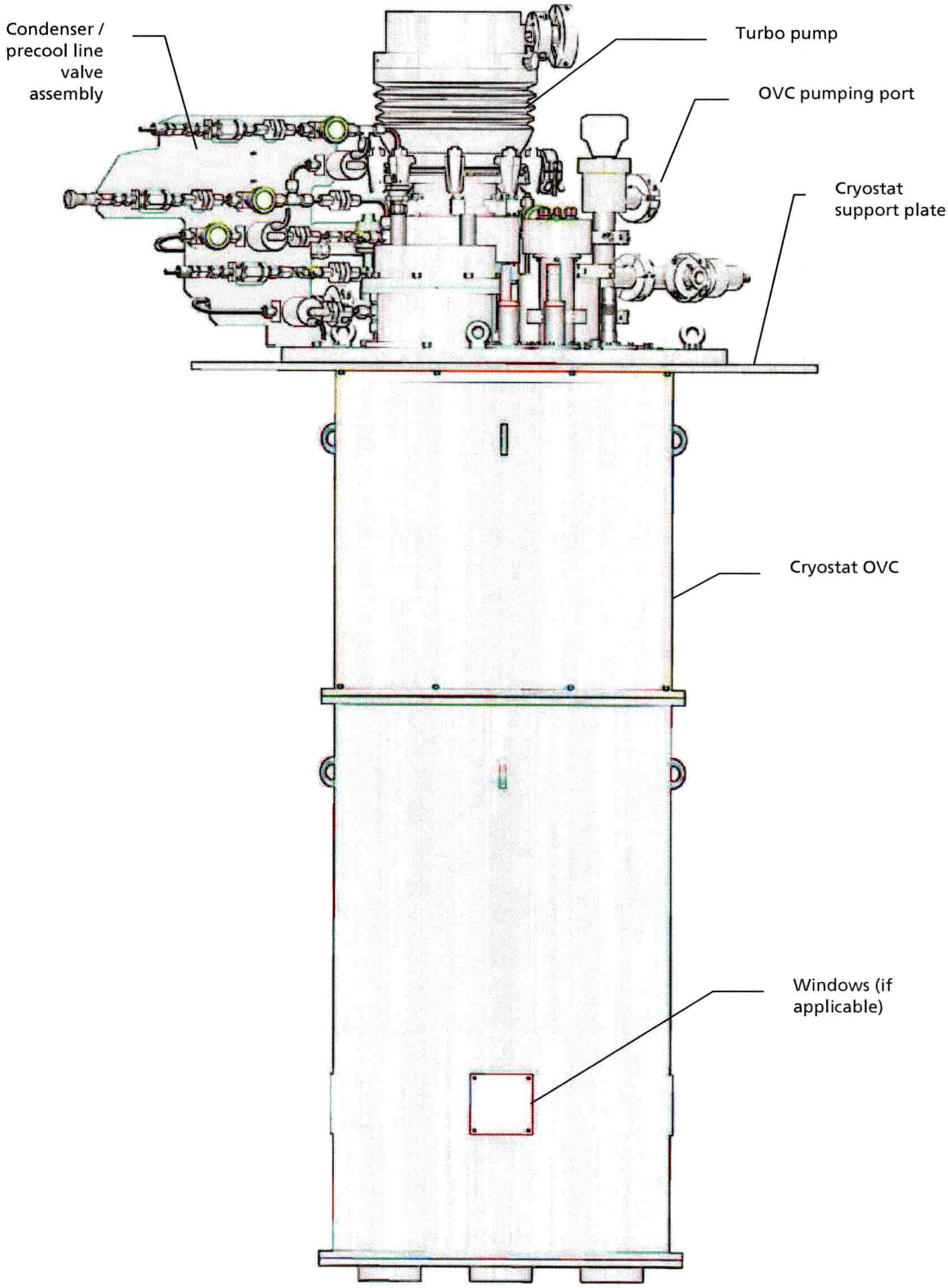



**Figure 2 Overview of cryostat (details may vary)**

The cryostat top plate provides access at room temperature to all system services (thermometry, pumping lines, superconducting magnet etc.) as well as those for the experimental sample (electrical, co-axial, optical). A typical top plate is shown in Figure 3.

| |
|---|
| Details of the cryostat top plate depend on system options. Please refer to the drawing supplied with your system. |

The cold head and turbo pump are also mounted on the cryostat top plate.

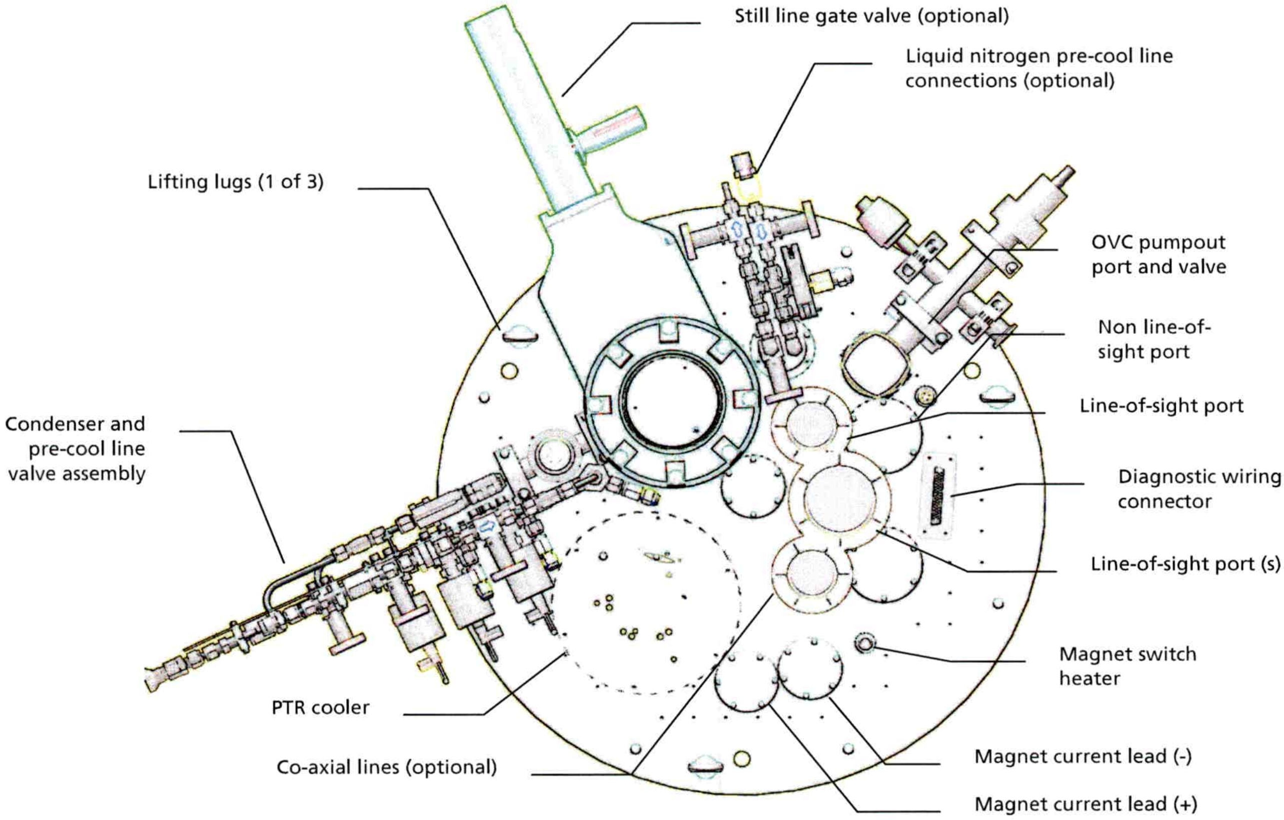



**Figure 3 Typical cryostat top plate**

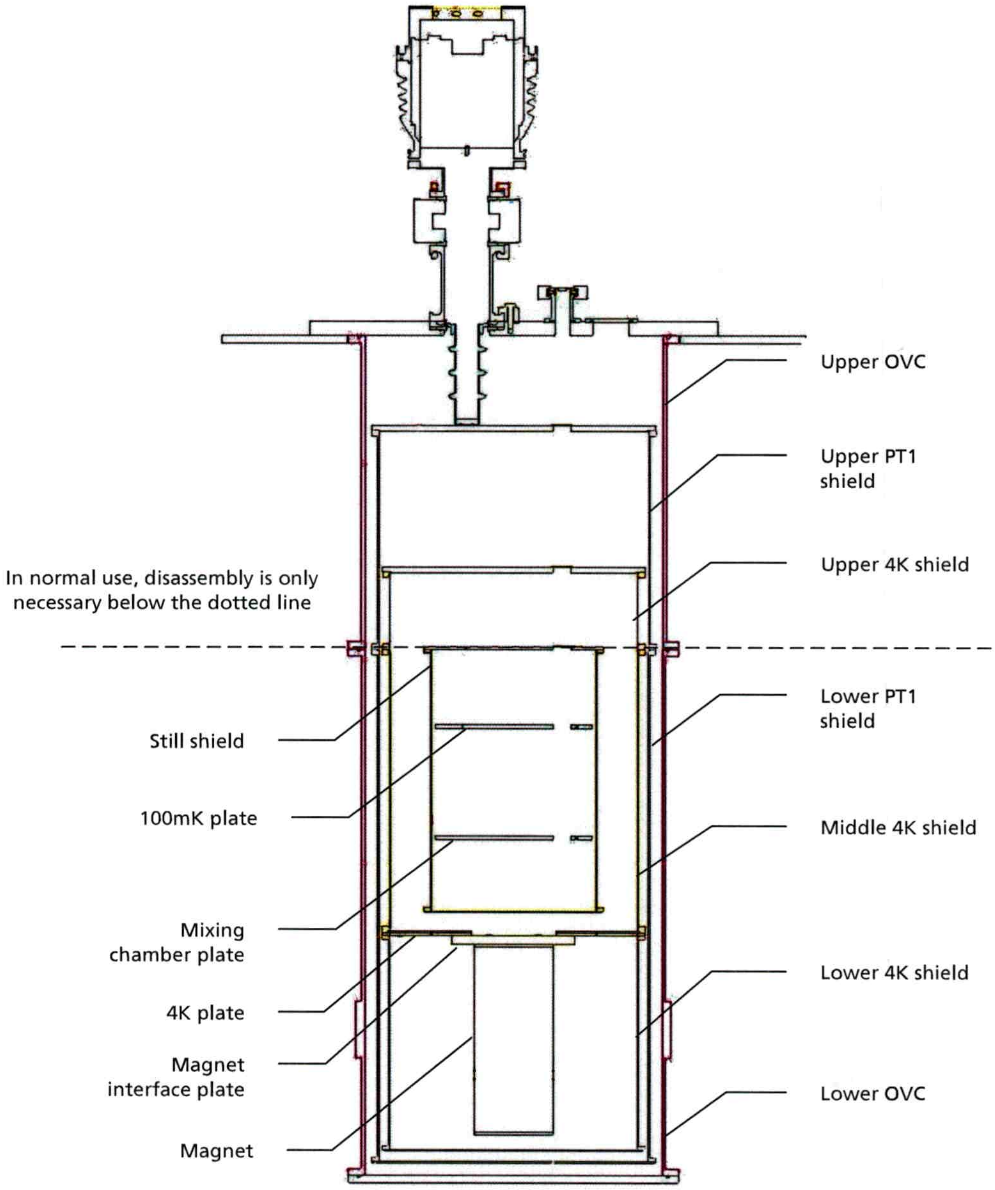



**Figure 4 Section through a Triton[200] system with magnet fitted (still shield bore tube not shown)**

Figure 4 shows the main components inside the cryostat and Figure 5 is a photograph after all shields and superconducting magnet have been removed.

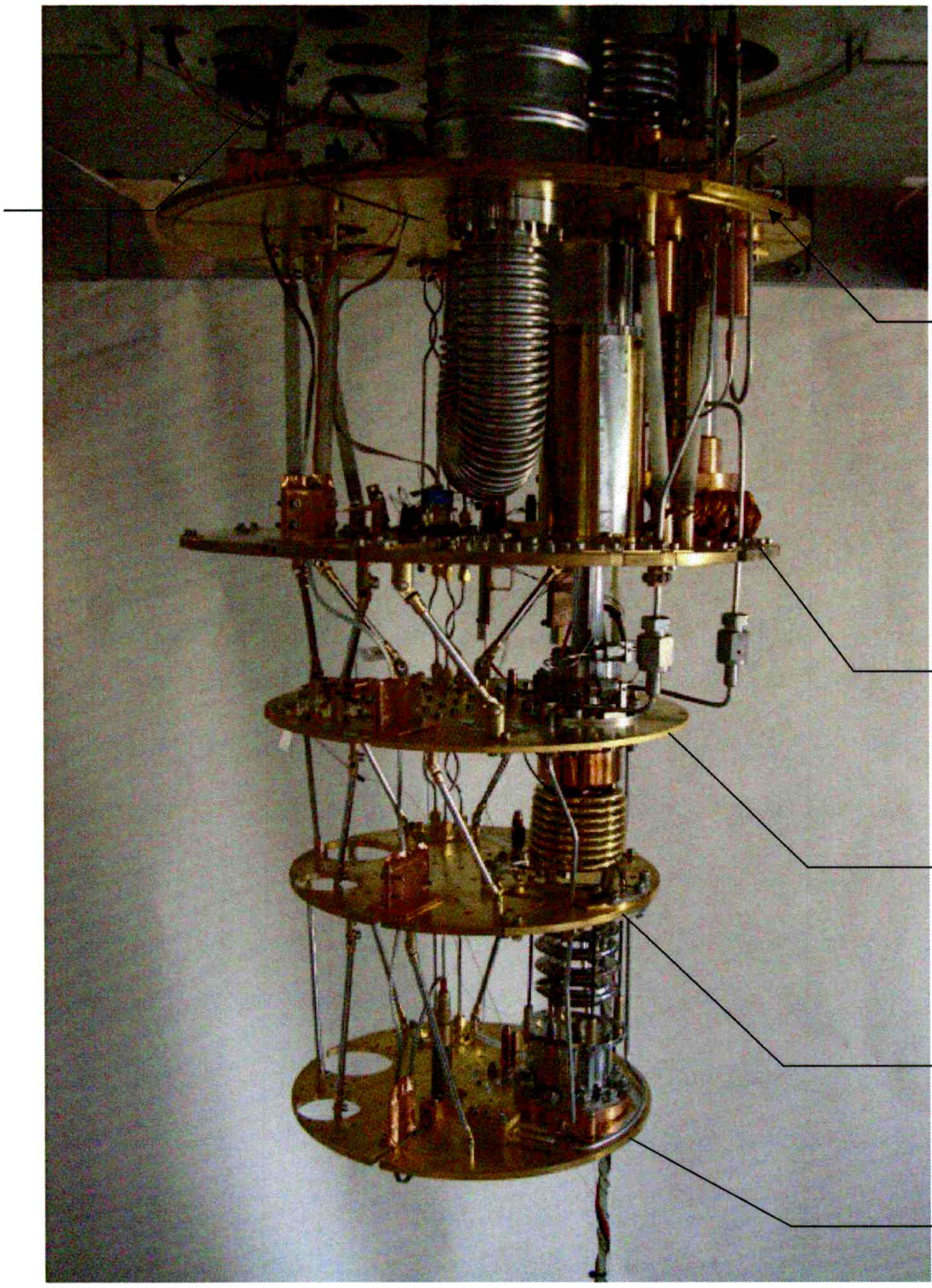



**Figure 5 Photograph identifying main items inside cryostat (details may vary)**

### Control cabinet

This combines many system modules, both electronic and mechanical, into a compact unit. The main items are:

- Mains distribution. The rack is connected to a source of power from the customer main supply.
- Gas handling system
- Lakeshore resistance bridge
- Controlling computer
- Reservoir for $^3He/^4He$ mixture (the "dump").

Further details are provided in Figure 6 (front view) and Figure 7 (rear view).

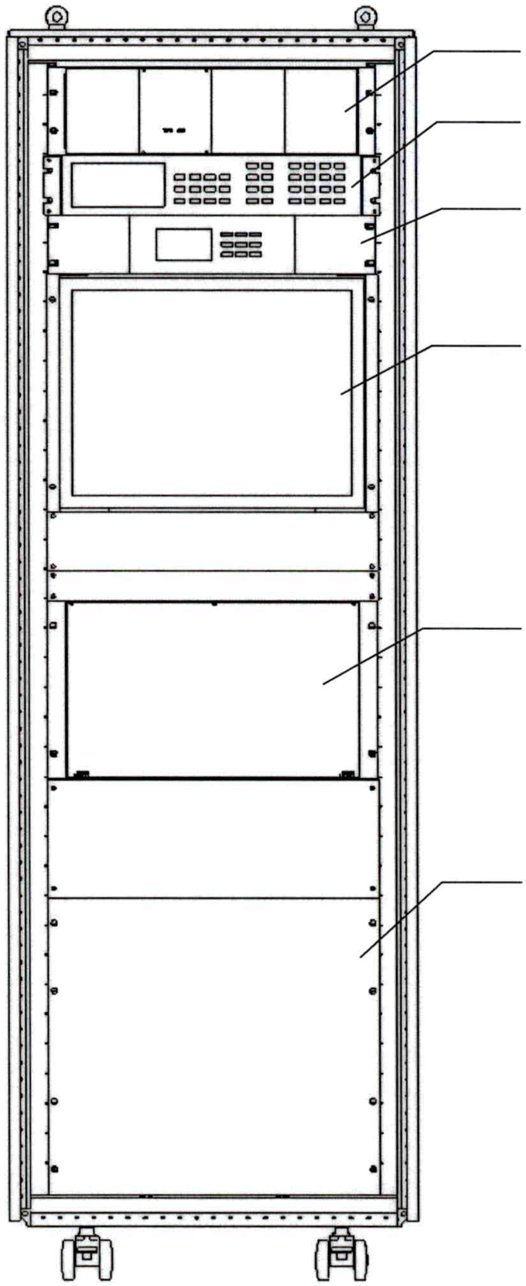



**Figure 6 Front view of control rack (details may vary)**

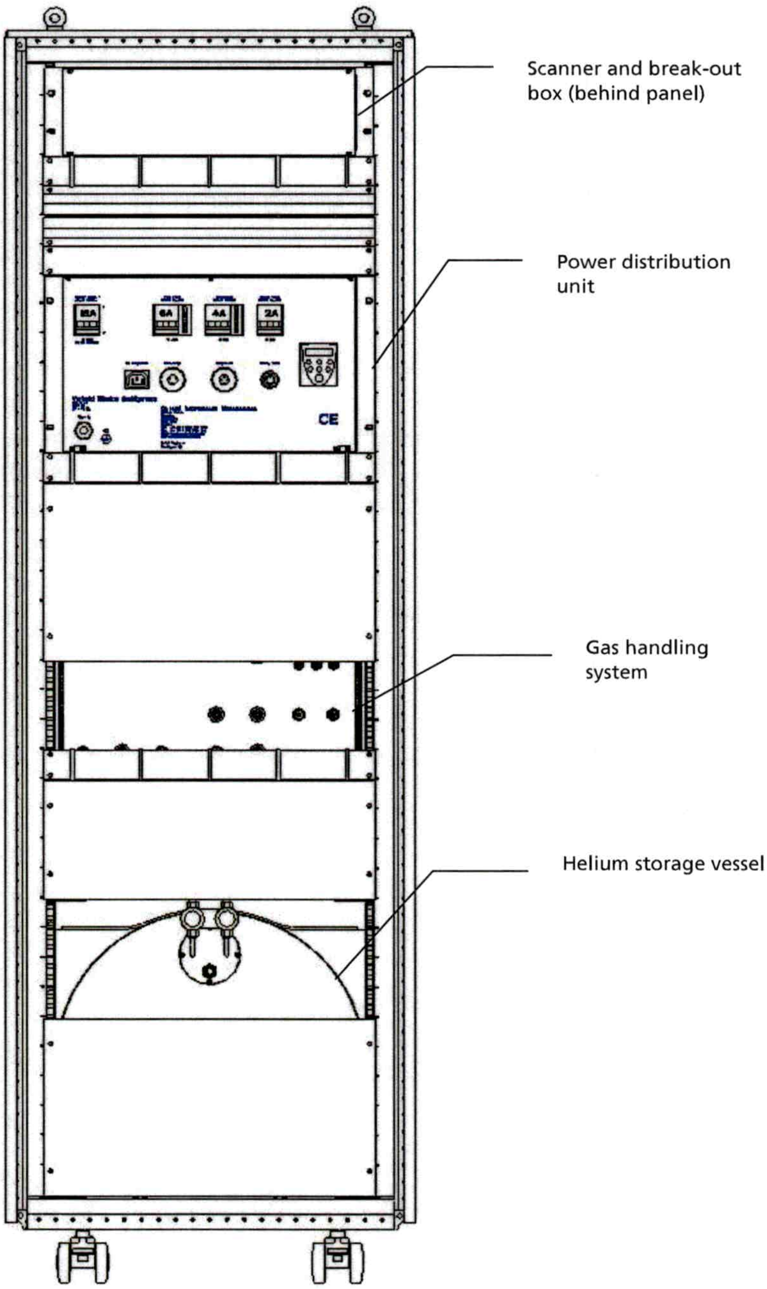



**Figure 7 Rear view of control rack (details may vary)**

## Handling and storage (including transport)

The module may be stored for up to 15 weeks in a storage environment as follows;

| | |
|---|---|
| Ambient temperature | -10 to 40 Celsius |
| Relative humidity | 30% to 75% (non-condensing) |
| Atmospheric pressure | 700 to 1060 mbar |

Temperatures over 40° C may lead to gas evolution from the adsorber and thus may contaminate the flexlines and the cold head.

***WARNING High pressure. Even after the unit is switched off, the compressor unit, the rotary valve, the cold head and the flexlines will be under pressure of up to 17 bar. Observe the appropriate safety regulations.***

***Avertissement de haute pression. Même après que l'unité est éteinte, le compresseur, la soupape rotative, la tête froide et les lignes flexibles seront sous pression de 17 barres. Respectez les règles de sécurité appropriées.***

If there is danger of freezing temperatures, drain the coolant from the compressor prior to storing or shipping the unit.

# 4. Setting up the system

This chapter describes how to change the sample and check the system before operation. It also includes routine checks that should be performed if the system has been unused for some time.

***Unless otherwise agreed, only an Oxford Instruments installation engineer may unpack your Triton$^{200}$ system.***

***A moins que vous vous etes mis d'accord avec Oxford Instruments avant, le système Triton$^{200}$ ne peut etre déballer que par votre l'ingénieur d'installation d'Oxford d'instruments.***

## Important! Warnings and cautions

***It is your responsibility to ensure your own safety and the safety of the people working around you (use hazard warning signs to make sure that anyone approaching the system is aware of the potential hazards). You must read all manuals supplied with the system and follow the recommendations contained in the manuals. This includes the manuals for parts of the system not manufactured by Oxford Instruments – this is important as not all warnings and operational instructions relevant to these parts are duplicated in this manual.***

***Il est de votre responsabilité d'assurer votre propre sûreté et la sûreté des personnes travaillant autour de vous (utilisez des panneaux d'avertissement de risque d'utilisation afin de s'assurer que les personnes qui s'approchent du système se rendent compte des risques). Vous devez lire tous les manuels fournis avec le système et suivre les recommandations contenues dans les manuels. Ceci inclut les manuels pour les composants du système non construits par Oxford Instruments - c'est important car tous les avertissements et instructions opérationnelles concernant ces pièces ne sont reproduits dans ce manuel.***

***The Triton$^{200}$ system should be handled with great care to avoid mechanical damage to any of the component parts.***

***Le système Triton$^{200}$ doit être manipulé avec grand soin pour éviter les dommages mécaniques des composants.***

***Do not tamper with any of the pressure relief devices fitted to the system or attempt to modify or remove them. Also ensure that the outlets of the relief devices are not obstructed. The correct operation of these relief valves is critical to the safety of the system.***

***Ne dérégler pas les dispositifs de décompression adaptés au système ou n'essayez pas de les modifier ou enlever. Assurez-vous également que les sorties des dispositifs de décompression ne sont pas obstruées. Le fonctionnement correct de ces soupapes de sécurité est critique à la sûreté du système.***

***The Triton$^{200}$ system must be kept vertical at all times.***

***Le Triton$^{200}$ doit rester vertical a tout moment.***

***Due to the supply filtering characteristics designed to filter at lower frequencies, particularly on the rotary valve controller, there can be a high (> 3mA) leakage current to ground. This current can be much larger at switch-on and can cause fast acting high-sensitivity residual current devices (also known as ground fault circuit interrupters) to trip.***
***En raison des caractéristiques du filtrage conçues pour filtrer les fréquences basses, en particulier sur le contrôleur de soupape rotative, il peut y avoir un haut (>3mA ; ) courant de la fuite à la terre. Ce courant peut être beaucoup plus grand à l'allumage et peut causer la chute rapide des courants résiduels( à haute sensibilité) des dispositifs (également connus sous le nom d'interrupteurs de circuit defectueux).***

***The compressor must not be tipped more than 5° at any time.***

***Le compresseur ne doit pas être incline de plus de 5°.***

***The control rack and some compressor options are air-cooled. To allow adequate circulation and prevent overheating they should not be placed less than 0.5m from a wall.***
***Le support de controle et quelques options de compresseurs sont refroidis à l'air. Pour permettre une bonne circulation et empêcher surchauffage, ils ne doivent pas être placés a moins de 0.5m d'un mur.***

***The control rack is protected by a circuit breaker in the event of an electrical malfunction.***

***Le support de controle est protégé par un disjoncteur en cas d'un défaut de fonctionnement électrique.***

The following list of equipment and consumables is required by the Oxford Instruments installation engineer in order to commission the system. All should remain available for the life of the equipment.

### Safety equipment

- Hazard warning signs, barriers, or controlled entry systems to ensure that anyone approaching the system is aware of the potential hazards.

### Lifting and access equipment

- A suitable method of lifting the system from the delivery vehicle (forklift or pallet truck).
- A suitable overhead hoist or crane for use in the laboratory.
- A lifting sling and shackles to suit the lifting points on the system.

### Useful Tools

- Spanners or wrenches, open ended metric set.
- Allen keys, metric set.
- Screw drivers, pliers, side cutters etc.
- Soldering iron for electrical work.
- Temperature controlled hot air gun.
- Digital multimeter (with low current ohms range).

### Consumables (some items are supplied in the system spares kit)

- Cooling water supply for PTR compressor and Pfieffer turbo pump
- 3-phase (and single phase) power supply of suitable voltage, power and frequency to supply the equipment.
- High purity (99.999%) $^4$He gas in high pressure bottle to top up the PTR in case of de-pressurisation in transit
- Liquid Nitrogen for cold traps and pre-cooling (depending on options)
- Roll of Mylar adhesive tape.
- Roll of aluminium adhesive tape.
- Tube of vacuum grease.
- Cotton or latex gloves for handling clean items.
- Metal polish and degreasing agent or solvent for general cleaning.
- Fishing line or dental floss for securing wiring within the cryostat (if required).
- GE varnish for thermal dumping of experimental wires (if required).

### Vacuum equipment

- A high vacuum pumping system to evacuate the cryostat vacuum space and other service functions. The system should include a turbomolecular pump or a diffusion pump with a liquid nitrogen cooled trap. It should be capable of reaching a pressure of $10^{-6}$ mbar.
- A mass spectrometer leak detector system for leak testing operations.
- A range of vacuum fittings (including a clean flexible pumping line) to connect the pumping system and leak detector to the cryostat vacuum pump out port.

### Compressed air supply

A standard laboratory supply of clean compressed air with minimum pressure of 5 bar is required to be connected to the rear of the gas handling system.

# System layout and interconnections

As your system will be installed and commissioned by an Oxford Instruments engineer, the information on the following pages (Figure 8, Figure 9, Figure 10 and Figure 11) is provided for reference only.

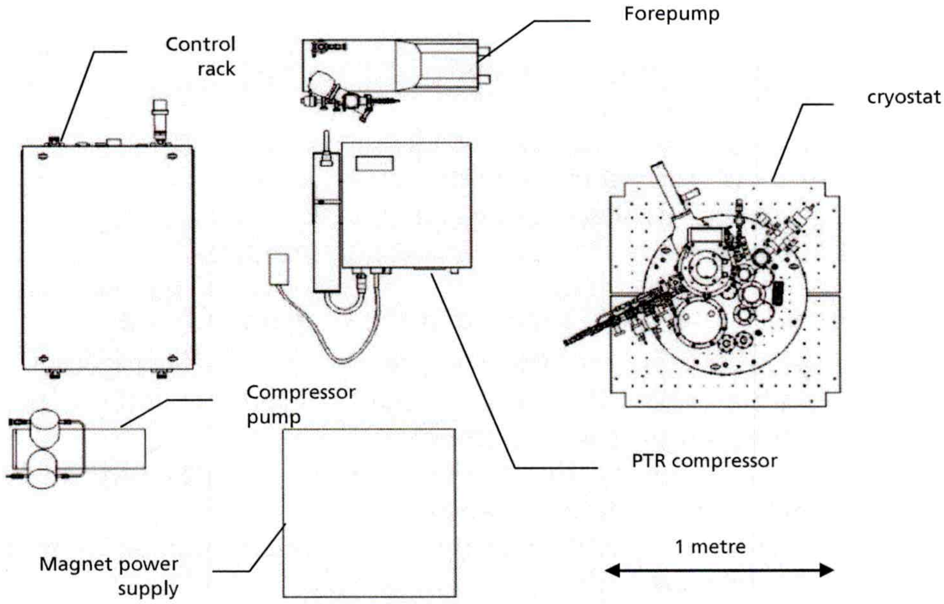



**Figure 8 Typical Triton$^{200}$ floor plan**

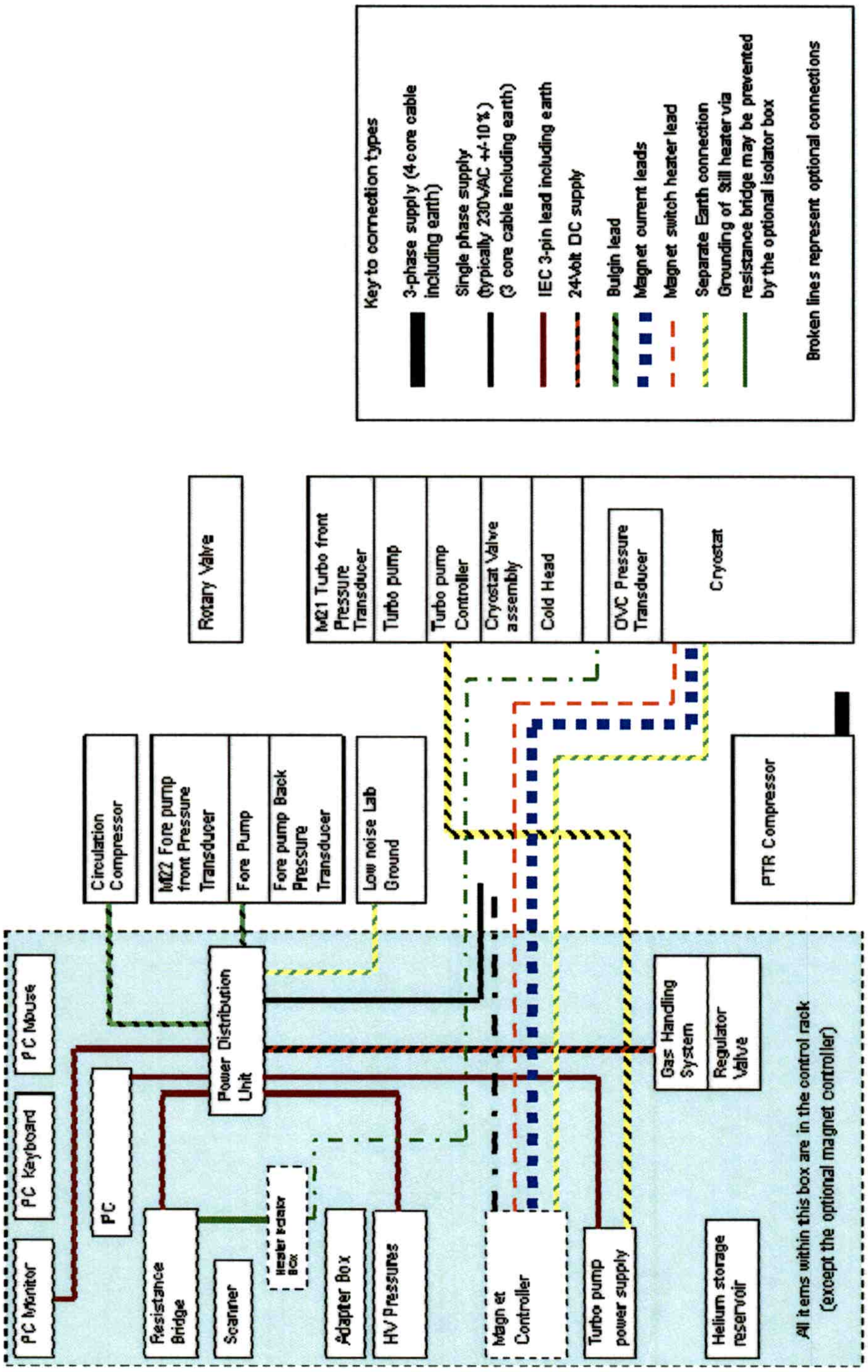



**Figure 9 System layout showing power and earthing interconnections**

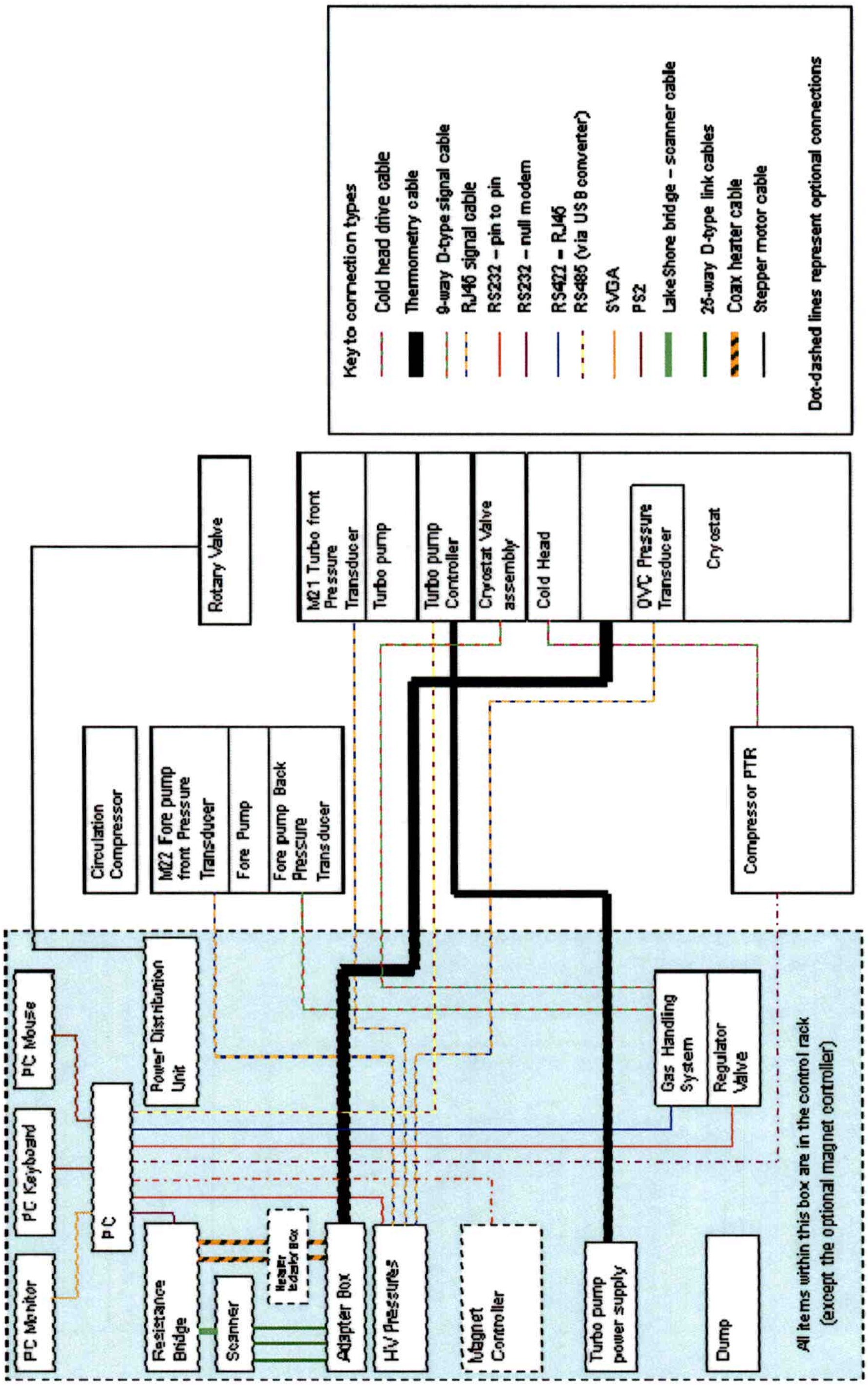



**Figure 10 System layout showing signal interconnections (exact details may vary)**

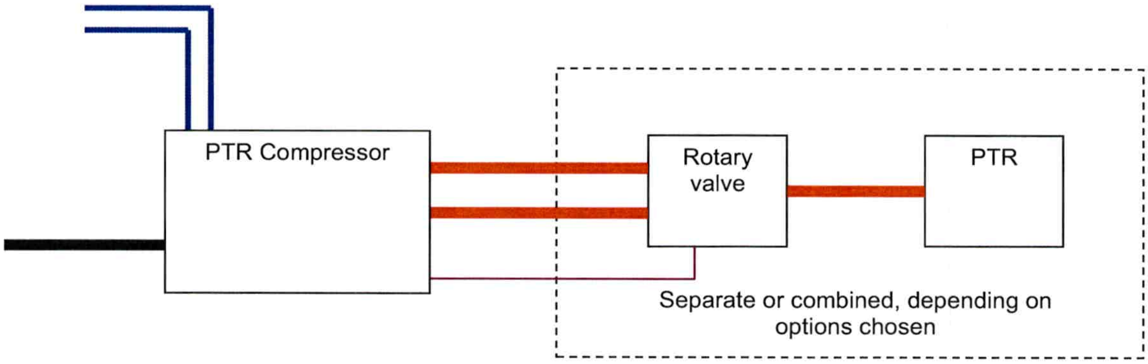
Table 2 gives additional detail for the signal cables.

| Cable Type | Function | Rack connection | System connection |
|---|---|---|---|
| Signal | Stepper motor pulses | Toshiba controller (if required) | Rotary valve |
| RS232 | Comms | PC COM port | Compressor |
| Signal | Analogue DC.V forepump outlet pressure | Beckhoff KL3464 (Ch3) or ADC in system PC | Pressure transducer on output of Forepump (Adixen) |
| Signal | Analogue DC.V forepump inlet pressure | Center Three or Multi-Gauge controller | Pressure transducer on input of Forepump (Adixen) |
| Signal | MV Analogue DC.V OVC pressure | Center Three or Multi-Gauge controller | Pressure transducer on cryostat OVC |
| Signal | M21 Analogue DC.V Still pressure | Center Three or Multi-Gauge controller | Pressure transducer on cryostat top plate |
| RS485 | Comms | PC USB adaptor | Pfeiffer Turbo controller |
| Power | Controller power | Pfeiffer TPS401 PSU | Pfeiffer Turbo controller |
| Signal | T sensors / heaters | LakeShore filter box | Cryostat top plate |
| Signal | V6, V7 & V8 actuation & status | GHS Sk1 9-way D-type | Cryostat top plate manifold 9-way D-type |
| RS232 | Comms | PC COM port | Magnet power supply |

**Table 2 Cables between control rack and system components (exact details may vary)**

As shipped, the cables are coiled in the back of the rack with the rack end connection already made. Each cable is clearly labelled where it should be connected. In general, the termination connectors are all different so the possibility for connection errors is minimised.

The Varian Multi-gauge or Leybold Center-Three will now display pressure readings from P3, P4 and the cryostat OVC.



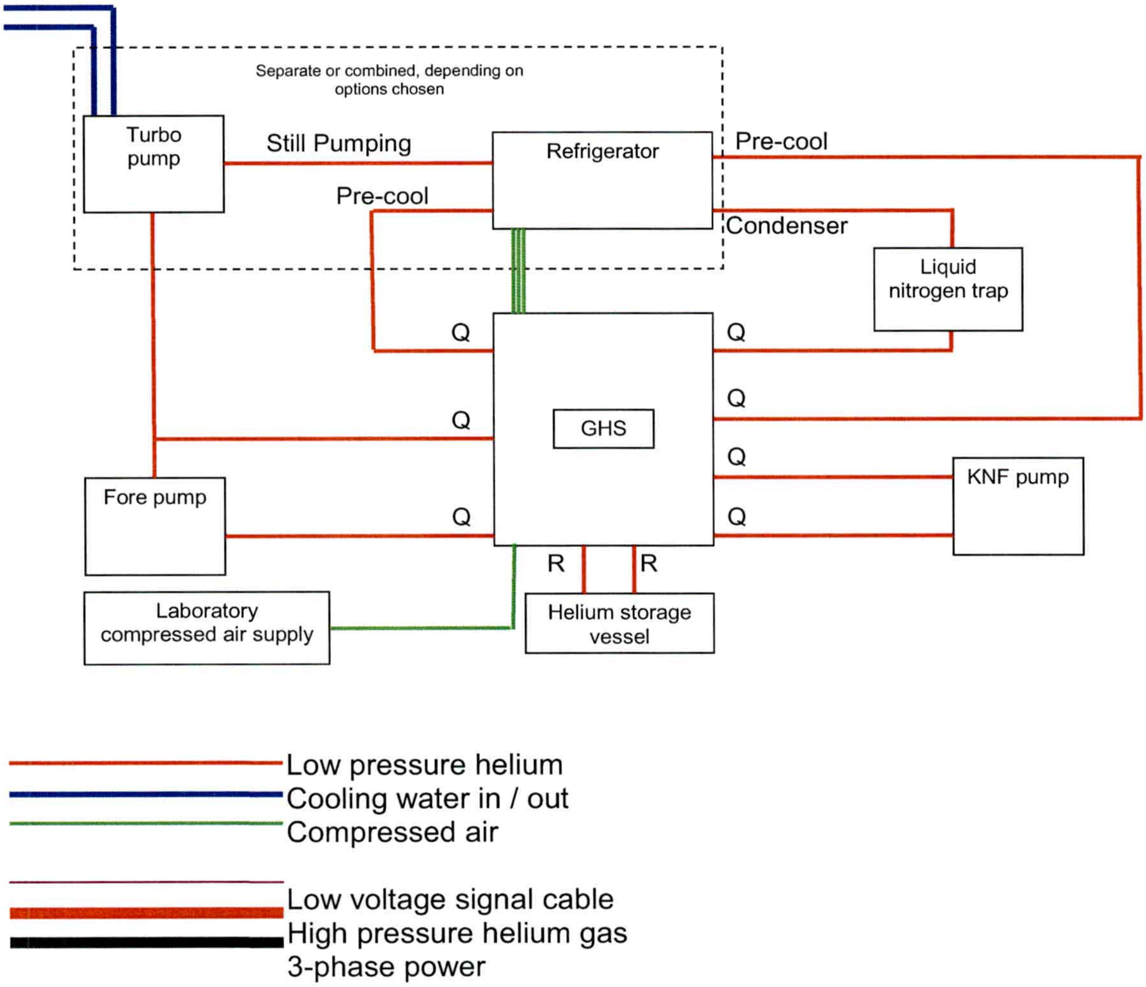



**Figure 11 High and low pressure gas interconnections**

# Connect the Control Rack

### Protective ground (also called Rack ground)

To minimise any electrical shock hazard the controllers mounted in the control rack must be connected to an electrical ground (Earth). This will typically be the single-phase earth connection. The rack should be grounded to this earth point.

### Functional ground (also called measurement ground)

There is an additional earth within the resistance bridge known as the measurement ground. Within the resistance bridge this is electrically isolated (> 500kΩ) from the rack ground and is required for the low-level thermometry signals. The multiplexer and break-out box are grounded to this measurement ground as is the screen of the 50-way diagnostic wiring lead to the cryostat.

***The Still heater supply is referenced to rack ground. The screen of its cable will connect the break-out box to rack ground by-passing the 500kΩ isolation. For operation at base temperature and when Still heat is not required, disconnect the Still heater lead.***
***L'alimentation du réchauffeur de "still"est référencé à la terre du support. L'écran de son câble connectera le contrôleur d'interface à la terre du support en déviant l'isolation de 500kΩ. Pour l'opération à température basse et quand le réchauffeur de "still" n'est pas exigée, déconnectez le fil du réchauffeur de "still".***

- ***Do not disconnect the protective ground inside or outside the instrument.***
- ***Do not use an extension lead without a protective ground conductor.***
- ***Do not have external circuits connected to the instrument when its protective ground is disconnected.***
- ***Ne déconnectez pas la connection a la terre à l'intérieur ou l'exterieur de l'instrument.***
- ***N'utilisez pas une rallonge sans conducteur de Terre de Protection.***
- ***N'ayez pas les circuits externes reliés à l'instrument quand sa connection a la terre est deconnectée.***

## System grounding

The control rack will include an appropriate mains distribution system. The mains distribution system includes a Schaffner FN 350-12-29 filter to ensure a low-noise supply.

However, if a cleaner single phase supply is available, it is possible to connect the resistance bridge directly to the single phase supply. It this case it is necessary to switch the source voltage requirement on the back of the bridge. Please see the resistance bridge manual for details.

Care should be taken to ensure the earth connection of the two supplies is common with no unbalanced EMFs or else current may flow in the RS-232 ground connection between the bridge and the PC which may result in either PC or bridge malfunction.

Grounding of the Triton$^{200}$ is summarised in Figure 9. It requires particular care to ensure operator safety and to avoid noisy earth loops. The system cold-head compressor is supplied from a 3-phase supply and should be grounded to the earth terminal in its supply breaker. Ensure the earth wire in the power cord is securely fixed at the breaker end.

The instrument rack and rotary valve controller will typically be supplied from a single-phase supply (see note above) and be grounded on that supply. The low-level measurements require a separate measurement ground which is isolated from both the 3-phase and single-phase earths. During assembly the following conditions must be achieved and checked: -

- The high pressure lines from the compressor to the cold head must be electrically isolating.
- The high pressure line from the rotary valve to the cold head must be electrically isolating.
- Any pumping lines between the cryostat and the pump must be electrically isolating.
- The cryostat mounted pressure transducers must be electrically isolated from the cryostat.
- The multiplexer (scanner) and filter box must be grounded via cable shields to the **measurement ground** of the resistance bridge.
- The 50-way diagnostic cable shield should be connected at both ends so that the **cryostat is grounded to the measurement ground** of the resistance bridge. All other cable shields to the cryostat should be electrically isolating as the instruments will be connected to the protective (rack) ground and the cryostat will be grounded to functional (measurement) ground. To maintain the cryostat isolation but still to achieve shielding the cable shields must be disconnected **at one end only.**
- The instrument rack should be grounded to the supply earth (i.e. the protective ground) of the Resistance Bridge, pc, rotary valve controller, manometer etc.

***If the system includes a superconducting magnet the cryostat is connected to the protective ground via the magnet power supply.***

***Si le système inclut un aimant supraconducteur le cryostat est connecté à la terre par l'intermediaire de l'alimentation de l'aimant.***

# Configure the experiment and mount the sample

Fitting and changing samples requires that the system be disassembled. However, the extent of the disassembly will depend on experimental requirements.

For clarity, the flow charts Figure 41 and Figure 42 distinguish between mounting the sample (requiring minimum disassembly) and configuring the experiment (significant disassembly). However, a decision should be made according to what is most appropriate for the circumstances at the time.

This section gives general advice on both wiring and mounting of samples.

***The mixing chamber must NOT BE STRAINED either by twisting or lateral movements of the sample holder.***

***La chambre de mélange ne doit pas mise sous pression par le vrillage ou les mouvements latéraux du porte echantillon.***

Remember that the cryostat should be kept as near vertical as possible.

The design of the sample holder is an important part of your experiment. Suitable designs and advice may be obtained by contacting Oxford Instruments Technical Support (see Chapter 9).

Clearly it is important to maximise the thermal contact between the sample and mixing chamber as well as minimising the heat leak on to the dilution unit/sample if the lowest temperatures are to be achieved.

Items mounted on the mixing chamber should be bolted to it securely. The best thermal contact is achieved by making a face to face connection between two clean metal surfaces. It is important to apply enough pressure to achieve good thermal contact, but not so much as to damage the threads in the copper mixing chamber base. It is also important to avoid the presence of superconducting joints in the thermal path from the experimental apparatus to the mixing chamber, for example, soldered joints. At the temperatures reached by the mixing chamber, the ratio of the thermal conductivities of the normal and superconducting states is very high, and the superconducting joint acts as a good thermal insulator.

Consider carefully the mounting position of any thermometers. If in doubt, refer to the booklet "*Introduction to Thermometry below 1 K*" for guidelines.

If the sample is to be mounted at the centre of field of a magnet it is important to use a suitable sample holder. It should be designed to minimise the problems associated with eddy currents induced by the changing field. Oxford Instruments have a range of suitable sample holders for your application.

> There is a tapped M6 hole (or small adaptor plate) for a sample rod in the centre of the mixing chamber plate for systems with magnets.

Think carefully about the wiring to the sample. It is important to minimise the amount of heat conducted down to the mixing chamber. In general it is wise to minimise the total number of wires to the sample, and wherever possible constantan or superconducting wire (with a high resistance matrix) should be used instead of copper. Even a small number of copper wires will have a noticeable effect on the base temperature operation of the system. Heat sinking of experimental services should be done thoroughly. All wiring should be thermally anchored at the PT1 and PT2 plates. Unusual wiring should also be anchored to the still plate, 100mK plate and mixing chamber before it is finally connected to the sample. In most cases it is sufficient to wrap wires around a copper post and secure them with GE varnish. Before each radiation shield is closed, it is important to check that there is no path for radiation to enter it (all the plates have mounting and access holes). Use aluminium reflective tape to cover any open holes.

When mounting a sample, particularly non-metallic samples, it's important to consider that the sample will be exposed to radiation from the Still. If the sample thermal conductivity is low, then to achieve sample temperatures below 20mK it will be necessary to enclose the sample in a polished metallic radiation shield firmly attached to the M/C. The signal wires are also exposed to radiation from the Still. For this reason, the connecting wires to the sample, inside the additional shield, must be sufficiently long to prevent heat load significantly warming the sample.

Finally, check all electrical leads for continuity and short circuits to ground.

## Start up the Control Software

To start the software, double-click on the icon. You will find this icon on the desktop or in the VeriCold folder. While the software boots, it searches for and initialises all the necessary instrumentation. It also starts the data logging and system logging automatically. This process shows a small progress dialog window during the time it takes to complete. If any device could not be located, and therefore, initialised, the dialog prompts the operator. You may click OK to continue the initialisation routine but the problem must be investigated for correct operation of the fridge.

Further description of the software is postponed to section 5.

## Check theThermometry

Once all the cables are connected, make sure that all thermometers are reading correctly by measuring each one with the resistance bridge. Compare the measured resistance values with the values listed in the expected resistance table on page 110.

Use the pc and software to perform this check by running a few scans of the channels as follows. Start the "Dilution Control" by clicking on that icon. The program will search for the devices needed and then show the scheme of the gas handling system. Go to the "thermometry" menu and select "open thermometry". The thermometry panel opens. Check the resistances and temperatures. There are some thermometers that are not calibrated for some temperature range and usually shown in red colour if out of range. Check each thermometer even if it is not in range. If thermometers are switched off, switch on and check. Switching on is done by double clicking the channel enable column. To scan through the channels make sure the "measure sequence" option on the "channels" tab is set to "sequential" (Refer to the Thermometry section of this manual).

## Check the Gas Handling System

Oxford Instruments recommends performing a coarse leak check during commissioning and after warming up the instrument. The residual gas from charcoal traps should be in the range of $p < 10$ mbar measured at the forepump pressure gauge P4 when the manual valve on the inlet of the forepump has been closed at 4K temperatures before warming up. In the usual case there is no need to close this valve when warming up the instrument and therefore some He from the high pressure side of the forepump will show up on the suction side of the forepump. In this case the pressure due to He is about 10-15 mbar.

| |
|---|
| A pressure above 15-20 mbar could indicate a leak in the mixture circuit. |

***If the residual gas pressure increases from run to run there is a strong possibility that the gas handling system is leaking. Immediately check for leaks (e.g. by using the technique for overpressure leak detection, as described in Practical Cryogenics) since you might be losing mixture. In addition, the contaminant gas will eventually block the impedance and cause malfunction of the system.***

***Si la pression de gaz résiduelle augmente d'une utilisation a l'autre il y a une forte possibilité que le système de transport de gaz fuit. Vérifiez immédiatement les fuites (par exemple en employant la technique pour la détection de fuite de surpression comme décrit dans le guide "Practical Cryogenics") car vous pourriez perdre du mélange. D'autre part, le gaz contaminant finira par bloquer l'impédance et causer le malfonctionnement du système.***

## Check the PTR compressor

Examine the pressure reading displayed on the compressor and compare it with the value given in the compressor documentation. Check that

- the high pressure lines are connected to the rotary valve
- the rotary valve is connected to the cold head
- the control lines for both rotary valve and compressor are connected.

# Fitting Shields and Superconducting Magnet

Use cotton or vinyl gloves to handle the radiation shields to prevent tarnishing and contamination with oils etc. from your hands.

***Before closing the PT2 shield, check for holes or slits in the PT2 base plate and PT1 base plate. Even very small openings to PT1 or room temperature will prevent the M/C reading its base temperature.***

***Avant de fermer le bouclier PT2 vérifiez si il y a des trous ou des fentes dans le plateau de base PT2 et PT1. Même de tres petites ouvertures sur le PT1 ou à température ambiante empêcheront la chambre de melange de lire sa temperature de base.***

***Use small amounts of Apiezon N-grease or H-grease to ensure good thermal contact between shield pieces and cooling plates. Grease from a previous run will normally be sufficient.***

***Utilisez un peu de graisses Apiezon ou H pour assurer un bon contact thermique entre les morceaux des bouclier et les plateaux de refroidissement. La graisse d'une procedure précédente sera normalement suffisante.***

***When mounting the Room temperature shield, make sure the O-rings and surfaces are clean to ensure proper vacuum. Dust or metal will most probably cause leakage.***

***Quand vous montez le bouclier à temperature ambiante, assurez-vous que les joints circulaires et les surfaces sont propres pour assurer un bon vide. Poussière ou métal peuvent causer des fuites.***

***Only tighten screws firmly. No real force should be applied otherwise there is a possibility of damaging threads. Damaged bolts should be replaced.***
***Ne serrez que les vis fermement. Aucune force ne doit être appliquée pour ne pas endommager les fils. Les boulons endommagés devraient être remplacés.***

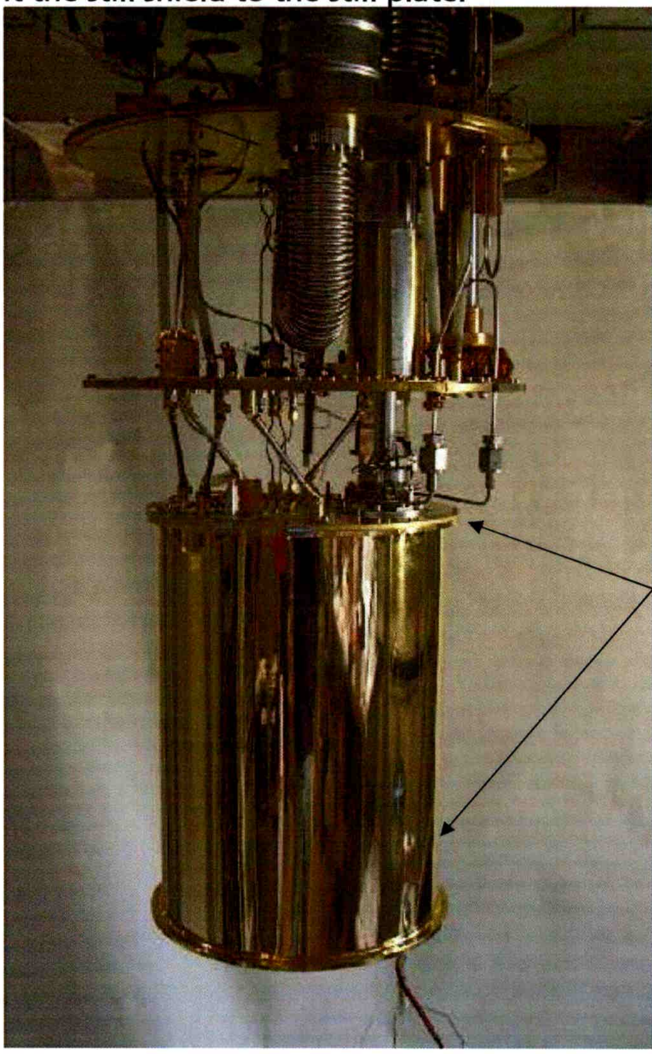
***Ensure that all screws that suspend a load (viz. a superconducting magnet) are engaged into the thread of the shield above by a length at least 1.5 times the diameter of the screw thread and that all screws used are stainless steel.***

***Veiller à ce que toutes les vis que de suspendre une charge (c'est-à-dire un aimant supraconducteur) sont engagés dans le fil au-dessus de l'écu par une longueur d'au moins 1,5 fois le diamètre du filetage et que toutes les***

***vis utilisées sont en acier inoxydable.***

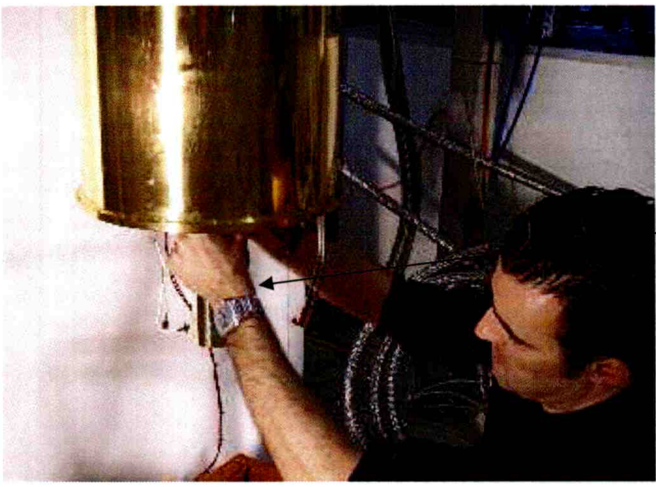
The following sequence of pictures demonstrates how to fit a superconducting magnet to a Triton$^{200}$ system.

**Fit the still shield to the still plate.**

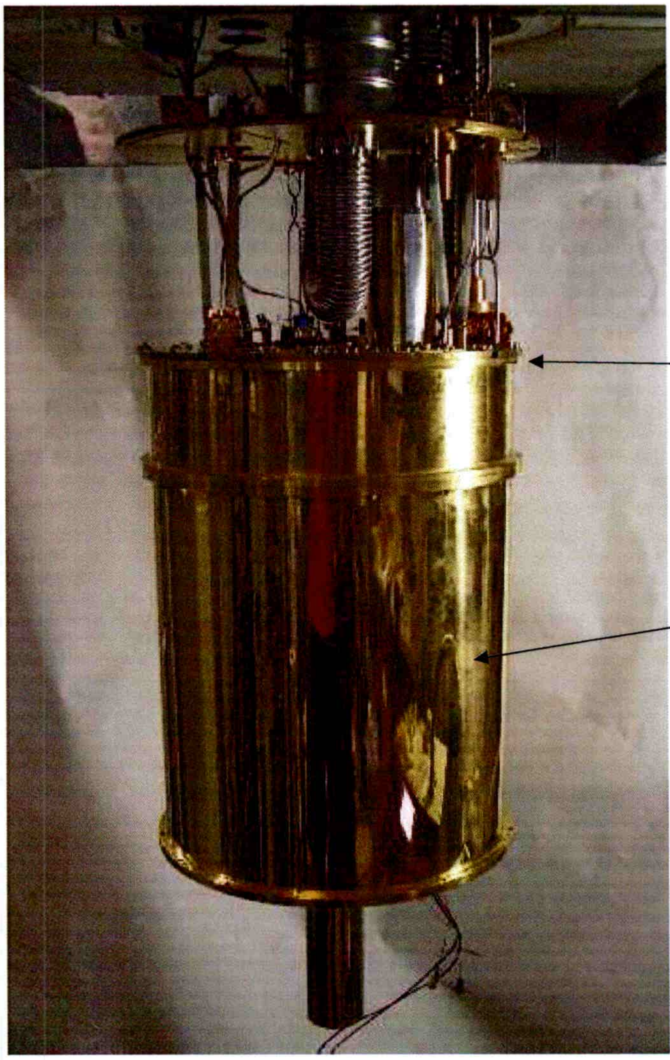


Connect the still shield...

...to the still plate.

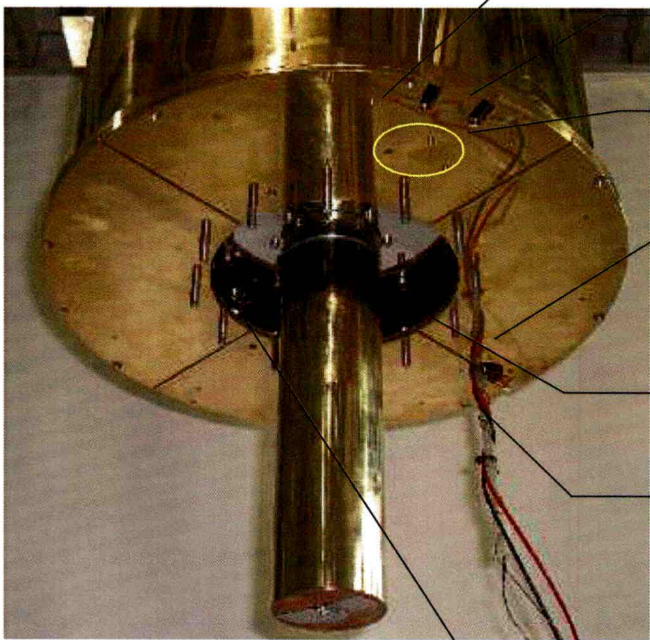


Screw in the still shield bore tube.



Bolt the upper section of the 4K shield to the 4K plate. Then bolt the lower section to the upper section.

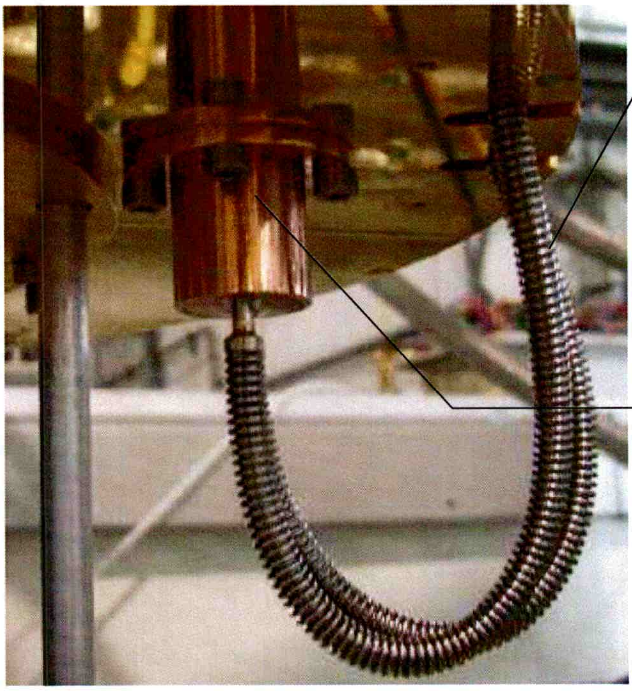
**Fit the 4K base plate.**



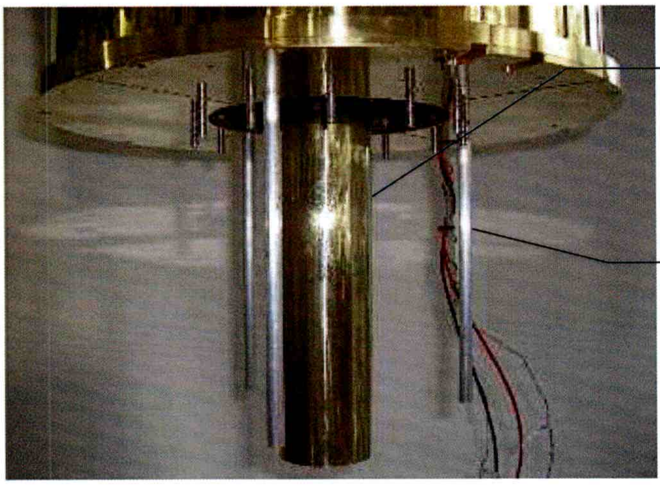

The 4K base plate is fitted to the bottom rim of the middle 4K shield. Orient the 4K base plate so that the current lead and magnet thermometry cabling, tied to the G10 rod, pass through the slot in the plate.

The 4K base plate is initially held in place using eight countersunk screws at this stage.

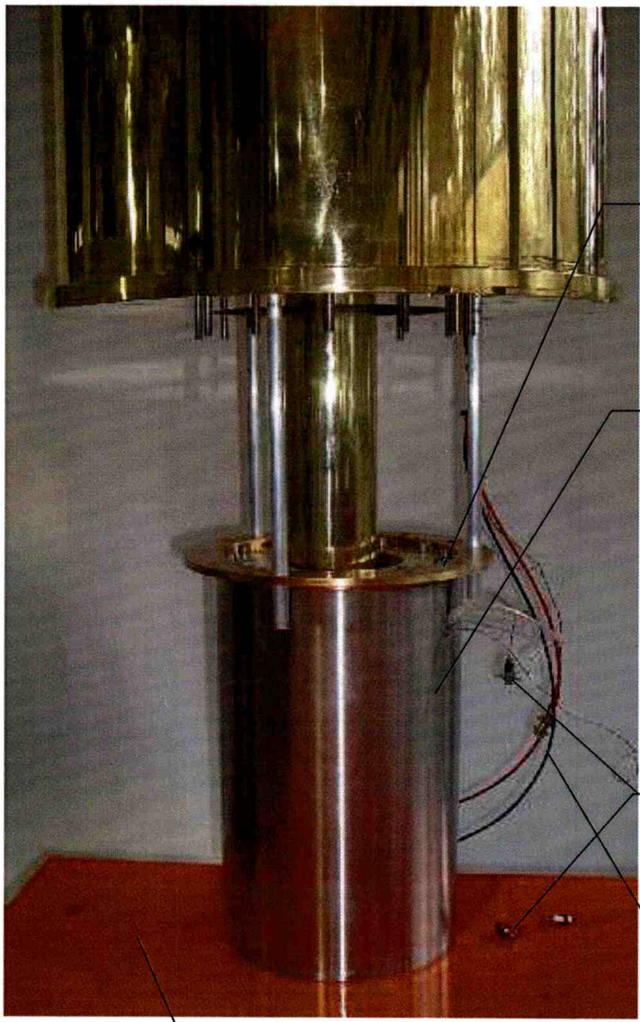
**Fit the liquid nitrogen pre-cool loop (optional).**



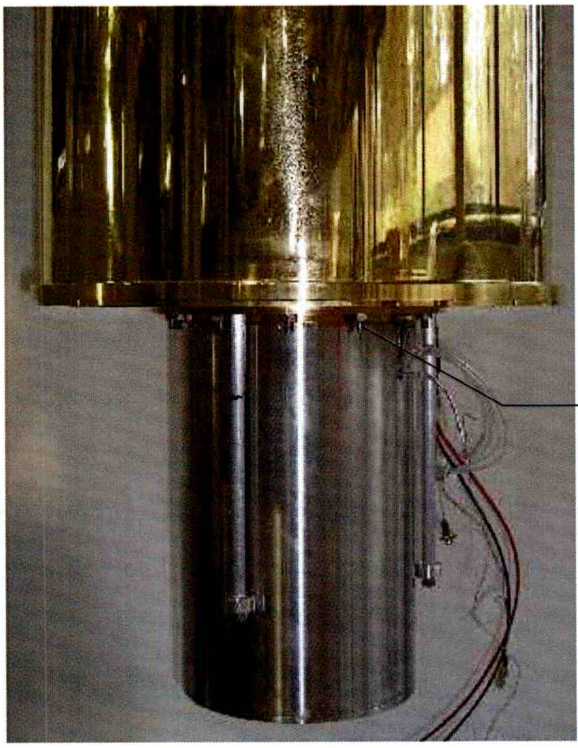

**Fit the magnet guide rods.**




**Raise the magnet on to the guide rods**


Magnet interface plate
magnet
Micro-D connectors for magnet switch
Micro-D connector for magnet thermometry
Jacking trolley

**Bolt the magnet interface plate on to the 4K base plate.**



12 x M8 bolts for mounting the magnet (via its interface plate) to the 4K plate

Use a battery powered digital multimeter (viz. a Fluke 110 series) to measure the following :-

- Start to End resistance across the magnet leads
- Resistance to ground from either the +ve or –ve lead.

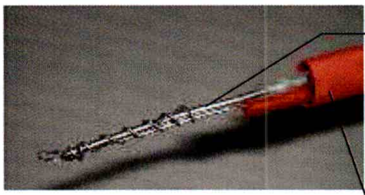
The start to end resistance should be equal to the value for the magnet start-end in the data sheet.

The resistance to ground should be >1 MΩ. If the reading is less than this, then contact Oxford Instruments for advice on how best to proceed.

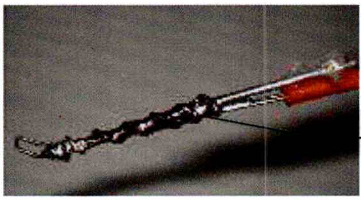
**Fit the magnet diagnostic thermometers.**
Fit the magnet diagnostic thermometers to the magnet interface plate (left) and base of the 4K can (right) using single M5 bolts.

**Connect magnet current leads.**

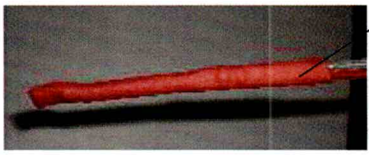
In this step the magnet current leads are soldered to the current supply leads from the top of the cryostat.



- Bind together the lead from the magnet (above) and lead from the cryostat terminal (below) with tinned copper wire.
- Fit a suitable length of heatshrink as shown.



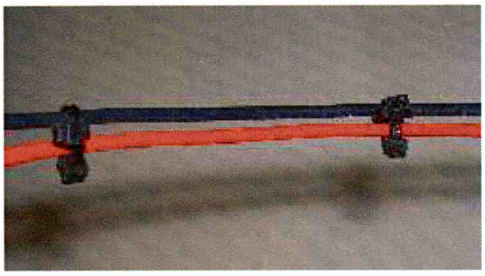
- Soft solder the leads and copper wire together



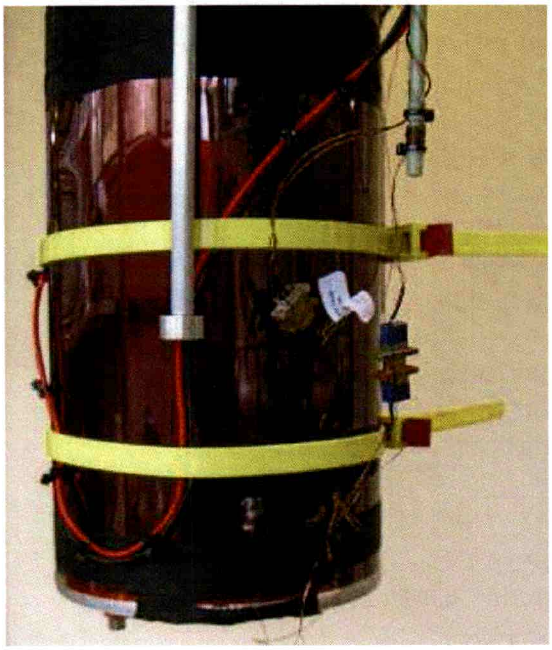
- Slide a second length of heatshrink on to the lead assembly and shrink into place.
- Fold over the end of the heatshrink and slide the first length of heatshrink down over it.
- Shrink into place.

**Secure the magnet current leads (to prevent movement when energising).**

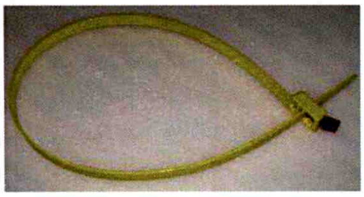
The +ve and –ve magnet current leads should be tied together using pairs of small black cable ties spaced every few centimetres, as shown.



The outer tie holds the leads together; the inner tie minimises the risk of damaging the leads when they need to be separated again.



Position the current leads around and against the magnet.



Use 2 large yellow cable ties to tie the current leads to the magnet. They should be positioned, as shown, inside the magnet guide rods. The exact orientation is not important.

**Due to differential thermal contractions, allow 1% additional length for the cable tie around the magnet circumference.**

**Connect the magnet switch and thermometry.**

Connect together the micro-D

connectors for the magnet thermometry (fine gauge wiring) and magnet switch heater (28 swg constantan).

Finally, ensure all delicate wiring is safely wrapped around the magnet lead support rod or taped to the magnet using cloth tape.

If your magnet is fitted with a persistent switch, then ensure that the switch cable is plugged into the 10-pin Fischer socket next to the current lead terminals on the top plate (see Figure 3). The switch cable has two larger spade connectors that are connected to the screw terminals on the back of the magnet power supply.

- Carry out a resistance check on the switch and wiring before connecting to the magnet power supply.

The switch resistance should be equal to the value in the data sheet with a small addition (of the order a few Ohms) for the lead resistance to the top plate and through the magnet support. Once this check is complete, connect the switch leads to the power supply terminals (note that the polarity is not critical).

**Check magnet resistance and resistance to ground.**
Use a battery powered digital multimeter (viz. a Fluke 110 series) to measure the following :-

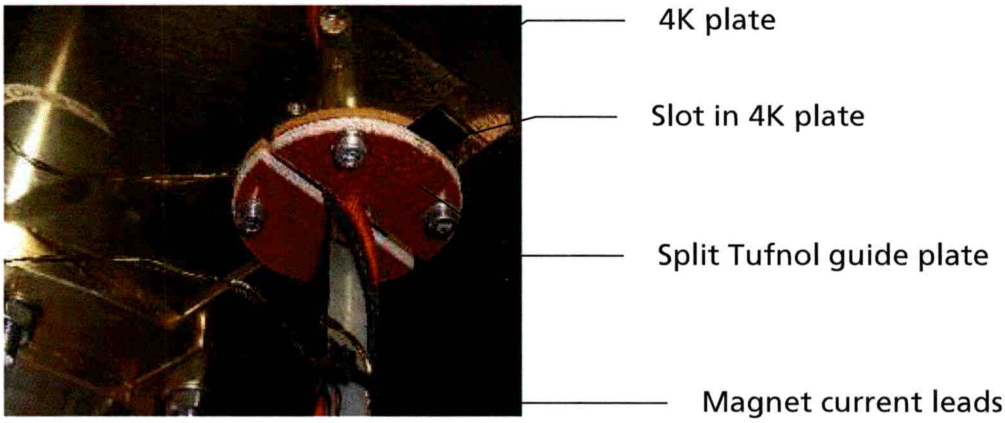
- Start to End resistance across the current leads at the cryostat top plate
- Resistance to ground from either the +ve or –ve lead.

The start to end resistance should be equal to the value for the magnet start-end in the data sheet with a small addition (of the order a few Ohms) for the lead resistance to the top plate and through the magnet support leads.

The resistance to ground should be >1 MΩ. If the reading is less than this, then carry out a basic inspection to identify where this "short to ground" originates. If the resistance to ground remains < 1 MΩ, contact Oxford Instruments for advice on how best to proceed.

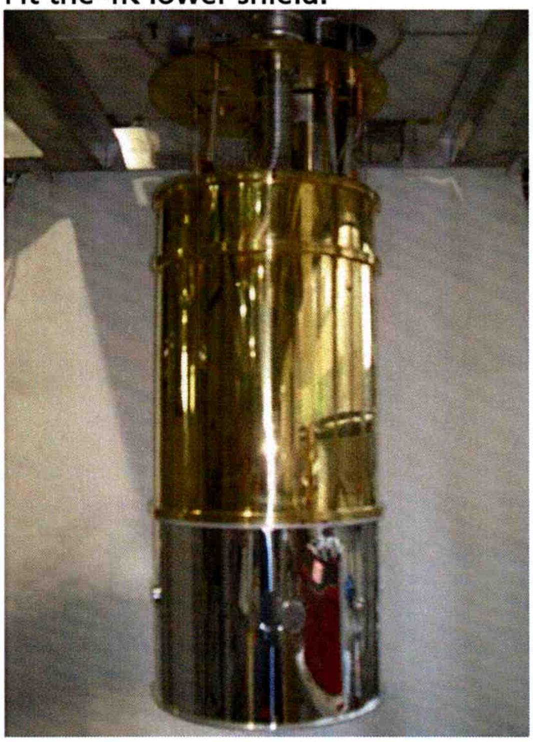
**Check no metal touch between still shield bore tube and magnet.**
Your system will have been provided with a G10 spacer fitted to end of the still shield if there is there is a small annular gap between the still shield bore tube and the magnet. Touches are only likely if this has been damaged.

**Fit the current lead guide plate.**

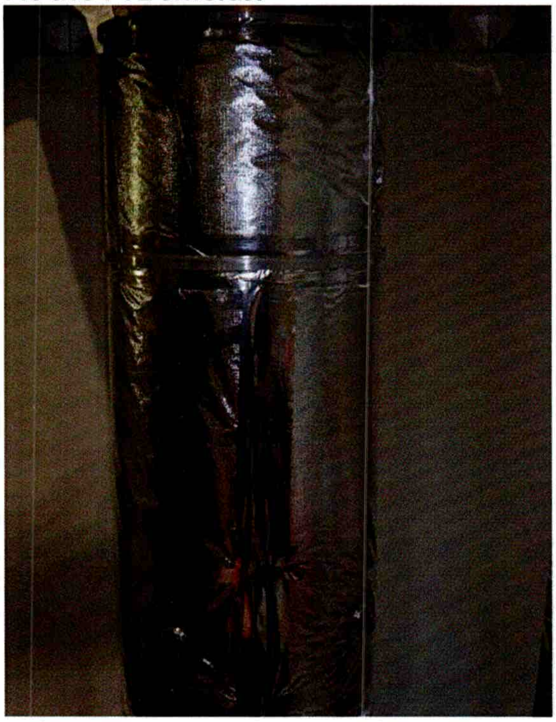



Bolt the split Tufnol guide plate to the 4K plate. This provides mechanical support to the rod carrying the magnet current leads and thermometry wiring.

**Fit the 4K lower shield.**



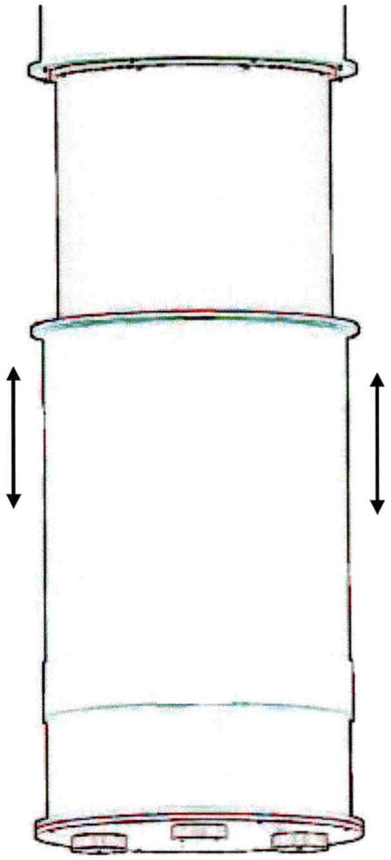
**Fit the PT2 shields.**



Take care not to damage the superinsulation.

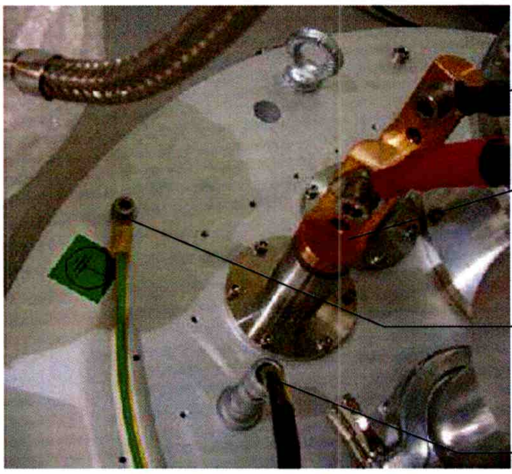
**Fit the OVC.**

- Support the base of the OVC
- Raise the OVC carefully, taking care not to damage the superinsulation.
- Ensure the O-ring is greased and will make a complete seal
- Fit the 12 bolts.



How to fit lower OVC

### Connect magnet electrical services on cryostat top plate.



# Pump out the OVC

Pump out the OVC (to a pressure below 1 x $10^{-2}$ mbar) via the NW25 vacuum valve on the cryostat top plate using a high vacuum pumping system before switching on the PTR. It is also recommended that you also check the OVC for leaks. To do this pump the OVC for at least 30 minutes to an hour, then connect a leak detector to the OVC pumping port valve and wait until the background helium signal drops to the $10^{-8}$ mbar l/s range (or a range with higher sensitivity). Monitor the signal on the leak detector and check for any signal rise while spraying recovery (or balloon) grade helium around the OVC (paying particular attention to the O-ring sealed joints). When you are satisfied that the OVC is leak tight, disconnect the leak detector but leave the OVC pumping using a high vacuum pumping system as the superinsulation will continue outgassing while the system is warm.

The pumping system may be used to evacuate the system until the PT2 stage reaches base temperature. After this point it should be disconnected as the cryopumping effects of the cold surfaces will be more effective than the pumping system. When the Dilution fridge is at about 4 K the pressure at the vacuum gauge is approximately $10^{-5}$ mbar and will fall to below $10^{-6}$ mbar once the dilution unit has cooled to base temperature.

***Make sure all other openings to the vacuum space are closed or have been blind flanged.***

***Assurez-vous que toutes autres ouvertures à l'espace de vide sont fermées ou ont été bloques.***

***Continuing to cool down the system with a leak will cause gas accumulation in the vacuum shield. During warm up this gas will be released and may cause dangerous overpressure. The cryostat itself has an overpressure valve which will open at a gauge overpressure of $p > 200$mbar.***

***Continuer à refroidir un système avec une fuite causera l'accumulation de gaz dans la chambre à vide. Pendant le préchauffage ce gaz sera libéré et peut causer une dangereuse surpression. Le cryostat lui-même a une valve de surpression qui s'ouvrira à une surpression p de plus de 200mbar.***

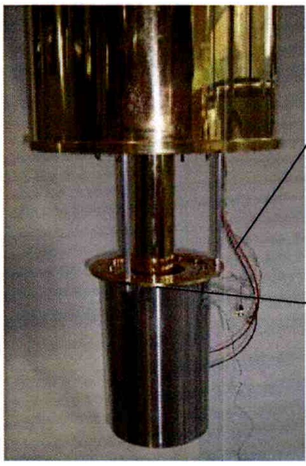
# Change of sample after data collection

Remove the lower OVC and PT1 shields.

Remove the lower 4K shield to allow access to the magnet

**Slacken the current leads, unstrap wiring and lower magnet.**

Unless it is necessary to remove the magnet completely, it is retained using simple support caps on the end of each guide rod.
Unscrew the still shield to provide access to the sample rod.



Slacken off the current leads and switch and temperature sensor wiring

Caps and bolts on the end of each guide rod

# 5. Operation

***It is your responsibility to ensure your own safety and the safety of the people working around you (use hazard warning signs to make sure that anyone approaching the system is aware of the potential hazards). You must read all manuals supplied with the system and follow the recommendations contained in the manuals. This includes the manuals for parts of the system not manufactured by Oxford Instruments – this is important as not all warnings and operational instructions relevant to these parts are duplicated in this manual.***

***Il est de votre responsabilité d'assurer votre propre sûreté et la sûreté des personnes travaillant autour de vous (utilisez des panneaux d'avertissement de risque d'utilisation afin de s'assurer que les personnes qui s'approchent du système se rendent compte des risques). Vous devez lire tous les manuels fournis avec le système et suivre les recommandations contenues dans les manuels. Ceci inclut les manuels pour les composants du système non construits par Oxford Instruments - c'est important car tous les avertissements et instructions opérationnelles concernant ces pièces ne sont reproduits dans ce manuel.***

## Introduction

This chapter describes how to operate the Triton$^{200}$ system. If you encounter any problems during operation please refer to the chapter **Maintenance and Faultfinding** toward the back of this manual (page 105) and the subsequent appendices.

## Liquid Nitrogen pre-cool (optional)

If your system is equipped with a liquid Nitrogen pre-cool circuit the cool down time from room temperature to approximately 77K can be substantially reduced. The following additional equipment is needed: -

1. Storage dewar with liquid Nitrogen (pressurized to approx.1-2 bar overpressure, a maximum pressure of 3 bar should not be exceeded).
2. Thermally isolated hose for Nitrogen transfer.
3. Pumping lines to evacuate liquid Nitrogen pre-cool.
4. Heat gun, hose for outlet of liquid Nitrogen pre-cool, protective foil.
5. Turbo pump backed with rotary pump or 2-stage rotary pump.

When mounting the thermal shields make sure that the heat exchangers on the plates and shields are firmly fixed in their position allowing for a good thermal contact (using Apiezon N-grease or H-grease). Tie the capillaries in position along the thermal shields with dental floss in order to avoid thermal shorts between the shields. Connect the storage dewar with a thermally isolated hose oriented with the Swagelok fitting to the input of the liquid Nitrogen pre-cool circuit. Tighten the Swagelok fittings and connect the outlet to a hose feeding the exhaust to a safe place.

***DANGER! The Nitrogen pre-cool outlet should be vented outside. If it is vented to a closed room, cold Nitrogen gas can fill the room from the floor up, displacing the Oxygen and causing asphyxiation without warning. As an additional precaution the laboratory should be fitted with Oxygen depletion sensors.***

***DANGER ! La sortie du système de pre-refroidissement de l'azote doit être ouverte dehors. Si elle est ouverte dans une salle fermée, le gaz froid d'azote peut remplir la salle à partir du sol, déplaçant l'oxygène et entraînant l'asphyxie sans avertissement. Par mesure de precaution, le laboratoire doit être aussi équipé d'un detecteur d'oxygène.***

Close and evacuate the system as usual. Start the cool down from room temperature with the automated 'full cool down' (see below), or cooldown manually if preferred. Open the manual valves of the pre-cool circuit on the room temperature flange to allow for the flow of the liquid Nitrogen through the loop.
At this point it is essential to use well isolated input hoses because any cold gas entering the liquid Nitrogen pre-cool circuit will reduce the flow substantially due to the much lower density of the gas. The higher the storage pressure the higher the flow as well and the shorter the pre-cool time. To further improve the cool down time, increase the pressure of the internal pre-cool circuit temporarily. By doing so, most of the cooling power of the PTR cooler is used to cool the internal assemblies as the heat load from the shields is cooled by the liquid Nitrogen pre-cool.

When the colder of the PT1 and PT2 stage temperatures is < 85K, stop the liquid nitrogen pre-cool by closing the valve of the storage dewar. Then close the valves on the liquid Nitrogen pre-cool loop as well and disconnect the storage dewar and transfer line.

Connect a suitable rotary pump to the liquid Nitrogen circuit using the supplied KF connector. Start pumping and open the circuit to the fore pump and evacuate the pre-cool circuit to approx. $10^{-3}$ mbar. Then close the valves and disconnect the fore pump.

Set the pressure of the internal pre-cool circuit according to the value in the registry which is done by restarting the 'start pre-cooling' or 'full cool down' (see below) in the software menu or by manually pre-cooling if preferred.

## Use of Liquid Nitrogen cold traps

The Triton$^{200}$ system is equipped with an external liquid nitrogen cooled "cold-trap". This is used for removing contaminants from the returning $^{3}He$ to prevent blockages of the mixture circulation loop to give reliable operation of the system.

Before using the trap it should be cleaned by attaching it to a vacuum pump via the KF flange to quick-connect adaptor supplied with your system. Pump the trap to below $10^{-2}$ mbar while warming it gently (the temperature of the trap should not exceed 100°C).

The trap should then be connected in the $^{3}He$ circulation path between the port on the GHS and the "Condenser Line" port on the top of the dilution unit. The connections are detailed in Figure 12 below.

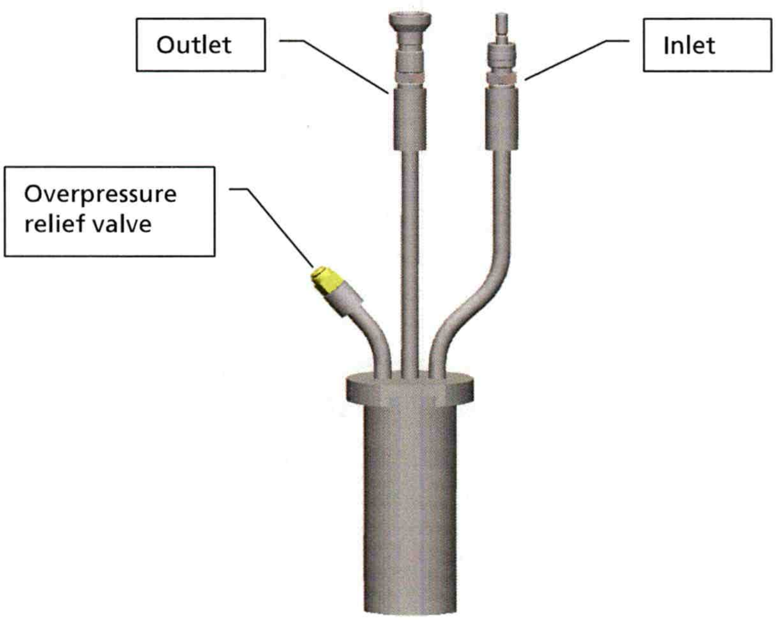



**Figure 12 Liquid Nitrogen Cold Trap**

The gender of the quick connects used on the cold trap should prevent it from being connected incorrectly.

The cold trap should be lowered slowly into the liquid nitrogen dewar and left to cool. During normal operation the nitrogen dewar will require re-filling every few days.

At the end of a run it is very important that you do not allow the cold trap to warm up unattended: if contamination as been caught in the trap this will evaporate as it warms and may cause a significant overpressure inside the trap. The trap is fitted with an over pressure relief valve – but this should not be relied upon to protect the system.

If the trap is to be warmed then you should first ensure that all mixture has been pumped back to the dump before disconnecting the trap from the system. It should then be attached to a vacuum pump via the KF flange to quick-connect adaptor supplied with your system and pumped on as it is allowed to warm. Once back at room temperature the trap can be baked out as described above.

## Start up the Control Software

The dilution refrigerator software is used to control and monitor the dilution refrigerators from Oxford Instruments. The software can be used to control the system manually or with full automation. Data logging and system status logging are included with the standard installation package. This section deals with the operation of the Dilution Control software. Topics regarding the installation and updating of the software are dealt with elsewhere.

To start the software, double-click on the icon. You will find this icon on the desktop or in the VeriCold folder. While the software boots, it searches for and initialises all the necessary instrumentation. It also starts the data logging and system logging automatically. This process shows a small progress dialog window during the time it takes to complete. If any device could not be located, and therefore, initialised, the dialog prompts the operator. You may click OK to continue the initialisation routine but the problem must be investigated for correct operation of the fridge.

> If a device fails to initialise, check that it is switched on and that all appropriate signal cables are connected (see Figure 10).

After the progress dialog disappears the message in the status bar at the bottom of the window shows 'ready' indicating that the software is now ready to be used. A new data log has been created and the data logging has started. All relevant temperatures and pressures are now being logged.

### Software Display

The software's graphical user interface displays a standard window containing a menu bar at the top, a schematic gas-handling circuitry plan with valves and pumps and the status bar at the bottom of the window.

*The main dialog*

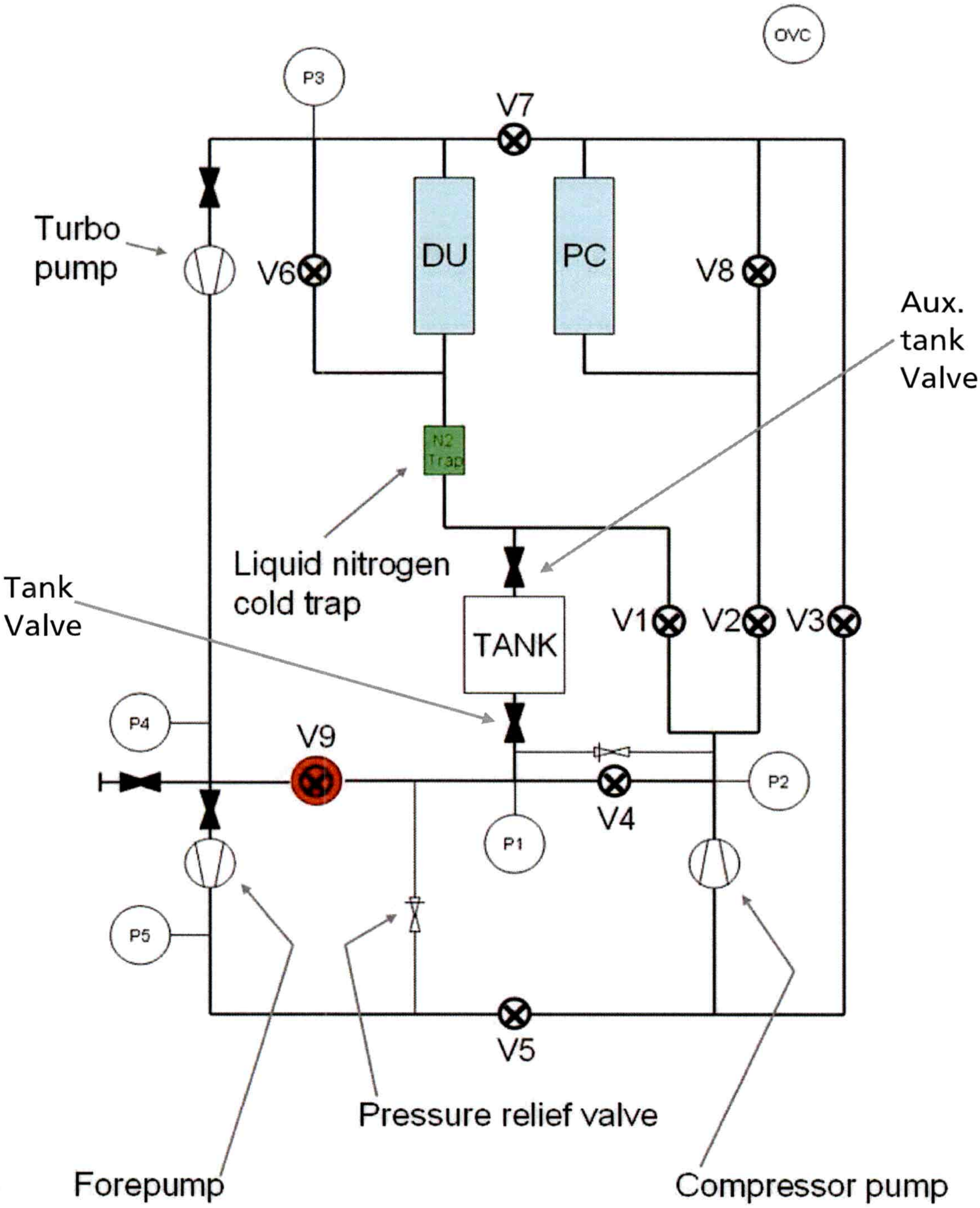



**Figure 13 The Main control dialog layout**

The main view (similar to Figure 13) of the gas-handling shows the circuitry including all controllable valves, the (gas-handling) KNF compressor switch, the fore-pump switch, the turbo-molecular pump, the regulation valve, and various pressure sensors. The display is an active surface and can be used to control the instrument manually.

During normal operation the tank valve should be open but **the auxiliary tank valve should remain closed.**

#### Opening & Closing Valves

The software-controllable valves are shown using the following standard representation:

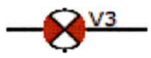



**Figure 14 Active valve symbol (state = closed)**

Clicking on the representation of a valve will toggle it open or closed. Right-clicking on a valve will show a small context menu from which the valve can be forced open or closed (Figure 15). The current state of a valve is indicated by its colour: Red means that the valve is currently closed; green means currently open; yellow means that there is discrepancy between the valve's current measured state and its command state, i.e. if the valve has received a close command but remains open, the valve will be shown in yellow. The state of a valve can also be seen by hovering the mouse over its representation and reading the tool-tip that then appears.

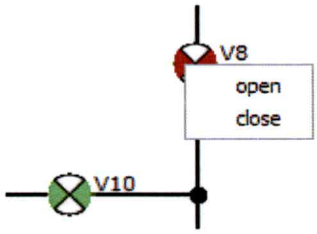



**Figure 15 Force open or closed menu**

The KNF compressor and forepump switches are also shown on the circuitry schematic.. As with the valves, the state can be toggled by clicking or using the context menu after a right-click. Again, the current state of each switch is indicated by its colour and its pop-up tool-tip.

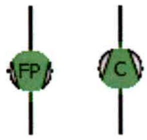



**Figure 16 Forepump and KNF compressor active controls (state = ON)**

The turbo-molecular pump is essentially the same i.e. it can also be toggled on and off, but some extra information regarding speed and power consumption is shown when the mouse is hovered over its representation.

Figure 17 Turbo pump active control (state = ON)

**Pressure Measurements**

The data from various pressure measurements in the system are represented by white circles in the main view. The abbreviated name of the sensor is shown inside the circle and the current pressure is shown in text nearby. When the mouse is hovered over the sensor representation, a small graphical visual aid is displayed which shows the relative changes in pressure over the last minute.

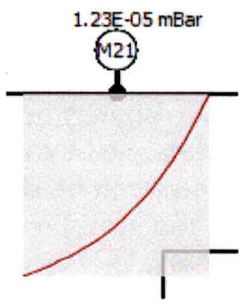



Figure 18 Instantaneous pressure plot showing recent changes in pressure

| Pressure gauge | Location | Measurement range |
|---|---|---|
| P1 | Condensing line | 10 Atm. – $10^{-1}$ mbar |
| P2 | Helium storage tank | 1 Atm. – $10^{-1}$ mbar |
| P3 | Turbo inlet pressure | 1 Atm. – $10^{-3}$ mbar |
| P4 | Forepump inlet pressure | 1 Atm. – $10^{-1}$ mbar |
| P5 | Forepump exhaust | 1 Atm. – $10^{-1}$ mbar |
| OVC | OVC | 1 Atm. – $10^{-8}$ mbar |

Table 3 Pressure gauges shown on the main control dialog

**The Regulation Valve – V9**

The user can also control the regulation valve operation by right-clicking on its representation. A context menu appears:

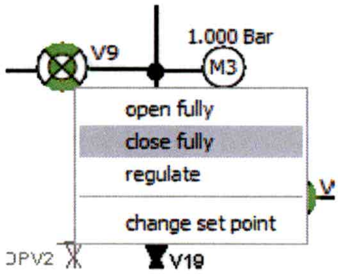


**Figure 19 Regulator valve control menu**

Here, the user can open or close the valve fully, which means regulation is not active. After choosing 'regulate' the valve will adjust the gas flow so that pressure at P2 is maintained near the regulation set pressure. The set point can also be set using this menu, in which case the user is prompted for input.

**Enabling the View**

After an extended period of inactivity, the view is changed to a non-interactive pictorial representation of the system. Several key temperatures are shown on a schematic but the user can no longer interact directly with system. The interactive view can be re-activated from the "Extras" menu (Figure 24) by selecting "Enable the View".

**The Main Menu bar**

The user can also use the menu functions collected in functional menus in the menu bar at the top of the main dialog for starting or stopping automation tasks, showing the thermometry, controlling logging and scheduling etc. Each functional menu is described below.

**The "Refrigerator" menu**

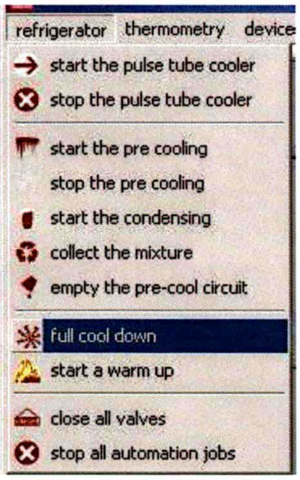


**Figure 20 Refrigerator automated tasks menus**

With this menu the user can start and stop all the major automated tasks. The 'start/stop the pulse tube cooler' menu entry will turn on/off the pulse tube compressor and rotary valve. This will not start or stop the pre-cooling or condensation or any other automatic task.

**Pre-cooling**

Choosing the 'start the pre-cooling' entry will initiate an automatic cooling process which will start by checking all the system devices are present and initialised. If the PTR is not running it is switched on and the rotary valve started. It then checks the cool-down channel sensor (as defined in the thermometry set-up (see Thermometry), this is typically the M/C cernox) and compares it with the registry threshold 'finish when temperature of cooldown is' (see the Registry Parameters table on page 119). If the M/C temperature is above the threshold the system begins adjusting the pressure in the pre-cool loop based on the cool-down channel temperature, the temperature intervals defined in the registry parameters, the pre-cool loop pressure defined by P2 and pressure set-points in the registry parameters. In general, the pre-cool loop pressure is reduced as the system cools to reduce the room-temperature gas heatload on the PT2 stage

Pre-cool loop pressure reduction is achieved by running the forepump and pulsing valve V7 allowing small amounts of gas to pass into the low-pressure Still circuit until P2 $\leq$ pressure step *n*. The extracted mixture is returned to the tank (via the forepump and compressor pump) by opening V4 and V5. Once the target pressure is achieved V4, V5 and V7 are closed and the forepump is switched OFF.

Pre-cool loop pressure increase is achieved by closing V3 and opening V5 and V2. Then the forepump is switched on and V9 is pulsed to increase the pressure measured at P2. When P2 $\geq$ pressure step *n*, the sequence closes V9 and V5 and opens V3 to allow the gas to circulate at the new pressure.

When the temperature of the system drops below the *n*th temperature threshold (see Cooldown from Room temperature on page 119), the pressure set-point in the circuit will be lowered to the *n*+1th entry, the loop pressure is re-adjusted. This process continues until the final temperature is reached.

#### Emptying the pre-cool loop

The 'emptying the pre-cool circuit' option first checks that the cool-down channel has cooled below 'finish when temperature of cooldown is' (see the Registry Parameters table on page 119). If not, the pre-cool process begins. If the system is cold, the pre-cool loop is evacuated by first closing V2 and opening V8 and V4 to allow the compressor pump to remove the bulk of the gas from the pre-cool line. Then V3 is closed and V5 and V7 are opened and the forepump is switched on. The turbo is switched on when P3 < 'pressure threshold before turning the turbo on' (see the Registry Parameters table on page 119). The pre-cool line is considered empty after the turbo has been on for 'timeout waiting for low pressure threshold' seconds (see the Registry Parameters table on page 119).

#### Condensing

Choosing the 'start the condensing' menu entry initiates the condensation process. After device checks and checks that the Still and M/C temperatures are below 20K the process starts by opening V1 and V5 and switching on the forepump and compressor pump. Next V9 is pulsed to remove mixture from the tank *via* the forepump and add it to the condensing line. This continues until the pressure measured at P2 is equal to the set point value for condensing. The pressure set-point for this valve is in the registry (see the Registry Parameters table on page 119) along with the other thresholds and time outs.

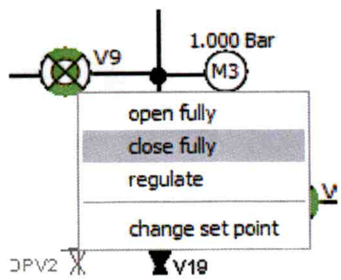



**Figure 21 Forcing the regulator valve to close**

The process stops when the tank pressure falls below the registry target. After the condensing process is complete, the turbo-molecular pump and the still heater are turned on and the unit begins to function as a fridge.

#### Collect the mixture

The 'collect the mixture' function will start heating the still and mixing chamber while pumping the gas back into the tank. After this routine finishes all the valves are closed and the pumps turned off.

**Full cooldown**

A 'full cool down' combines these routines in the pre-cooling, evacuate then condense sequence. The system will pre-cool to 10K in about 24 hours. The cycling and cooling to base temperature elapsed time depends on the thermal mass on the mixing chamber and the heatloads introduced by experimental services.

**Warm-up**

The 'start a warm-up' task analyses what state the system is in, then takes steps to remove the mixture from the dilution unit to prevent pressure build up within the unit. It heats the Still and M/C and performs a similar routine to the 'collect the mixture' routine but stops the PTR and rotary valve.

To remove the mixture from the system manually at the end of a run, first close V9 and open V4 and wait for P1 and P3 to read (approximately) the same pressure. V1 should then be closed. The mixture is now being returned back to the tank using the "Single Shot" technique. With no heat load on the system removing the mixture in this way could take many hours.

If you wish to remove the mixture more quickly, first turn off the turbo pump close V9 and open V4 and wait for P1 and P3 to read (approximately) the same pressure. V1 should then be closed. Once the turbo pump has slowed open V2 and V3. This will circulate mixture around the pre-cool circuit. As mentioned earlier in this manual, shorting the pre-cool circuit in this way can place a large heat load on the dilution unit. Monitor the pressure in the still on P3 and the forepump exhaust pressure P5, if these rise above 50 or 600 mbar respectively then close V2. As these pressures recover V2 can be opened and closed again. With experience the user can determine the optimal sequence for their system.

Once the bulk of mixture has been returned to the tank, V2 and V3 should be closed and V8 and V7 opened to allow the fridge pumps to pump on both the dilution unit, pre-cool circuit and the liquid Nitrogen cooled external trap. When P3 reads below 1 mbar the turbo pump can be restarted to remove the last of the mixture.

Once the mixture has been returned to the tank the PTR can be switched off and the system can be left to warm to room temperature. If the system is not intended to run again in the near future, then it can just be left to warm (very) slowly on its own. However, the rate of warming can be increased by softening the vacuum space if a fast turn around is required.

#### Softening the Vacuum Space

Once the coldest part of the system is about 80 K, the vacuum space may be softened. The vacuum space should *only* be softened with dry, clean nitrogen – the boil-off from a transport dewar is ideal. Use a gas bladder to transfer a small quantity of gas from the storage dewar. Never connect a high-pressure gas cylinder to the vacuum space.

If you intend to soften the vacuum space do not leave the system unattended as it warms – you should monitor the pressure to ensure it does not rise too high, however the OVC is fitted with a pressure relief valve.

The most rapid warming may be achieved by submerging the OVC pumping line into an open container filled with liquid nitrogen and *slowly* opening the OVC valve once the coldest part of the system is above 80K. The low pressure in the OVC will "pump" on the liquid causing it to boil and fill the vacuum space with clean nitrogen gas. Once the system is at atmospheric pressure the valve should be left open – this way any increase in the OVC pressure as the system warms can be safely vented back though the liquid "one-way valve".

#### Interrupting Automated jobs

At any stage during any of the automated jobs the user can choose 'stop all automation jobs' in order to halt the automation. Choosing this option will not undo any task, but will interrupt it. The user can then start or re-start an automation task or take manual control of the system.

The current status of the automation task is shown in the status bar at the bottom of the window.

#### The "Thermometry" menu

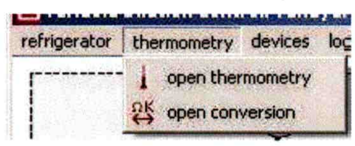



**Figure 22 Thermometry menu**

This menu has 2 options. 'Open thermometry' opens the thermometry dialog. The standard system is supplied with the LakeShore AC370 resistance bridge and its control dialog is shown and described below (Figure 30) (see the Thermometry section). The 'open conversion' option allows the resistance to temperature conversion to be checked for any of the DLL style sensor calibration curves supplied with the system.

The "Logging" menu

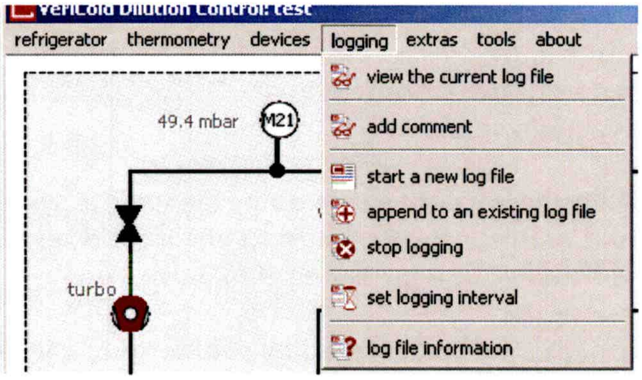



**Figure 23 Logging menu**

This menu can be used to control the data logging. The current log file can be viewed by choosing the first menu entry. The VeriCold log file viewer will be started and it will load the current log file using the Log File Viewer. With 'start a new log file' the user will create a new file into which the system will be then logged. With 'append to an existing file' the user can append the data on to an older file. This may be useful to preserve continuity of data. 'stop logging' will close the log file and stop the data logging. With the entry 'set logging interval' the user can adjust the frequency of the data in the log file.

The "Extras" menu

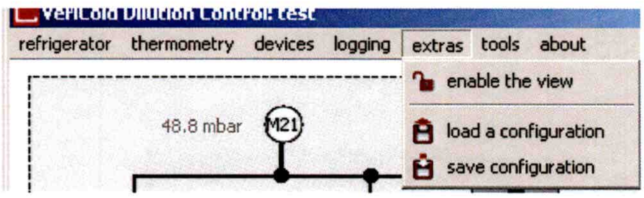



**Figure 24 Extras menu**

This menu can be used to re-enable the active control panel if it has timed-out to disabled. The 'save configuration' option will export the registry entries relevant to the system to 2 files; "SystemName Complete.reg" and "SystemName Thermometry.reg" in C:\Vericold\init\". The load option allows retrieval of these settings files.

**The "Tools" menu**

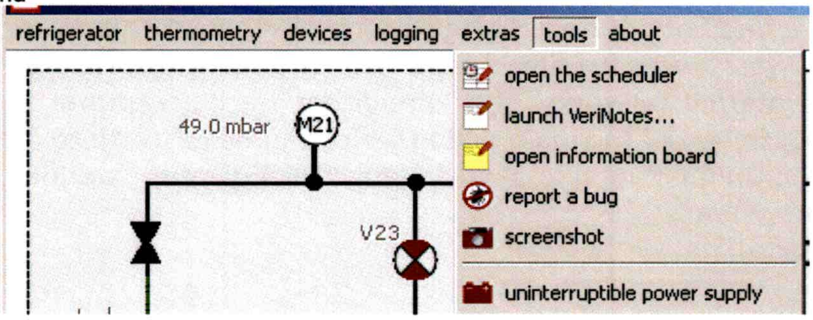



**Figure 25 Tools menu**

This menu contains some peripheral tool options. The scheduler is described below (see The Scheduler section). VeriNotes (Figure 26) is a useful tool which encourages operators to make an on-screen log of operations, adjustments and observations made on the system during the full operation or experiment cycle.

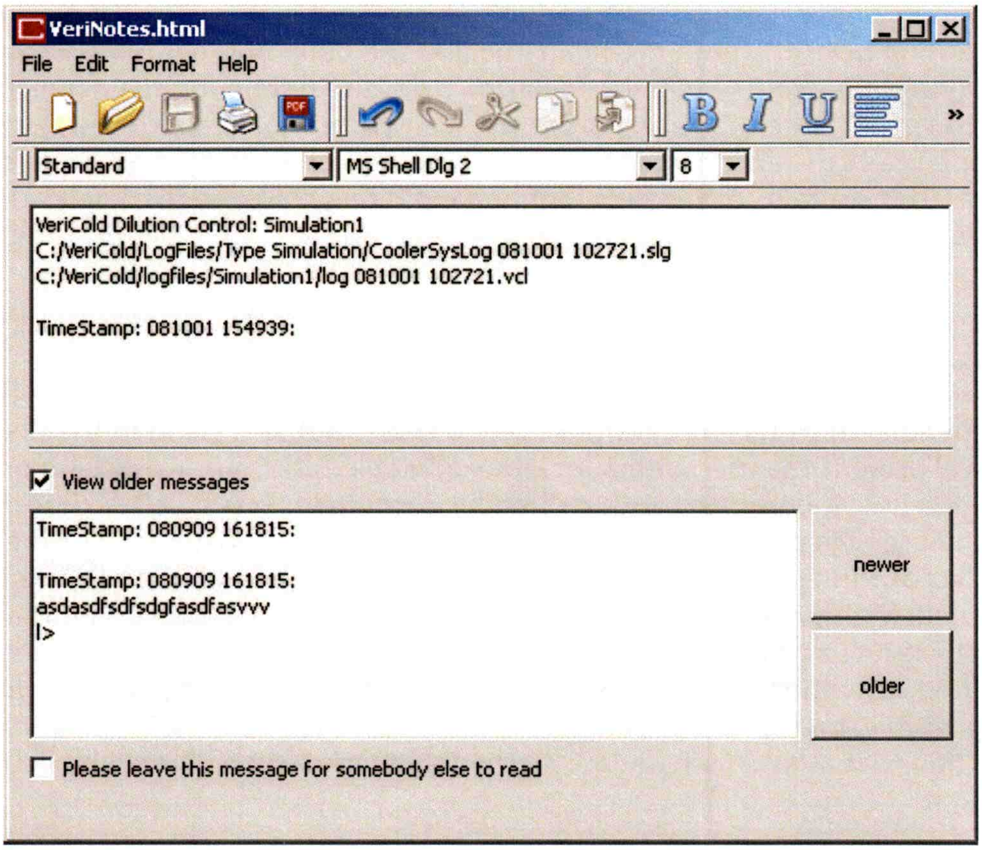



**Figure 26 VeriNotes dialog with "older messages" pane enabled**

The "report a bug" brings up a dialog to send observed software errors to the VeriCold software teams ftp site. At the time of writing this facility is only available on internal networks. The "screenshot" facility captures an instantaneous image of the main dialog which can be pasted into documents, e-mails etc. The Uninterruptable power supply (UPS) gives the option to configure a UPS for the system.

**The "About" menu**

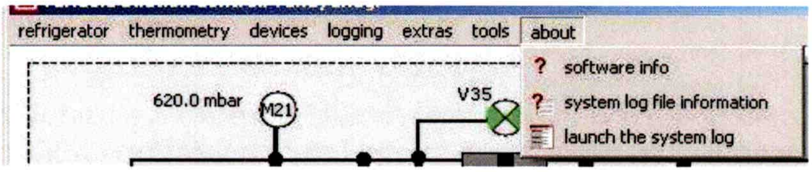



**Figure 27 About menu**

This menu gives background information on the application. The "software info" option gives the path the file name and the build number or build date of the application. The "system log file info" gives the system log file name, its path, its size and the time and date it was last written to. "launch the system log" opens a text viewing window to read the real-time contents of the system log file. This contains commands sent and error flag status of the application and is a useful tool to diagnose control faults. This file should be returned to Oxford-VeriCold when reporting an error.

**The Scheduler**

With the scheduler, a user can execute an automated task at some future time. The scheduler appears empty when opened first. Double-clicking in the first task field will present the user with a list of schedulable tasks. After choosing one of these, the user is presented with a calendar entry field. Finally, after choosing a date the user can pick a time for the task. When the user changes this time and clicks out of this entry box, the entry fields are no longer editable and the task is scheduled. Multiple tasks can be scheduled but the user must take care that they are not executed concurrently.

The scheduler window cannot be closed if there are scheduled tasks - it will remain visible, on top of all running applications. This prevents the user from forgetting that a task is scheduled. A scheduled task can be deleted by double-clicking it.

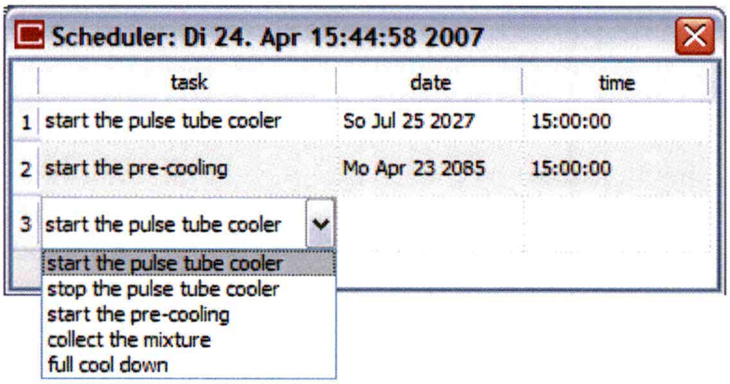



**Figure 28 The automated task scheduler**

**The Status Bar**


**Figure 29 The status bar**

The status bar at the bottom of the main window shows the status of the running, or the exit status of the most recently completed automation task.

### *Thermometry Dialog*

Upon opening the thermometry user interface, the user will see the following:

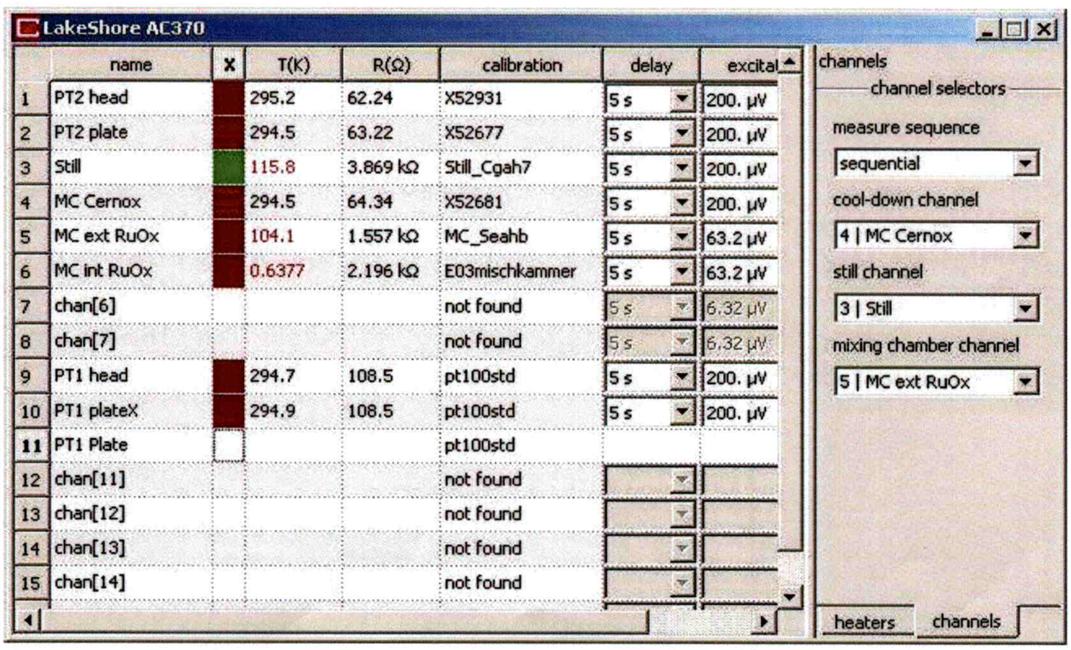



**Figure 30 The main thermometry dialog**

The view shows the resistance bridge channels in numbered rows. The first column lists the user-assigned channel names. The user can rename any channel by double-clicking on its field. The resistance bridge measures its channels sequentially, and the second column shows those channels which are enabled, i.e. scheduled to be measured by the bridge. A red field indicates that the channel will be measured as part of the sequence, i.e. the channel is enabled. A measurement typically takes several seconds and a green field indicates which channel is currently being measured. A disabled channel is shown empty and the row is 'greyed-out'. The user can enable or disable channels by double-clicking this field.

The next column, titled 'T(K)' shows the temperatures for each channel. When the mouse is hovered over any of these cells, the current rate of change of temperature is shown in a 'tool-tip' flag. The resistances follow in the next column, followed by the calibrations used for each channel. Generally, each thermometer has its own calibration file which the software uses to convert resistance to temperature. The user can change the calibration of a thermometer channel by double-clicking on one of these fields and choosing a suitable calibration file. The options are

1. VeriCold thermometry calibration, *.dll.
2. LakeShore coefficient file, *.cof.
3. VeriCold coefficient file, *.vcc.
4. Other – contact Oxford / VeriCold for advice

Two further columns controlling the settle time (delay) and the excitation used when measuring the resistances are shown. All of these settings are set at Oxford Instruments and should not normally need to be changed. However, the user may want to change the excitation if effects due to resistance self-heating are observed.

The right hand side of the view contains a 'stacked tab', the first of which is entitled 'channels'. The user can control the measurement sequence with the first drop-down selection box: All of the enabled channels can be measured in sequence (the normal mode). Or all measurements can be stopped. This can be helpful if the temperatures do not need to be recorded, e.g. if the system is at open at room temperature. The resistance bridge uses relays to multiplex the resistances. Unnecessary switching of these relays can shorten their lifetime.


**Figure 31 Channels panel of the thermometry dialog**

The other drop-down boxes can be used to identify certain channels necessary for the software automation. Specifically, there are fields to specify the 'cool-down channel', the mixing chamber channel and the still channel.
It is important for the software automation that these channels be set correctly and enabled. The user can disable any of these channels but will be warned when doing so. Further, automated tasks may not start properly if any of these channels are disabled. All of these channels are set at Oxford-VeriCold and should not normally need to be changed.

The software can control two heaters: the 'Still' heater and the mixing chamber (M/C) heater. The next tab, entitled 'heaters' provides access to these heaters.

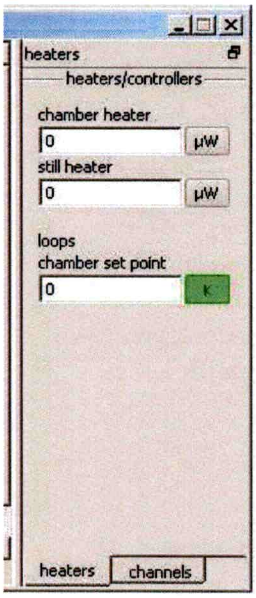



**Figure 32 Heaters panel of the thermometry dialog**

A number, in micro-Watts, can be entered into the 'chamber heater' or 'still heater' field. When the button next to the field is pressed the heater is switched on with this power. A user entered power will be updated with a more exact number from the resistance bridge. Note that changing the heater resistances will require a change in the software settings for the power calculation to be accurate.

It is possible to adjust the heater power with the temperature monitoring in scanning mode and the heater output ON. This is not advisable, particularly for the M/C heater. When setting a new heater power both the range and proportion of the applied range must be set. On some occasions there can be a delay between these settings. The range is set first then the proportion. There could be tens of seconds between these two events which may result in large powers being dissipated in the M/C heater unintentionally. To set a new heater output: -

1. Set the 'measure sequence' to 'single measurement'.
2. Switch off the heater output.
3. Set the new heater power.
4. Switch on the heater output (check that new range and proportion update on the bridge front panel almost immediately).
5. Set the 'measure sequence' back to 'sequential'.

> If the M/C heater has been disconnected with the heater ON, the output voltage of the resistance bridge (LakeShore) will drift up to the rail voltage even if the requested output is 0% (requesting 0% does not switch off the output). Once the voltage hits the rail the LakeShore firmware disables the heater output and it stays disabled until the voltage comes back within range. The output can remain diasbled for a long time after the M/C heater is reconnected as only the small leakage current (typically of order 10nA) will bring the voltage from the output filter back in range. If this problem is observed, switching off the bridge for about 60 seconds, if this is possible, should clear the problem.

***Remote Control options***

In addition to the remote desktop functionality available in Windows XP, the system pc also has TightVNC server installed which starts when the pc is booted. If a TightVNC client is installed on a remote pc, this pc can be used to take full control of the system pc.

***Remote Access Protocol***

Oxford Instruments also provides access to its software via the standard TCP/IP protocol. The server listens on port 22518, which may be changed by the user (see registry settings on page 119). The user can send text commands to this port. The software can be also be configured to not listen on any port and to not receive incoming connections.

A subset of commands is listed below. Note that these commands are preliminary and are subject to change. For information regarding protocol always refer to the most recent manual.

'valve' plus a number with 'open' or 'close' will open or close the named valve. E.g. user string 'valve 1 open' or 'open valve 1' will open the valve V1. The Dilution software will answer accordingly with 'valve 1 open'.

Use 'turbo' with 'on' or 'off' to control the turbo. Response: 'turbo pump on'.
Use 'comp' with 'on' or 'off' to control the KNF compressor. Response: 'compressor on'.
Use 'fore' or 'pump' or 'forepump' with 'on' or 'off' to control the forepump. E.g. 'forepump on' or 'fore on'. The response will be 'forepump on'.

'help' or '?' will be answered with a description of some of the more useful commands.

Status commands:
'status' will return the general state of the cooler, including the position of the valves.

'thermometry' or 'temperatures' will return a description of the thermometer setup including the most recent measurements. The response to this command is structured as follows:
The first part of the response is the keyword `'Thermometry:'`. This is followed by,
`'channel'` which is followed by the channel number.
`'name'`, the user-assigned channel name
`'calibration'`, the resistor's calibration file DLL
`'enabled'`, followed by a '0' (zero) or '1' (one) indicating whether the channel is enabled (1) or disabled (0).
`'assigned as'` followed by the software description of the channel or `'not assigned'` if the channel has no particular relevance for the automation.
`'time'`, followed by the time of the last measurement on the channel. This number is in seconds elapsed since the 1st of January 1970.
`'resistance'` followed by the resistance of the channel in Ohms.
`'temperature'` followed by the temperature of the channel in Kelvin.

Finally, after all channels have been listed, the heater powers are given:
`'mixing chamber heater power (Watt): '`
`'still heater power (Watt): 0.0'`.

The user must parse through this status text to find the information needed. A colon ':' separates a keyword from its information, and a semi-colon ';' separates keywords: 'keyword1: info1; keyword2: info2;' etc. The information from each channel is separated by a new line character '\n'. A full example of a status is given below:

```
Thermometry:
channel 1; name: 4K X41236; calibration: C:/VeriCold/thermometry/X41236.dll; enabled: 1;
assigned as: 4K channel; time: 1180434649.0; resistance: 51.726; temperature: 291.863;
channel 2; name: 4K Platte X38078; calibration: C:/VeriCold/thermometry/X38078.dll; enabled:
1; assigned as: not assigned; time: 1180434660.0; resistance: 57.8805; temperature: 292.477;
channel 3; name: CA 08 Still; calibration: C:/VeriCold/thermometry/CA08.dll; enabled: 1;
assigned as: still channel; time: 1180434671.0; resistance: 3920.09; temperature: 35.6848;
channel 4; name: MK SF21; calibration: C:/VeriCold/thermometry/SF21.dll; enabled: 1; assigned
as: not assigned; time: 1180434682.0; resistance: 1461.51; temperature: 331.153;
channel 5; name: MK X43043; calibration: C:/VeriCold/thermometry/X43043.dll; enabled: 1;
assigned as: cool down channel; time: 1180434616.0; resistance: 56.7267; temperature: 291.649;
channel 6; name: MK in; calibration: C:/VeriCold/thermometry/E02mischkammer.dll; enabled: 1;
assigned as: mixing chamber channel; time: 1180434626.0; resistance: 1024.31; temperature:
7.73396;
channel 7; name: chan[6]; calibration: C:\VeriCold\Thermometry\none.dll; enabled: 0; assigned
as: not assigned; time: 0.0; resistance: 0; temperature: 0;
channel 8; name: chan[7]; calibration: C:\VeriCold\Thermometry\none.dll; enabled: 0; assigned
as: not assigned; time: 0.0; resistance: 0; temperature: 0;
channel 9; name: 77K pt100; calibration: C:/VeriCold/thermometry/pt100std.dll; enabled: 1;
assigned as: 77K channel; time: 1180434632.0; resistance: 107.292; temperature: 291.681;
channel 10; name: 77K -2 pt100; calibration: C:/VeriCold/thermometry/pt100std.dll; enabled: 1;
assigned as: not assigned; time: 1180434638.0; resistance: 107.374; temperature: 291.891;
```

```
channel 11; name: chan[10]; calibration: C:\VeriCold\Thermometry\none.dll; enabled: 0;
assigned as: not assigned; time: 0.0; resistance: 0; temperature: 0;
channel 12; name: chan[11]; calibration: C:\VeriCold\Thermometry\none.dll; enabled: 0;
assigned as: not assigned; time: 0.0; resistance: 0; temperature: 0;
channel 13; name: chan[12]; calibration: C:/VeriCold/thermometry/X38051.dll; enabled: 0;
assigned as: not assigned; time: 1177688924.0; resistance: 4668.12; temperature: 1.98619;
channel 14; name: chan[13]; calibration: C:/VeriCold/thermometry/X38051.dll; enabled: 0;
assigned as: not assigned; time: 1177688930.0; resistance: 469670; temperature: 1.40001;
channel 15; name: chan[14]; calibration: C:/VeriCold/thermometry/pt100std.dll; enabled: 0;
assigned as: not assigned; time: 1177688936.0; resistance: 9.9986; temperature: 53.6035;
channel 16; name: chan[15]; calibration: C:/VeriCold/thermometry/pt100std.dll; enabled: 0;
assigned as: not assigned; time: 1177689005.0; resistance: 0.00096117; temperature: 31.1308;
mixing chamber heater power (Watt): 0.0;
still heater power (Watt): 0.0;
```

### *Remote Access Programming*

Using LabView you can connect to the Port by using the TCP Open Connection vi. If you are connecting from a remote pc you must supply the IP of the machine on which the VeriCold Dilution Control is running and the port. Use the TCPWrite vi to send the text commands and the TCPRead vi to read the responses from the port. The diagrams below give a very simple read – write example:

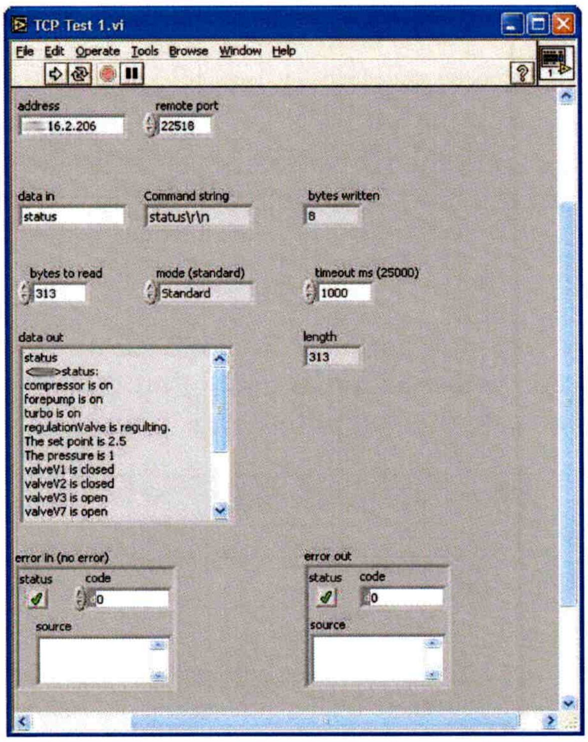



**Figure 33 Example vi front panel**

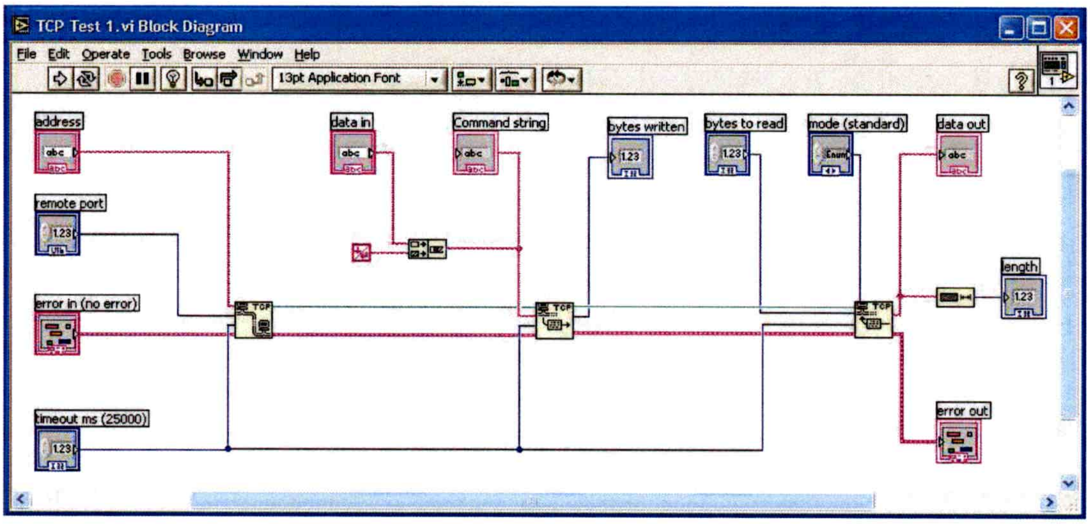



Figure 34 Example vi block diagram

You will need to parse the text responses to extract the data you need. Please refer to the National Instruments website and the LabView handbooks for more information and examples.

### *Error Message Dialogs*

**Messages shown during software boot-up:**

If a message is shown during the software boot-up sequence, it is usually because one or more of the machines could not be identified or initialised properly.

Generally, if you see a message during software boot-up saying that something could not be 'initialised', you should make sure that the device in question is turned on and connected to the computer.

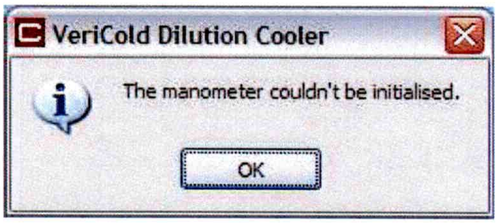



Figure 33 Manometer "not found" error dialog

If you encounter a message similar to the following, it means that the software has not been configured to use the named device. To use the instrument you will need to change the relevant software settings in the registry (see the Registry Parameters table on page 119).


**Figure 34 Regulator valve "not found" error dialog**

Messages Shown at Any Time

If channels necessary for an automation task are not enabled, the task will present a warning with a message similar to the following:


**Figure 35 Thermometry channel not enabled or not configured error dialog**

The task will not be executed. You should open the thermometry panel and enable or assign the named channel before proceeding.

If the compressed air sensor has been found and identified correctly, the following message means that the compressed air pressure may not be sufficient to switch the valves. The system will automatically shut down the gas-handling system. You must ensure that compressed air is connected properly before continuing.

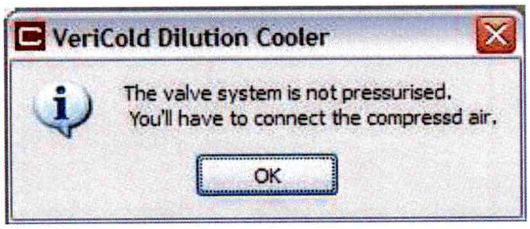



**Figure 36 Compressed air pressure at GHS is too low error dialog**

If the internal software monitoring of the system encounters a situation which may result in damage to the system, it will shut down the automation and will try to put the system into a safe state, taking the necessary steps to avoid damage to the system parts. The turbo, fore-pump or the KNF compressor may be turned off, and valves may be opened or closed.
The following message will then be presented to the user.

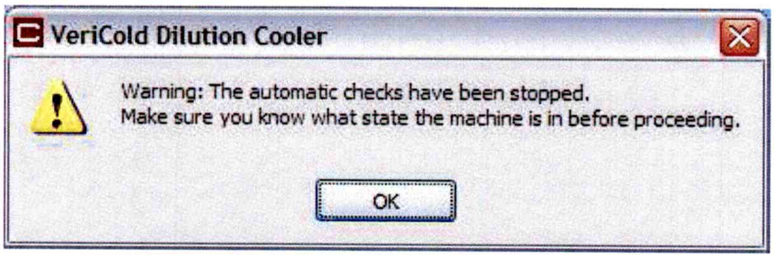



**Figure 37 Follows on from Figure 36**

This message is accompanied by a notice to the user containing more detailed information.
The user must rectify the source of the problem before continuing.

## Temperature Control

This section should be read in conjunction with the manual for the Lakeshore 370 bridge that supplied with your system documentation.

Closed loop control of the M/C heater is achieved by downloading the M/C sensor calibration (*.340 see below) to the resistance bridge and sending a temperature set-point from the dilution control application to the bridge. For convenience, it is desirable to display both the measured resistance and the control channel temperature on the bridge simultaneously. To accomplish this press the "Display Setup" button on the bridge and use the ▲ button to change the # of display locations" to two. Then select display location 2 and use the ▲ button again to set this to display the channel you wish to control against (by default the MC sensor channel is 6), then use the ▲ button to set the source to Kelvin and continue pressing enter until you reach the end of the menu and are returned back to the main screen.

The bridge should now display the measured resistance(s) on the left hand side of the display and "NO CURVE" on the right hand side. To assign a curve to that channel press "Input Setup" and use the ▲ button to move to the correct channel, press enter until you see "No Curve" displayed and then use the ▲ button to assign the correct curve to that sensor, then continue pressing enter until you reach the end of the menu.

The bridge should now display the measured resistance(s) on the left hand side of the display and the temperature measured on the control channel on the right hand side. However, if the system is at a temperature outside of the calibration range of the sensor then the "T.UNDER" or "T.OVER" messages will be displayed. Typically the system will be at base temperature prior to temperature controlling, so "T.UNDER" is the most likely message.

In the current version it is necessary to enter the PID values for the control loop from the resistance bridge front panel. The LakeShore bridge has the facility to store a table of PID parameters so that different values can be used over different temperature ranges, referred to as 'zones' in the Lakeshore manual. For details on entering PID values refer to the LakeShore 370 manual, sections 2.10 (for PID theory), 4.11 (for PID setting) and 5.3 (for setting up zone parameters).

Having referred to the LakeShore manual, press the "PID" button and enter appropriate values (these will depend on the nature and heat capacity of your experiment – refer to your system test results for sensible initial guesses).

If the system is currently displaying "T.UNDER" for the channel you wish to control on, it should first be warmed to a sufficiently high temperature such that the sensor is in its calibration range. Press "Control Setup" and ensure that the system is set for "Open Loop" control. In the software panel (see Figure 32) enter a fixed power to apply (typically a few hundred μW will be sensible figure), as the system warms the "T.UNDER" will be replaced with the measured temperature.

Whilst the system is warming you should de-select all resistance channels other than the control channel so that the bridge will only measure the control channel whilst it is controlling. To do this, in the software panel (Figure 30), double click in the box below the column headed "X" for the sensor you want to deselect. When the box is clear (i.e. not Red or Green) then this sensor will not be included in the LakeShore scan. Repeat for all the sensors until only the control sensor is active.

Once the system has warmed sufficiently set the applied power applied back to zero (the system will start to cool, so you must start the temperature control before it cools back below the end of the calibration range).

Press "Control Setup" and use the ▲ button to select "Closed Loop PID", press enter and ensure that the control channel is set to the correct channel, the set-point is in Kelvin and that the current limit is sensible.

Entering a set point temperature in the software (Figure 30) will now update the temperature setpoint on the bridge display.

Use the "Heater Range" button to control the coarse gain of the control loop and to ensure adequate power is available to reach the setpoint temperature (remember the cooling power available in a dilution refrigerator is approximately a quadratic function of temperature).

To stop the temperature control, set the setpoint temperature to 0, and then change the control setup back to open loop. The other sensor channels can now be re-selected in the software and they will then be measured automatically.

## Operation of the integrated superconducting magnet

### Preparing to run the superconducting magnet

Connecting and running superconducting magnets within a system is straightforward, but care must be taken to follow a simple set of instructions to avoid damaging your dilution refrigerator. If your refrigerator has been supplied with a superconducting magnet, the data sheets specific to your system will include the **magnet performance characteristics** sheet (within which the data referred to below is listed).

Prior to running the magnet, ensure that the +ve and –ve leads are disconnected from the magnet power supply and that they are both isolated from ground (i.e. not touching the case of the power supply).

Use a battery powered digital multimeter (viz. a Fluke 110 series) to measure the following :-

- Start to End resistance across the current leads
- Resistance to ground from either the +ve or –ve lead.

The start to end resistance should be equal to the value for the current leads since the magnet will have zero resistance.

The resistance to ground should be >1 MΩ. If the reading is less than this, then carry out a basic inspection to identify where this "short to ground" originates. If the resistance to ground remains < 1 MΩ, contact Oxford Instruments for advice on how best to proceed. Once these magnet checks are complete, re-connect the +ve and –ve current leads to the magnet power supply. Make a thorough check that the earthing connections shown in Figure 9 are in place.

If your magnet is fitted with a persistent switch, then ensure that the switch cable is plugged into the 10-pin Fischer socket next to the current lead terminals on the top plate (see Figure 3). The switch cable has two larger spade connectors that are connected to the screw terminals on the back of the magnet power supply.

- Carry out a resistance check on the switch and wiring before connecting the switch cable to the magnet power supply.

The switch resistance should be equal to the value in the data sheet with a small addition (of the order a few Ohms) for the lead resistance to the top plate and through the magnet support. Once this check is complete, connect the switch leads to the power supply terminals (note that the polarity is not critical).

**Running the superconducting magnet**

The superconducting magnet can be run either in manual or remote mode. Within this document, it is assumed that the user is running the power supply in remote mode using the software provided to run the dilution refrigerator. In order to do this connect the magnet power supply to the computer using the cable provided. Select magnet controller from the devices menu.

> If you wish to operate the magnet from the power supply front panel (or check the internal flash memory settings) please refer to instructions in the magnet power supply manual.

When the magnet is to be run to field, suitable warnings should be put in place regarding the hazards associated with magnetic fields (see section 2).

To control the magnet select **magnet controller** from the **devices** menu to give the control panel shown in Figure 38. If your magnet is fitted with a persistent switch, the heater for this can also be set using the front panel screen.

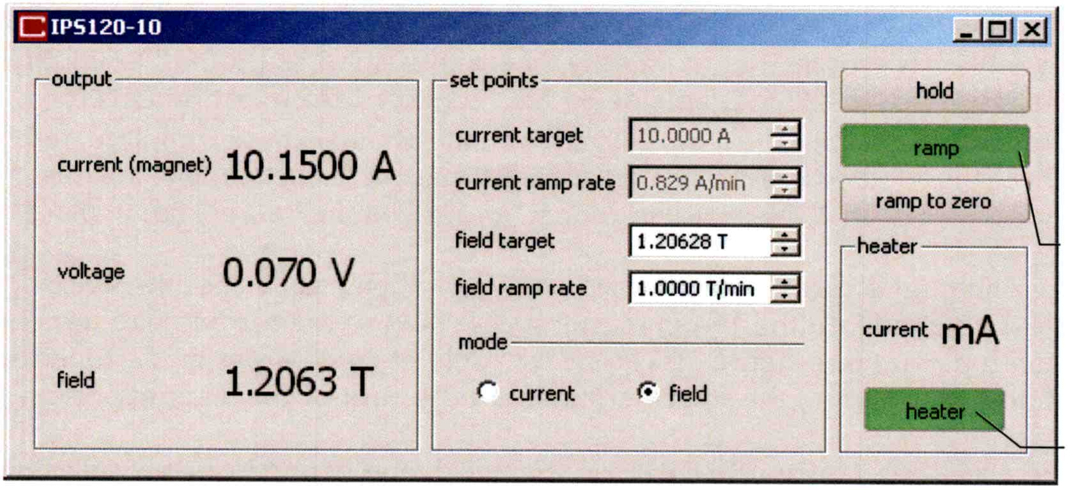



**Figure 38 Superconducting magnet control panel**

To run the magnet to a desired field and put persistent, proceed as follows:

- Select field (control) mode

Current target and ramp rate are now greyed out.

- Set the field target
- Set the field ramp rate
- Click heater to energise the switch heater - wait 60 seconds
- Click ramp

The magnet ramps to the field target.

- Click heater to turn off the switch heater - wait 60 seconds

This puts the magnet in persistent mode at the target field.

- Click ramp to zero

This runs the current in the magnet leads to zero.

> In principle you may now turn off the magnet power supply but this is not normally advisable

To run the magnet to zero or a new field value proceed as follows:

- Set the field target

> This must be the previous persistent field otherwise the power supply will detect an error.

- Set the field ramp rate
- Click ramp

The magnet ramps the current to equal the current flowing in the magnet.

- Click **heater** to energise the switch heater - wait 20 seconds

The magnet power supply now controls the magnet.

- Click **ramp to zero**

This runs the current in the magnet to zero.

- Click **heater** to turn off the switch heater - wait 60 seconds.

### Precautions when running the superconducting magnet

When running the superconducting magnet, it is very important that the peak temperature of the magnet windings does not exceed the critical temperature of the superconductors used. If this happens, the magnet will quench. The quench in a cryofree system is relatively benign since there is no liquid helium to boil off from a magnet helium bath and the pulse tube refrigerator simply carries on cooling. Your system has been carefully designed and modelled so that no damage will occur to the main system components due to the eddy currents in conductive components during a quench. However, it is strongly advised to avoid magnet quenching since some system parts (in particular the turbo molecular pump and the sintered heat exchangers) will experience a pulse of pressure which may reduce their operational life.

Judging when a magnet will quench depends crucially on the "critical surface" of a superconductor. The critical current is dependent on both magnetic field and temperature (see Figure 39) and as the critical surface is approached, the superconductor approaches a quench condition.

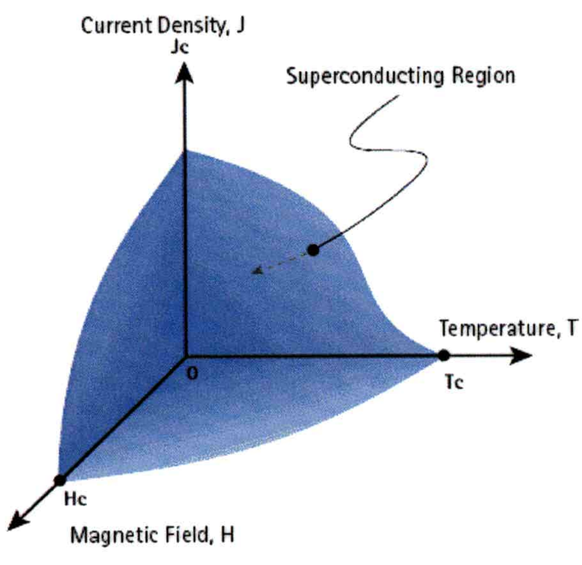



**Figure 39 Superconductor critical surface**

Your system has been carefully designed to match the magnet cooling through to the second stage of the pulse tube to allow magnet operation in all conditions up to a temperature of 5 Kelvin. The guaranteed ramp rates and the maximum field in the magnet characteristics data sheet are well within the T=5K limit.

A spontaneous quench may occur, especially on the first run of a magnet after a thermal cycle. In the event of a magnet quench, the following steps should be taken:

- Turn off the turbo molecular pump
- Check the pressure in the helium storage vessel (gauge M3) to determine if there has been any loss of mixture
- Review peak temperatures
- Repeat the magnet checks detailed in this section
- Run auto condense routine if all dilution unit temperatures are < 10K.

The refrigerator will then return to base temperature.
An example temperature profile from a cryofree refrigerator when running an 8 tesla magnet is given in Figure 40. This example was for a system with no experimental wiring. The 4K plate, magnet top and magnet bottom were all at T=3.35K and the mixing chamber was below 10mK before the magnet was run.

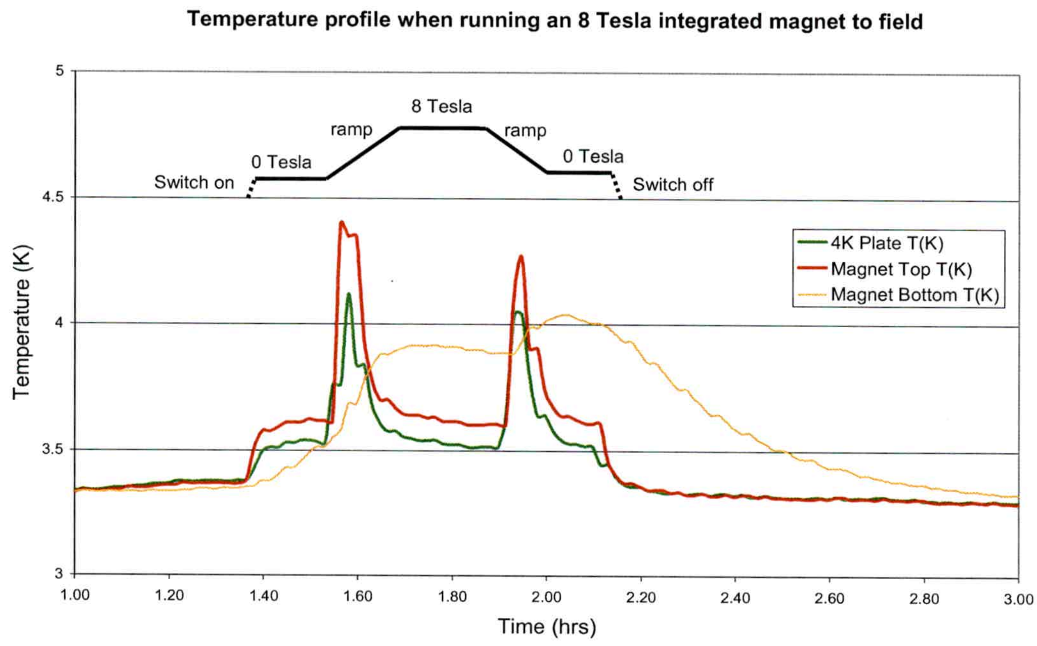



**Figure 40 Typical temperature profile for a Triton[200] with 8 tesla magnet**

The magnet ramp sequence is as follows:

- The superconducting switch was turned on. The magnet top and 4 K plate temperatures increased over a ten minute period to 3.6 K and 3.5 K respectively.
- At the start of the magnet ramp, there is appreciable heating due to AC losses in the superconductors. The magnet temperature peak then subsides and returns to T=3.6 K at the magnet top when held at 8 Tesla field. The magnet bottom sensor exhibits a large thermal lag and is less representative of the superconductor temperature.
- After holding the magnet at field for a short time, the magnet was ramped back down to zero field. Heating again occurs when ramping. The value of the magnet top sensor returns to T=3.6 K.
- The heater to the superconducting switch is then switched off and the temperature of the magnet top and 4 K plate return to 3.35 K. The thermal lag to the magnet bottom sensor is again evident.

Users should note that the mixing chamber will take longer to return to base temperature than the 4 K plate does in the above example. This is due to the eddy current heating effects at very low temperatures. Oxford Instrument can provide advice on this after taking measurements at low fields using a primary thermometer.

The ruthenium oxide temperature sensor on the mixing chamber plate will not read correctly when the magnetic field is applied since this type of sensor has a non-linear magneto-resistance characteristic. Once the magnetic field is set to the desired value, the trend of the mixing chamber back to base temperature can be observed.

# 6. Quick guide

The following table and flowcharts provide a summary of normal operation of the system. Table 4 provides a comprehensive numbered list of tasks; Figure 41 and Figure 42 summarise this information in flowcharts for system with and without magnets, respectively.

| | Task |
|---|---|
| 1. | **CONFIGURE EXPERIMENT** |
| | |
| 2. | **MOUNT SAMPLE** |
| | |
| | **FIRST STEPS** |
| 3. | Run software |
| 4. | Check heaters |
| 5. | Check thermometry |
| 6. | Check GHS |
| 7. | Check pumps |
| 8. | Check compressor |
| | |
| | **BEGIN ASSEMBLY** |
| 9. | Fit still shield |
| 10. | Fit shield tail |
| 11. | Inspect and tape over radiation paths through still shield |
| 12. | Bolt 4K upper shield to cryostat top plate |
| 13. | Bolt 4K middle shield to 4K upper shield |
| 14. | Bolt 4K base plate to 4K middle shield |
| | |
| | **FIT MAGNET** (or skip to 25) |
| 15. | Position magnet on guide rods, raise and fit guide rod support caps |
| 16. | Bolt magnet interface plate to 4K base plate |
| 17. | Check magnet resistance + resistance to ground |
| 18. | Fit magnet thermometers. |
| 19. | Solder current leads together. |
| 20. | Connect magnet thermometry connectors and check readings using Lakeshore resistance using the software. |
| 21. | Strap magnet cabling to magnet. |
| 22. | Connect magnet switch heater. Disconnect at back of IPS and measure resistance +ve/-ve and resistance to ground. Reconnect at IPS. |
| 23. | Disconnect current leads from magnet power supply (rear terminals) and check resistance and resistance to ground. Reconnect |

| | |
|---|---|
| 24. | Check that there is no metal touch between still shield bore tube and magnet. |
| | |
| | **FINISH ASSEMBLY** |
| 25. | Bolt 4K lower shield to 4K upper shield |
| 26. | Bolt lower PT1 shield to upper PT1 shield |
| 27. | Bolt lower OVC to upper OVC |
| | |
| | |
| | **PUMP SYSTEM ( & begin cooldown)** |
| 28. | Pump and bake liquid nitrogen cold trap |
| 29. | remove any condensed gases from previous run |
| 30. | Pump out OVC |
| 31. | Begin cooling |
| 32. | Leak test and continue pumping |
| 33. | Close hand valve on top of cryostat |
| | |
| | **COOL down and run system** |
| 34. | Control temperature |
| 35. | Control field |
| | |
| | **WARM system to room temperature** |
| 36. | Hit warmup button (returns mixture to dump, turbo evacuates mixture from m/c etc) |
| 37. | When thermos (m/c cernox) above 20K Check dump pressure same as before run- M3 |
| 38. | When Pressure in front of turbo < 10-3mbar (M21)? Use software to turn off all pumps (turbo, adixen, KNF) |
| 39. | Use software to Close any open valves |
| 40. | Close turbo gate valve (on top of cryostat) |
| 41. | Heat PT if faster warmup required (needs user psu) |
| 42. | Soften OVC vacuum with nitrogen |
| 43. | Leave till system at RT |
| | |
| | **BEGIN Disassembly** |
| 44. | unbolt lower OVC from upper OVC |
| 45. | unbolt lower PT1 shield from upper PT1 |
| 46. | unbolt 4K lower shield |
| 47. | Unbolt magnet interface plate from 4K plate |
| 48. | Unstrap magnet cabling |
| 49. | Lower magnet on guide rods |
| 50. | Unscrew still shield tail |
| | |

| | **REMOVE Magnet** |
|---|---|
| 51. | Disconnect switch and heater micro-D |
| 52. | Cut off heatshrink and de-solder current lead connections |
| 53. | Unbolt magnet interface plate from 4K plate |
| 54. | Unscrew guide rod end caps and remove magnet |

**Table 4 Summary task list**

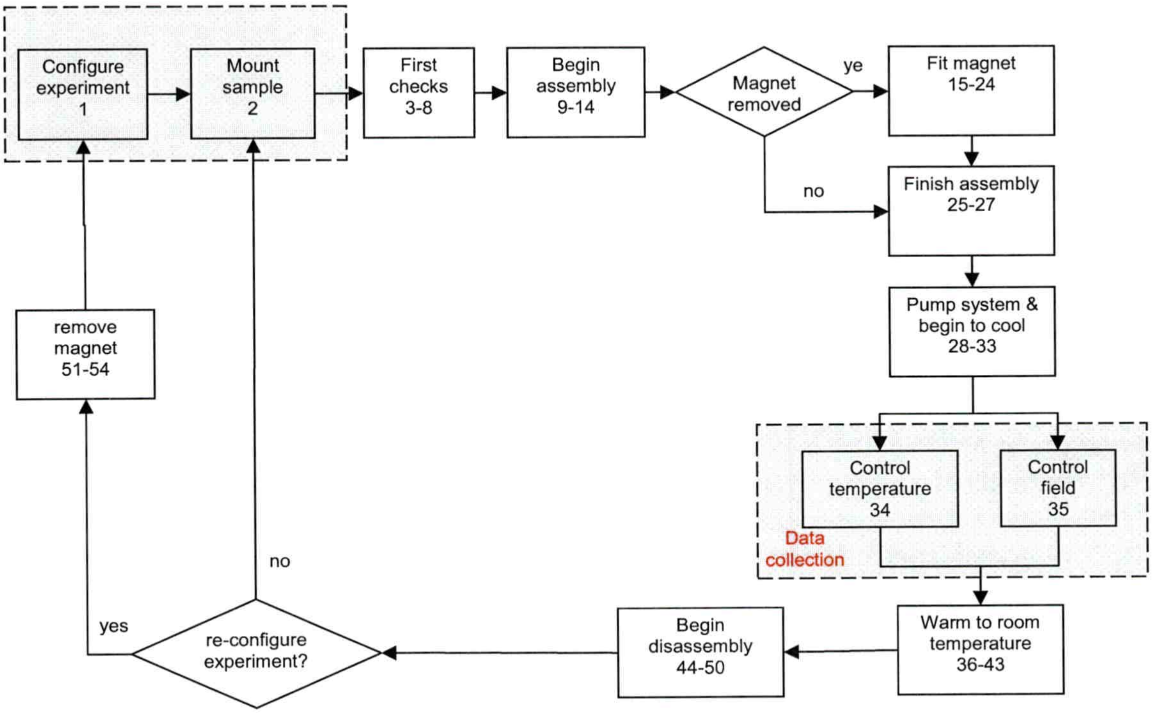



**Figure 41 Operational flowchart for systems with magnets**

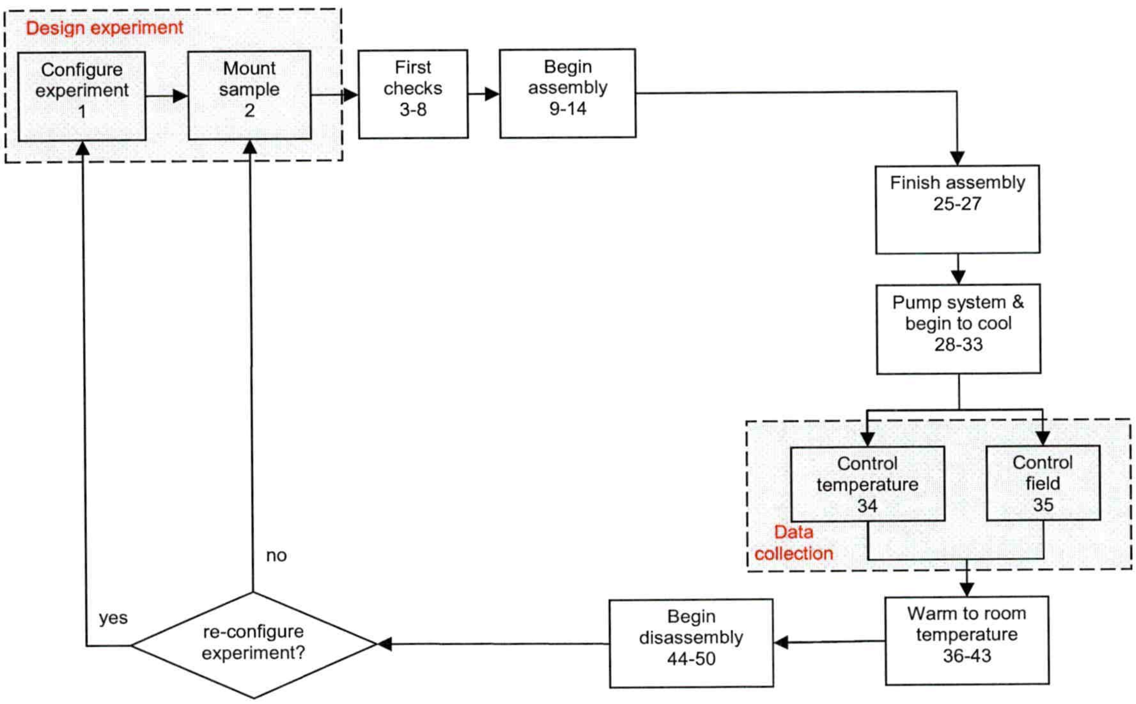



**Figure 42 Operational flowchart for systems without magnets**

# 7. Technical Data

## Specifications of Triton$^{200}$

### *System configuration*

Pulse tube cooler
Typical sample space 240mm dia. x 240mm length depending on tail options, for systems without magnets. Sample access for systems with magnets will depend on the magnet design.

Position of M/C (default off-centre)
Top plate access Not line of sight 3 (2x 40mm dia., 1x 50mm)
Line of sight 1 (40mm/50mm ( optional))
Optical access at M/C level 4 (optional)
Bottom optical access 1 (optional)

Fully automated via dedicated control software.
Remote operation: Remote Desktop, TightVNC or TCP port.

Segmented shields for full access to experimental space.

All systems fitted with superinsulation.

### *Pre-cooling system*

Pulse tube based – no cryogen liquids needed
Vibration isolation of PT2 and PT1 stages from pulse tube cooler
Separate KNF compressor based pre-cooling cycle for fast system and sample cooling.

### *Gas handling infrastructure*

Turbo molecular pump (water cooled)
Dry roughing pump - Automatic (PC-controlled) gas handling system including storage vessel for $^3He/^4He$ mixture
Cold traps on PT1 stage
External liquid nitrogen cold trap

### *Thermometry Instrumentation*

PT1 stage: PT 100 (2 pc)
PT2 stage: Cernox (2 pc), individual calibration
Still: $RuO_2$ (1 pc), generic calibration

100mK plate $RuO_2$ (1 pc) with generic calibration
M/C $RuO_2$ (1 pc) with generic calibration (optional individual calibration), M/C Cernox (1 pc) with individual calibration.

Temperature controller: Lakeshore 370 AC + 16 channel multiplexer

*Control rack mains connection*

230VAC±10%, 50/60 Hz, 3kW

*PTR Compressor Coolant (Water)*

Refer to individual compressor manual.

*Turbo pump Coolant (Water)*

Refer to individual turbo pump manual.

### *Environmental Requirements*

The operating environmental conditions listed in Table 5 must be observed.

| | |
|---|---|
| Installation | Category II (normal plug-in mains connection) |
| Environment | Pollution degree 2 (normal environments) |
| Maximum magnetic field at control rack | 50 Gauss (0.5 mT) |
| Ambient temperature | 15 to 35 (40) Celsius<br>Thermometry accuracy is reduced above 35 Celsius |
| Atmospheric pressure | 86kPa to 106 kPa |
| Maximum operating altitude | 2000m |
| Relative humidity | 30% to 75% non-condensing |
| Maximum humidity for T < 31°C | 80% |
| Maximum humidity 31°C <T< 40°C | Decreasing linearly from 80% to 50% |

**Table 5 Operating environmental requirements**

Maximum humidity depends on ambient and coolant water temperature. Please refer to the appropriate compressor manual for further details.

## Diagnostic Wiring (typical)

*Cryostat top plate wiring: 50 way D connector*

| Pin # | Function | Component |
|---|---|---|
| 1 | Sensor I+ | PT2 Head Cernox resistance sensor |
| 34 | Sensor I- | |
| 18 | Sensor V+ | |
| 2 | Sensor V- | |
| 35 | Sensor I+ | PT2 Plate Cernox resistance sensor |
| 19 | Sensor I- | |
| 3 | Sensor V+ | |
| 36 | Sensor V- | |
| 20 | Sensor I+ | Still RuO2 resistance sensor |
| 4 | Sensor I- | |
| 37 | Sensor V+ | |
| 21 | Sensor V- | |
| 5 | Sensor I+ | 100mK plate RuO2 resistance sensor |
| 38 | Sensor I- | |
| 22 | Sensor V+ | |
| 6 | Sensor V- | |
| 39 | Sensor I+ | M/C External Cernox resistance sensor |
| 23 | Sensor I- | |
| 7 | Sensor V+ | |
| 40 | Sensor V- | |
| 24 | Sensor I+ | M/C External RuO2 resistance sensor |
| 8 | Sensor I- | |
| 41 | Sensor V+ | |
| 25 | Sensor V- | |
| 9 | Sensor I+ | Free |
| 42 | Sensor I- | |
| 26 | Sensor V+ | |
| 10 | Sensor V- | |
| 43 | Sensor I+ | Free |
| 27 | Sensor I- | |
| 11 | Sensor V+ | |
| 44 | Sensor V- | |
| 45 | Heater V+ | M/C Heater |
| 29 | Heater V- | |
| 28 | Heater I+ | Still Heater |
| 12 | Heater I- | |
| 13 | Sensor I+ | PT1 Head PT100 |
| 46 | Sensor I- | |
| 30 | Sensor V+ | |
| 14 | Sensor V- | |
| 47 | Sensor I+ | PT1 Plate PT100 |
| 31 | Sensor I- | |
| 15 | Sensor V+ | |
| 48 | Sensor V- | |

## Experimental wiring connectors (optional)

### *24 way Fischer connectors*

Your system may be fitted with 24 way Fischer connectors for experimental use. Each connector is wired using 12 twisted pairs of 0.1mm diameter constantan wire terminating on a 25 way micro D connector mounted on the mixing chamber.

| 24 way Fischer pin # | | Function | 25 way D type pin # |
|---|---|---|---|
| 1 | Twisted pair | Customer use | 1 |
| 2 | | Customer use | 14 |
| 3 | Twisted pair | Customer use | 2 |
| 4 | | Customer use | 15 |
| 5 | Twisted pair | Customer use | 3 |
| 6 | | Customer use | 16 |
| 7 | Twisted pair | Customer use | 4 |
| 8 | | Customer use | 17 |
| 9 | Twisted pair | Customer use | 5 |
| 10 | | Customer use | 18 |
| 11 | Twisted pair | Customer use | 6 |
| 12 | | Customer use | 19 |
| 13 | Twisted pair | Customer use | 7 |
| 14 | | Customer use | 20 |
| 15 | Twisted pair | Customer use | 8 |
| 16 | | Customer use | 21 |
| 17 | Twisted pair | Customer use | 9 |
| 18 | | Customer use | 22 |
| 19 | Twisted pair | Customer use | 10 |
| 20 | | Customer use | 23 |
| 21 | Twisted pair | Customer use | 11 |
| 22 | | Customer use | 24 |
| 23 | Twisted pair | Customer use | 12 |
| 24 | | Customer use | 25 |

### *SMA and SMB type connectors*

Your system may be fitted with SMA or SMB connectors for experimental use. Each connector is wired to a terminating connector. Please note that the outer screen of each connector is electrically grounded to the insert.

## Fischer connector pin labels

### 24 way Fischer connector for experimental wiring

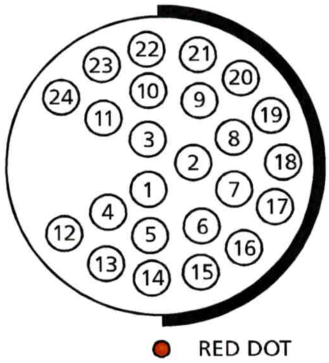



**Figure 43 Pin numbers on a 24 way hermetically sealed Fischer viewed onto receptacles from the outside of the cryostat. Fischer part number 105 A093 (DBEE) (Mating connector Fischer part number SE105 A093)**

Note: The connector on the cryostat is a socket, and the pins are in the connector on the lead.

## Flying leads for Fischer connectors

Leads attached to Fischer connectors by Oxford Instruments are colour coded according to the following convention.

| | |
|---|---|
| 1 | Red |
| 2 | Blue |
| 3 | Green |
| 4 | Yellow |
| 5 | White |
| 6 | Black |
| 7 | Brown |
| 8 | Violet |
| 9 | Orange |
| 10 | Pink |

| | |
|---|---|
| 11 | Turquoise |
| 12 | Grey |
| 13 | Red/Blue |
| 14 | Green/Red |
| 15 | Yellow/Red |
| 16 | White/Red |
| 17 | Red/Black |
| 18 | Red/Brown |
| 19 | Yellow/Blue |
| 20 | White/Blue |

| | |
|---|---|
| 21 | Blue/Black |
| 22 | Orange/Blue |
| 23 | Yellow/Green |
| 24 | White/Green |
| | |
| | |
| | |
| | |
| | |
| Body | Screen |

Leads with less than 24 wires are colour coded in the same way. For example, if you have a 10 way lead you should simply ignore the information given for pins 11 to 24.

# 8. Maintenance and Faultfinding

***Some faultfinding and maintenance operations may require the AC mains power supply to be connected. Only skilled personnel who are aware of the hazards involved may carry out these operations.***

***Quelques opérations de dépannage et d'entretien peuvent exiger que l'alimentation au secteur AC soit connectée. Seul le personnel qualifié et conscient des risques peut effectuer ces opérations***

## Regular Maintenance Tasks and Intervals

| Interval | Component | Maintenance task | Instructions |
|---|---|---|---|
| 18000h | PTR compressor | Replace adsorber | See manual from manufacturer |
| 18000h | PTR rotary valve | Replace or refer to manual | Next section |
| 20000h or 4 years | Adixen pump | Oil draining<br>Replace bearing<br>Replace seal | See manual from manufacturer |
| 3 years | Pfeiffer turbo pump | Change lubricant reservoir<br>Change bearing | See manual from manufacturer |
| 4000h | KNF Compressor | Replace Diaphragm | Next section |

### The KNF Compressor Pump

The diaphragms in the KNF compressor pump should be changed every 4000 hours. This is *very* **important** as a diaphragm failure can result in either mixture loss, which can be expensive to rectify, or mixture contamination, which can be time consuming to rectify and requires the correct scrubbing equipment. The Beckhoff coupler on the back of the control rack includes a clock counter which records the number of hours the KNF compressor has been running. Periodically this should be checked to ensure the 4000 hours has not been exceeded.

Due to the importance of this maintenance, Oxford Instruments requires that the old diaphragms be returned to our factory for inspection after this service. Note, that failure to do so may invalidate your warranty in the case of a diaphragm failure.

### Replacing the VeriTube compressor Adsorber

The adsorber is mounted to the compressor using Aeroquip connectors and can be dismounted by opening the Aeroquip connectors.

***Be careful not to open the fittings while opening or closing the Aeroquip connectors; use two wrenches. Open fittings will result in helium loss due to leakage.***

***Faites attention à ne pas ouvrir les garnitures en ouvrant ou en fermant les connecteurs Aeroquip; utilisez deux clés. Ouvrir les garnitures aura comme conséquence la perte d'hélium due à des fuites.***

The adsorber may be shipped to Oxford Instruments for regeneration. Please refer to contact details for Oxford Instruments NanoScience Customer Support on page 111 of this manual.

## Preventative maintenance

***Access within the equipment and removal of connecting cables is restricted to suitably skilled and competent persons.***

***L'accès à l'équipement et le déplacement des câbles de connexion est limité aux personnes convenablement habiles et compétentes.***

**Maintenance Interval:** Six months or as for cleaning if more frequent.

## Cleaning requirements

Interval between cleaning is as required by appearance.

***Ensure that the AC supply to the equipment is isolated at the external disconnect device before cleaning.***

***Soyez sure que l'alimentation de l'equipment est isole au niveau de susteme de deconnexion externe avant de nettoyer.***

To remove surface dust and light markings, the equipment may be wiped down using lint free cloth, barely moistened with clean water. For removal of heavy marks, the use of a proprietary aerosol foaming cleaner is permissible. Test carefully on a small inconspicuous area to ensure that the product does not damage the surface finish.

## Troubleshooting

This section provides advice on simple faults and operational errors and gives an immediate solution where possible.

> If in doubt or if you need further advice please contact Oxford Instruments NanoScience Customer Support giving the results of the checks you have performed.

| Symptom | Diagnosis and suggestions |
|---|---|
| Cryostat outer vacuum chamber (OVC) cannot be pumped to high vacuum<br><br>Or<br><br>Water condenses on the cryostat body when the system is running | Check the OVC for leaks. In particular check the OVC O-ring sealed joints.<br><br>There may be too much moisture in the OVC and it should be pumped with a rotary pump (when the system is warm), with the gas ballast valve open. |
| PTR will not cool down | Check the PTR compressor pressure and OVC vacuum. |
| Poor temperature stability | Check the PID settings on the M/C temperature control. |

| Symptom | Diagnosis and suggestions |
| --- | --- |
| System will not reach specified minimum temperature | Check that the M/C heater is switched off.<br><br>Check the PT2 plate temperature.<br><br>Check the quality of the vacuum in the OVC.<br><br>Check the connections to the thermometer. The measured mixing chamber temperature may be higher than the real temperature.<br><br>Have you added any wiring to the M/C that could introduce a high heat load?<br><br>Check the cryostat for mechanical problems. Warm the system to room temperature and remove the shields as if you were going to change the sample. Check whether the Still shield touches the sample/sample holder or any other parts of the dilution unit. Also check if any of the mixing chamber wiring (diagnostic or experimental) is touching the Still shield. |
| Sensor not reading correctly | Check the cryostat wiring and the external connecting leads. |

## 50 way sensor/heater connector – diagnostic wiring resistance checks

The typical values below are with the system at room temperature and with a standard set of sensors and diagnostic wiring. If your system has been customised, these values may vary. All resistance values are in ohms where 'k' designates 1000.

Date | | Time |

| | **50-way Cryostat top plate** | | | **50-way Cryostat top plate** | | | **50-way Cryostat top plate** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Device** | Pins | Expected | Recorded | Pins | Expected | Recorded | **Device** | Pins | Expected | Recorded |
| **sensor** | 1-34 | 150 | | 39-23 | 250 | | **Heater** | 29-45 | 5.8K | |
| **sensor** | 1-2 | 150 | | 39-40 | 250 | | **Ground** | 29-Grnd | Inf | |
| **leads** | 1-18 | 100 | | 39-7 | 200 | | **Heater** | 12-28 | 3.82K | |
| **leads** | 2-34 | 100 | | 23-40 | 200 | | **Ground** | 12-Grnd | Inf | |
| **Ground** | 1-Grnd | Inf | | 39- Grnd | Inf | | | | | |
| **sensor** | 19-35 | 150 | | 24-8 | 2.4K | | **sensor** | 13-46 | 160 | |
| **sensor** | 19-3 | 150 | | 24-25 | 2.4K | | **sensor** | 13-14 | 160 | |
| **leads** | 19-36 | 100 | | 24-41 | 200 | | **leads** | 13-30 | 60 | |
| **leads** | 3-35 | 100 | | 8-25 | 200 | | **leads** | 14-46 | 60 | |
| **Ground** | 19-Grnd | Inf | | 24- Grnd | Inf | | **Ground** | 13-Grnd | Inf | |
| **sensor** | 20-4 | 2.32K | | 9-42 | Inf * | | **sensor** | 47-31 | 160 | |
| **sensor** | 20-21 | 2.32K | | 9-10 | Inf * | | **sensor** | 47-48 | 160 | |
| **leads** | 20-37 | 120 | | 9-26 | Inf * | | **leads** | 47-15 | 60 | |
| **leads** | 4-21 | 120 | | 10-42 | Inf * | | **leads** | 31-48 | 60 | |
| **Ground** | 20-Grnd | Inf | | 9- Grnd | Inf | | **Ground** | 20-Grnd | Inf | |
| **sensor** | 5-38 | 2.4K | | 43-27 | Inf * | | | | | |
| **sensor** | 5-6 | 2.4K | | 43-44 | Inf * | | | | | |
| **leads** | 5-22 | 200 | | 43-11 | Inf * | | | | | |
| **leads** | 6-38 | 200 | | 27-44 | Inf * | | | | | |
| **Ground** | 5-Grnd | Inf | | 43- Grnd | Inf | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

* These values are for standard system wiring. If extra sensors have been fitted these values may vary.

# 9. Customer Support

## Warranty

The Oxford Instruments customer support warranty is available to all our customers during the first 12 months of ownership from date of delivery. This warranty provides:

- Repair to faults that are a result of manufacturing defects at Oxford Instruments.

## Technical support

To obtain technical support you will need to quote your Oxford Instruments order number. Please contact your nearest Customer Support centre as follows:

**Europe, RoW, Main Office**
Tel: +44 (0)1865 393 311
E-mail: helpdesk.nanoscience@oxinst.co.uk
Web: www.oxford-instruments.com

**USA Office**
Tel: +1 800 447 4717
E-mail: csg@ma.oxinst.com
Web: www.oxford-instruments.com

**Japan Office**
Tel: +81 03 5245 3261
E-mail: oikkcsri@oxford-instruments.ne.jp
Web: www.oxford-instruments.com

**China Office**
Tel: +86 21 63608530/1/2/3
E-mail: info@oxford-instruments.com.cn
Web: www.oxford-instruments.com

## Additional services available from Oxford Instruments

**Oxford Instruments Direct** – provides one-stop shopping for cryogenics, magnetic, vacuum and associated laboratory products as well as hard to find reference for low temperature physics, optics, thermometry and laboratory safety practices. You can also visit on-line at www.oxinstdirect.com. Ordering parts is easy via phone, fax or email. Online ordering is available in North America.

## About Oxford Instruments

Oxford Instruments specialises in the design, manufacture and support of high-technology tools and systems for industry, research, education, space, energy, defence and healthcare.

We combine core technologies in areas such as low temperature and high magnetic field environments; X-ray, electron and optical based metrology; nuclear magnetic resonance, advanced growth, deposition and etching. Our aim is to be the leading provider of tools and systems for the emerging nanotechnology and bioscience markets.

### Oxford Instruments NanoScience Limited

Oxford Instruments NanoScience creates high performance environments for low temperature and high magnetic field applications in physical science research and process development down to the atomic scale.

The business has a strong capability in advanced cryogenics and applied superconductivity. Through the application of these technologies we deliver solutions that meet the exacting needs of scientists working at the forefront of fundamental physics, applied physics, materials science and next generation device development. With an extensive customer network, a strong reputation for performance and quality, we value the support we have provided to world leading research scientists in their pursuit of excellence.

# 10. Appendix A. Thermometry Calibration Data

## M/C temperature sensor (depending on options)

Figure 44 below shows the generic calibration curve for the M series $RuO_2$ resistance sensor used to monitor the mixing chamber temperature.

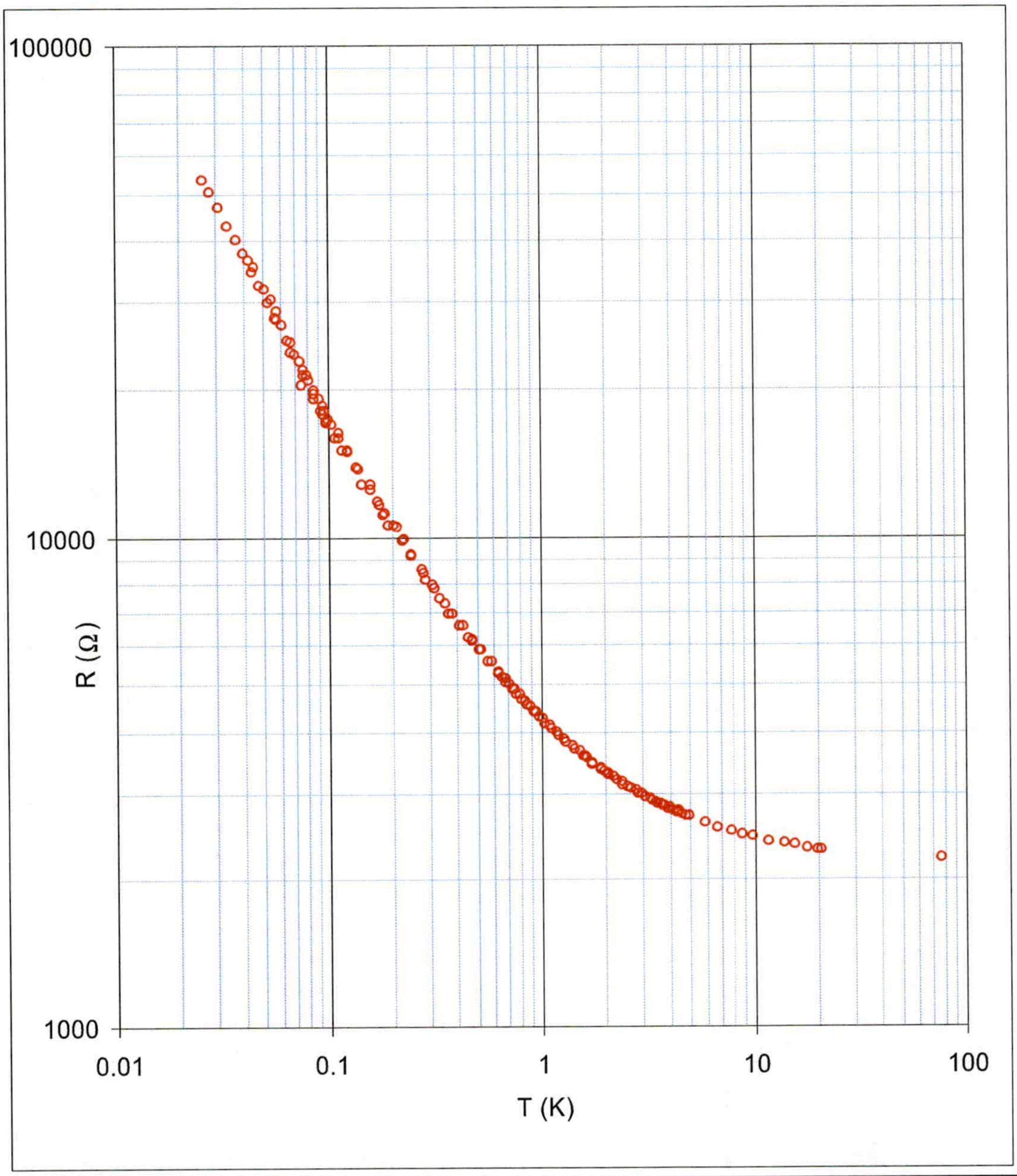


**Figure 44 The generic R vs. T curve for the Oxford M series (2003) $RuO_2$ resistance sensor. The nominal room temperature resistance is 2.21 kΩ**

| T (K) | R (ohms) | T (K) | R (ohms) |
|---|---|---|---|
| 0.0260 | 53176.6 | 0.563 | 5550.3 |
| 0.0283 | 50059.1 | 0.583 | 5537.0 |
| 0.0307 | 46753.3 | 0.628 | 5256.5 |
| 0.0342 | 42856.7 | 0.637 | 5295.6 |
| 0.0370 | 40126.6 | 0.658 | 5158.0 |
| 0.0400 | 37593.3 | 0.678 | 5133.8 |
| 0.0426 | 36440.0 | 0.687 | 5030.0 |
| 0.0440 | 34577.4 | 0.712 | 5009.9 |
| 0.0450 | 35188.3 | 0.733 | 4877.2 |
| 0.0480 | 32329.1 | 0.750 | 4887.0 |
| 0.0510 | 31829.6 | 0.771 | 4761.8 |
| 0.0526 | 29958.3 | 0.792 | 4763.0 |
| 0.0545 | 30214.2 | 0.815 | 4641.2 |
| 0.0565 | 27758.0 | 0.840 | 4631.8 |
| 0.0577 | 28640.2 | 0.860 | 4533.4 |
| 0.0579 | 27531.6 | 0.892 | 4512.2 |
| 0.0620 | 26792.7 | 0.920 | 4401.2 |
| 0.0651 | 25034.1 | 0.952 | 4386.7 |
| 0.0670 | 23744.0 | 0.981 | 4282.3 |
| 0.0674 | 24850.2 | 1.019 | 4259.5 |
| 0.0706 | 23456.6 | 1.046 | 4164.5 |
| 0.0748 | 22670.8 | 1.097 | 4132.2 |
| 0.0764 | 20376.0 | 1.122 | 4052.7 |
| 0.0767 | 21292.0 | 1.186 | 4002.0 |
| 0.0772 | 21839.1 | 1.213 | 3929.8 |
| 0.0807 | 21338.3 | 1.291 | 3872.4 |
| 0.0818 | 20755.8 | 1.318 | 3808.3 |
| 0.0869 | 19902.7 | 1.418 | 3737.4 |
| 0.0870 | 19074.0 | 1.441 | 3686.1 |
| 0.0875 | 19484.1 | 1.517 | 3650.3 |
| 0.0917 | 18984.0 | 1.588 | 3563.6 |
| 0.0928 | 18042.0 | 1.628 | 3561.1 |
| 0.0950 | 17746.0 | 1.637 | 3535.2 |
| 0.0956 | 18420.8 | 1.754 | 3444.0 |
| 0.0977 | 18015.8 | 1.756 | 3471.7 |
| 0.0986 | 17172.0 | 1.898 | 3359.1 |
| 0.0993 | 17076.0 | 1.906 | 3382.2 |
| 0.0996 | 17038.0 | 1.989 | 3320.0 |
| 0.0997 | 17026.0 | 2.054 | 3304.6 |
| 0.1018 | 17329.1 | 2.063 | 3276.7 |
| 0.1048 | 16891.5 | 2.195 | 3241.1 |
| 0.1087 | 15898.0 | 2.256 | 3197.7 |
| 0.1125 | 16172.4 | 2.386 | 3167.3 |
| 0.1134 | 15842.1 | 2.431 | 3129.5 |
| 0.1177 | 14950.0 | 2.574 | 3104.2 |
| 0.1239 | 14881.5 | 2.641 | 3063.7 |
| 0.1245 | 14986.6 | 2.785 | 3040.9 |
| 0.1379 | 13840.8 | 2.856 | 3006.6 |
| 0.1395 | 13766.6 | 2.957 | 2995.7 |
| 0.1464 | 12786.0 | 3.116 | 2941.7 |
| 0.1594 | 12753.3 | 3.256 | 2929.7 |
| 0.1609 | 12471.6 | 3.307 | 2902.3 |
| 0.1737 | 11745.6 | 3.475 | 2886.6 |
| 0.1741 | 11628.3 | 3.560 | 2856.1 |

| | | | |
|---|---|---|---|
| 0.1828 | 11047.1 | 3.646 | 2855.3 |
| 0.1877 | 11139.9 | 3.758 | 2823.0 |
| 0.1924 | 10556.0 | 3.821 | 2828.2 |
| 0.1932 | 10552.0 | 3.979 | 2790.2 |
| 0.1932 | 10546.0 | 3.997 | 2802.9 |
| 0.2044 | 10499.5 | 4.210 | 2773.7 |
| 0.2110 | 10452.7 | 4.213 | 2758.9 |
| 0.2259 | 9787.5 | 4.382 | 2737.9 |
| 0.2301 | 9844.6 | 4.411 | 2762.0 |
| 0.2491 | 9125.7 | 4.413 | 2748.6 |
| 0.2501 | 9189.9 | 4.601 | 2714.0 |
| 0.2761 | 8586.7 | 4.638 | 2710.7 |
| 0.2828 | 8424.6 | 4.769 | 2696.9 |
| 0.2911 | 8168.0 | 4.956 | 2691.2 |
| 0.3096 | 7958.5 | 5.859 | 2619.8 |
| 0.3147 | 7862.9 | 6.820 | 2561.2 |
| 0.3373 | 7452.7 | 7.875 | 2511.9 |
| 0.3545 | 7315.7 | 8.748 | 2480.4 |
| 0.3675 | 6935.2 | 9.973 | 2443.8 |
| 0.3873 | 6936.8 | 11.844 | 2402.4 |
| 0.4149 | 6576.7 | 13.899 | 2369.5 |
| 0.4276 | 6563.5 | 15.653 | 2347.8 |
| 0.4536 | 6210.1 | 18.044 | 2322.5 |
| 0.4749 | 6108.0 | 20.160 | 2306.7 |
| 0.4765 | 6174.6 | 20.918 | 2301.5 |
| 0.5121 | 5854.2 | 77.000 | 2214.1 |
| 0.5244 | 5856.2 | 273.000 | 2202.5 |

**Table 6 The generic R vs. T data for the Oxford M series (2003) $RuO_2$ resistance sensor. The nominal room temperature resistance is 2.20 kΩ**

## Lakeshore sensors

Generic calibration details for these sensors can be found on Lakeshore's web-site www.lakeshore.com/temp/sen/rrtd.html

Specific calibrations for cernox or $RuO_2$ system sensors will be included on the CD supplied with the system.

# 11. Appendix B. System General Assembly Drawing

The system general assembly drawing can be found on the following pages (hard copy only).

# 12. Appendix C. Registry Parameters, typical values

The Dilution Control application uses the Windows registry to store system parameters. The parameters can be found under the "VeriCold Dilution Control -> Type_0?" key which will typically be under HKEY_CURRENT_USER -> Software -> VeriCold Technologies GmbH

| Parameter | Parent Key\Hive | Typical Value |
|---|---|---|
| the script server port number | VeriCold Dilution Control\Main Window | 22518 |
| finish when temperature of cooldown is | cool down from room temperature | 10 (K) |
| pressure (bar) step number 0 | cool down from room temperature | 0 |
| pressure (bar) step number 1 | cool down from room temperature | 2.5 |
| pressure (bar) step number 2 | cool down from room temperature | 2.2 |
| pressure (bar) step number 3 | cool down from room temperature | 1.8 |
| pressure (bar) step number 4 | cool down from room temperature | 1.6 |
| pressure (bar) step number 5 | cool down from room temperature | 1.2 |
| pressure (bar) step number 6 | cool down from room temperature | 0.8 |
| pressure (bar) step number 7 | cool down from room temperature | 0.5 |
| pressure (bar) step number 8 | cool down from room temperature | 0.3 |
| temperature step number 0 | cool down from room temperature | 0 |
| temperature step number 1 | cool down from room temperature | 180 |
| temperature step number 2 | cool down from room temperature | 120 |
| temperature step number 3 | cool down from room temperature | 80 |
| temperature step number 4 | cool down from room temperature | 50 |
| temperature step number 5 | cool down from room temperature | 40 |
| temperature step number 6 | cool down from room temperature | 30 |
| temperature step number 7 | cool down from room temperature | 20 |
| temperature step number 8 | cool down from room temperature | 5 |
| | | |
| pressure threshold before turning the turbo on (mbar) | evacuating pre-cool | 1 |
| timeout waiting for low pressure threshold (seconds) | evacuating pre-cool | 1200 |
| timeout waiting for pressure before turning turbo on (seconds) | evacuating pre-cool | 300 |
| | | |
| Close the tank at the end of condensing | condensing | True |
| Regulation pressure during condensing (bar) | condensing | 2.5 |
| still power at the end of condensation | condensing | 0.001 |
| timeout for final tank pressure in seconds | condensing | 21600 |
| wait on this tank pressure before finishing | condensing | 0.05 |
| final pressure for collect mixture in | collecting the mixture | 3 |

| | | |
|---|---|---|
| mbar | | |
| final pressure for complete collect mixture in mbar | collecting the mixture | 0.5 |
| timeout for collect mixture in seconds | collecting the mixture | 180 |
| timeout for complete collect mixture in seconds | collecting the mixture | 1200 |

**Table 7 Registry parameters used by the Dilution Control Application**

## Parameter descriptions

### Cooldown from Room temperature

During the cooldown from room temperature the pressure in the pre-cool circuit giving optimum heat transfer is a function of temperature. The "**temperature step number *n***" defines the range of temperature for which the threshold pressure of the pre-cool loop is "**pressure (bar) step number *n***" where *n* is and integer. The control logic is "reduce the pressure to the defined value until the system cools to the defined temperature". The pressure is not a set-point but more like a target threshold. The system will pulse valve V35 to reduce the pressure in the pre-cool loop until the measured pressure "M1" falls below the value defined by "**pressure (bar) step number *n***". Once the temperature of the M/C fall below "**temperature step number *n***" the control loop move on to step *n + 1* until the M/C temperature is below the value defined by "**finish when temperature of cooldown is**".

### Forepump back-pressure transducer

A quadratic fit is used to convert the sensor voltage to pressure. In general the quadratic term is set to zero as a y = m*x + c linear fit gives sufficient accuracy for control. In this case **scaling[0]** = c, **scaling[1]** = m, and **scaling[2]** = the quadratic parameter, typically = 0. At the time of writing two types of transducers are used a standards (see below).

| Transducer | Swagelok | Keller |
|---|---|---|
| Range | 0 – 1.6 bar abs | 0 – 2.0 bar abs |
| Output | 0 – 10V | 4 – 20mA* |
| scaling[0] | 0 | -0.48 |
| scaling[1] | 0.16 | 0.2323 |
| scaling[2] | 0 | 0 |

*A 535ohm load resistor is wired in series and the voltage across the load is used as the pressure signal.

**Table 8. Registry parameters to convert the output of the forepump back-pressure transducer to pressure**